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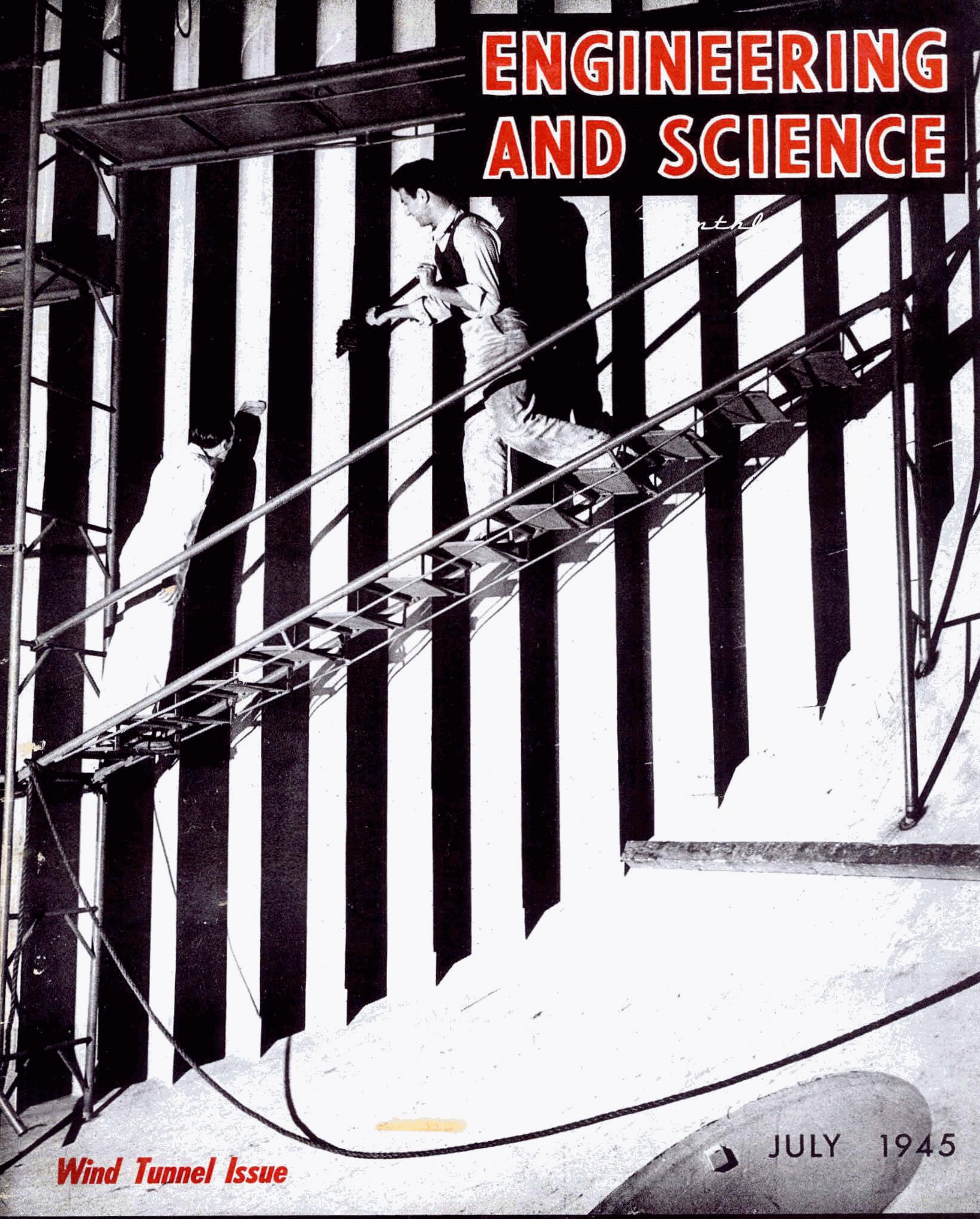

Wind Tunnel Issue

JULY 1945

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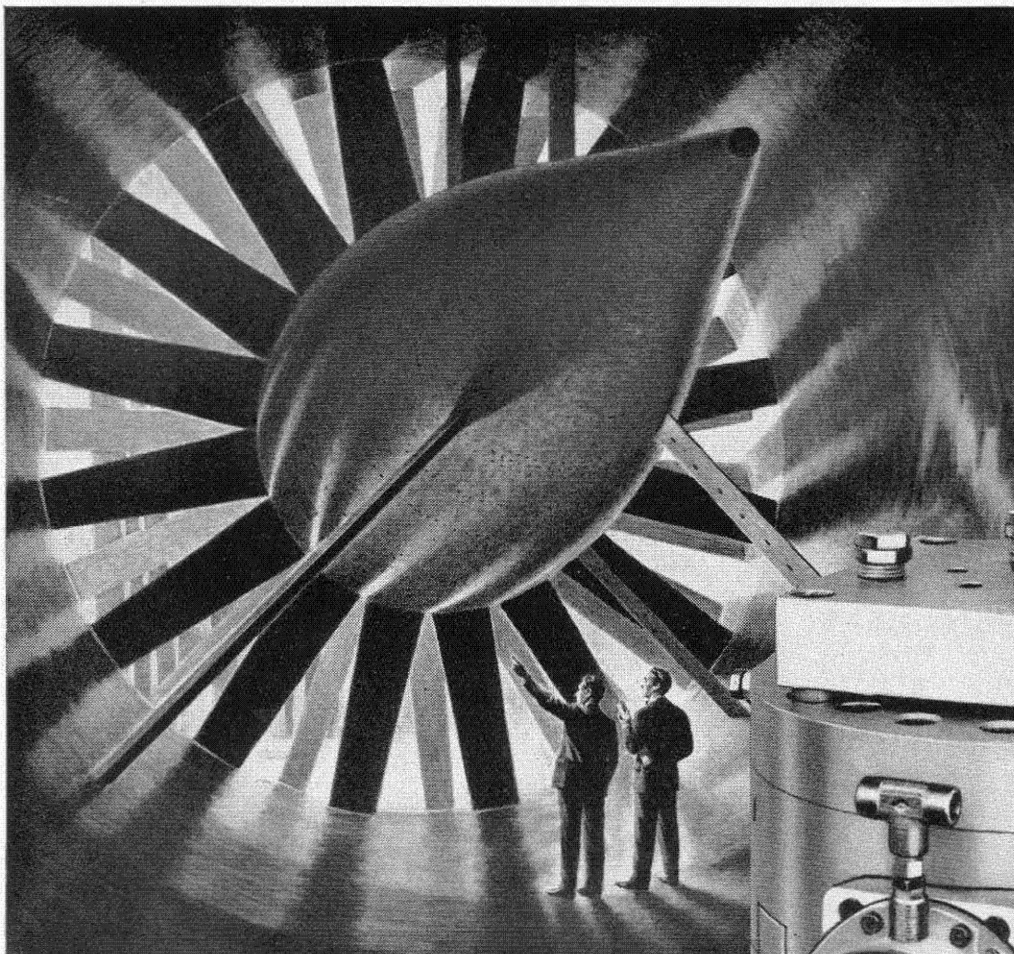
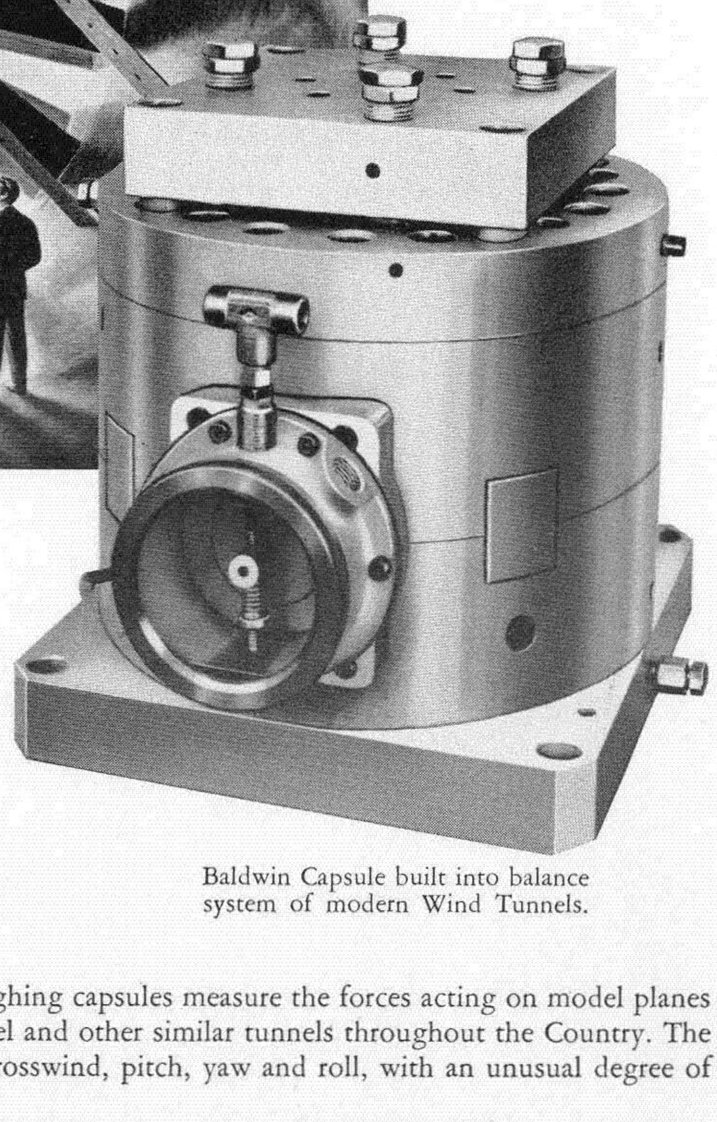


The Heart of the Wind Tunnel



Baldwin Capsule built into balance system of modern Wind Tunnels.

Specially designed and built Baldwin hydraulic weighing capsules measure the forces acting on model planes in the southern California Cooperative Wind Tunnel and other similar tunnels throughout the Country. The balance system measures the forces of lift, drag, crosswind, pitch, yaw and roll, with an unusual degree of sensitivity, accuracy and flexibility.

Baldwin also designed and built hub-operating mechanism for the giant adjustable fans that create man-made hurricanes, attaining wind speeds up to 700 miles per hour. The Baldwin Locomotive Works, Baldwin Southwark Division, Philadelphia 42, Penna.

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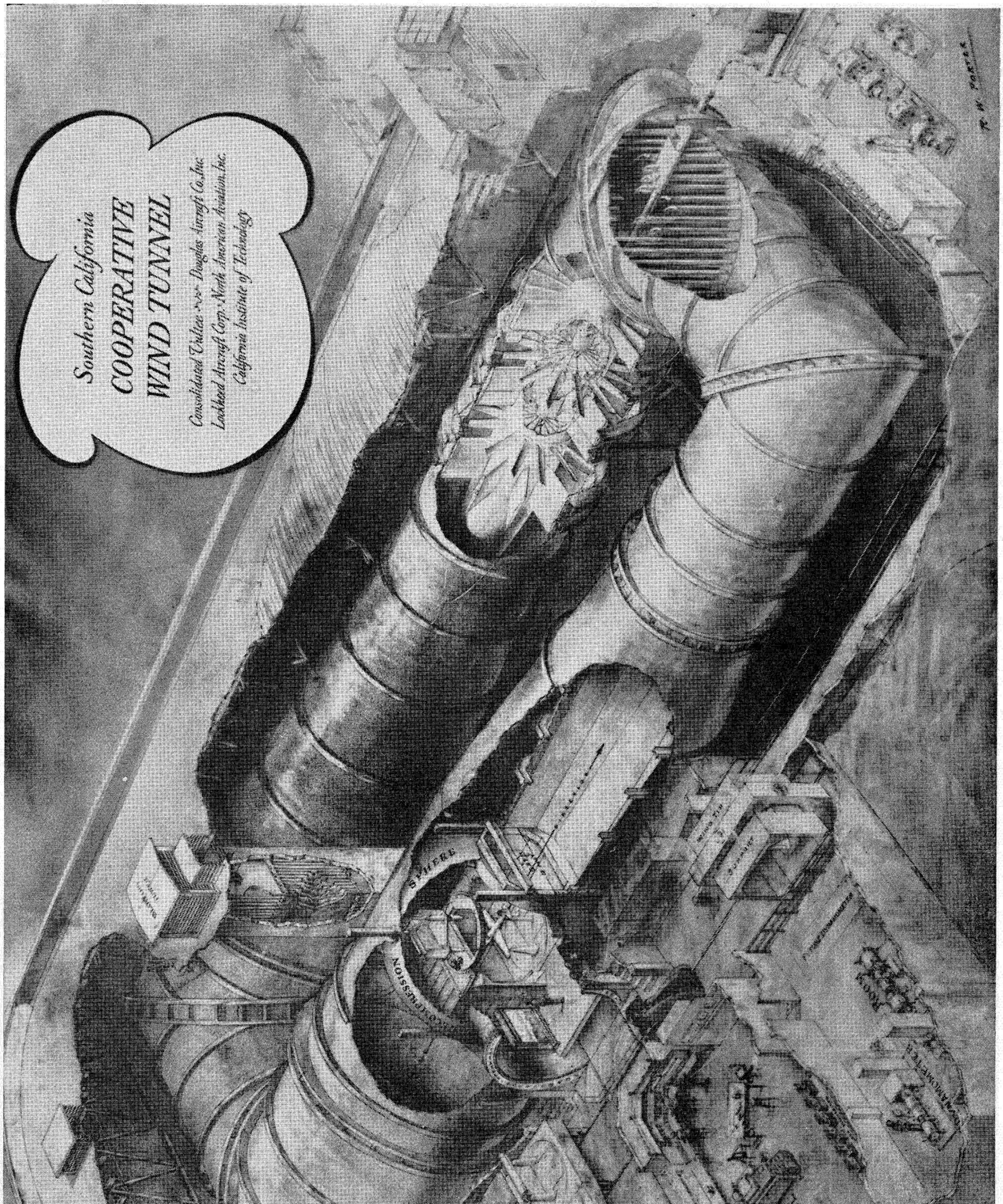

FIG. 1. Cutaway drawing of Southern California Cooperative Wind Tunnel.

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DR. CLARK B. MILLIKAN

THE SOUTHERN CALIFORNIA COOPERATIVE WIND TUNNEL

THE articles covering the Southern California Cooperative Wind Tunnel have been prepared by the staff of the tunnel under the supervision of Dr. Clark B. Millikan, Director. The staff who have been primarily responsible for the design of the wind tunnel and its complex components include the following: Dr. C. B. Millikan, Director, Professor of Aeronautics; Dr. A. L. Klein, Associate Professor of Aeronautics; Dr. E. E. Sechler, Associate Professor of Airplane Structures; Dr. N. B. Moore, Curtiss-Wright Corporation; M. Serrurier; P. V. H. Serrell; J. E. Smith; L. G. Fenner; M. de Ferranti; W. Hertenstein; H. F. Richards; A. Fejer; F. M. Graf; J. W. Hill; J. B. Taylor; H. O. Cox; and K. P. Gow.

In addition, members of the California Institute of Technology and cooperating companies' staffs, too numerous to mention, have made essential contributions to the design and successful construction of the laboratory. The problems involved in the construction of many elements of the wind tunnel were of extreme difficulty and required the highest degree of ingenuity, accuracy, and workmanship. The following organizations, which furnished the major components of the project, by their successful solution of these problems, made the completion of the laboratory possible: Consolidated Steel Corporation, Ltd.; Baldwin Locomotive Works; Tate-Emery Company; Westinghouse Electric Corporation; General Electric Company; International Business Machines Corporation; Gay Engineering Corporation of California; Carrier Corporation; Curtiss Propeller Division of Curtiss-Wright Corporation; Wm. C. Crowell Company; The Fluor Corporation, Ltd. The assistance and cooperation of the Light and Power Department, City of Pasadena, in arranging electric power supply, and of the California Consumers Corporation, in furnishing refrigeration for the dehumidifier, contributed greatly to the project.

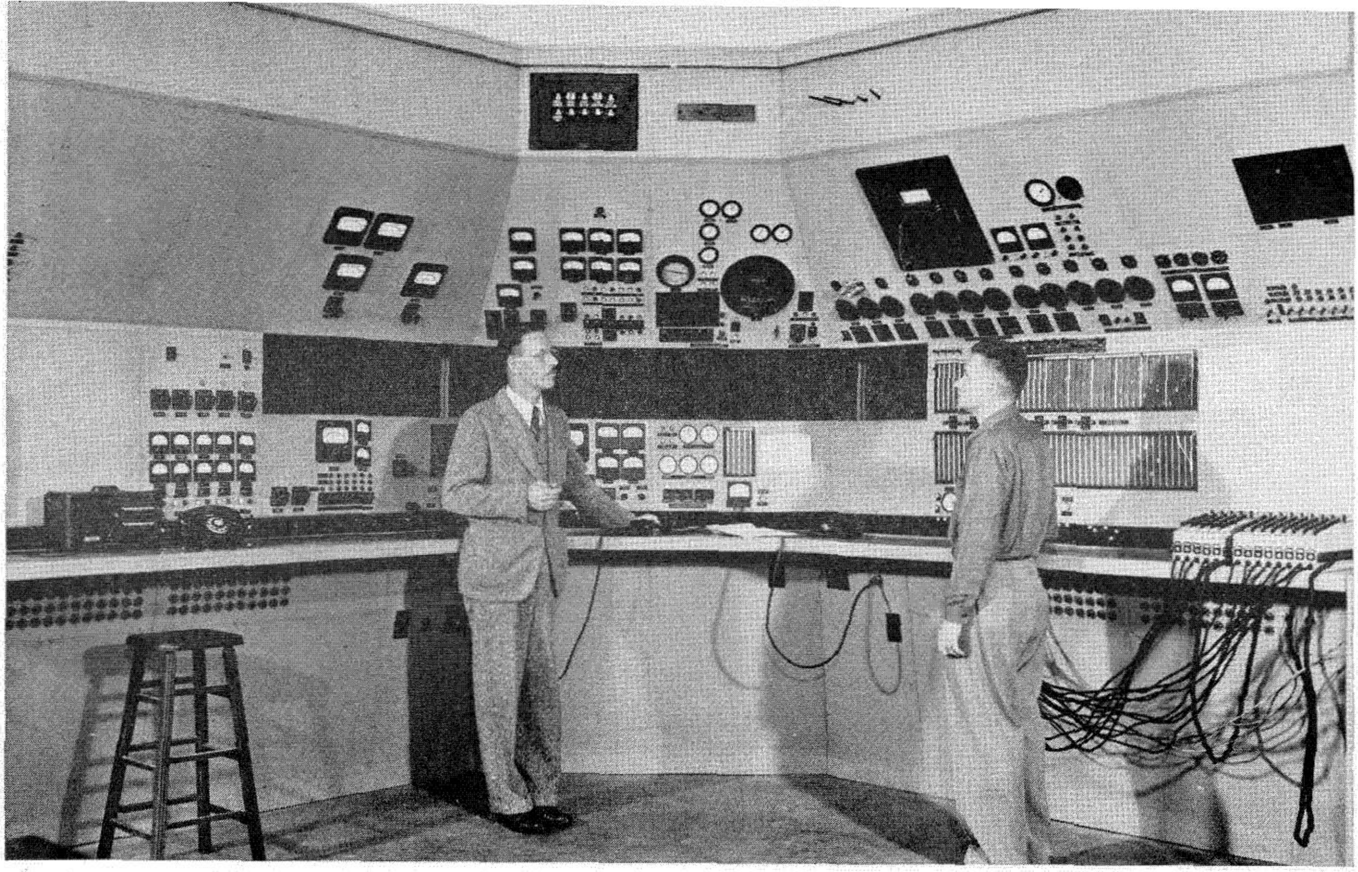


FIG. 2. Console of control room, which provides centralized operation by means of remote control and indication circuits.

INTRODUCTION

THE Southern California Cooperative Wind Tunnel is an achievement remarkable not only for its technical features, but perhaps even more significantly for the concept of cooperation upon which it is based, and which is emphasized in its name. Under the impetus of wartime necessity, the traditionally highly competitive aircraft industry, through joint and closely cooperative action, astounded the world by "achieving the impossible." With the coming of peace, the competitive spirit, with its emphasis on individual initiative, will return to the industry.

Even under peacetime competition, however, there are certain fields of activity in which joint action is so intrinsically desirable as to justify its permanent incorporation in the aeronautical industry. One of the most important of these fields is that of research and development, involving particularly the highly complex facilities required for the analysis and solution of the difficult problems encountered in the development of modern, high-speed aircraft.

The Cooperative Wind Tunnel provides such a facility. It is a $2,500,000 project, financed and owned by four Southern California aircraft companies—Consolidated Vultee Aircraft Corporation, Douglas Aircraft Company, Inc., Lockheed Aircraft Corporation and North American Aviation, Inc.—and operated by the California Institute of Technology. Under the cooperative arrangement, these four aircraft companies thus continue in peacetime to employ the most important elements of wartime cooperative development, while retaining the advantages of the flexibility and initiative of private ownership and management. The Cooperative Wind Tunnel represents a highly significant and valuable experiment in cooperative organization on the part of one of the nation's great industries.

The wind tunnel was originally conceived as a design instrument for use by airframe manufacturers in carrying out the aerodynamic development of current and new aircraft. The design was jointly supported by the cooperating Southern California companies and the Curtiss-Wright Corporation, which is constructing an essentially identical wind tunnel. It had to satisfy a number of very special requirements: Size had to be such as to make the construction of complete airplane models relatively simple. Operating conditions had to cover speeds up to the velocity of sound, and also scales, or Reynolds Numbers, as large as possible. Accuracy had to be extremely high, and the time required to make the tests and obtain complete data had to be held to the absolute minimum. Wide flexibility was required in the type of test which could be conducted, and the transition from tests on one project to those on another had to be rapidly and easily made. The tunnel, therefore, has many new features which are justified by and can only be understood and appreciated in the light of these very special requirements.

GENERAL FEATURES

THE general arrangement of the Cooperative Wind Tunnel is shown in *Fig. 1*. The heavily reinforced steel tube, seven-eighths inches in thickness, is of circular cross-section and is sheltered by a reinforced concrete and frame building. The maximum inside diameter of the tunnel is 31½ feet, while the working section is 12 feet wide and eight and one-half feet high. A bank of vanes is provided at each corner to guide the airflow smoothly around the turn. This is shown in the cutaway of the turn at the right of *Fig. 1*. The control room is on a mezzanine above the second floor, shown in the lower left portion of *Fig. 1* and in *Fig. 2*.

At the upper left of the control room in *Fig. 1* are shown two partitioned model rooms with wood and metal shops immediately adjoining. The engineering offices, drafting room, photographic laboratory, technical library and other work rooms are on the first floor. The model is mounted within the decompression sphere shown at the

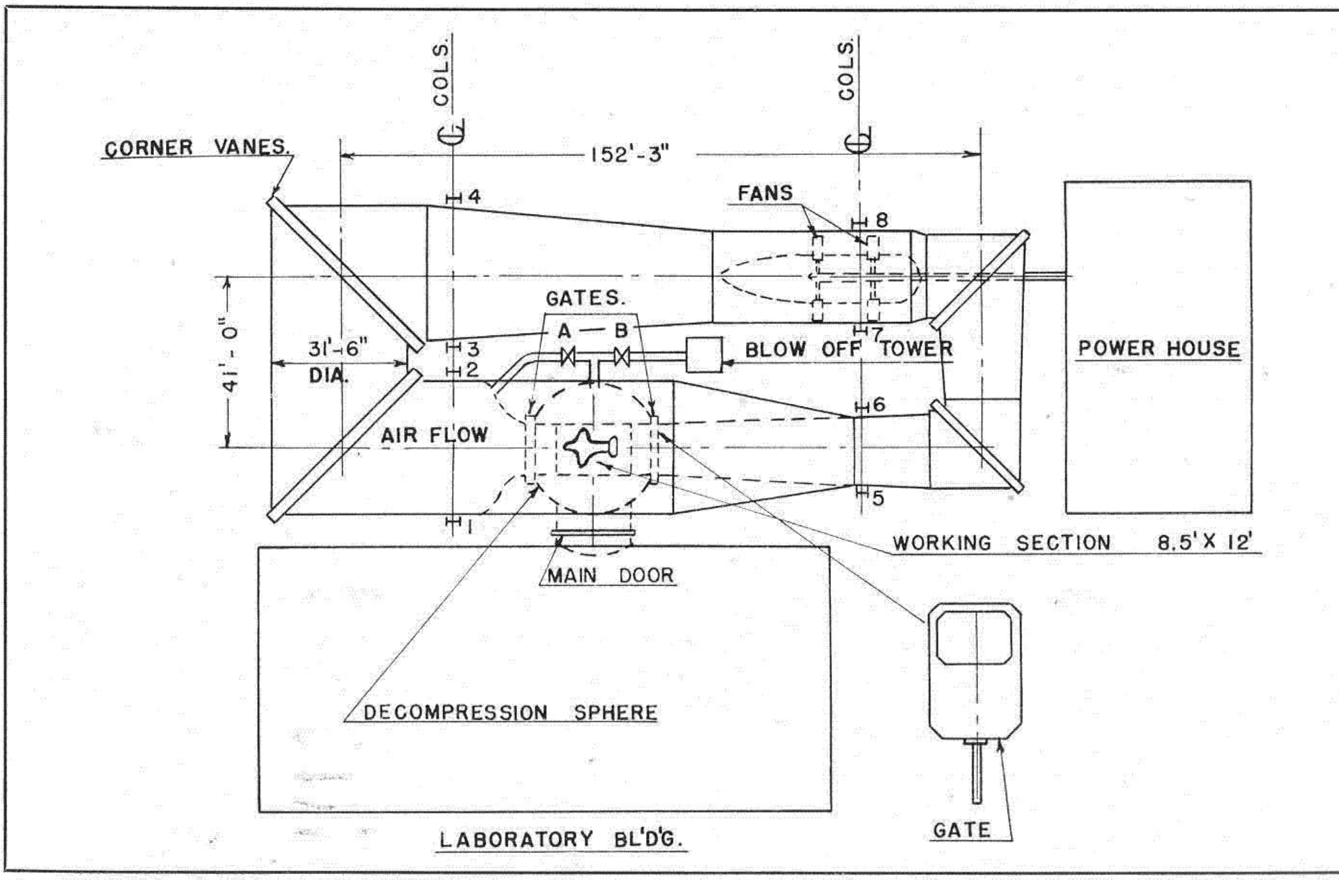


FIG. 3. Diagrammatic plan view of tunnel, showing supporting columns.

FIG. 4. Side view of tunnel during construction.

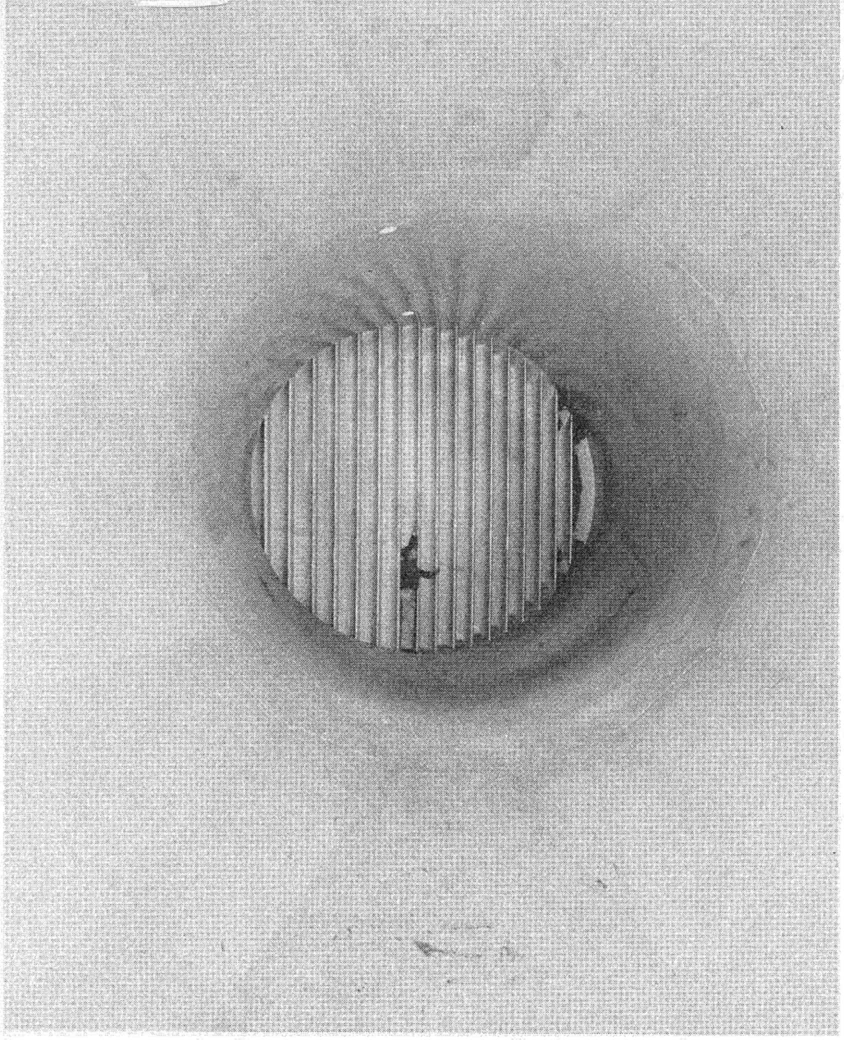


FIG. 6. Turning vanes downstream from working section.

(FIG. 5. Cover illustration, shows adjustable turning vanes at one corner of tunnel.)

left center of *Fig. 1.* This chamber, which may be entirely closed off from the rest of the tunnel in less than a minute, is essentially an air lock, 31½ feet in diameter, and contains a throat or Venturi which is 12 feet wide and eight and one-half feet high. Dynamometers are provided for use in conjunction with power models. The dynamometer room is shown adjacent to the control room in the lower left portion of *Fig. 1.*

The fan system, shown in the right center portion of *Fig. 1,* is connected through the 30-foot steel shaft to two-power units with a total capacity of 12,000 *hp.* These units consist of a 2,000 *hp* direct current motor, supplied by a motor-generator set, and a 10,000 *hp* alternating current induction motor.

Several separate types of mountings are provided for the models, depending upon the type of models tested and the nature of the test to be performed. Test mounts are installed on small flat cars, which operate on steel floor rails that may be pushed directly from the model room into the decompression sphere.

A unique feature of the tunnel operation is an ingenious system of translating the test data to the final results by means of equipment supplied by International Business Machines Corporation. The data are recorded automatically on printed working sheets and on punched cards. The final result is obtained through additional I. B. M. machine operations. Provision is made for the control of temperature and humidity of the air within the tunnel. Some of the interesting features of the wind tunnel are discussed in some detail in the following sections.

PURPOSE AND REQUIREMENTS

THE general purpose of all wind tunnel tests is to obtain data from which the airplane designer can develop the design of a new airplane. Because of the extreme complexity of modern high performance airplanes, a great many varieties of data are required before it is possible to lay out a balanced design. In most instances it is impossible or at least very uneconomical to obtain accurate design information from airplanes in flight, thus making it highly desirable to be able to obtain data by other methods than flight testing. For this reason wind tunnels have been developed.

Many types of wind tunnels have been built, but all have the purpose of creating a uniform stream of air which passes through a test chamber in which a scale model of an airplane is mounted. The model is mounted on struts or wires fastened to a system of balances which enable the tunnel operator to measure the forces and moments acting on the model.

The forces and moments which act on the airplane, and on the model in the wind tunnel, depend on its attitude with respect to the direction of the air stream. That is, they depend on its angle of attack and angle of yaw. The variation of the forces and moments with these angles is important to the airplane designer. For this reason it is necessary that the model-supporting mechanism which is attached to the balances be capable of varying the angles of attack and yaw of the model in the wind tunnel. In fact a typical run of a wind tunnel test consists of varying either the angle of attack or the angle of yaw, while holding the other angle at a fixed value, and recording the magnitudes of the forces and moments at each of a number of positions of the model.

Certain types of investigations which may be carried out in a wind tunnel are of more theoretical interest than of immediate applicability in the design of aircraft, and really belong to the field of fluid mechanics. Apart from investigations of this sort, wind tunnel tests fall generally into one of two classifications. Tests may be conducted for the purpose of obtaining basic aerodynamic data

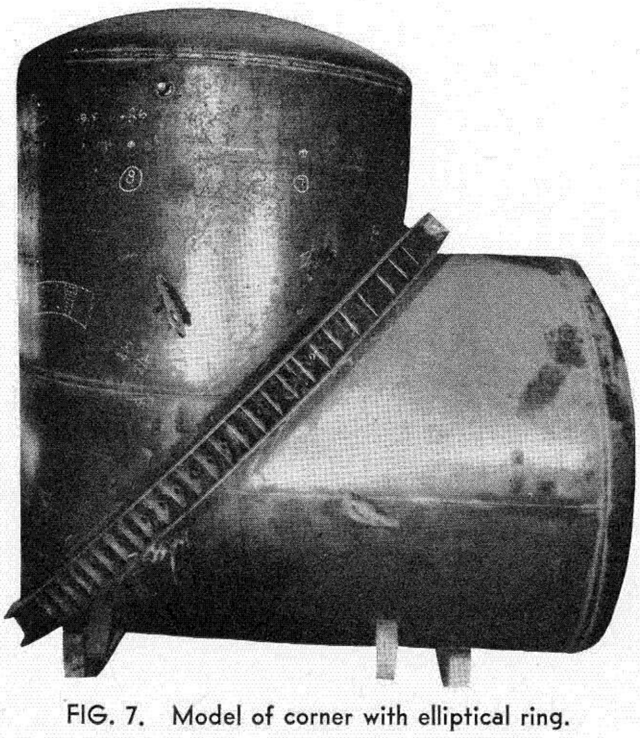


FIG. 7. Model of corner with elliptical ring.

without having in mind a specific airplane to which the results are to be applied, or they may be conducted on a scale model of an existing or proposed airplane with a view to predicting the performance and flying qualities of the full-scale airplane.

Tests of the first class usually involve systematic changes in the model configuration and routine measurements of the forces and moments acting on the model. The model might for example represent a horizontal tail surface consisting of the stabilizer and a movable elevator. Systematic changes could be made in the elevator nose-shape, and the investigation could be extended by testing each nose-shape with each of several elevator hinge-line positions. The data accumulated from such a series of tests would be of value to an airplane designer because it might turn out that one of the combinations of elevator nose-shape and hinge-line locations tested had just the characteristics he requires, but whether this were true or not, the data would enable him to predict, probably with considerable accuracy, the characteristics of a new and untried combination.

Even though the airplane designer makes use of many data of the sort just described, he must still resort to tests of the complete airplane in order to make sure that the final design meets all requirements. A scale model of the airplane is built which reproduces very accurately all the details of the external shape of the airplane. The internal structure of the airplane is not reproduced in the wind tunnel model, since the forces measured by the wind tunnel balances are caused solely by the flow of air over the model. In addition to including such details as gun turrets, bomb-bay doors, retractable landing gears, etc., wind tunnel models have movable flaps and control surfaces, and are frequently tested, with running propellers driven by small electric motors contained within the model. From the point of view of design, it is necessary to know not only the forces and moments acting on the complete airplane, but also the increment added by each part of the airplane separately. For this reason, the model is built so that the wing alone may be tested without the fuselage, nacelles, or tail surfaces. The model may be built up by adding the fuselage, nacelles, tail surfaces, gun turrets, etc., in turn, so that the effects of each component of the airplane on the characteristics of the airplane as a whole may be investigated. Thus it is possible to trace the origin of good or bad characteristics and to determine details of the design which require revision to effect improvements.

With the development on the one hand of airplanes of very large size, and on the other of airplanes with extremely high speeds, it has become necessary to build wind tunnels of greater and greater complexity in order to enable the testing of models under conditions which correspond closely to those met by the full-size airplane.

The Cooperative Wind Tunnel is capable of producing an air stream of very high speed and it is anticipated that tests will be carried out at air speeds up to the speed of sound (750 miles per hour). Such tests will provide much useful information regarding the so-called "compressibility effects" which play such a large part in the flight of a high-speed airplane, but concerning which there is much to be learned.

Aerodynamic theory demonstrates, and it may be observed experimentally, that under identical conditions a small scale model does not possess exactly the same characteristics as the full-size airplane, so that the forces and moments measured by the wind tunnel balances do not correspond exactly to those which affect the motion of the full-size airplane. However, the small scale of the wind tunnel model may be compensated for by increasing the density of the air stream in which it is tested. It is for this reason that the Cooperative Wind Tunnel is of the variable-density type, capable of testing models at air pressures up to four times atmospheric pressure (58.8 pounds per square inch absolute). The tunnel may also be operated under reduced pressures down to approximately 0.1 of atmospheric pressure (1.5 pounds per square inch absolute). An advantage of this arrangement is that at low pressures, less power is required to produce a high-speed air stream than is required at atmospheric or higher pressures.

STRUCTURAL FEATURES

THE geometry of the Cooperative Wind Tunnel is similar to that of other well-known wind tunnels now in operation, such as the Wright Field 20-foot tunnel, the Wright Brothers Memorial Wind Tunnel at Massachusetts Institute of Technology, and the Boeing Tunnel at Seattle. Since there are great advantages in being able to control the pressure of the air in the duct, the Cooperative Wind Tunnel was designed so that air could be maintained at any desired pressure between approximately 1.5 pounds per square inch absolute and 58.8 pounds per square inch absolute.

Since the duct acts as a pressure vessel, it was designed in accordance with standard practice for such vessel. The duct is constructed of steel plate approximately one inch thick and is arc welded. Approximately 3,000,000 pounds of steel were used in the fabrication and erection of the tunnel. Approximately 17 miles of electric arc welding were required. Large sections of the duct were prefabricated in the shops of the Consolidated Steel Corporation in Maywood, California, and trucked from there to Pasadena, where they were erected by the company's field force.

The tunnel is supported on eight columns, as indicated in *Fig.* 3. The general construction is shown in *Fig.* 4. These columns have spherical ends so that each is the equivalent of a portion of a sphere 18 feet in diameter. The tunnel is free to "roll" on the eight columns—at least so far as the columns are concerned. The tunnel is restrained from moving horizontally (in any direction) by a pin which is located midway between columns three and four and engages a plate welded to the tunnel. The tunnel is restrained from rotating about this pin by a link which connects the tunnel and the base of column seven. Thus the tunnel is restrained horizontally in a statically determinate manner. It can expand or contract without restraint.

After the tunnel was completed (structurally) the distribution of the weight between the eight columns was measured and then redistributed to conform to design assumptions. The load in each column was measured by mounting a special (20-foot) extensometer on each column. The zero reading was determined by jacking the tunnel up so as to take the weight off the columns (four at a time). It was found that column three was carrying about 50 per cent more than its design load and that column four was correspondingly unloaded.

The problem of transferring the concentrated loads from the columns to the shell in such a manner as to avoid unduly high stresses is a complicated one. The basic theory can be found in Timoshenko's *Theory of Plates and Shells.* Herman Schorer in an article entitled "Design of Large Pipe Lines," published in *Transactions of the A. S. C. E. 1933,* clearly illustrates the application of the theory.

The corners of the tunnel contain turning vanes for efficiently turning the air (see *Figs. 5 and 6*). These are mounted in an elliptical section about three feet long, which is inserted between the ends of the cylindrical shells. The forces acting on the elliptical ring are the following:

(a). Dynamic air forces on the vanes.
(b). Air pressure on inside of elliptical ring.
(c). Loads due to stresses in shell plate wherever it is intersected by the elliptical ring.

Loads (a) and (b) are fixed and do not depend on the elastic properties of the elliptical ring. Loads (c) are known if the elastic properties of the elliptical ring correspond to those of the cylinder which has been cut away. This relationship, however, is very difficult to establish.

Two types of construction were considered:

1. The ends of the vanes to be fastened to the elliptical ring so as to act as stay bolts.
2. The ends of the vanes to be fastened through slip joints so that no axial loads could be transmitted to the vanes.

Both types of construction had been used previously for wind tunnels, but no data were available on which a choice could be based. The staff of the Cooperative Tunnel selected method (1) above, because in their opinion it saved considerable material, eliminated a lot of "dirty" expansion joints and provided a much more rigid elliptical ring, thus being much more satisfactory so far as carrying loads (c) above. A typical corner may be seen at the right of *Fig. 4*.

A design of the elliptical ring was made on the basis of statics, neglecting bending stresses in the ring and assuming that the loads due to stresses in the shell were not changed because of the elastic properties of the ring. These assumptions seemed reasonable, but it was felt that some further substantiation was necessary; so a scale model was constructed (six feet in diameter—approximately one-fifth scale). Because of the materials available, the dimensions of the model were such that a pressure of 53 pounds per square inch on the model caused the same unit stresses as would a pressure of 47 pounds per square inch in the tunnel. The model is shown in *Fig. 7*.

The stresses in the model were measured by using Huggenberger strain gages on the elliptical rings and shell, and dial gages on the vanes. The results showed that the model had not been built with sufficient accuracy to secure the results ultimately desired, but nevertheless they showed that the design assumptions were satisfactory. After the stress measuring program had been completed, the model was proof-tested as this practice is defined in the A.P.I.-A.S.M.E. code. This test consisted of painting the surface of the model with whitewash and then gradually raising the pressure until flaking of the whitewash indicated yielding of the material. The pressure in the model reached 175 pounds per square inch before any flaking of the whitewash was detected. The pressure was then gradually increased to 225 pounds per square inch. At this pressure the distortion was large over the entire model and there seemed to be no reason for carrying the pressure higher.

The decompression sphere was designed on somewhat the same basis as the corner structures. A model of this section was also built and tested in a similar manner. In general the model test results indicated satisfactory behavior.

The fan for the 10 foot *Galcit** tunnel until quite recently has been equipped with wooden blades. During approximately 15 years of operation a number of wooden fan blades have been wrecked and on one occasion the loose blades broke through the comparatively thin concrete shell surrounding the fan. The fan blades for the cooperative tunnel are aluminum alloy, so that there is every reason to believe that the danger of losing a fan blade is negligible; nevertheless an attempt has been made to provide for that contingency. The fan shaft and bearing supports are strong enough to resist the unbalanced certrifugal force occasioned by the loss of one-half of the blades—all on one side of the hub. The shell surrounding the fan section is twice as thick as required by pressure considerations. It is further reinforced by a steel cone, filled with concrete, surrounding the shell at each fan.

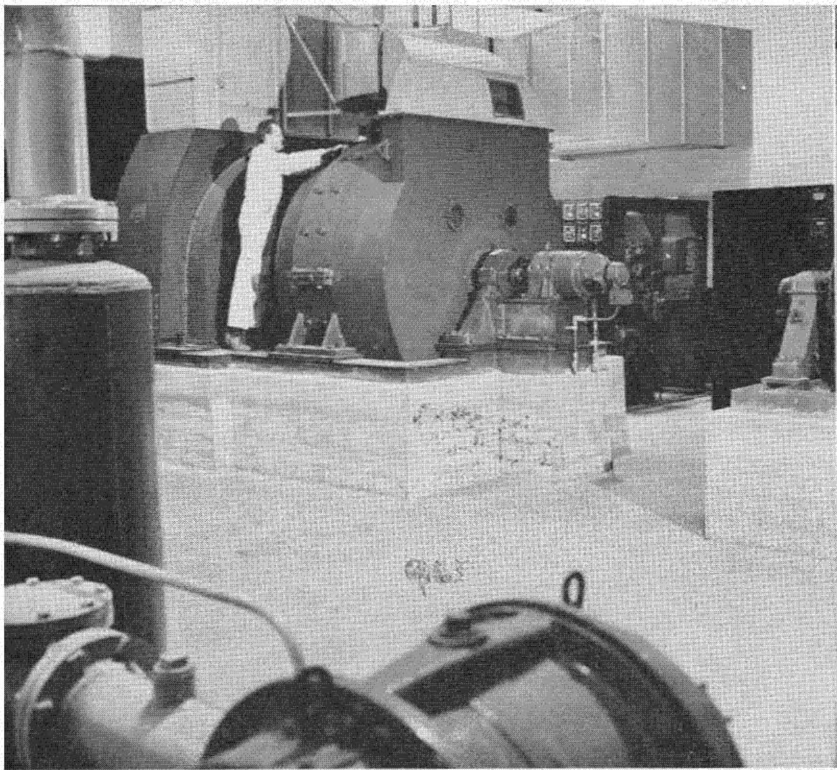
The shell and the reinforcement of openings, etc., conform to the A.P.I.-A.S.M.E. code. The stiffening rings, which prevent the shell from collapsing because of external pressure, were designed so as to buckle under an external pressure of 60 pounds per square inch. The design formulae can be found in Timoshenko's *Strength of Materials* or *Theory of Elastic Stability*.

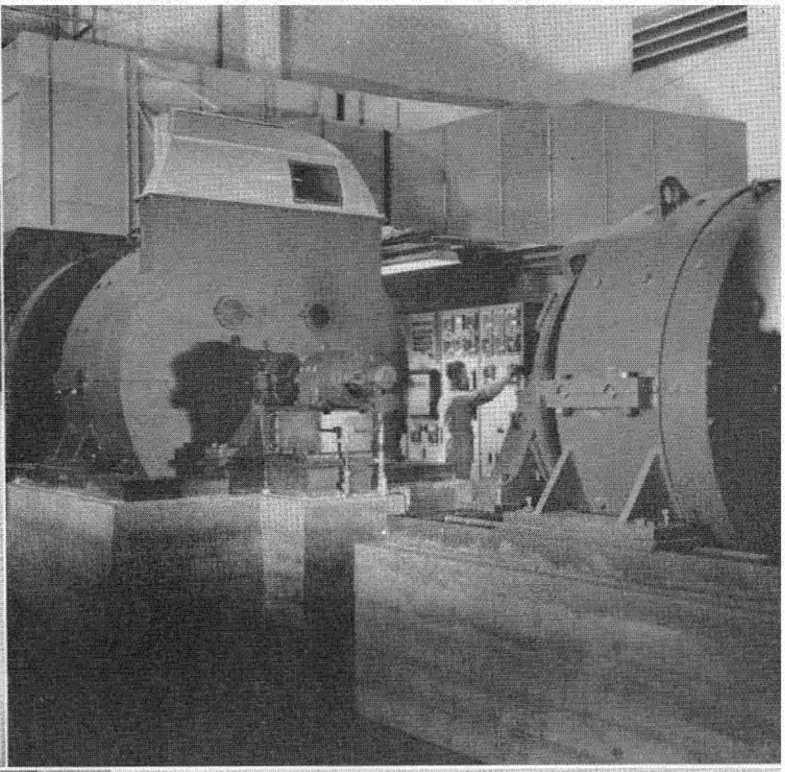
*Guggenheim Aeronautical Laboratory, California Institute of Technology.

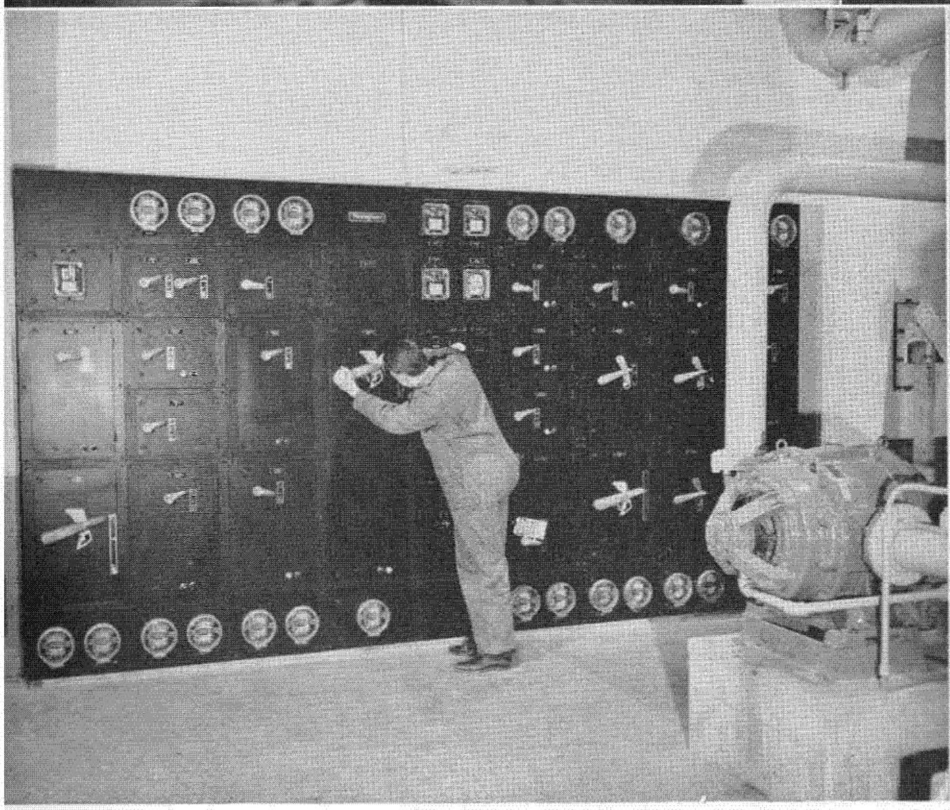
MAIN DRIVE POWER PLANT AND CONTROLS

THE fan system in the Cooperative Wind Tunnel is driven by a two-element electric motor set with a peak rating of 12,000 *hp*. The basic unit of this set is a variable speed direct current motor supplied through a separate motor-generator, which is made up of a variable voltage direct current generator directly coupled to and driven by an alternating current motor of the synchronous type. These three machines, comprising the direct-current system, have a top rating of approximately *2,000 hp* at from 300 to 570 *rpm*. Power requirements beyond the capacity of the direct current system are supplied by an alternating current, adjustable speed, induction motor provided with a wound rotor and slip rings and carrying a short time rating of 10,000 *hp*. The speed and torque of this alternating current machine are controllable by means of a slip regulator of the liquid rheostat type, involving movable electrodes immersed in an electrolyte solution. Both motors are separately forced air cooled and are assembled as a three-bearing set, driving the fan propeller shaft directly through flexible couplings. A portion of the power room is shown in *Figs. 8 and 9*. One of the power panels is shown in *Fig. 10*.

This split system of drive motors was devised to take advantage of standard developed machines in a combination providing flexibility and reliability at moderate cost. The particular combination selected, in conjunction with a controllable pitch propeller fan system, is calculated to permit comparatively high efficiency operation over the complete speed and power range and at the various air densities attainable. This is possible since a substantial portion of the high air speed region may be operated at approximately full shaft speed, thus effecting low slip losses in the induction motor secondary resistive device. The reader is reminded that appreciable losses are inherent in the operation of such an induction motor substantially below its designed top speed. Full advantage is taken of the wind tunnel characteristic that power requirements at various speeds are essentially proportional to the cube function of the comparative speeds, so that at one-half the maximum air speed only one-eighth, or roughly 1500 *hp*, is required to drive the fan.







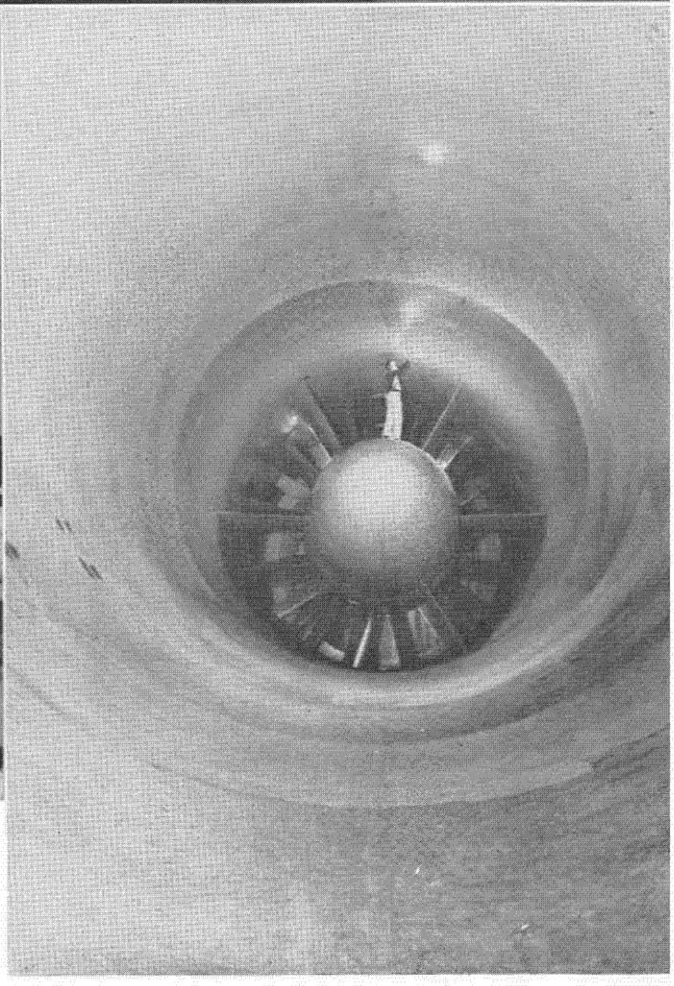


FIG. 8 *(upper left)*: Main power drive. FIG. 9 *(upper right)*: Main power drive, portion of panel, and generator. FIG. 10 *(lower left)*: One of the power panels in power house. FIG. 11 *(lower right)*: Upstream view of the fan system. Diameter of the tunnel in that region is 12 feet 10 inches.

One of the functions of the direct-current component in this system is to enable a quick slow-down of the air in motion in the tunnel by means of absorbing power back into the electrical system through provisions for regenerative braking feed-back. Regenerative braking occurs when the fan is driven at a speed substantially below that corresponding to the combination of air velocity and propeller screw pitch. Under such conditions the fan operates as a turbine to absorb power, which then drives the direct-current motor as a generator to pump electrical energy back into the supply system. This is desirable especially at high air densities, since comparatively large amounts of energy are stored in the high speed recirculating wind stream, which must be stopped before the procedure of quick change of a model rigging cart may be effected.

Thus it may be understood that the direct-current system covers the lower half of the speed range independently, does its share in the upper end of the loading, and regulates to stabilize and maintain precise speed at any setting, besides operating as a brake on emergency slow-downs. The duty of the induction motor is to

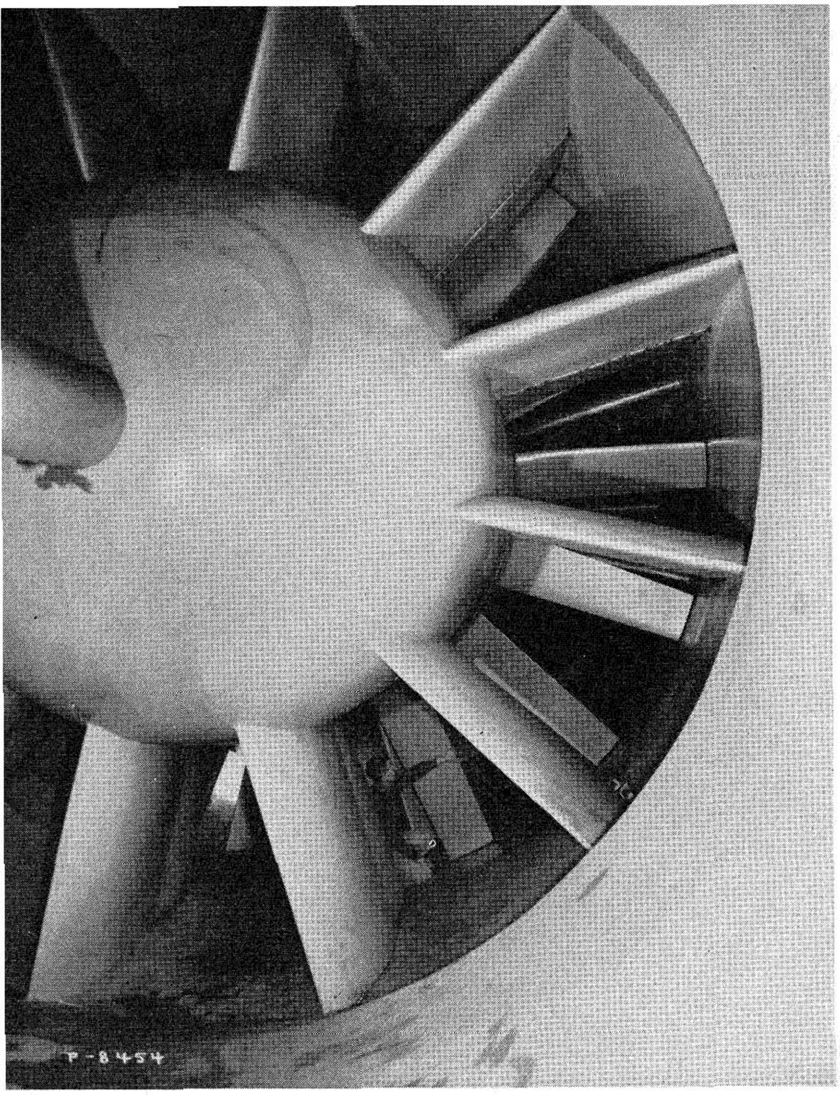


FIG. 12. Downstream view of fan installation showing blades behind prerotation vanes.

carry the major load over the upper half of the speed scale.

Another important requirement for precision testing is met by the adaptability of the direct-current machines to a modern electronic speed regulator with which this drive is equipped.

Electricity is purchased wholesale from the Pasadena Municipal Light Plant. Service is brought to the laboratory underground through a 17,000 volt cable. At the wind tunnel substation the voltage is stepped down to 2300 volts for use in the main machinery and in a separate transformer bank in the same station where it is reduced to 440 volts for auxiliaries and for supplying local transformers for small power and light circuits.

The system of control installed provides for centralized operation at a master control console *(Fig. 2)* by means of remote control and indication circuits. With the exception of selection of type of operation and required speed, all functions are automatic. This involves the extensive use of interlocking and interpretive relays and contactors to initiate such operations as forced draft cooling of the main drive units, circulation and cooling of the slip regulator electrolyte, starting sequences, the allocation of power requirements between the direct-current machine and the alternating-current machine, and the condition of regenerative braking. Among the numerous automatic features is a regulator for maintaining a favorable power factor of the system. This device interprets the phase relationship of incoming current and voltage and adjusts the excitation of the main drive synchronous motor to maintain a preset power factor within the limits of the equipment capacity. Direct control of starting and operation of the main machines is effected through metal clad switchgear, utilizing air-break circuit breakers carrying a fault interrupting rating of 150,000 kilovolt-amperes.

Since this power machinery is used for experimental purposes it is susceptible to unusual load conditions and is therefore provided with an extensive system of interlocks and automatic protective devices. This includes a multi-point strip chart temperature recorder-controller which indicates and records temperature of various machine windings, transformers, tunnel air and slip regulator electrolyte. This device is arranged to transmit warning signals to the console operator on approach of excessive temperatures and to initiate automatic shutdown prior to dangerous conditions.

Excitation and control of the main drive equipment and also for the auxiliaries, such as model power motor generators and compressor drive, is supplied by a separate five unit 125 *hp* set having four exciter generators. Protection of major machines is insured by the use of a storage battery for tripping circuits.

Preliminary tests of the equipment under actual load conditions indicate that satisfactory operation may be expected.

FAN SYSTEM

THE wind tunnel air drive installation comprises the electrical power system described above, directly connected to two tandem mounted fans by means of shafting and flexible coupling.

The requirements that the fan of the Cooperative Wind Tunnel must meet are usually severe: Operating at highest possible efficiency over the entire range of tunnel pressure, it should be able to absorb the entire power input of the 12,000 *hp* drive. The pressure rise across the fan should be reasonably uniform over the cross section of the tunnel and the flow leaving the fan should at all times be purely axial in direction.

The design resulting from these requirements is an unusually flexible fan arrangement, operating at a maximum of 595 *rpm* and consisting of two identical stages and a set of flow straightening vanes, located downstream of the second corner of the wind tunnel. The diameter of the tunnel in that region is 21 feet 10 inches and the hub diameter of the fan is 12 feet. See *Fig. 11.*

Each fan stage consists of a set of 12 stationary prerotation vanes and a set of 16 fan blades with detachable coupling located between the two fan hubs, making it possible to use either the first stage alone or both stages. The prerotation vanes are equipped with adjustable 30 per cent trailing edge flaps. Pitch of the fan blades can also be adjusted. Both of these adjustments can be made by remote control. This control is arranged in such a manner that it is possible to change all of the flap angles and blade angles simultaneously by means of a master push button, or to carry out the change separately for each of the following five groups: prerotation flaps of first stage, blades 1-8 of first stage, blades 9-16 of first stage, prerotation flaps of second stage, blades 1-16 of second stage. It is envisaged that the master push button will be used for all adjustments during a run, while the separate controls will be needed whenever the tunnel pressure or speed is appreciably changed. In the region of high pressures (about one and one-half to four atmospheres) only one-half, *i. e.*, eight of the blades of the first stage will be used. The other half of the blades of that stage and all the blades of the declutched second stage will be set to give no thrust. In the intermediate pressure range (about one and one-half to three-fourths atmospheres) all blades of the first stage will be used, while both stages will have to operate at the lowest tunnel pressures. At the proper combination of blade pitch and flap angles the flow will leave the fan with approximately axial direction, *i. e.*, without appreciable rotation. Any small rotation left in the flow is removed by means of a set of six straightening vanes located just downstream of the second fan stage.

The fans are coaxially mounted in the east run of the tunnel near the corner adjacent to the power house. They are 21 feet nine and one-half inches in diameter, with one-quarter inch nominal clearance between blade tip and tunnel shell. See *Fig. 12*. Each fan carries 16 forged aluminum alloy blades held in socket assemblies, which are bolted to flats on the periphery of a seven foot diameter hub. The blade socket in which the inner end of the blade is held is a forged alloy steel hollow cylinder, flanged at the hub attaching end. The blade enters and is rotatably mounted in the socket near its outer end on three angular contact ball bearings. The outer pair of bearings carry the centrifugal force load of about 100 tons.

In addition to the function already mentioned, the blade socket houses a series arrangement of two bevel gear units and a planetary gear unit connecting the end of the blade with the pitch control shaft, which enters the socket through the flange. About 2600 turns of the latter are required for one turn of the blade. Chevron seals are provided where blade and pitch control shafts enter the socket, to prevent loss of lubricant.

The fan hub is a steel weldment consisting of an outer forged ring, 16 inches wide by three and one-half inches thick, joined to a sleeve 20 inches long by 29 inches in diameter by two web plates two and one-half inches thick. The 16 flats on the outer periphery are machined to give the blade axis an upstream angular inclination of one degree 18 minutes from the plane of rotation. Under these circumstances centrifugal force imposes a moment on the blade which counteracts a portion of the moment due to air thrust. The fan hub is pressed on and keyed to a forged alloy steel solid shaft which is 14 inches in diameter where it passes through the hub, and 10 feet long. The fan shaft is supported near the end by two spherical self-aligning roller bearings. The downstream bearing mount contains, in addition to the radial bearing, a thrust bearing to carry the full load air thrust of 18 tons.

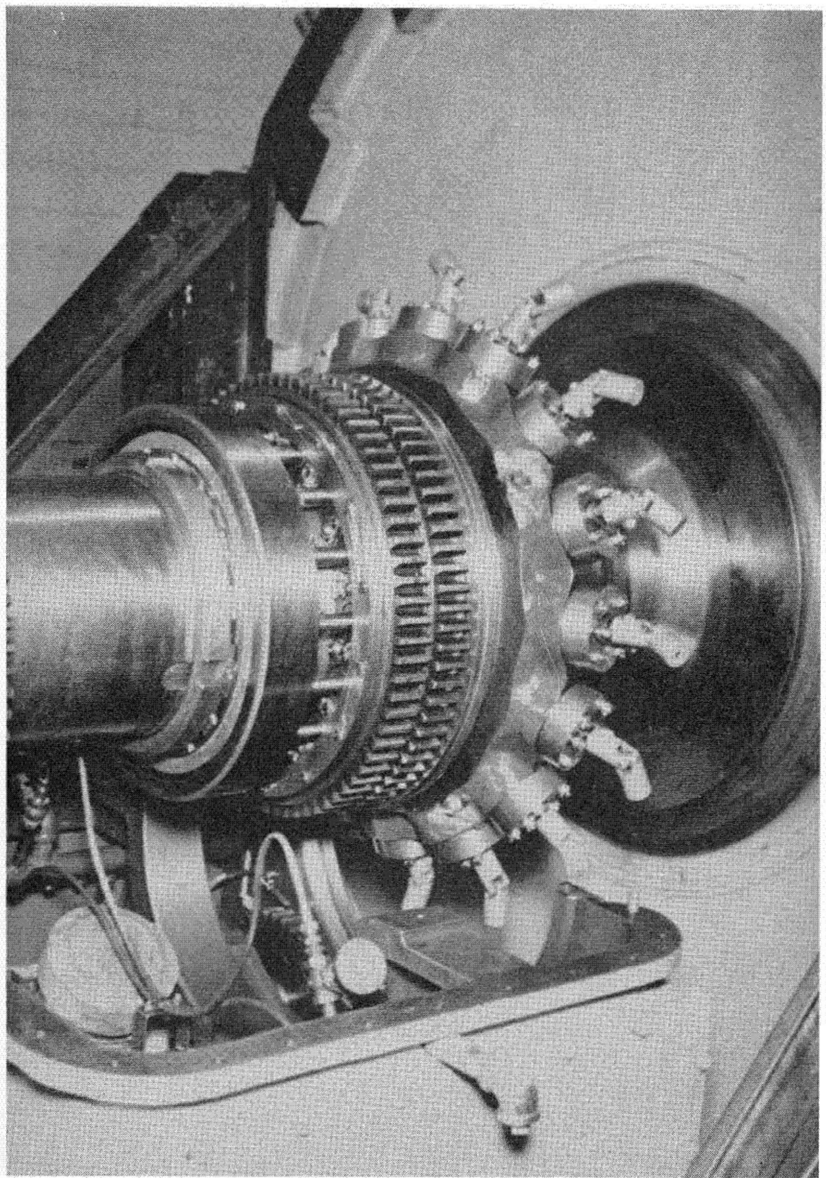
A declutchable flexible coupling connects the two fan shafts and provides for operation of the upstream fan singly or the two fans as a unit. When the tunnel is operating with the upstream fan alone, the blades of the downstream fan will be set at full feather pitch to keep the fan slowly windmilling and prevent Brinnelling of the roller bearing races. A 16-inch diameter hollow steel drum shaft 30 feet long supplies the connection between the upstream fan shaft and the motor in the power house. A plain seal bearing supports the motor end of the drive shaft and a spherical roller bearing the fan end. The drive shaft is connected to the upstream fan shaft by a flexible coupling which is identical to the one connecting the two fan shafts. Motor and drive shaft are connected by an extended type flexible coupling which will permit an offset of one-fourth inch between the shafts and a change of two and one-half inches in the gap between them. These allowances are necessary because of expansion and a strain in the tunnel structure.

The 22-inch long babbitted bearing is swivel mounted on the tunnel shell and carries the 10-inch diameter drive shaft journal. In addition to its function as a support, the bearing provides a seal against loss of air to or from the tunnel. Hub oil is fed to a circumferential cavity at the center of the bearing from an overhead supply tank and flows through the clearance space around the journal toward both ends of the bearing. Flow of oil from the atmospheric end is collected in a drain tank vented to the atmosphere, and the flow from the tunnel end in a drain tank vented to the tunnel. Float-controlled pumps return the oil from the drain tank through a filter to the overhead supply tank. The oil supply tank is vented in such a manner that the air pressure above the oil is either atmospheric or tunnel pressure, whichever is the higher.

The drive shaft is completely enclosed in a steel tube 22 feet long, one end of which is welded to the tunnel shell and the other to the upstream nose of the nacelle. All parts of the fan installation, including fan shafts, bearing mounts, hubs, sockets, etc., are enclosed in a 12-foot diameter by 50-foot long nacelle.

The flow of air through the fan section takes place in the annular space between the nacelle and the tunnel shell. See *Fig. 12*. The nacelle is supported by means of three sets of vanes which extend radially between the nacelle and the tunnel shell. A set of 12 equally spaced prerotation vanes is located just upstream of each fan, and a set of six straightening vanes a short distance downstream of the fans. The trailing third of each prerotation vane is attached to a shaft located at the forward end of the flap. The shaft is carried on ball-bearing mounts, one just inside the wall of the nacelle and

FIG. 13. Pitch control gear box, showing connection to control rods.



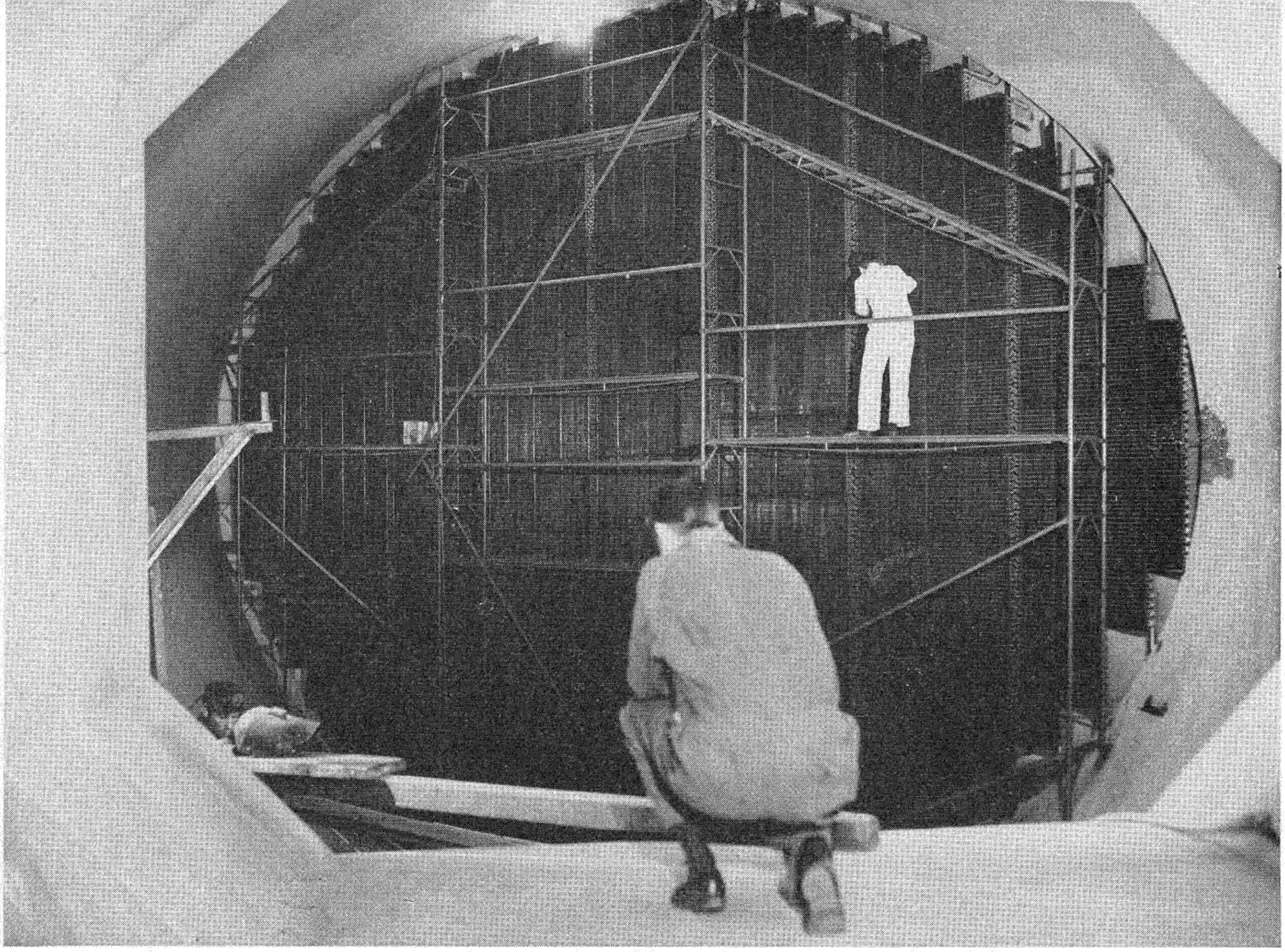


FIG. 14. The cooling radiator at corner upstream of working section consists of 80 units of finned copper coils.

one just outside the tunnel shell. The shaft is sealed at the shell by means of a chevron-packed stuffing box.

The flap shaft is rotatable by means of a lever, nut, and lead screw mechanism. The lead screws controlling the flaps on each set of prerotation vanes are connected together by means of universal joint assemblies so that the 12 flaps of a set can be rotated as one. There is a 25¾-inch wide continuous slot in the nacelle at each fan, through which the blades project into the air stream.

A continuous fairing structure which is attached to the hub fills the nacelle slot except for a three-eighths-inch clearance gap at each side. The 22-inch diameter blade access holes in the fairing are filled by cuffs which are attached to the blades. Seal plates extending between the hub and the fairing structure on both sides of the fan completely blank off the blade socket pockets and minimize windage losses. A differential gear box is mounted on each fan shaft on the upstream side of the fan. This gear box, shown in *Fig. 13*, gathers the 16-blade socket pitch-control shafts and provides a mechanical connection between control shafts attached to rotating and non-rotating structure.

Two group-control shafts project from the upstream gear box and a single one projects from the downstream box. The blades on the upstream fan may be connected to either of two pitch-control groups by means of a manual adjustment within the differential gear box. The two group-control shafts on the box provide separate pitch control for the two-blade group. The 16 blades on the downstream fan are controlled in a single group. Extensions of the three-blade pitch control shafts from the differential gear box pass through stuffing boxes at the tunnel shell and connect to worm gear reducer nuts mounted on concrete blocks on the floor. The two-flap pitch control extension shafts connect to identical floor units. Universal joint assemblies are incorporated in all five control lines to provide for the relative motion of tunnel and ground.

Actuating power, control, and indication for flap and blade pitch change are supplied by an external pitch control system. This is an assemblage of electric motors, miter gear units, magnetic clutches and special gear boxes, mounted on a concrete foundation on the floor near the fan section.

Each of the two-flap and three-blade pitch-control shafts continues on from the worm gear reducer and couples into the output shaft of a special gear box. These gear boxes serve several purposes. They contain dials from which the pitch can be read, and fine and coarse autosyn generators which transfer pitch indication to the console in the control room. They also mount the limit switches which control travel limits of blade and flap. In addition the boxes provide facilities for changing the gear ratio between the input and output shafts if it becomes desirable to alter the rate of pitch change. The motors and auxiliary elements of the system are arranged and electrical controls are set up so that the special gear boxes may be driven simultaneously by the master motor or independently by the individual motors.

The main drive lubricating system provides a continuous flow of cooled and filtered lubricating oil through the nacelle roller bearings and differential gear boxes. In the system are a storage tank, filter, filter circulating pump, two supply pumps, oil cooler, distributing manifold with pressure relief line back to the storage tank, orifice plates, control valves, distributing piping, teleflow meters, temperature indicators, thermo-switches, and collection piping. The 200-gallon storage tank is hung from the east side of the tunnel near the large hatch. The pump, filter, cooler, and distributing manifold are grouped on the floor near by.

In operation, oil is supplied at the rate of 12 gallons per minute to the distributing manifold, from which it flows into the supply lines and to the various nacelle units. After flowing through the units it drains into the collection piping and is returned to the storage tank. The latter is vented to the tunnel so that flow conditions are independent of tunnel pressure. In each supply line near the nacelle unit a teleflow meter is installed. This is a device which prevents operation of the main drive motor whenever oil flow is not established.

A temperature indicator and thermoswitch are mounted in the case of each roller bearing at a point where they are in contact with the outflowing oil. The temperature indicator gives a remote reading at the console in the control room. The thermoswitch stops the main drive motor if the oil temperature exceeds 190 degrees *F*.

COOLING AND DEHYDRATING

THE cooling specifications of the Cooperative Wind Tunnel call for continuous operation of the equipment at a power input of 12,000 *hp*, with the temperature of the air inside the tunnel limited to about 125 degrees *F*. The radiator, which removes the corresponding amount of heat, *i.e.*, about 500,000 *B.t.u.* per minute, shown in *Fig. 14*, is located in the fourth wind tunnel corner just upstream of the contraction. It consists of 80 units of finned copper coils, each coil having three rows of tubes in depth.

In order to insure the smallest possible pressure drop across this radiator, it was placed with the tubes running parallel to the plane of the corner ellipse. The corner vanes, similar to those shown in *Fig. 6*, turn the air by only 45 degrees; thus the air arrives normal to the radiator face and is turned by an additional 45 degrees, completing the full 90 degree turn, on leaving the radiator. This final turn is achieved by means of small turning vanes that are integral parts of the radiator fins. The radiator coils are provided with water circulation entering and leaving through the tunnel corner vanes. The water is cooled by circulation over a cooling tower. About 3,600 gallons per minute of cooling water can be circulated in this system.

Recently it has become known that the relative humidity of the air is one of the important parameters of high speed flow. Furthermore, any appreciable accumulation of moisture would cause considerable inconvenience and complications. Therefore, it became advisable to control the humidity of the air inside the tunnel. This is done by means of a so-called dehydrator, an air

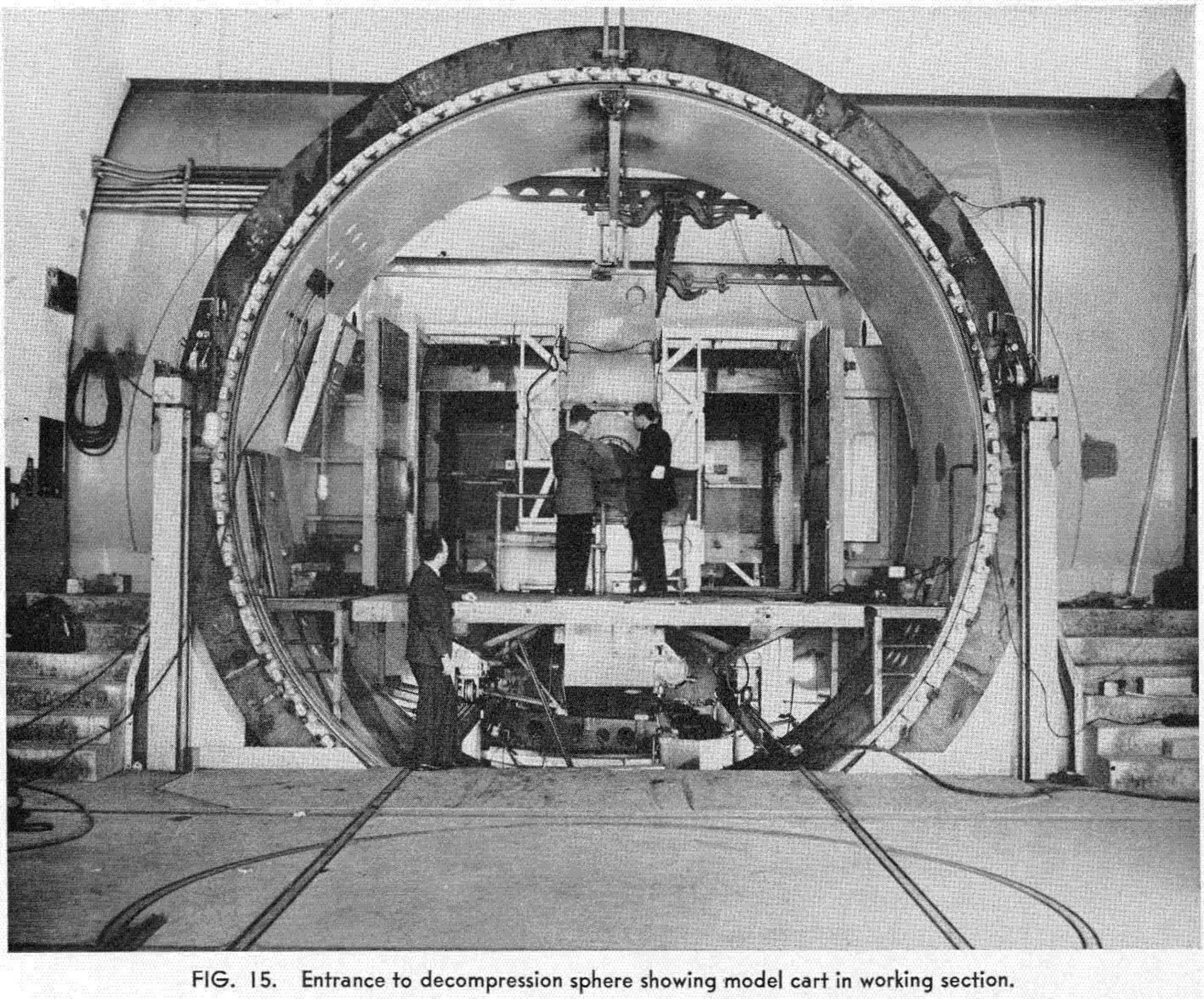


FIG. 15. Entrance to decompression sphere showing model cart in working section.

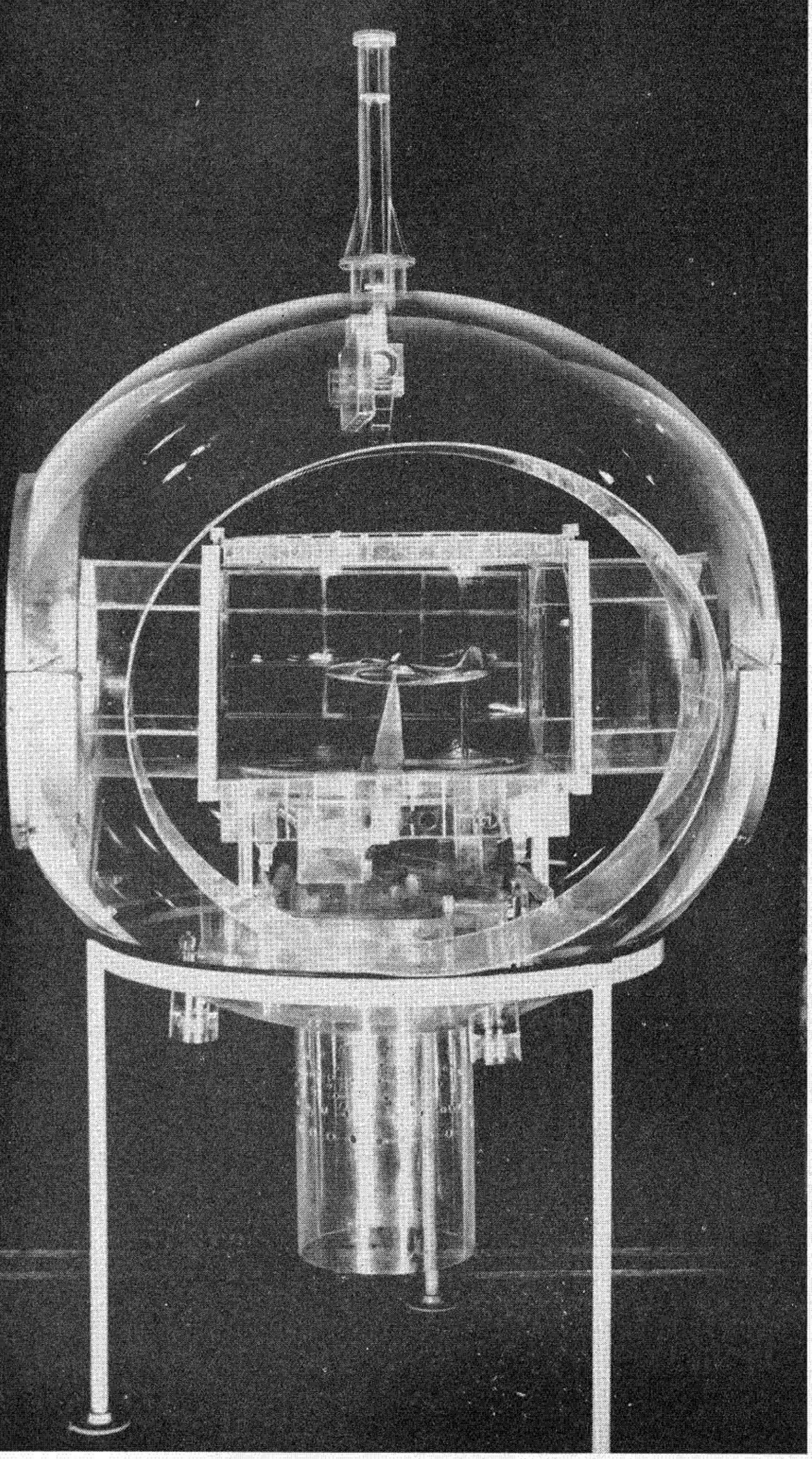


FIG. 16. View of plastic model of decompression sphere looking into the sphere through large door.

to brine heat exchanging coil which reduces the temperature of the air passing over it to about 40 degrees *F*.

The brine is cooled by ammonia, which is piped to the wind tunnel from the neighboring refrigerating plant of the California Consumers Corporation. During periods of shutdown, the tunnel air can be circulated through the dehydrator by means of a 3,000-*cfm* circulating fan. Furthermore, all fresh air entering the tunnel through the air compressors also passes over the dehydrator before entering the tunnel.

WORKING SECTION

THE working section of the Cooperative Wind Tunnel, having a cross-sectional dimension of 8½ by 12 feet, is located within a steel sphere 31½ feet in diameter, shown in *Fig. 15*. This sphere is essentially an air lock to permit access to the working section without disturbing all of the air in the steel duct of the tunnel, which contains some 185,000 cubic feet of air. It is frequently necessary to service the high-speed motors in the model, or to adjust delicate recording devices. Should the tunnel be under pressure at the time, it would require several hours to release this pressure and compress the air to its original testing pressure after adjustments had been made. A plastic model of the sphere and working section were constructed as shown in *Figs. 16, 17, and 18*.

With the large decompression sphere, less than one-tenth of the air inside the tunnel need be released, and the operators can work on the model at normal atmospheric pressure. The time required to close off the sphere, reduce it to atmospheric pressure, change or adjust the model, and prepare for testing at the original pressure is approximately seven minutes. Other tunnels exist where the operators may enter the pressurized area through a small air lock, but there is constant danger of severe discomfort should the body be subjected to sudden changes in pressure. The tunnel is pressurized with three air compressors located in the power house. About three and one-half hours are required to bring the pressure in the tunnel up to about 45 pounds per square inch.

The decompression sphere is provided with a massive steel door 19 feet in diameter, shown in the partially closed position in *Fig. 19* and completely closed in *Fig. 20*. Two large gate valves are provided at the entrance and exit of the working section, which seal off the sphere and working section from the pressurized tunnel. The entrance to the working section from the tunnel is shown in *Fig. 21*. The opening downstream is shown in *Fig. 22* with the gate valve completely open. The gate valve completely covers this opening when model changes are to be made during operation. *Fig. 23* shows the valve starting to close.

The models to be tested are mounted on large steel tables or carts, which can be rolled into or out of the sphere on steel tracks when the main door is open. *Fig. 24* shows one of these tables in position, ready for entrance into the sphere. The table is then rolled into the sphere and into position as shown in *Fig. 25*. The steel cart or table is then lowered into place by mechanical arrangement. The model supports rest on oil pads and their motion is restrained by devices to be described in more detail later. The multiple plugs to the recording devices, previously arranged on the table, are connected directly with the sensitive indicators and gages in the control room. After the suitable adjustments have been made, the large door to the decompression sphere is closed and the gate valves into the tunnel are opened; the unit is then ready for operation.

As indicated in the next section, three types of model supports are provided. While a test is being conducted, using one table, models can be installed for testing on the other tables outside the tunnel. When tests on the first model are completed, the table or cart is rolled out of the tunnel, the second is moved in, and the next test is ready to proceed. The use of the multiple model table saves hours or even days of tunnel time whenever a new model is tested. Furthermore, it is of interest to note that these tables or carts can be run into one of the model shops, where mounting of the models can be done behind drawn curtains. This provision makes it possible for different companies to have models at the wind tunnel simultaneously and still maintain the desired security.

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.

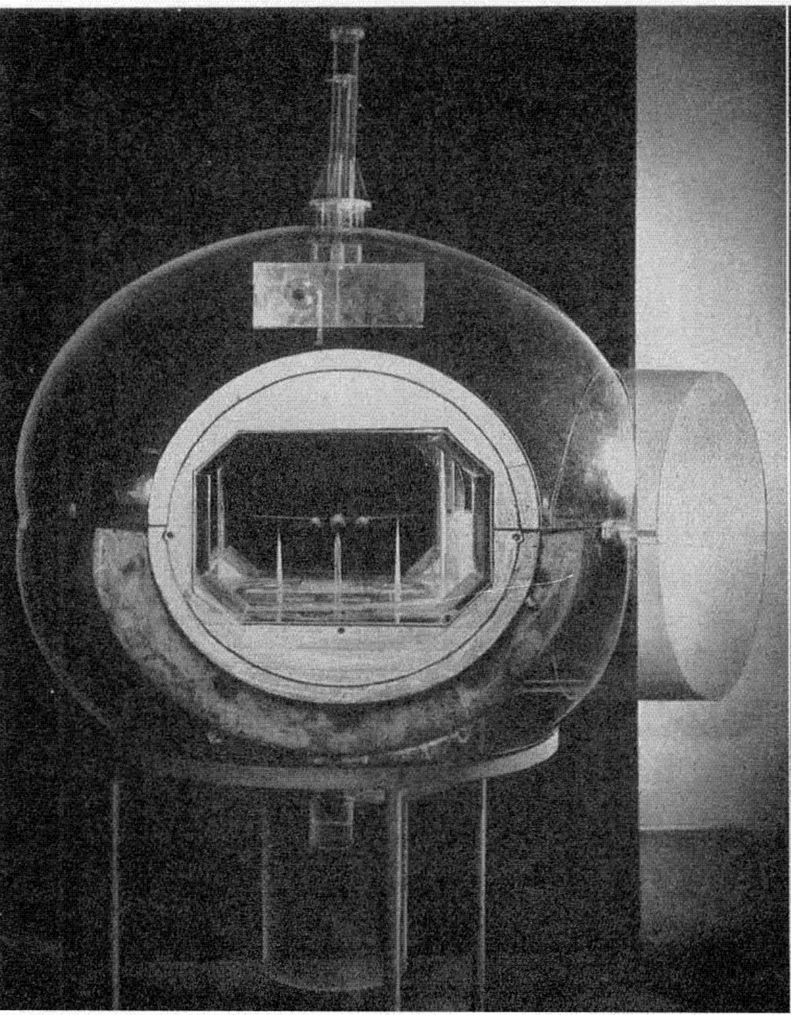
There are three ways in which the model may be supported in the tunnel working section. For determining the properties of wing sections, wing sections with flaps or other control devices, stub wing nacelle models, or other models which can be supported from wall to wall in the tunnel, a ring supporting 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.

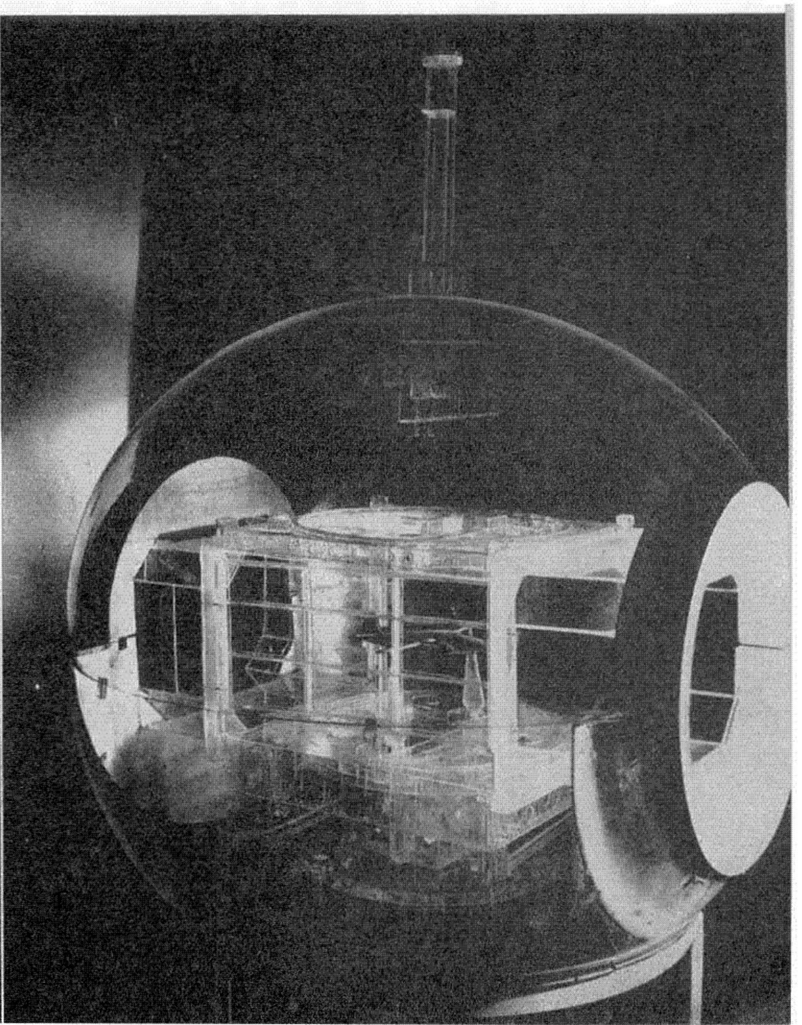
The second model supporting system is that most commonly associated with wind tunnels—the three-point system (see *Fig. 27*). In this, a scale-size model of a complete airplane is supported by means of two vertical model support arms (trunnion arms) attached to points on the wings, and a third strut 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.





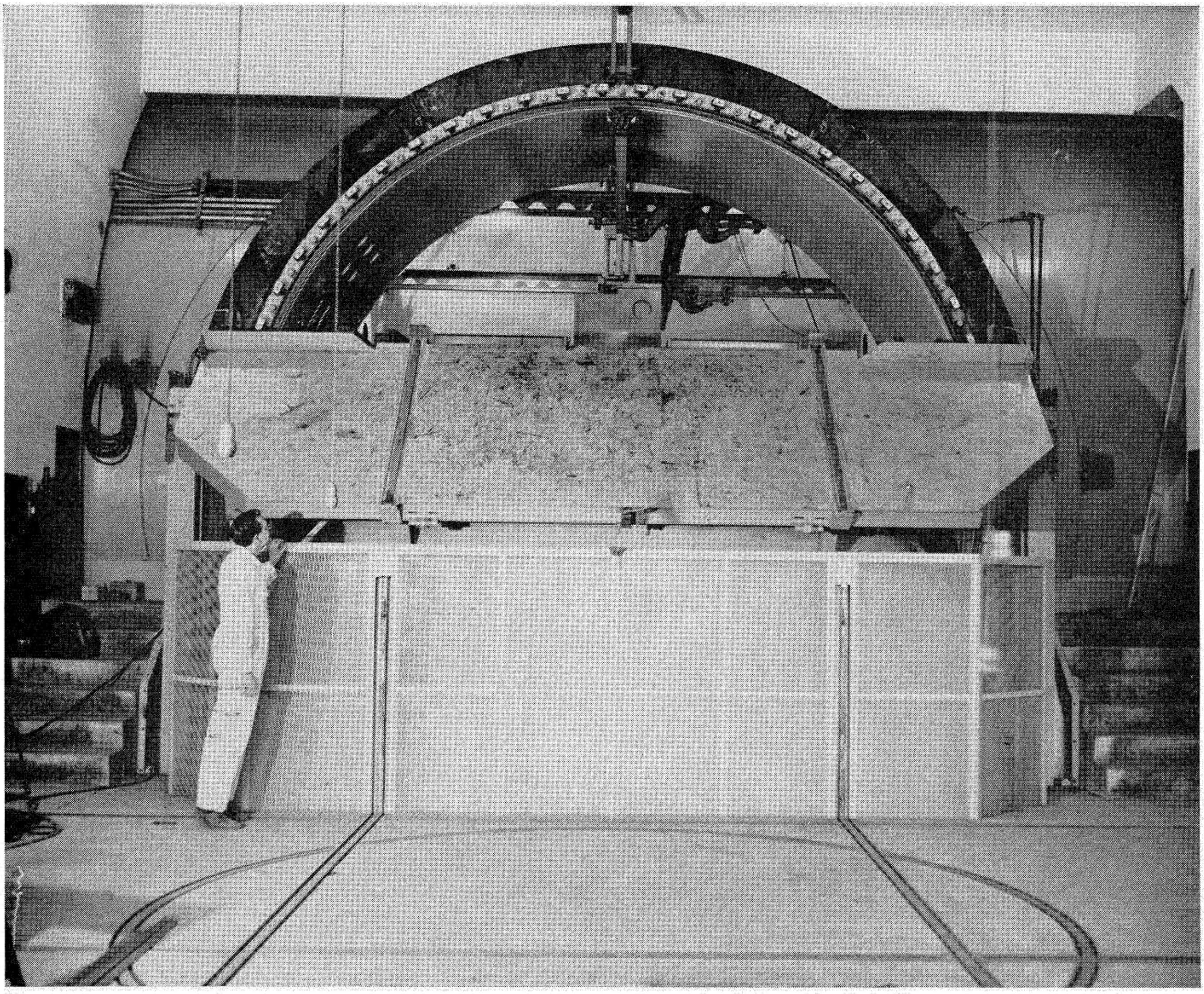


FIG. 19. Showing massive steel door of decompression sphere partially closed.

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

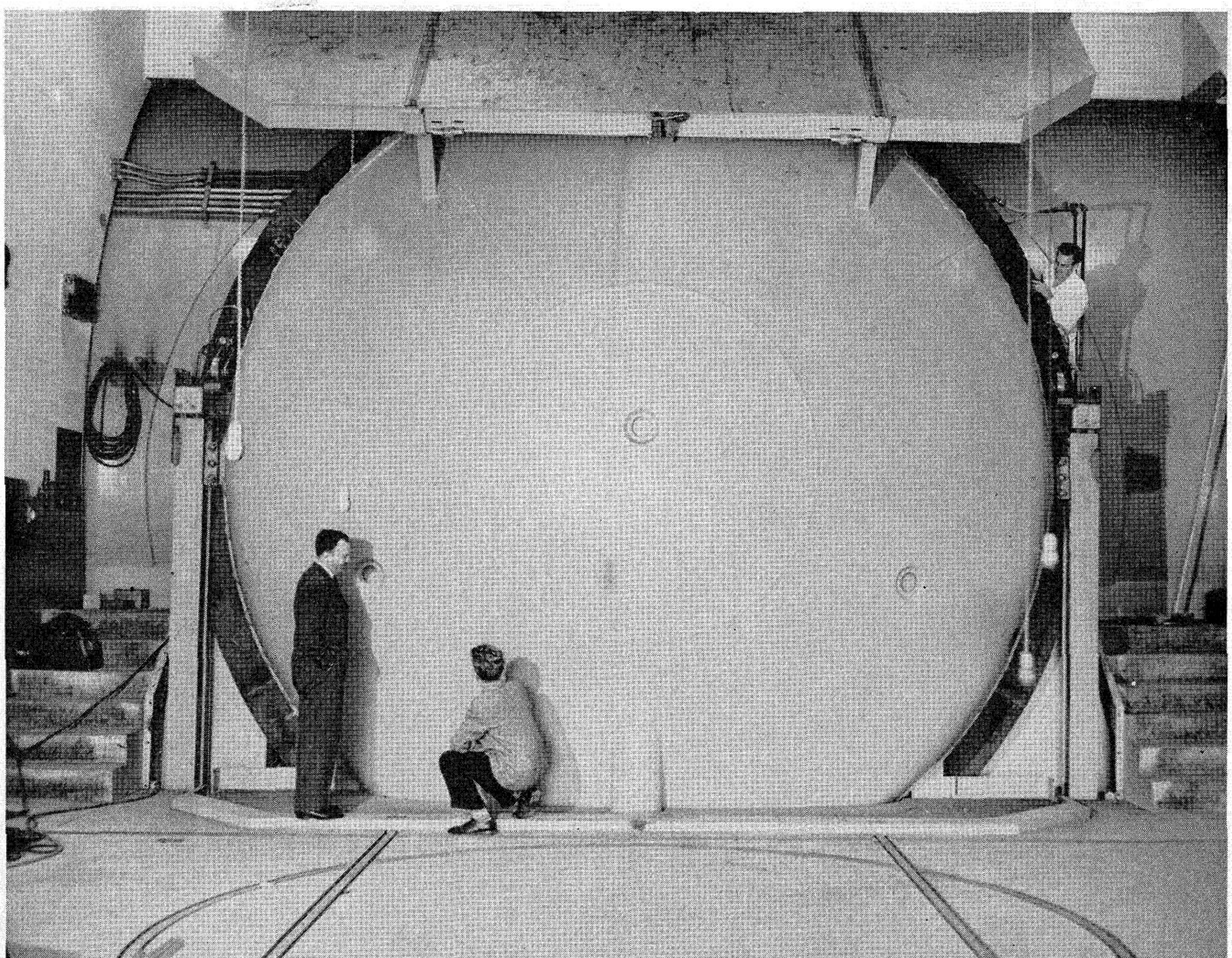


FIG. 20. Door of decompression sphere is fully closed in this view.

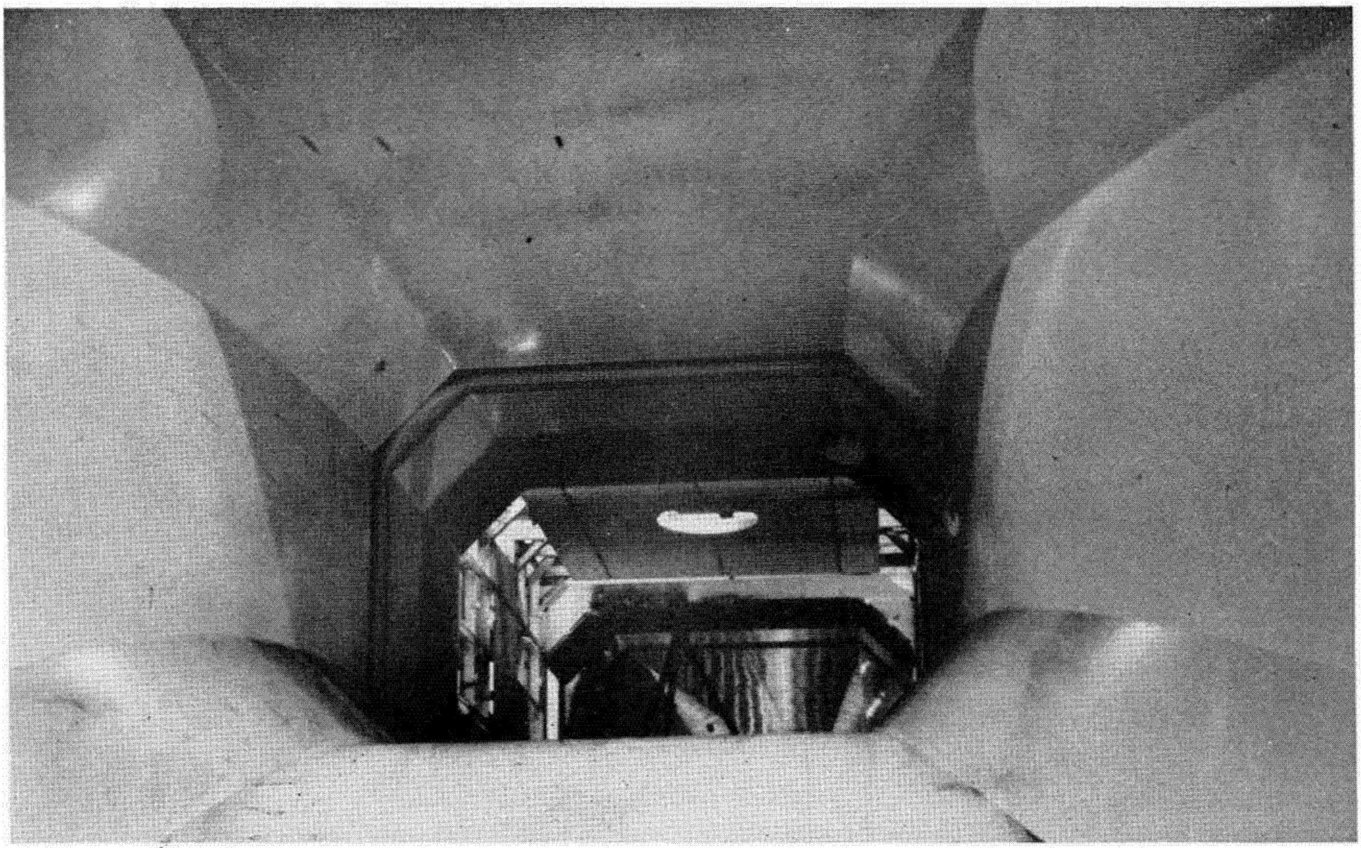


FIG. 21. View showing contraction entrance to working section.

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.

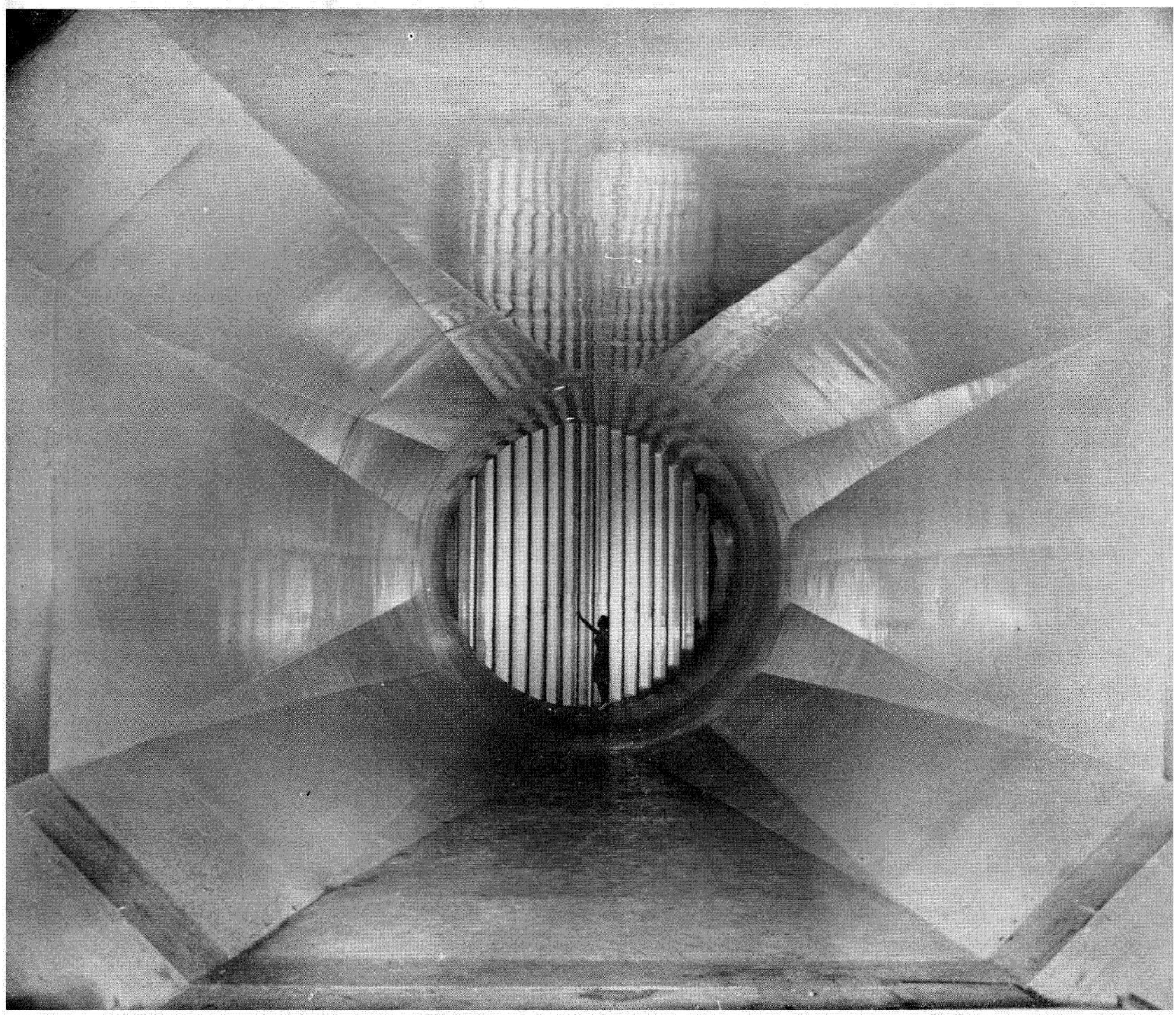
In order to rotate the model in yaw, a vertical axis is established on the large ring and the whole ring is rotated by means of a remotely controlled worm and gear drive, with the large ring rotating on the flat pads of the base frame. The worm-gear housing is actually connected to the base frame through,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



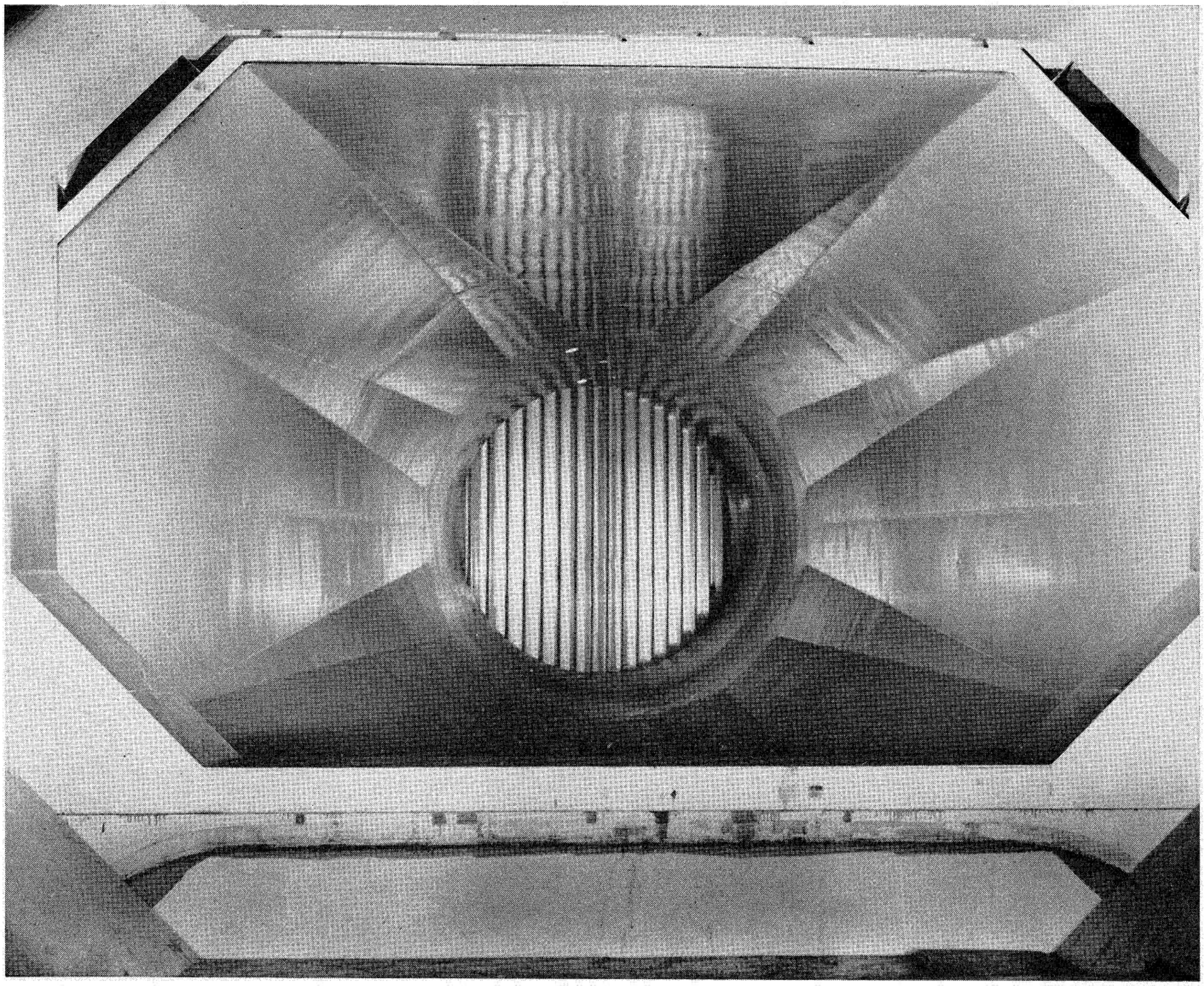


FIG. 23. Exit downstream from working section, showing gate valve beginning to close.

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

TABLE NO. I—INDICATOR RANGES IN THE TATE-EMERY SYSTEM

Tate-Emery Indicator	High Range	*Smallest Dial Division	Low Range	*Smallest Dial Division
Venturi Pressure (lbs./sq. ft.)	0 to 1,000	1	0 to 100	0.1
Lift Force	0 to +30,000	50	0 to +3,000	5
(pounds)	0 to −15,000	50	0 to −1,500	5
Drag Force	0 to + 5,000	10	0 to + 500	1
(pounds)	0 to − 2,500	10	0 to − 250	1
Pitching Moment	0 to +10,000	20	0 to +1,000	2
(foot-pounds)	0 to −10,000	20	0 to −1,000	2
Rolling Moment	0 to +10,000	20	0 to +1,000	2
(foot-pounds)	0 to −10,000	20	0 to −1,000	2
Yawing Moment	0 to +10,000	20	0 to +1,000	2
(foot-pounds)	0 to −10,000	20	0 to −1,000	2
Cross Wind Force	0 to + 5,000	10	0 to + 500	1
(pounds)	0 to − 5,000	10	0 to − 500	1

*The electrical system furnished by the International Business Machines Corporation indicates and records to one-tenth of the smallest dial division.

to the system produces a readable signal at the indicator in the control room.

INDICATING SYSTEMS

Hydraulic connections from the weighing sides of the capsules transmit pressures to the pressure-sensitive elements in the Tate-Emery indicator cabinet located in the control room. The indicator cabinet is shown at the right of *Fig. 30*. Combinations of pressure-sensitive elements in each indicator permit weighing pressures to

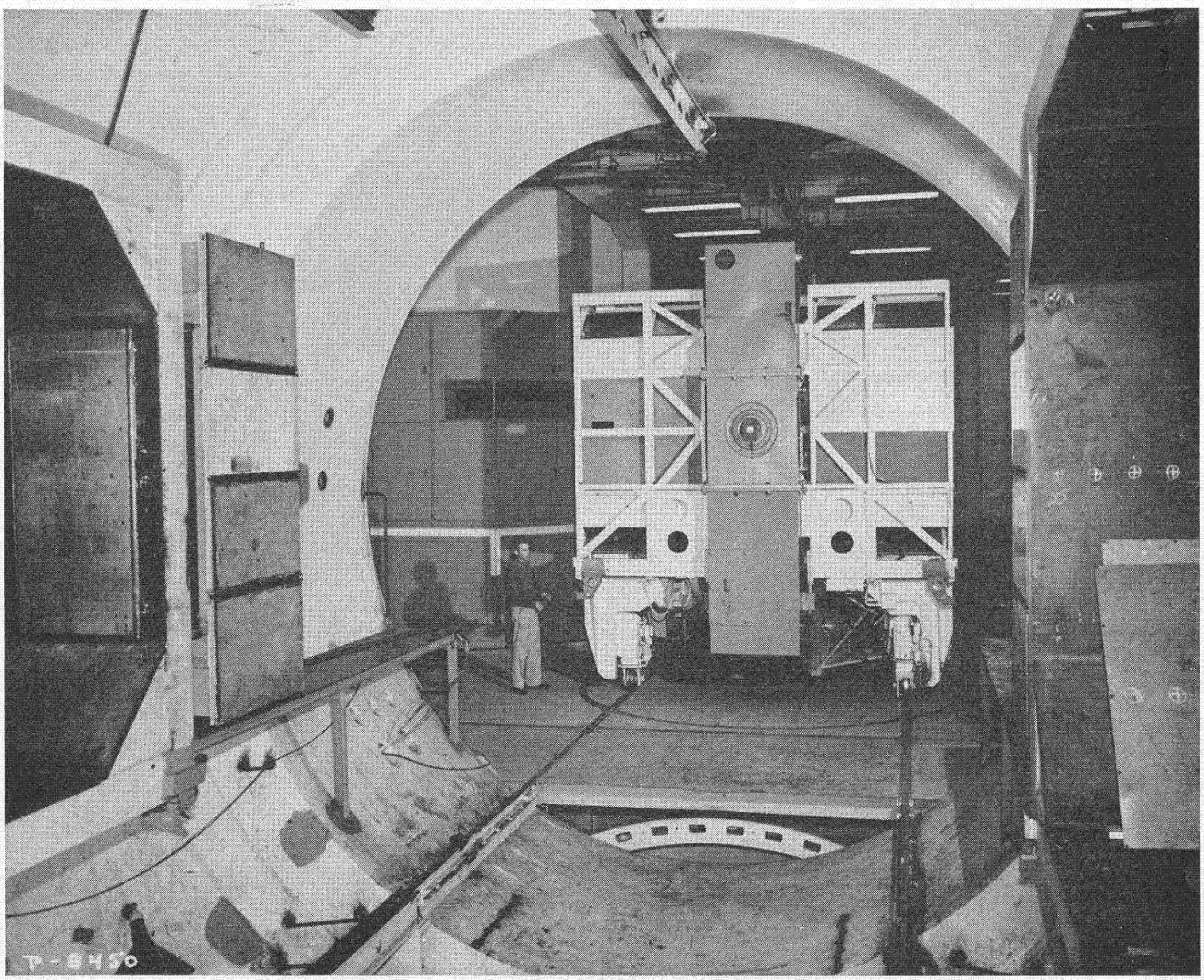
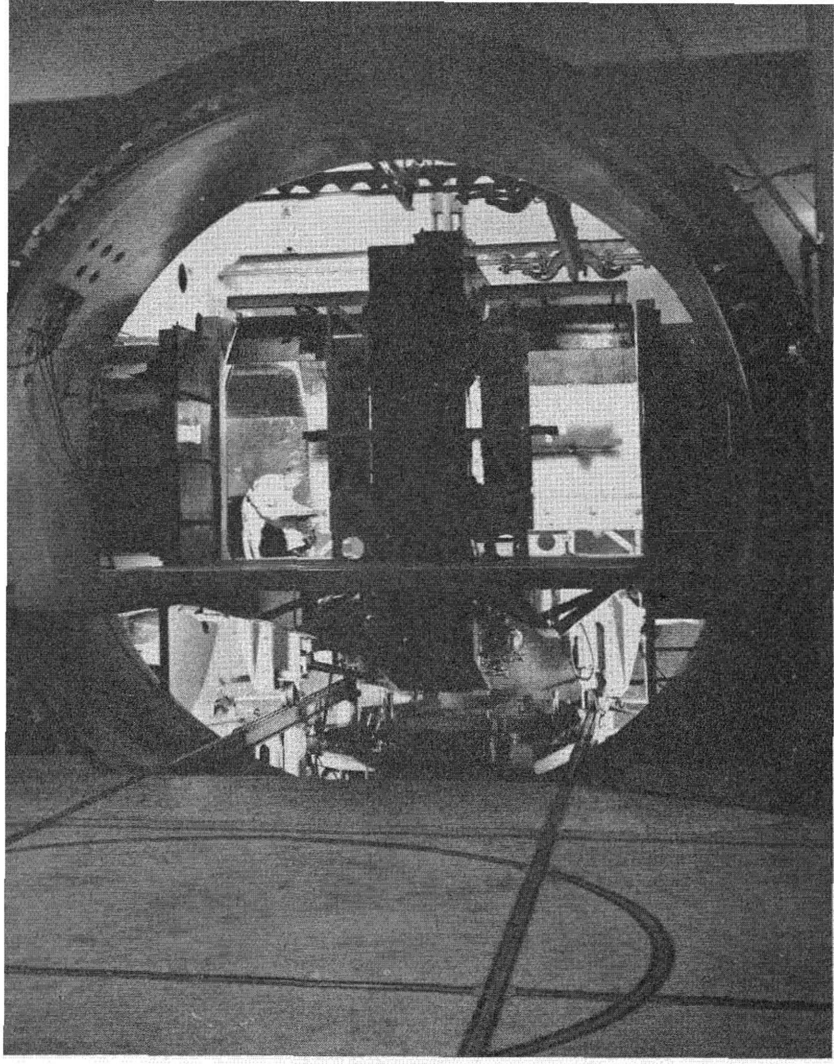


FIG. 24. The model cart is shown at entrance to decompression sphere ready to be rolled into working section.



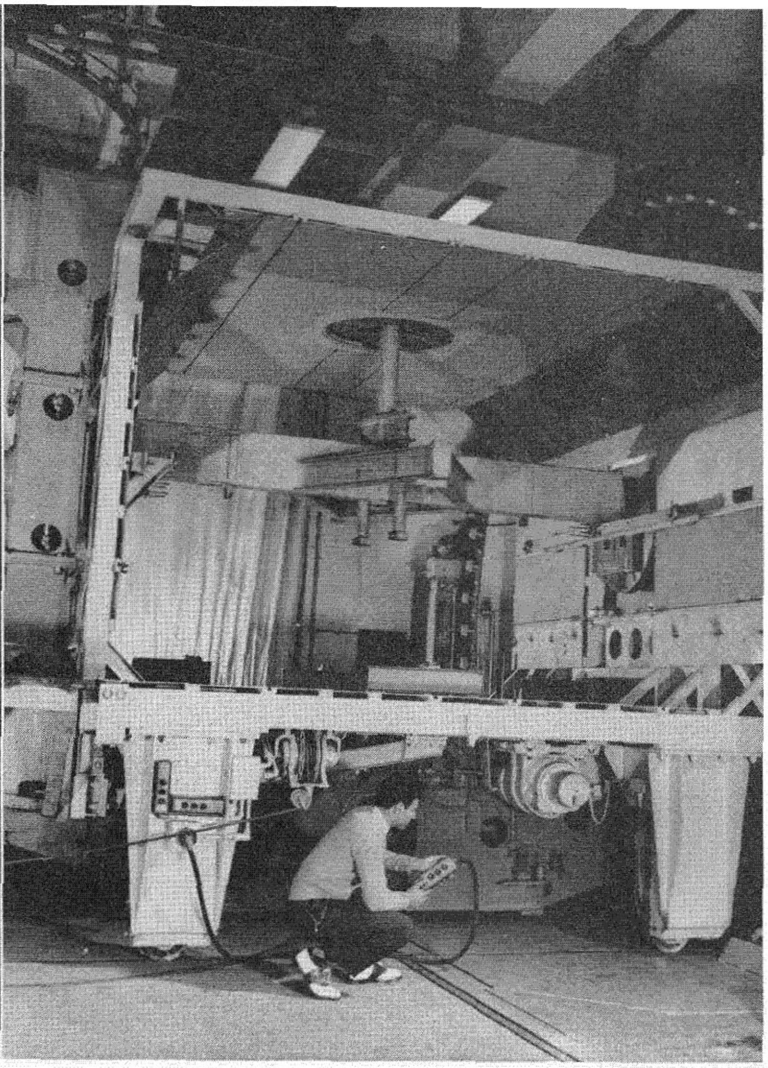


FIG. 25 *(at left)*: Showing model cart in position in working section. FIG. 26 *(at right)*: End view of model cart showing surface plates.

be added to give the sum, or subtracted to give the difference, of the pressures due to forces being exerted in the tunnel suspension system.

In the case of a single indicator, a servo-motor (an outside source of energy) tends to prevent any movement of the pressure-sensitive element due to changes in hydraulic pressures. The servo-motor system in the indicator is air operated. Air is employed because, in association with an orifice, it provides an exceedingly simple as well as exceptionally sensitive device without the necessity for complex auxiliaries. Air enters the system through a reducing valve and a filter and functions through a simple jet orifice system. Oil pressure from the weighing side of the hydraulic capsule enters the pressure-sensitive element. The servo-motor balances the pressure through an isoelastic spring system by a direct pull on the slide rod, tending to prevent movement of the pressure-sensitive element. The force required to restore the element to its original point (the restoring force) is measured by the isoelastic spring system. The isoelastic spring system is a special type helical spring having a linear characteristic between force exerted and deflection. Temperature errors are eliminated by the use of isoelastic metal, which is an elinvar type of alloy.

Indication of the force required to balance the pressure-sensitive element is produced by means of a rack and pinion which operate off the slide rod of the servo-motor. The linear motion of the slide rod produces rotation of the pinion, which in turn rotates the pointer on the front of the Tate-Emery indicator dial.

High and low ranges are provided for all Tate-Emery indicators. These ranges have a ratio of 10 to 1; *i. e.*, the high range has 10 times the capacity of the low range. Change of range can be made during a test by merely depressing a switch. Zero adjustment of each indicator, to compensate for dead weight changes, is accomplished by flicking a toggle switch. Zero adjustment and change of ranges can be made at each indicator or at the I.B.M. lamp bank located on the console.

Indicator ranges provided in the Tate-Emery system are shown in Table I.

AUTOMATIC MEASURING AND RECORDING

ONE of the outstanding features of the tunnel is a group of devices known as I.B.M. automatic measuring and recording machines. They were invented, designed, and built by the International Business Machines Corporation especially for the Cooperative Wind Tunnel and mark one of the latest advances in the field of measuring and computing equipment to meet new requirements in the field of science. When the tunnel was in its formative stages, Dr. A. L. Klein pointed out that if devices were to be developed enabling not only the automatic measuring of test data, but also recording of punched cards, the latter could be automatically processed by I.B.M. standard equipment to compute dimensionless coefficients. The problem was presented to International Business Machines Corporation with the request that development of suitable devices be undertaken and that standard equipment for computing be furnished.

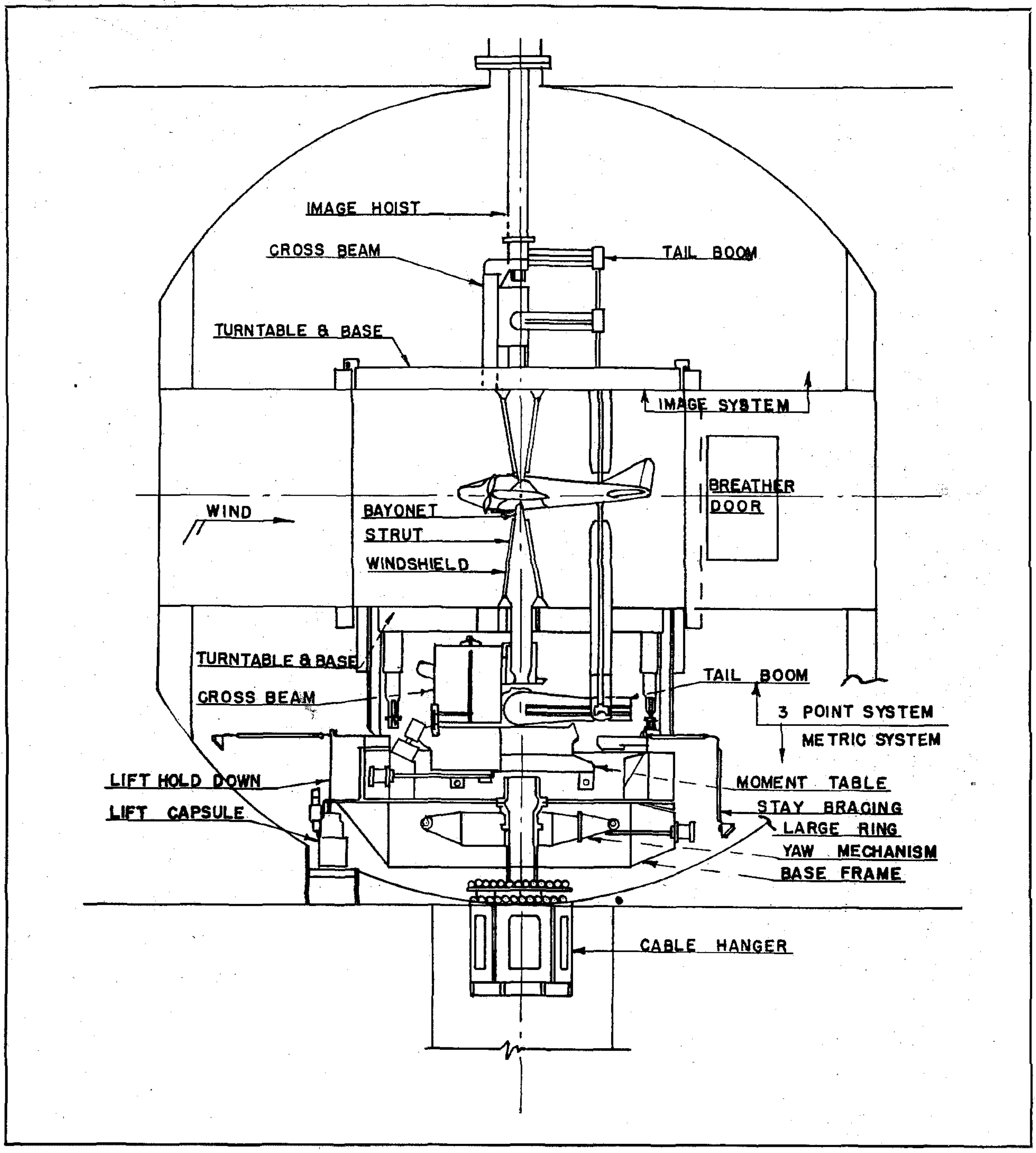


FIG. 27. Diagrammatic view of three-point system and metrical system.

Thomas J. Watson, president of I.B.M., requested J. W. Bryce, I.B.M. senior scientist, to take charge. The research and development work were started under the supervision of A. H. Dickinson, senior engineer.

R. I. Roth and J. N. Wheeler, assistant engineers, and Mr. Dickinson collaborated in inventing and developing mechanisms and circuits for accurately measuring the settings of instruments and for translating the measurements into digital form for indication and recording. The entire development was carried out in accordance with the requirements of the Cooperative Wind Tunnel. Catherine Bryan, I.B.M. system's servicewoman, collaborated in developing a computing procedure using the company's standard equipment for performing mathematical computations on punch cards prepared by I.B.M. automatic measuring and recording machines.

A model embodying the principles was constructed and after a period of testing was approved. Production of a complete complement of equipment was started, and its installation at the Cooperative Wind Tunnel was completed in December, 1944. This equipment was presented to the California Institute of Technology as a gift by Thomas J. Watson, president of the International Business Machines Corporation.

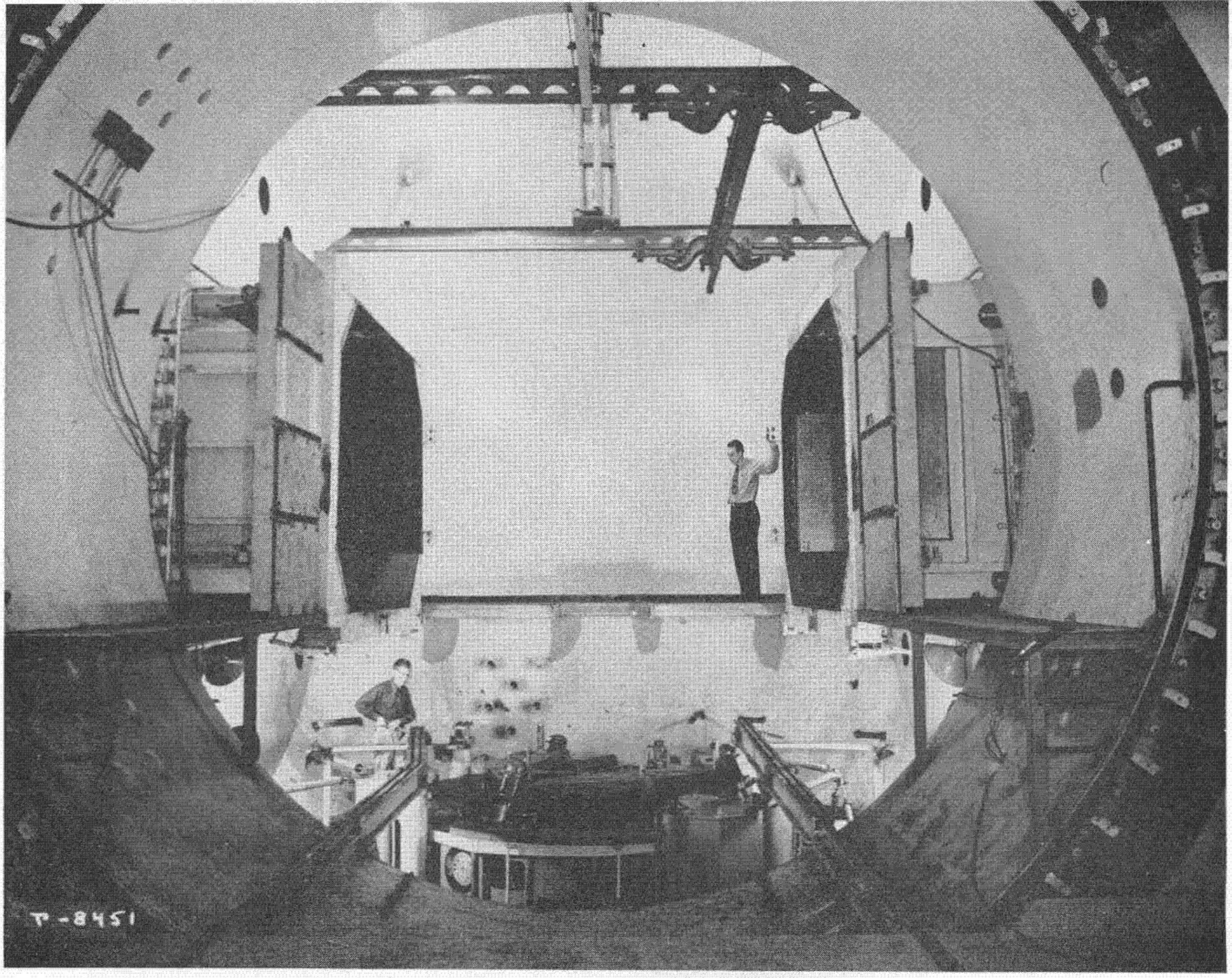


FIG. 28. Top side of metrical system.

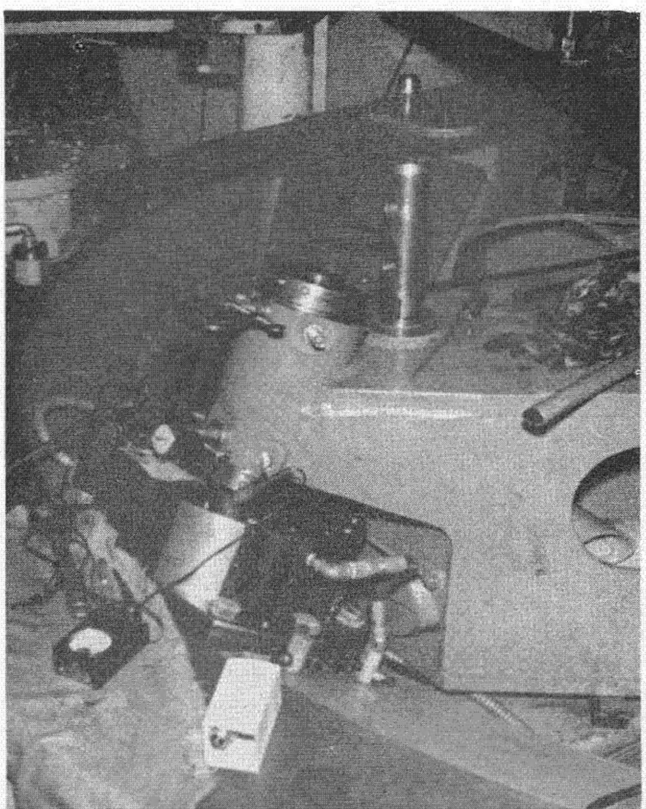


FIG. 29. Showing one of three oil pads which rest on large ring on top side of metrical system.

The I.B.M. automatic measuring and recording machines permit the continuous display, in true numerical form, of test data and the automatic recording of such data by printing on a worksheet and by punching in record cards. Subsequently the cards are processed rapidly by I.B.M. standard equipment to apply mathematical corrections and to transform the test data into dimensionless coefficients for study by aerodynamicists.

The machines reduce the amount of time required to perform a series of tests on a model airplane. Adjustments of the model to each point in a test series are expedited since the visual reading and interpolating of dials are eliminated. These new machines automatically and accurately determine and display, in numerical form, the settings of many instruments. Also the necessity of writing down numerous data for each test point is eliminated, since the instrument settings are concurrently recorded under control of the machines upon depression of a button. The new I.B.M. machines have a sensitivity of better than one part in ten thousand in determining the settings of instruments which register such test data as pressures, forces, moments, and angles.

I.B.M. automatic measuring and recording machines are shown schematically by the heavy lines in *Fig. 31*. Nine follow-up units are provided, seven being applied to weighing gages which give a measure of the forces and moments exerted on the model airplane as it is supported in the tunnel wind stream. The remaining follow-up units are associated with receivers of autosyn telemetering devices which give a measure of the angles of the plane with respect to the wind stream. When applied to a weighing gage, a follow-up unit determines its setting by measuring linear motion to one ten-thousandth of an inch. When applied to an autosyn telemetering receiver, the follow-up unit determines its setting by measuring angular motion to one-hundredth of a degree.

Follow-up units measure electro-mechanically with the aid of electronic tubes at a rate of from two to four measurements per second, which are translated into digit representations electrically. The devices receiving digit representations in turn electrically control the presentation of digits on the lamp banks, together with the positive or negative characteristic and decimal point location. Such digit-representing devices also electrically control recording operations upon depression of the record button. The printing and punching of more than 80 columns of figures occur in less than three seconds. The lamp banks and the I.B.M. equipment are shown in *Fig. 30*.

Certain data relating to a model plane may remain relatively fixed in value throughout a series of the tests and these are set up on keyboard units. These units also electrically control the display of numbers on the lamp banks and data recording by the printer and the punch. Each keyboard unit handles a single column of numbers and can be associated with other units to form a multi-columnar structure. *Fig. 31* also shows a sample worksheet and a group of punched cards resulting from a series of tests.

Utilization of I.B.M. standard machines to perform calculations automatically on punched cards reduces the time interval between completion of tests on a model and the availability of finally computed data to aerodynamicists for analysis. The calculations for each test point in a series require one and one-half minutes or less of operations by the machines.

Fig. 32 shows diagrammatically the various machines which accurately and rapidly perform the necessary additions, subtractions, and multiplications as the data are transformed into dimensionless coefficients. A photograph of the computing room is shown in *Fig. 33*. There is also shown in *Fig. 32* a worksheet upon which are printed the finally computed dimensionless coefficients. By analysis of these coefficients aerodynamicists can determine and predict the flight characteristics of the full-scale airplane, based on the model tested in the tunnel.

MODEL POWER SUPPLY AND DYNAMOMETERS

IN order more adequately to simulate true flight-test conditions, certain models will be equipped with high-speed electric motors driving scale-size propellers running at top speeds equivalent to those in actual flight. For this purpose the laboratory in the Cooperative Wind

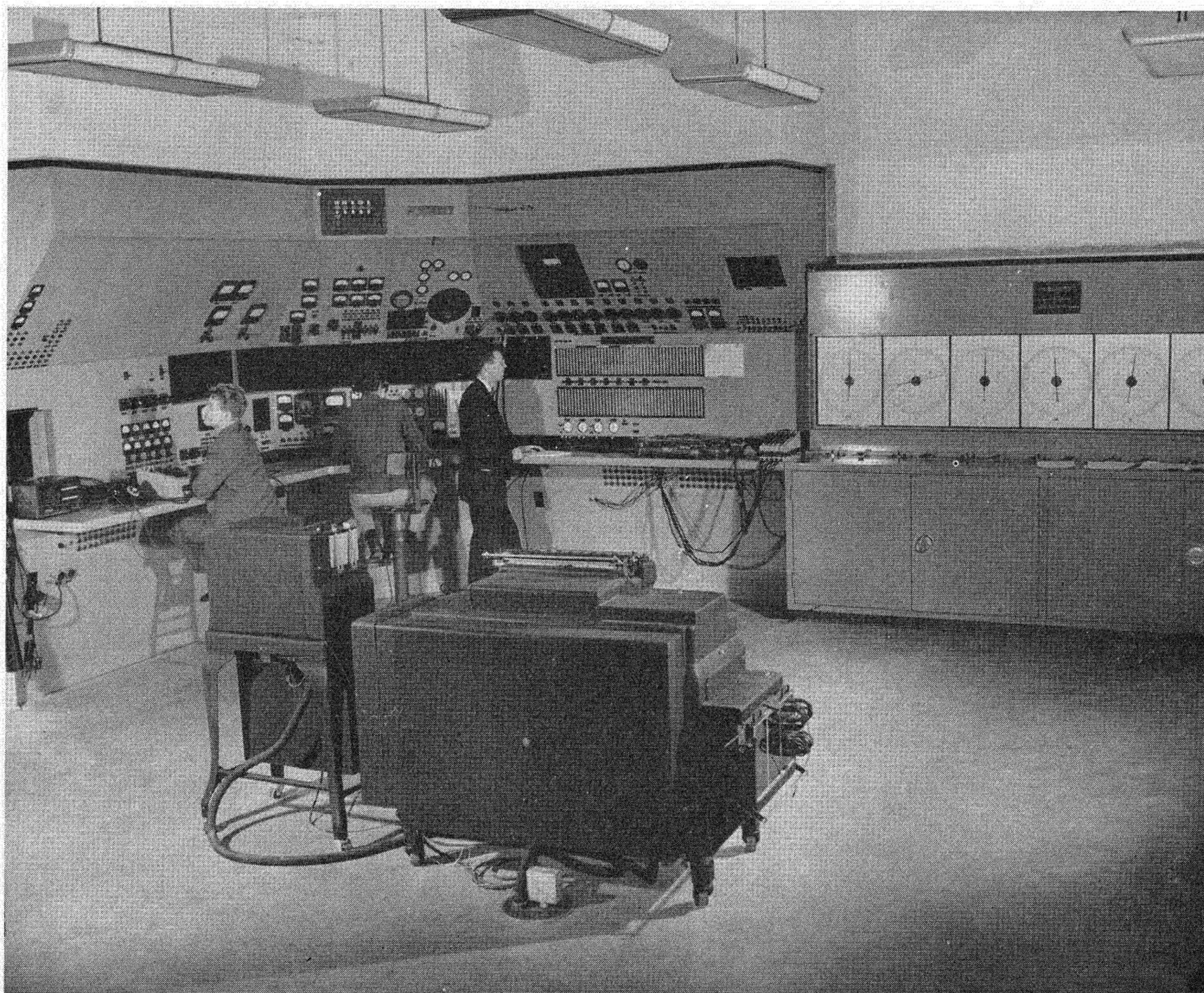


FIG. 30. Another view of master control room, showing load indicators at right and I.B.M. recorders in foreground. (See Fig. 2.)

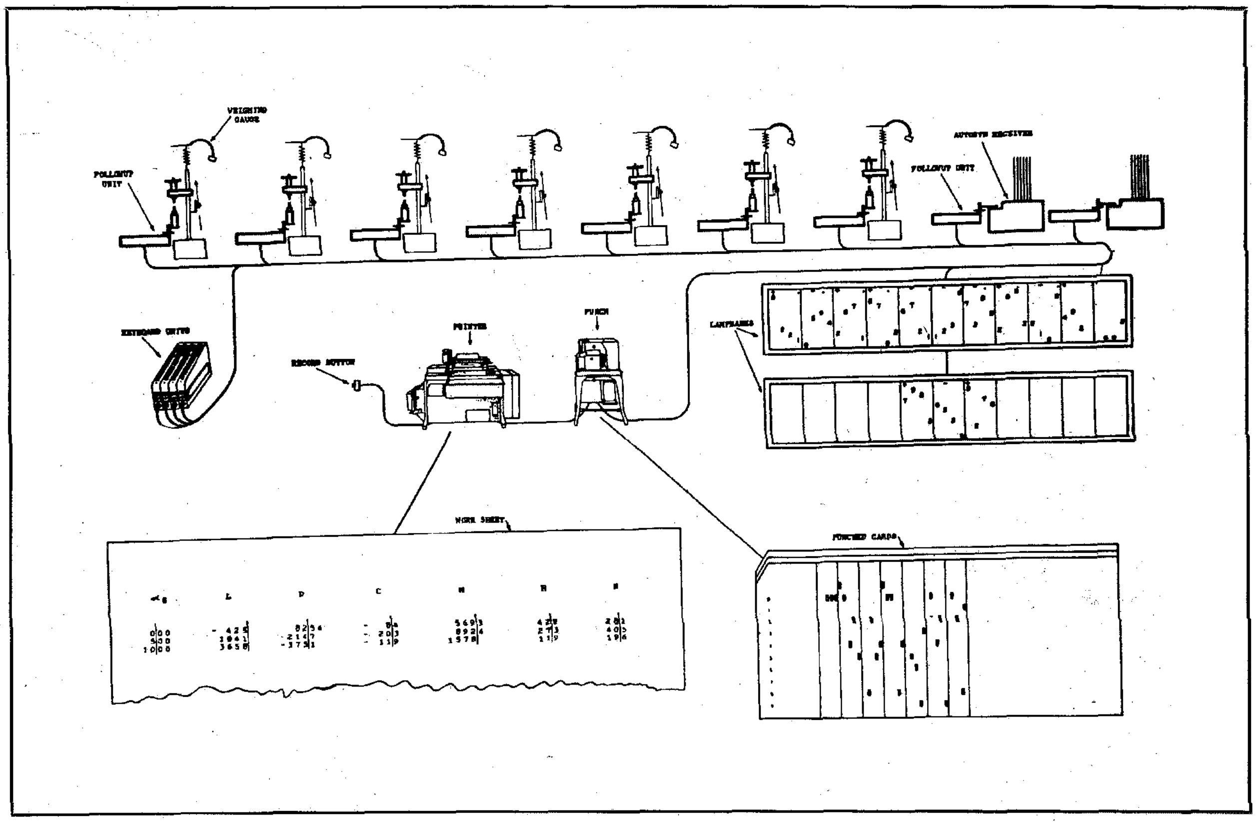


FIG. 31. Line drawing showing I.B.M. measuring and recording system.

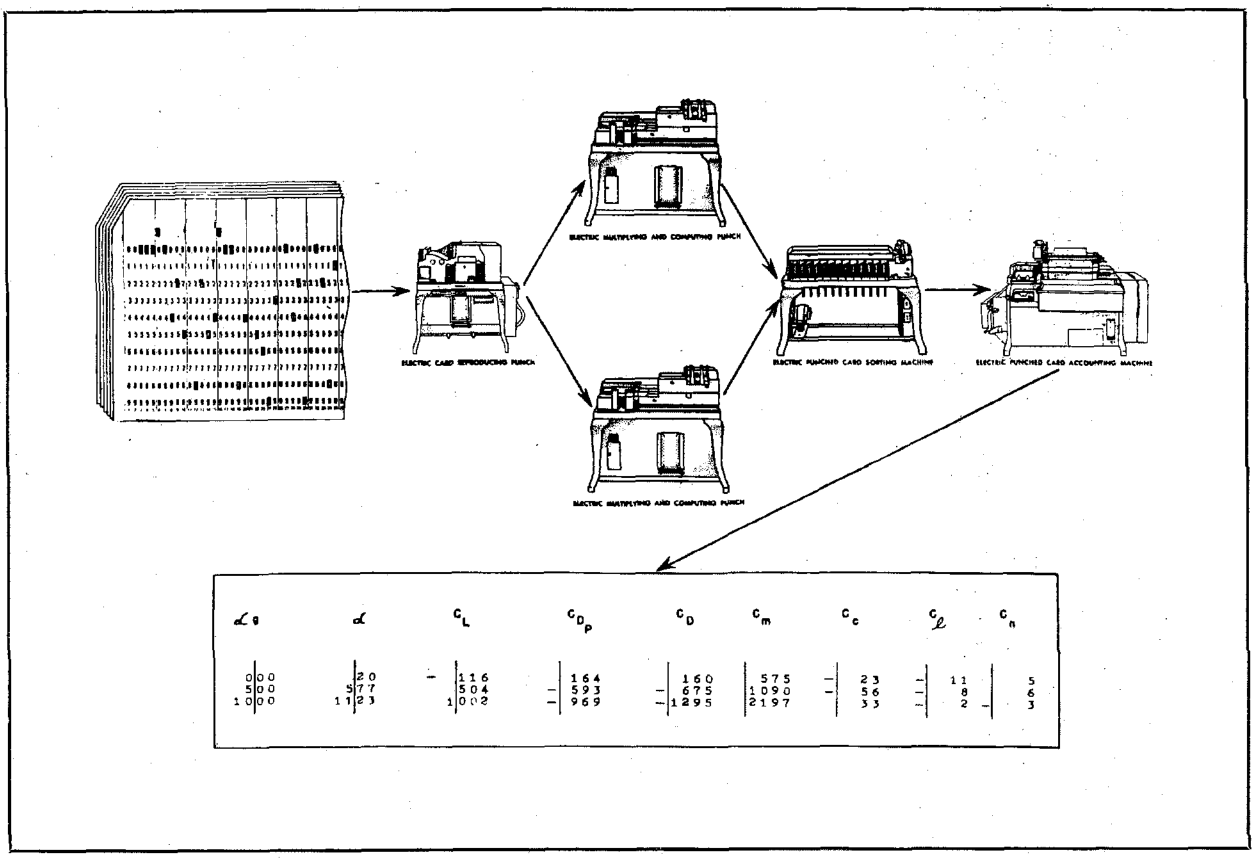
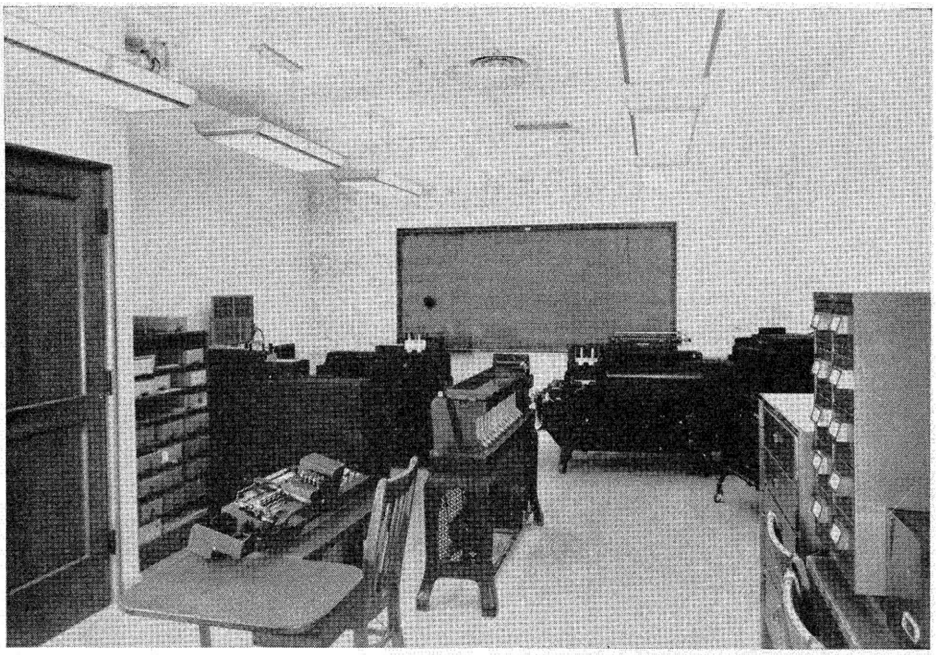


FIG. 32. Line drawings of I.B.M. computing equipment used in the measuring and recording system.



AT LEFT:

FIG. 33. Computing room, showing equipment illustrated in Fig. 32.

Tunnel is equipped with a system of high-frequency power supply, regulation, and control, together with electric torsion dynamometers and wide-range power metering equipment for model motor calibration.

Model power supply is provided by means of two adjustable-frequency, adjustable-voltage, alternating-current generators, each driven by a variable speed direct-current motor. The generators are rated at 200 *kv* amperes and may be operated in parallel to supply model power loads up to 400 *hp* over a frequency range of 50 to 450 cycles per second. Voltages are available up to 600 volts. The dual generator supply has been installed to enable operation of multi-motored models, such that one or more motors may be run at a speed different from all other motors on the model. The two frequency sources are also intended to permit testing contra-turning propeller models with right- and left-hand propellers at the same or differing speeds.

For aerodynamic purposes the test data required involve power delivered to the model propellers. In order to determine this power precisely the model motors are calibrated prior to operation in the tunnel. This calibration procedure involves measuring the performance of each model motor in terms of speed and torque output compared with watts input, or, in other words, determining the relationship between mechanical output and electrical input.

To cover the wide range of anticipated sizes and speeds of these model motors, three dynamometers and their associated absorption and control equipment are being installed for use in calibration. One dynamometer has a nominal rating of 100 *hp* with an operating speed range of 3,500 to 13,000 *rpm*. A second similar machine carries a speed range of 3,500 to 16,000 *rpm*. One of the two 100 *hp* dynamometers is a hollow-shaft unit, the other having an extended solid shaft.

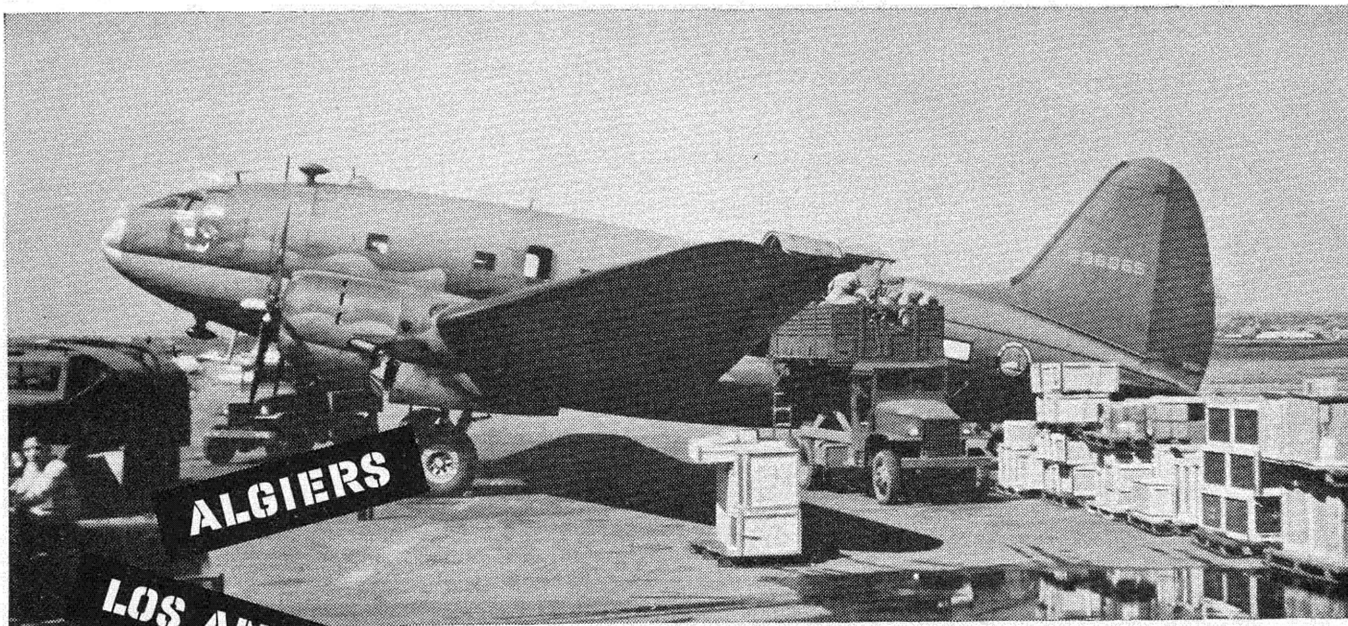
These provisions, when arranged for concentric connection to a special coupling, will permit calibrating double motor units of the contra-turning (opposite rotation) type. The third dynamometer is an extra-high-speed machine having a nominal rating of 35 *hp* and a speed range of 15,000 to 27,500 *rpm*. All machines are of the cradled induction type and are provided with motor generators to effect speed control and power absorption.

Metering is provided to measure power inputs from ½ to 400 *kw* with a range of voltages from 60 to 600 volts, a range of frequencies from 60 to 450 cycles, and a range of currents from 5 to 400 amperes. A model power-dispatching switchboard is equipped with circuit breakers for metering and feeder protection, and a system of remote-controlled and interlocked contactors to permit energizing and metering any one of six separate operating channels from either of the two generator sources, together with test channels to the dynamometer stations and to two model rigging shops.

Speed determination of the dynamometers and model motors is made with an electronic precision tachometer. This is an instrument which indicates speed in terms of frequency generated in a miniature pilot alternator built into each model motor. The range of this instrument is from 1,000 to 30,000 *rpm*. This pilot alternator generates a pulsating voltage exactly in step with the speed of the model motor. This voltage is amplified and fed into a precision potentiometer arranged in such a way that a separately-powered, extended-scale indicating instrument is made to follow the balance point of the potentiometer bridge network and thus indicate speed.

DEVELOPMENT FOR WAR AND PEACE

THE Southern California Cooperative Wind Tunnel, which has been created through the joint efforts of Consolidated Vultee, Douglas, Lockheed, and North American aircraft companies and the California Institute of Technology, is dedicated to the development of aeronautical science in war and peace, in the hope that America will always retain her leadership in the air. It is dedicated with the conviction that America's future depends upon a strong air force to preserve peace, and world air lines to maintain her prosperity, and that her aeronautical scientists and engineers will always keep America in the forefront of the aeronautical development upon which her air future rests.



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It didn't come the way you may have thought it would. It hasn't changed your everyday life much . . . as yet. In fact, it wouldn't be surprising if you are still thinking about the Air Age as something promised for *tomorrow*. But take a look at what has actually happened.

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[*Aviation offers a bright future for College Engineers: Write Engineering Personnel Bureau, Curtiss-Wright Corporation, Passaic, N. J.*]

JUST recall the historic record-breaking day when 14,000 planes were over Germany in one 24-hour period. That meant probably 50,000 men in the air at one time. Thousands of tons of bombs, shells, medicine, food — delivered to one country within a few hours. *Mass air travel and mass air-cargo transport are here!*

Huge, modern air transports, powered by Wright Cyclones, with cargo space nearly equal to two average box cars, now fly across the country coast-to-coast in approximately 6 hours . . . Giant planes take off every 13 minutes to hop the Atlantic and every 90 minutes to span the Pacific . . . 3 Curtiss Commandos recently transported 23,000 pounds of critical radar equipment from Miami to India in just 4 days . . . You are living in the Air Age *right now!*

To make air travel convenient, hundreds of air terminals are already established — more on the way. For instance, 15 nations are already seeking landing facilities at New York's new Idlewild airport. Set your hopes high—the Air Age has already begun.

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C. I. T. NEWS

ATHLETICS

By H. Z. MUSSELMAN,
Director of Physical Education

STAN CLARK and Jack Cardall participated in the National Intercollegiate Tennis Tournament at Northwestern University, June 25-30. Clark, seeded seventh, and one of the three seeded players from the Pacific Coast, rapidly won recognition for his fine play and upset the dope bucket to reach the semi-finals. Here he was eliminated by Lieutenant Frank Mehner of West Point, who later was defeated by Francisco Segura of Miami University in the finals. Cardall met his defeat in the fourth round, and the pair playing in the doubles tournament was eliminated in the third round.

Ken Shauer and Roland Nielsen represented the Institute in the national A.A.U. track and field meet held at Randall's Island, New York, on June 30. Shauer, running the 440, qualified in his heat, but failed to place in the finals. Nielsen tied for third in the pole vault in the junior meet, and placed sixth in this same event in the senior meet.

Coach Dr. Floyd Hanes and two members of his championship Caltech track team were awarded medals by the Helms Olympic Foundation, Bill Schroeder, managing director, making the presentation on an N.B.C. radio sports broadcast. Coach Hanes was honored as the "track coach of the year," Shauer was designated as the most "inspirational" member of the team, and Bill Frady was given a medal for being the high point man of the season.

Four Caltech men, four from U.S.C., and one each from U.C.L.A. and Pepperdine, were named on the All-Conference baseball team. Selected from Caltech were Co-Captain John Anderson, who had a pitching record of three wins with no losses and hit .410; John Schimenz, .437, catcher; Dick Roettger, .361, pitcher and first baseman; and Milt Strauss, .449, outfielder. Strauss, Schimenz, and Anderson were the three top hitters of the league. Anderson led the league in pitching, runs scored, and hits, while Schimenz led in home runs, runs batted in, and stolen bases. They were a valuable and versatile battery. Schimenz, by a vote of the squad, was awarded the Alumni Baseball Trophy and plaque for the current season.

Championship charms are being presented to all members of the track, baseball, and swimming teams.

Chief Specialist Mason Anderson, who coached the 1944 football team to such a fine record, received his commission in June and after conducting a few weeks of spring football practice was transferred to another station.

Only four lettermen—Milt Strauss and Bill Libbey, tackles, Norman Lee, guard, and Jerry Wozniak, half—remain from the 1944 championship squad. Returning from last year's second stringers are Merle Kam, guard, and Lloyd Chamberlain, Flavius Powell, and Stanley Mendes, backs. John Schimenz, who made his letter at the University of Kansas last year, will be a welcome addition, as will a number of high school lettermen, who just entered the Institute this semester.

The team this year can't be expected to reach the records of the 1944 "wonder team," but it will be good enough to meet all opponents on equal terms.

Due to semester finals and vacation, it is necessary to conclude the season early in October.

The schedule:

*Friday, September 7—Redlands, at Rose Bowl.
*Friday, September 14—Occidental, at Rose Bowl.
**Saturday, September 22—Omitted.*
Saturday, September 29—U.C.L.A. Jr. Varsity, at Coliseum.
*Saturday, October 6—San Diego State, at San Diego.
Saturday, October 13—Occidental, at Occidental.

*Night games.

COMMENCEMENT EXERCISES

On June 22 in Dabney Garden, in the presence of many relatives and friends, commencement exercises were held for 254 V-12 and civilian seniors, some *in absentia*.

After the concert and processional, the invocation and chaplain's address were given by the Reverend Curtis Beach.

The commencement address was given by Dr. Robert A. Millikan, who also conferred the degrees. Candidates for certificates and degrees were presented by Dean Franklin Thomas, Dr. W. R. Smythe, Professor W. W. Michael, and Dr. John P. Buwalda.

Thirty-three candidates received Senior Certificates, 154 candidates received the degree of Bachelor of Science, 58 Master of Science, and nine Doctor of Philosophy.

CHICAGO ALUMNI MEETING

On June 5 a small group of Caltech alumni met for a luncheon meeting in the Faculty Club at Illinois Tech.

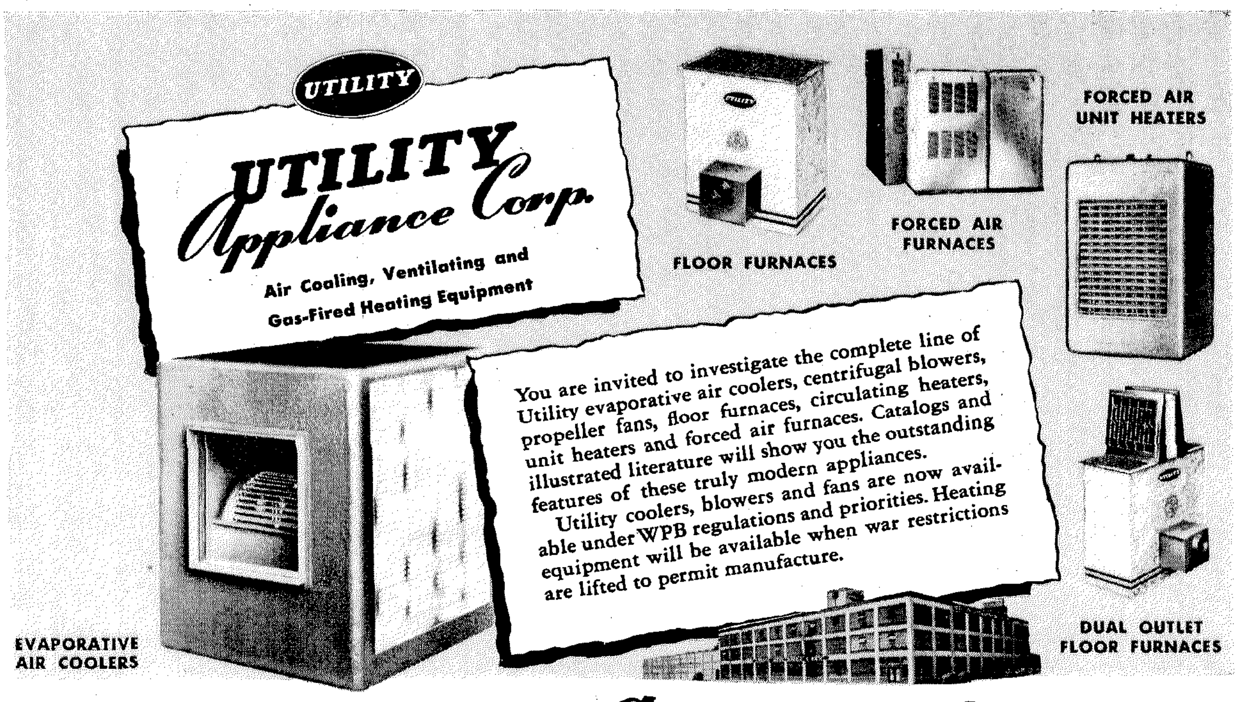
Harry Farrar, past president of the Alumni Association, was guest speaker. Mr. Farrar spoke briefly on some of the recent outstanding campus developments, such as the wind tunnel and the new mechanical engineering building.

Organization of a formal Chicago chapter was discussed but no action was taken for the present because of war activities.

C. I. T. Men in Service†

Name	Class	Rank	Service	Location
McAnlis, R. C.	'44	*	U.S.N.R.	*
McBreen, K. L.	'44	Ensign	U.S.N.R.	*
McClain, J. F., Jr.	'42	*	U.S.N.R.	*
McClung, R. M.	'39	2nd Lt.	U.S.A.	Illinois
McCoy, H. M.	'35	Capt.	U.S.A.	*
McDonald, G. D., Jr.	'44	*	U.S.N.R.	*
McGarrity, R. V.	'44	*	U.S.N.R.	*
McGee, C. G.	'43	*	U.S.N.R.	*
McKee, G. T.	'23	*	U.S.A.	Overseas
McKibbon, P. S.	'42	*	U.S.N.R.	*
McKillip, J. C. S.	'36	Lt.	U.S.N.	*
McNaughton, J. B.	'44	Lt.	U.S.N.R.	*
McNeal, Don	'35	Major	U.S.A.	*
McQuate, J. T.	'44	Ensign	U.S.N.R.	*
McRae, J. W.	'34	Major	U.S.A.	*
McWethy, R. E.	'43	*	U.S.N.R.	*
Mead, O. J.	'43	Ensign	U.S.N.R.	*
Mead, R. R.	'33	Lt.	U.S.A.	Washington
Mechling, W. B.	'38	Lt.	U.S.N.R.	*
Menard, H. W.	'42	Ensign	U.S.N.R.	Overseas
Mendenhall, John	'33	*	U.S.N.R.	*
Mercereau, J. T.	'24	Lt. Col.	U.S.A.	Virginia
Merryfield, L. W.	'42	Pvt.	U.S.A.	California
Mettler, R. F.	'44	Ensign	U.S.N.R.	New York
Meyer, G. F.	'42	Lt.	U.S.N.R.	Overseas
Meyer, R. G. H.	'37	*	U.S.A.	Overseas
Miller, C. B.	'44	Midshp.	U.S.N.R.	Annapolis, Md.
Miller, D. D.	'40	*	U.S.A.	*
Miller, J. A.	'41	*	U.S.A.	*
Miller, K. M.	'44	2nd Lt.	U.S.A.	*

†List begun in June issue.
*Information lacking.



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Utility coolers, blowers and fans are now available under WPB regulations and priorities. Heating equipment will be available when war restrictions are lifted to permit manufacture.
EVAPORATIVE AIR COOLERS
DUAL OUTLET FLOOR FURNACES

Name	Class	Rank	Service	Location
Miller, S. S.	'37	Lt.	U.S.N.R.	California
Mills, W. E., Jr.	'44	Ensign	U.S.N.R.	*
Mitchel, Ted S.	'33	Lt.	U.S.N.R.	Florida
Mitchel, W. P.	'42	Ensign	U.S.N.R.	*
Mitchell, J. A.	'44	*	U.S.N.R.	*
Mitchell, R. K.	'44	Ensign	U.S.N.R.	California
Mohr, W. H.	'29	Lt. Col.	U.S.A.	Overseas
Monning, J. C., Jr.	'33	Lt. Col.	U.S.A.	Overseas
Moody, Max W.	'24	Lt. Cmdr.	U.S.N.R.	Overseas
Moore, C. K.	'37	*	U.S.A.	Wright Field, Ohio
Moore, F. H.	'44	Ensign	U.S.N.R.	*
Moore, R. L.	'42	Lt.	U.S.N.R.	California
Moorman, T. S.	'38	Lt.	U.S.A.	*
Morgan, A. J. A.	'44	S 1/c	U.S.N.R.	California
Morison, Bradley	'45	Midshp.	U.S.N.R.	Rhode Island
Morris, F. W., Jr.	'44	2nd Lt.	U.S.A.	New Jersey
Morris, L. P.	'34	Lt. Cmdr.	U.S.N.R.	California
Morse, Chas.	'36	Capt.	U.S.A.	Overseas
Munk, W. H.	'39	*	U.S.A.	Washington
Murphy, D. B.	'44	Ensign	U.S.N.R.	Overseas
Murphy, J. N.	'37	Lt.	U.S.N.R.	Overseas
Nakada, Yshinao	'40	Sgt.	U.S.A.	Minnesota
Naldrett, D. A.	'44	Ensign	U.S.N.R.	*
Neiswander, R. S.	'40	Lt. (j.g.)	U.S.N.R.	Annapolis, Md.
Nestler, W. W.	'36	Capt.	U.S.A.	Florida
Newby, C. T.	'40	Lt.	U.S.N.R.	Virginia
Newman, S. F.	'44	Ensign	U.S.N.R.	New York
Nichols, R. M.	'36	*	U.S.N.R.	Overseas
Norsworthy, T. W.	'44	*	U.S.N.R.	*
Novitski, Edward	'42	*	U.S.N.R.	*
Nye, L. C.	'30	Capt.	U.S.A.	Overseas
Oberholtzer, W. E., Jr.	'36	Lt.	U.S.N.	Pearl Harbor
Oder, F. C. E.	'40	Major	U.S.A.	North Carolina
Offeman, Richard	'37	Ensign	U.S.N.R.	*
Ofsthun, S. A.	'38	Lt.	U.S.A.	*
Oliver, C. W., Jr.	'44	Lt. (j.g.)	U.S.N.R.	Overseas
Olmsted, Harold	'33	Cmdr.	U.S.N.R.	Overseas
Olson, C. B.	'42	Lt. Cmdr.	U.S.N.	Washington, D.C.
Olson, C. W.	'44	Ensign	U.S.N.R.	*
Ortiz, J. P.	'39	1st Capt.	Army of	Mexico
Osborn, J. E.	'39	Ensign	U.S.N.R.	Overseas
Osborne, H. G.	'42	Ensign	U.S.N.R.	Overseas
Osborne, L. S.	'44	Ensign	U.S.N.R.	Massachusetts
Osgood, G. M.	'44	Midshp.	U.S.N.R.	New York
Ours, S. R.	'44	Lt. Cmdr.	U.S.N.	*
Paller, Jack	'36	Lt.	U.S.N.R.	Overseas
Palmer, C. S., Jr.	'40	Lt.	U.S.A.	Dayton, Ohio
Palmer, J. G.	'41	*	U.S.N.R.	*
Palmer, R. J.	'44	*	U.S.N.R.	*
Parch, N. T.	'41	Ensign	U.S.N.R.	Washington, D.C.
Parish, E. W., Jr.	'39	Lt.	U.S.N.R.	Overseas
Park, N. R.	'37	War Off. (Jun. Gr.)	U.S.A.	Overseas
Parker, J. E.	'38	Lt.	U.S.A.	*
Parker, T. B.	'44	Lt.	U.S.A.	*
Parr, W. S.	'35	Lt. Cmdr.	U.S.N.	Overseas
Pastoriza, R. B.	'44	*	U.S.N.R.	Rhode Island
Patterson, G. B.	'41	*	U.S.A.	*
Paulson, J. J.	'41	Lt.	U.S.N.R.	Overseas
Pearce, R. B., Jr.	'44	Lt.	U.S.A.	*
Pearne, J. F.	'34	Lt.	U.S.N.R.	*
Pendery, D. W.	'44	*	U.S.N.R.	*
Phelps, J. M.	'44	*	U.S.N.R.	*
Philleo, R. A.	'27	Major	U.S.A.	*
Phipps, R. R.	'44	Ensign	U.S.N.R.	*
Pilorz, B. H.	'44	Ensign	U.S.N.R.	Overseas
Pischel, E. F.	'44	*	U.S.N.R.	*
Popp, L. E.	'44	*	U.S.N.R.	*
Porush, I. I.	'41	*	U.S.A.	*
Potter, W. T.	'35	Ensign	U.S.N.R.	*
Powlesland, K. L.	'43	Ensign	U.S.N.R.	Virginia
Price, H. A.	'42	Pvt.	U.S.A.	Michigan
Price, L. H.	'44	*	U.S.N.R.	*
Pritchett, J. D.	'30	*	U.S.A.	Virginia
Proctor, Herman, Jr.	'44	Ensign	U.S.N.R.	*
Putt, D. L.	'38	Lt.	U.S.A.	*
Radford, J. G.	'34	Lt. Cmdr.	U.S.N.R.	Washington, D.C.
Rambo, Lewis	'43	Ensign	U.S.N.R.	New Jersey
Randall, R. O.	'44	*	U.S.N.R.	*
Rattray, Maurice, Jr.	'44	*	U.S.N.R.	*
Reid, D. C.	'43	Ensign	U.S.N.R.	Overseas

Name	Class	Rank	Service	Location
Reimers, G. I.	'41	Ensign	U.S.N.R.	Washington, D.C.
Rempel, J. J.	'44	Ensign	U.S.N.R.	Massachusetts
Renshaw, W. C.	'20	Lt. Cmdr.	U.S.N.R.	Overseas
Reynolds, R. W.	'27	*	U.S.A.	*
Rhoades, Rex	'43	Ensign	U.S.N.R.	New Jersey
Richards, R. T.	'17	Lt. Col.	U.S.A.	Overseas
Richardson, O. B.	'30	Lt. Cmdr.	U.S.N.R.	California
Riddell, R. B.	'44	*	U.S.N.R.	*
Ridland, A. C.	'43	*	U.S.A.	Colorado
Riggs, E. H.	'27	Major	U.S.A.	California
Rikel, Chas. R.	'44	Ensign	U.S.N.R.	*
Ritter, John	'35	Lt.	U.S.N.R.	Overseas
Roberts, W. F.	'44	*	U.S.N.R.	*
Roese, H. V.	'42	*	U.S.M.C.	Overseas
Rogers, W. V.	'27	Major	U.S.A.	*
Rooke, D. R.	'34	Lt.	U.S.N.R.	Washington, D.C.
Ross, E. H.	'28	*	U.S.A.	*
Routt, Robert	'41	Ensign	U.S.N.R.	Massachusetts
Rula, A. A.	'44	2nd Lt.	U.S.A.	*
Rupert, C. S., Jr.	'41	Lt.	U.S.N.R.	Overseas
Russell, R. L.	'33	Lt. (j.g.)	U.S.N.R.	Alaska
Ryan, F. R.	'41	*	U.S.A.	*
Sadler, K. H.	'44	*	U.S.N.R.	*
Sanders, LeRoy	'44	2nd Lt.	U.S.A.	Massachusetts
Sandifer, V. E.	'41	*	U.S.A.	California
Saplis, Raymond	'44	*	U.S.A.	Georgia
Saunders, G. R.	'44	*	U.S.N.R.	*
Savit, C. H.	'42	Pvt.	U.S.A.	Wright Field, Ohio
Saye, Roland S.	'43	Lt. (j.g.)	U.S.N.R.	Virginia
Schaar, H. W.	'44	*	U.S.N.R.	*
Schaffner, P. C.	'37	*	U.S.A.	Overseas
Schardt, A. W.	'44	Pvt.	U.S.A.	Missouri
Schauer, E. H.	'42	*	U.S.A.	*
Schei, D. A.	'44	Ensign	U.S.N.R.	*
Schneider, Arthur	'43	Cadet	U.S.N.R.	California
Schneider, C. L.	'34	Capt.	U.S.A.	*
Schrader, C. G.	'40	*	U.S.N.R.	Washington, D.C.
Schroder, L. D.	'32	*	U.S.A.	*
Schubert, Wm.	'41	Lt. (j.g.)	U.S.N.R.	Annapolis, Md.
Schultz, W. F.	'32	Capt.	U.S.A.	Overseas
Schuman, Daniel	'37	Lt. (j.g.)	U.S.N.R.	Overseas
Schureman, K. D.	'42	Lt.	U.S.N.R.	Overseas
Scoech, W. A.	'38	Lt.	U.S.N.R.	*
Scoles, A. B.	'38	Lt.	U.S.N.R.	*
Scott, W. R., Jr.	'44	Ensign	U.S.N.R.	Overseas
Scribner, Orville	'42	Lt.	U.S.A.	Overseas
Scully, C. N.	'38	Major	U.S.M.C.	Camp Pendleton, Calif.
Seed, R. W.	'44	*	U.S.N.R.	*
Seekins, C. W.	'42	*	U.S.N.R.	Maryland
Seiler, D. D.	'44	Lt.	U.S.N.	*
Seymour, S.	'26	Lt. Col.	U.S.A.	Fort Benning, Ga.
Shalecky, F. H.	'40	Ensign	U.S.N.R.	Overseas
Sharp, Robert P.	'34	Capt.	U.S.A.	Overseas
Shefchik, D. R.	'44	*	U.S.N.R.	*
Shields, John C.	'30	*	U.S.A.	California
Shields, J. E.	'22	Major	U.S.A.	Overseas
Shor, George	'44	Ensign	U.S.N.R.	New York
Shores, V. R.	'41	*	U.S.A.	*
Shugart, D. F.	'22	Colonel	U.S.A.	Florida
Shugart, H. E.	'16	*	U.S.A.	South Carolina
Shuler, W. R.	'32	Colonel	U.S.A.	Fort Lewis, Wash.
Shults, Mayo G.	'44	Ensign	U.S.N.R.	*
Sidler, A. W.	'38	Ensign	U.S.N.R.	*
Sieger, R. J.	'44	Ensign	U.S.N.R.	*
Silberstein, R. F.	'41	Sgt.	U.S.A.	Overseas
Silvertooth, E. W.	'40	*	U.S.N.R.	Washington, D.C.
Skalecky, F. W.	'41	*	U.S.N.R.	Overseas
Skinner, M. J.	'42	*	U.S.N.R.	California
Skinner, R. H.	'23	Major	U.S.A.	Overseas
Smith, Frank, Jr.	'44	*	U.S.N.R.	*
Smith, G. F.	'44	Ensign	U.S.N.R.	Washington, D.C.
Smith, J. C.	'42	*	U.S.N.R.	Maryland
Smith, Joe N.	'37	Capt.	U.S.A.	*
Smith, M. C.	'43	Cpl.	U.S.A.	Overseas
Smith, P. H.	'44	*	U.S.N.R.	*
Smith, R. C.	'20	Major	U.S.A.	Colorado
Smith, R. L.	'39	Major	U.S.M.C.	Overseas
Snodgrass, R. P.	'41	Lt.	U.S.M.C.	Overseas
Snow, Neil	'36	*	U.S.A.	South Carolina
Snyder, Willard	'39	*	U.S.N.R.	Overseas
Snyder, William	'43	*	U.S.A.	*
Sogorka, J. J., Jr.	'44	*	U.S.N.R.	*
Soike, R. J.	'44	Ensign	U.S.N.R.	Overseas
Southwick, T. S.	'27	Capt.	U.S.A.	California
Spaulding, A. T., Jr.	'44	*	U.S.N.R.	*
Spencer, N. C.	'41	*	U.S.A.	*
Sperling, M. H.	'29	Lt.	U.S.N.R.	New Jersey
Spooner, W. A.	'40	Ensign	U.S.N.R.	Overseas
Staatz, D. S.	'40	Lt.	U.S.A.	Texas
Staley, R. R.	'42	Ensign	U.S.N.R.	Washington, D.C.
Stanford, H. W.	'44	Lt.	U.S.A.	Overseas
Stevens, J. B.	'40	Lt. (j.g.)	U.S.N.R.	Overseas
Stewart, Davis	'42	Ensign	U.S.N.R.	Maryland
Stewart, W. A.	'41	Pvt.	U.S.A.	Overseas
Stirling, C. W.	'43	Cmdr.	U.S.N.	Washington, D.C.
Stone, W. S.	'38	Lt.	U.S.A.	*
Stone, W. W., Jr.	'40	*	U.S.A.	*
Strickland, C. P., Jr.	'43	Lt. (j.g.)	U.S.N.R.	Maryland
Strickler, R. F.	'41	*	U.S.A.	*
Strong, H. D., Jr.	'39	Ensign	U.S.N.R.	*
Stroud, S. G.	'41	Ensign	U.S.N.R.	Massachusetts
Stuppy, L. J.	'35	Major	U.S.A.	Overseas
Suggs, R. L.	'33	*	U.S.A.	*
Sullivan, R. B.	'44	2nd Lt.	U.S.A.	*
Sutton, R. A.	'43	Lt. (j.g.)	U.S.N.R.	
Swanson, W. M.	'44	*	U.S.N.R.	*
Swift, F. T.	'30	Lt.	U.S.N.R.	Overseas
Tarbet, T. V.	'31	Lt. Cmdr.	U.S.N.R.	*
Taylor, G. F.	'29	Major	U.S.A.	Illinois
Taylor, G. S.	'44	*	U.S.N.R.	*
Taylor, J. C.	'35	*	U.S.A.	Florida
Taylor, R. M.	'39	*	U.S.N.R.	*
Tenney, F. H.	'43	Lt. (j.g.)	U.S.N.R.	Overseas
Terhune, C. H., Jr.	'41	*	U.S.A.	Wright Field, Ohio
Thayer, E. M.	'33	*	U.S.N.R.	*
Thompson, F. W.	'29	Lt.	U.S.N.R.	*
Thompson, W. C., Jr.	'45	Cpl.	U.S.A.	Overseas
Tiemann, Cordes T.	'41	*	U.S.A.	*
Timm, W. C.	'44	Ensign	U.S.N.R.	*
Tindle, J. W.	'41	*	U.S.A.	Florida
Titzler, H. N.	'44	Lt.	U.S.A.	*
Todd, George	'40	Lt.	U.S.N.R.	*
Tomamichel, J. J.	'42	Lt.	U.S.N.R.	*
Tookey, W. A.	'44	*	U.S.N.R.	*
Towler, J. W.	'30	*	U.S.A.	*
Trimble, W. M.	'44	2nd Lt.	U.S.A.	New Jersey
True, L. J., Jr.	'42	Lt. (j.g.)	U.S.N.R.	California
Tuedio, James	'44	Ensign	U.S.N.R.	*
Turner, C. C.	'44	*	U.S.N.R.	*
Turner, W. R.	'42	*	U.S.N.R.	*
Tyler, R. M.	'39	Lt.	U.S.N.R.	Overseas
Tyra, T. D.	'41	*	U.S.N.R.	Overseas
Ukropina, J. R.	'44	*	U.S.N.R.	*
Urbach, Kenneth	'42	2nd Lt.	U.S.A.	New Jersey
Urgin, Nick	'34	Lt. (j.g.)	U.S.N.R.	*
Urmston, J. W.	'33	Cpl.	U.S.A.	*
Van Dyke, G. R.	'40	Capt.	U.S.A.	Montana
Van Horn, J. W.	'38	2nd Lt.	U.S.A.	*
Van Reed, Mabry	'35	Capt.	U.S.A.	Virginia
Veenhuyzen, P. N. A.	'42	*	U.S.N.R.	California
Velazquez, J. L.	'39	Ensign	U.S.N.R.	Virginia
Veronda, Carol	'42	Ensign	U.S.N.R.	Massachusetts
Voelker, J. F.	'26	Major	U.S.A.	Dallas, Texas
Wadsworth, J. F., Jr.	'44	Capt.	U.S.A.	*
Walker, D. F.	'44	*	U.S.N.R.	*
Walker, R. L.	'40	Lt.	U.S.A.	California
Walkowicz, T. F.	'44	Capt.	U.S.A.	*
Wallman, D. H.	'36	*	U.S.N.R.	*
Warfel, J. G.	'33	Lt. Cmdr.	U.S.N.R.	Washington, D.C.
Warner, H. F.	'37	Lt.	U.S.A.	Pennsylvania
Watkins, J. M.	'40	Lt.	U.S.N.R.	Washington, D.C.
Wayne, J. C.	'44	Capt.	U.S.A.	*
Weaver, F. E.	'44	Ensign	U.S.N.R.	Rhode Island
Webster, G. M.	'22	Lt. Col.	U.S.A.	Oregon
Weeks, A. D.	'43	Lt. (j.g.)	U.S.N.R.	New York
Weight, R. H.	'41	S 1/c	U.S.N.R.	Chicago, Ill.
Wein, E. T.	'44	2nd Lt.	U.S.A.	*
Weir, G. B.	'40	Major	U.S.A.	Overseas
Weisman, G. H.	'29	Lt.	U.S.N.R.	*
Wheeler, F. A.	'29	Lt. Cmdr.	U.S.N.R.	Annapolis, Md.
Whelan, T. M.	'36	Lt.	U.S.N.R.	Overseas
Whipp, D. M.	'36	Major	U.S.N.R.	Overseas
Whitfield, H. H.	'41	*	U.S.A.	*
Whitmore, J. F.	'45	*	U.S.N.R.	*
Whittlesey, D. W.	'40	*	U.S.N.R.	Maryland
Whittlesey, J. W.	'40	Lt. (j.g.)	U.S.N.R.	Overseas
Widdoes, L. C.	'41	Lt.	U.S.N.R.	Washington
Widenmann, J. A.	'42	Lt.	U.S.N.R.	*
Wight, R. D.	'44	Lt.	U.S.A.	*
Wilferth, L. E., Jr.	'45	*	U.S.N.R.	*
Wilking, A. P.	'33	Lt. (j.g.)	U.S.N.R.	Texas
Wilkinson, W. D., Jr.	'30	*	U.S.A.	New York

Name	Class	Rank	Service	Location
Willard, K. A.	'35	Lt.	U.S.A.	Washington, D.C.
Williams, R. S.	'44	Capt.	U.S.A.	*
Willits, R. M.	'43	Ensign	U.S.N.R.	Overseas
Wilson, J. H.	'44	Ensign	U.S.N.R.	*
Wilson, L. S.	'41	2nd Lt.	U.S.A.	*
Winchell, Robert	'39	Major	U.S.A.	New Jersey
Winter, P. H.	'44	Ensign	U.S.N.R.	Overseas
Wolf, P. L.	'44	*	U.S.N.R.	*
Wolfe, Samuel	'41	*	U.S.A.	*
Wood, F. W.	'42	Lt.	U.S.A.	Idaho
Wood, G. M.	'44	*	U.S.N.R.	*
Woodard, C. J.	'45	Midshp.	U.S.N.R.	*
Woodard, G. E.	'34	Ensign	U.S.N.R.	*
Writt, J. J.	'44	Ensign	U.S.N.R.	*
Wuslich, Joseph	'44	Ensign	U.S.N.R.	*
Wyckoff, Donald	'37	Ensign	U.S.N.R.	San Francisco, Calif.
Yoho, L. W.	'44	Ensign	U.S.N.R.	*
Young, J. A., Jr.	'43	2nd Lt.	U.S.A.	Massachusetts
Young, W. B.	'44	*	U.S.N.R.	*
Zimmerman, D. Z.	'36	Lt.	U.S.A.	Washington, D.C.
Zipser, Sidney	'30	Lt.	U.S.A.	Overseas
Zivic, J. A.	'44	Lt.	U.S.N.R.	*

PERSONALS

IT WILL be helpful if readers will send personal items concerning themselves and others to the Alumni Office. Great interest has been shown in these columns, but more information is required. Do not hesitate to send in facts about yourself, such as change of position or location, present job, technical accomplishments, etc. Please help.

—Editor.

1918

EARL MENDENHALL holds the position of vice-president and general manager of the Sterling Electric Motors, Los Angeles, Calif.

1922

CHARLES F. RITCHIE is a chemical engineer for Mallinckrodt Chemical Works at St. Louis, Mo.

FRANK R. BRIDGEFORD is a chemical engineer for the Virginia-Carolina Chemical Company at Richmond, Va.

JOHN J. SAWYER has been assigned to a station in the southwest Pacific as an American Red Cross assistant field director. Previous to his assignment, Sawyer was a major in the U. S. Army from which he received an honorable discharge.

1923

LIEUTENANT-COLONEL VERNON P. JAEGER, a chaplain in the U. S. Army, was awarded the Bronze Star Medal for "meritorius service in support of combat operations from 12 July 1944 to 2 May 1945." Since the close of the Italian campaign, Colonel Jaeger has been with American troops in the disputed area in the vicinity of Trieste, Gorizia, and Udine.

1924

ROY O. ELMORE since graduation has, in the capacities of insurance company engineer and executive, rendered policy auditing and insurance engineering service for all classes of insureds located throughout the 12 western states. Mr. Elmore's company has an office in Los Angeles, Calif.

1925

VICTOR H. HANSON of the E. I. duPont de Nemours Company, Inc., has recently been transferred from Pasco, Wash., to the DuPont plant in Wilmington, Del.

PROFESSOR G. HARVEY CAMERON, head of the Hamilton College physics department, was appointed to the faculty of the War Department's University Study Center overseas. One of the staff of 10 physicists selected for this work, Professor Cameron will serve either in England or France from seven months to a year. Professor Cameron received his doctorate from the Institute and was at one time assistant to Dr. Robert Millikan and among the first to do doctoral work on the cosmic ray.

KENNETH C. McCARTER is chief landscape architect on the Blue Ridge Parkway and has an office in Roanoke, Va.

1927

EDWARD P. JONES recently assumed the duties of senior right of way agent in charge of the right of way department, District X, Division of Highways, Stockton, Calif. Previous to his promotion, he was

in charge of that department for District VIII, San Bernardino, Calif.

RICHARD M. DODGE is buyer for the Texas Company, Chicago, Ill.

1928

FRANK NOEL, since completion of his assignment as resident engineer at Modesto, Calif., last fall, has been in the Division of Highways, District X, right of way department, making calculations and writing deeds with postwar construction plans.

MAJOR F. GUNNER GRAMATKY is in command of an engineer unit engaged in restoring the streets of Manila.

1929

LIEUTENANT-COLONEL THOMAS EVANS was released in June from active duty in the corps of engineers. He has assumed duties as head of the department of civil engineering at Georgia School of Technology, Atlanta, Ga.

CLARENCE G. SCHULZE has recently established an engineering organization in Los Angeles, Calif., which, at present, is engaged in war work, with future plans being laid for postwar developments.

1930

ROSCOE DOWNS is project manager for Bressi and Bevanda, contractors, of Los Angeles, Calif. Mr. Downs has been with this firm and its predecessor since graduation. Among some of the important works constructed by this firm are several sections of the Colorado River Aqueduct.

NATHAN D. WHITMAN, Jr., announces the opening of an office in Pasadena, Calif., making available his services as consulting engineer.

1931

WILLIAM FRED ARNDT is in charge of submarine sonar section, responsible for all submarine sonar developments at the U. S. Navy Underwater Sound Laboratory, New Loudon, Conn. He has recently purchased a home in the village of Quaker Hill, Conn.

1934

HAROLD T. HOLTOM is construction engineer for Macco-McKittrick-Morrison, Naval Ordnance Test Station, Inyokern, Calif.

DR. GEORGE W. HOUSNER was commended for outstanding performance of his duties as chief analyst of the First Operations Analysis Section of the Fifteenth Air Force, which took part in directing activities in Africa, Sicily, and Italy.

1935

DR. ARTHUR IPPEN has just received recognition for the excellent work he has been doing at Lehigh University by appointment as associate professor at the Massachusetts Institute of Technology, to head the division of hydraulics in the department of civil engineering.

1936

PAUL S. JONES is an ensign in the Seabees and is stationed somewhere in the western Pacific area.

1937

CAPTAIN HUGH F. WARNER has just completed four years of active duty, his present assignment being chief of the purchasing and termination section, Ammunition Branch, Pittsburgh Ordnance District. On St. Valentine's day of this year Captain Warner became the father of a son, named Jeffrey Degen.

1938

WILLIAM BRENNER was given the task at Westinghouse Electric Corporation

of designing the main drive unit, a 10,000 *hp* induction motor, which was installed in the new Southern California Cooperative Wind Tunnel. He is now working on the design of the two 25,000 *hp* units for the new tunnel at Moffett Field to be completed next year.

BOYNE GRAINGER of the Tidewater Associated Oil Company is being transferred to Coalinga, Calif., as production foreman.

1939

LAWRENCE G. BORGESON is the west coast supervisor, radar and sonar, for R.C.A. Service Company, Inc., San Francisco, Calif.

1940

J. EWING HITE, Jr., was killed in action on Luzon, March 12. He was a first lieutenant in the 25th Division, 35th Infantry, which landed at Hawaii in May, 1942, and was in the Pacific area until the time of his death. He was killed along with two of his enlisted men when three Japs ambushed his patrol—the Japs also being killed.

ROBERT W. GRIGG announces the birth of a son, Robert George, on May 5. His first child, a daughter, is now two years of age. Mr. Grigg is a member of the technical staff of the Bell Telephone Laboratories, New York City.

HERBERT M. WORCESTER, Jr., and Miss Juanita Ritter, of Long Beach, Calif., were united in a June wedding in Pasadena, Calif., where they intend to live.

CAPTAIN WALTER R. LARSON (U.S. Air Force) in training at Roswell Field, N. Mex., will soon leave for Lincoln, Nebr., for a short period, transferring to Tucson, Ariz., to finish the course with B 29's.

1941

DALE E. TURNER is employed by the Superior Oil Company as a geophysicist. In March of this year he was transferred to the main geophysical office in Bakersfield.

GEORGE IRVING REIMERS announces the birth of a son, Adrian Joseph, on June 12.

LIEUTENANT (j.g.) JOHN B. HIATT is the father of a son, John B., Junior, born on May 17.

ENSIGN JEREMY A. JONES visited his family in southern California on a recent leave, returning to the Supply Corps, Aviation Supply Office, Philadelphia, Pa.

1942

ROBERT J. CLARK is a designer at North American Aviation, Inc., Inglewood, Calif. (Correction, April issue *E. & S.*). On December 25, 1944, he was married to Miss Joan Elizabeth Shaver, of Pasadena, Calif.

LIEUTENANT EARLE A. CARR, U.S.N.R., is now with the Electronics Field Service Group, Naval Research Laboratory, Anacostia Station, Washington, D. C., having been transferred from Boston, Mass.

1944

ENSIGN RONALD STAFFORD JOHNSON, U.S.N.R., and Miss Roberta O. Lamon were united in marriage on March 10 at Cambridge, Mass.

1945

ENSIGN RICHARD A. JASPER (Seabees) and Miss Betty Ann Junker, of Pasadena, Calif., were united in marriage at Providence, R. I., following the bridegroom's commissioning at Camp Endicott.

To think ahead, to design ahead, to anticipate the need for change has ever been a driving force at North American Aviation. It has never been the policy at North American to "freeze" design. In fact, the policy has been just the opposite, for the entire creative engineering and design staff at North American believes to a man that when you're through making changes, you're through.

NORTH AMERICAN ENGINEERS BUILD FOR THE FUTURE—Participation in the Cooperative Wind Tunnel...maintaining a fine wind tunnel at the plant... the recent installation of an advanced type pressure chamber...extensive laboratory research facilities—many such "tools" of aeronautics are utilized to good advantage by North American engineers. Primarily, of course, it is the men themselves, the alert, progressive group of planners for aviation's future, who stand out at North American with a deserved reputation for excellence.

North American Aviation

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PLANES THAT MAKE HEADLINES...the P-51 Mustang fighter (A-36 fighter-bomber), the B-25 and PBJ Mitchell bomber, the AT-6 and SNJ Texan combat trainer. North American Aviation, Inc. MEMBER, AIRCRAFT WAR PRODUCTION COUNCIL, INC.