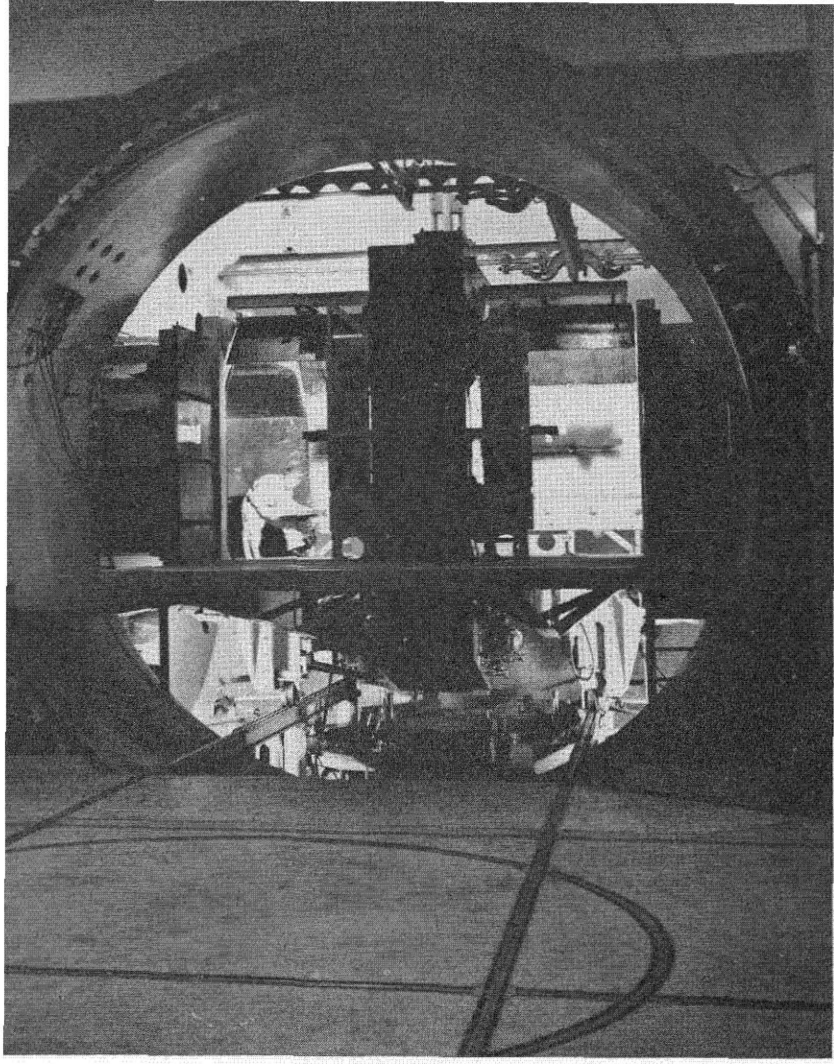

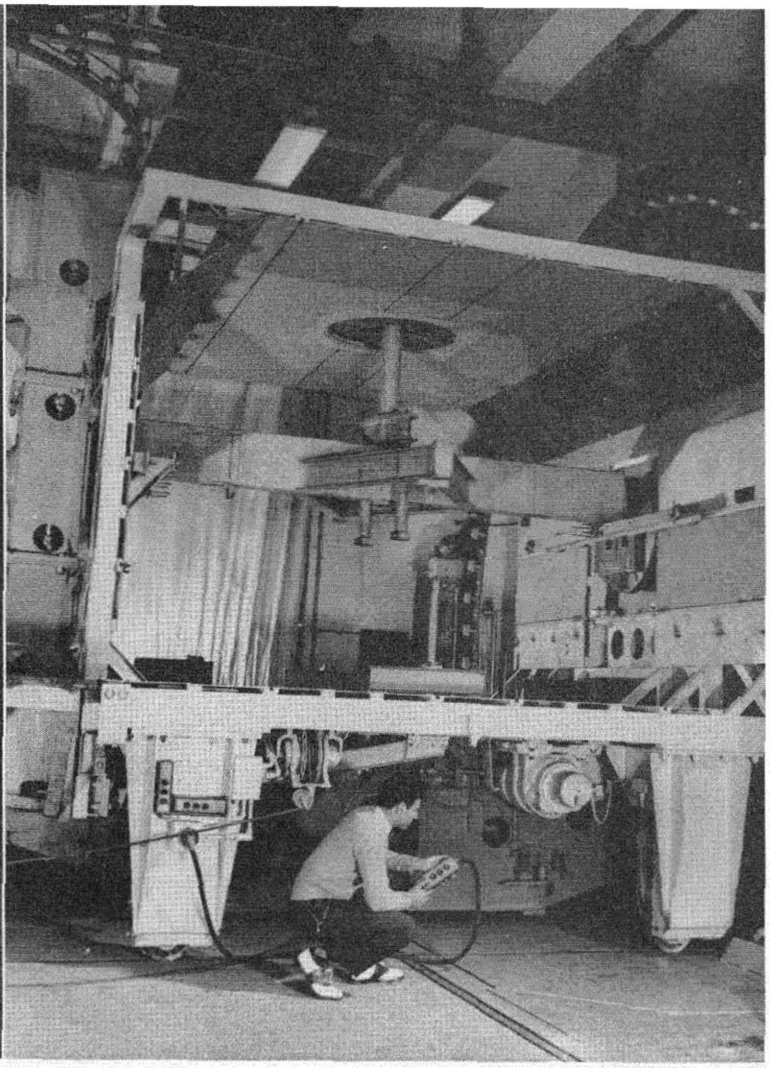

FIG. 25 *(at left)*: Showing model cart in position in working section. FIG. 26 *(at right)*: End view of model cart showing surface plates.

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.

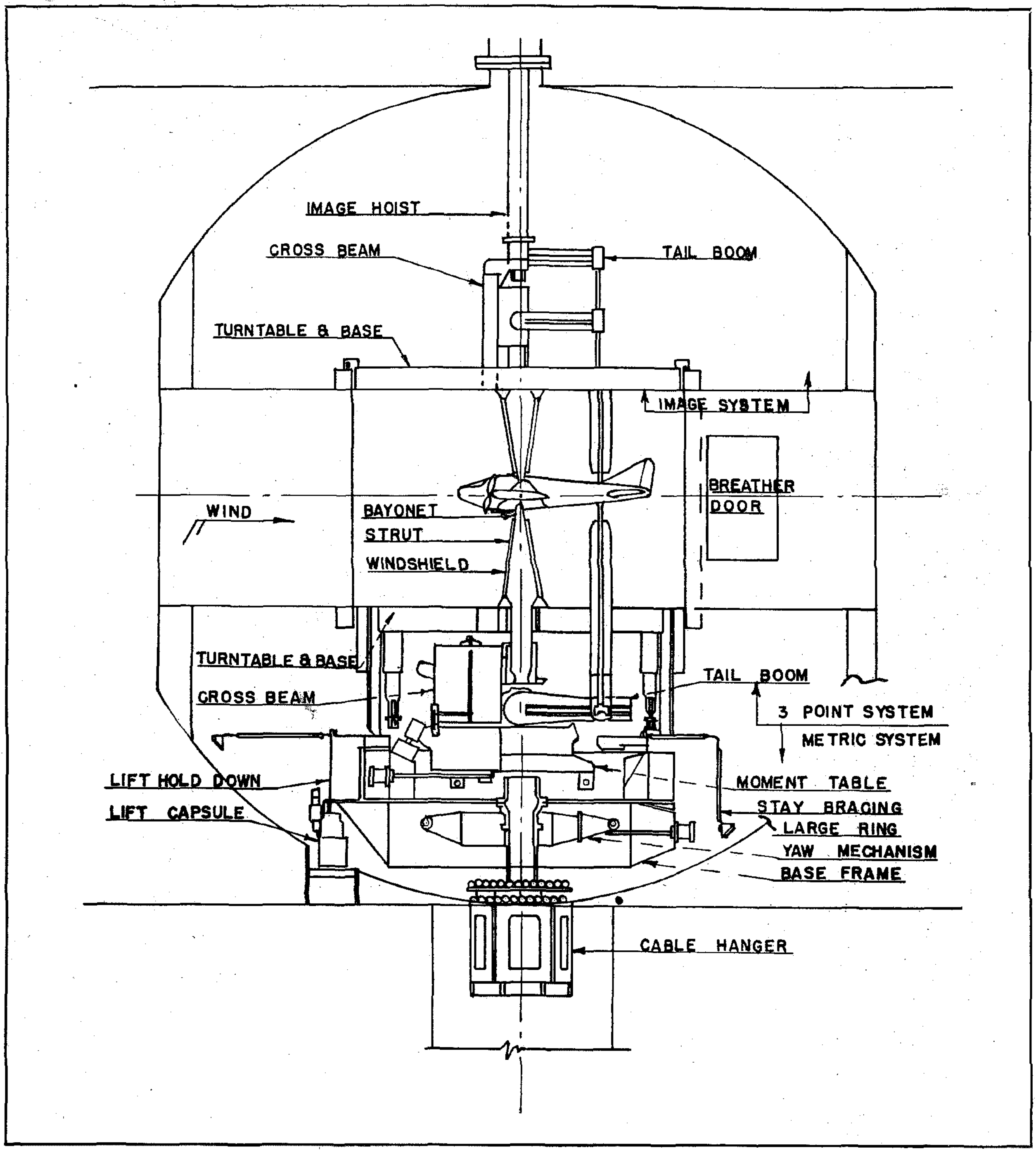

FIG. 27. Diagrammatic view of three-point system and metrical system.

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.

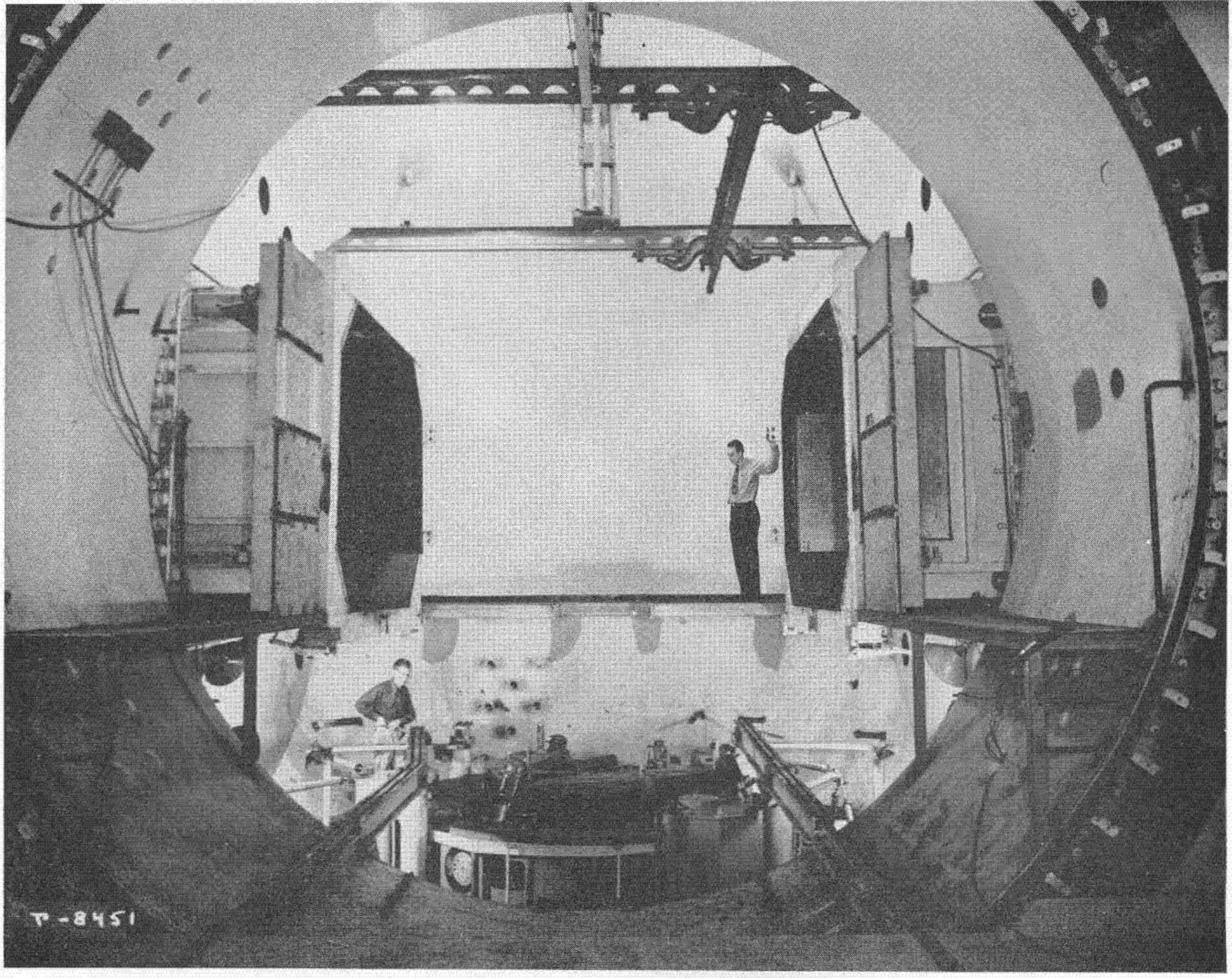

FIG. 28. Top side of metrical system.

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

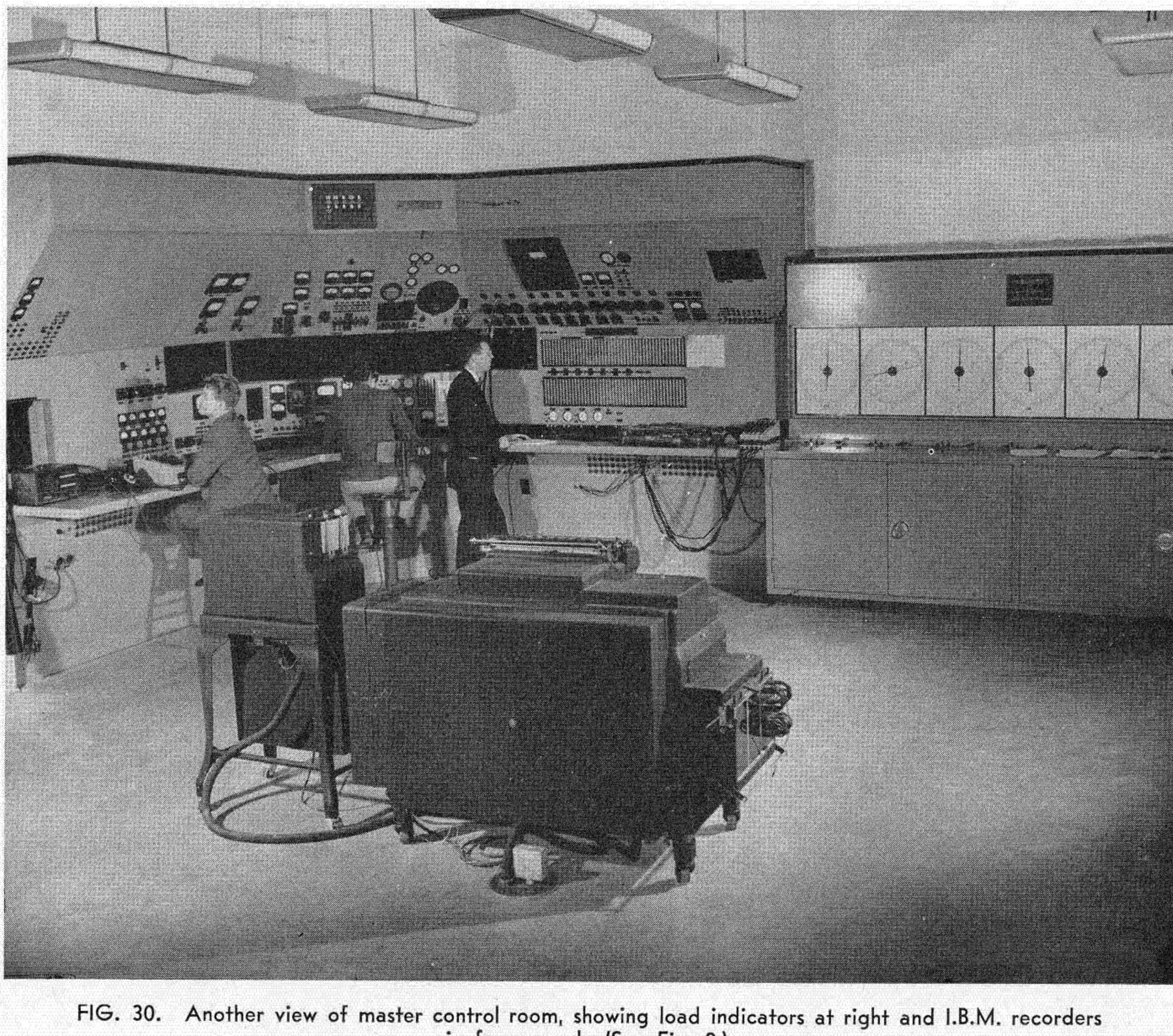

FIG. 30. Another view of master control room, showing load indicators at right and I.B.M. recorders in foreground. (See Fig. 2.)