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

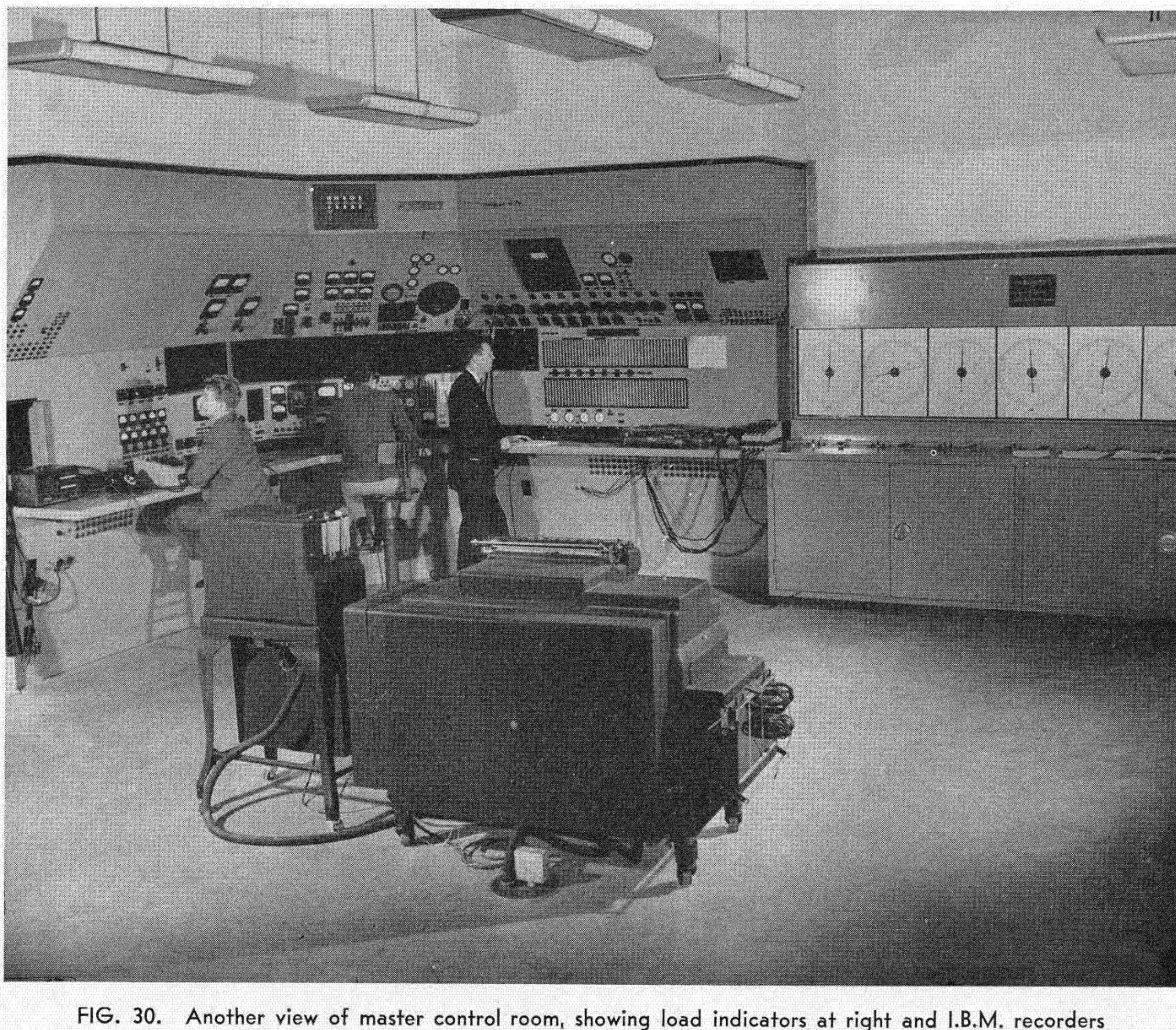


FIG. 30. Another view of master control room, showing load indicators at right and I.B.M. recorders in foreground. (See Fig. 2.)

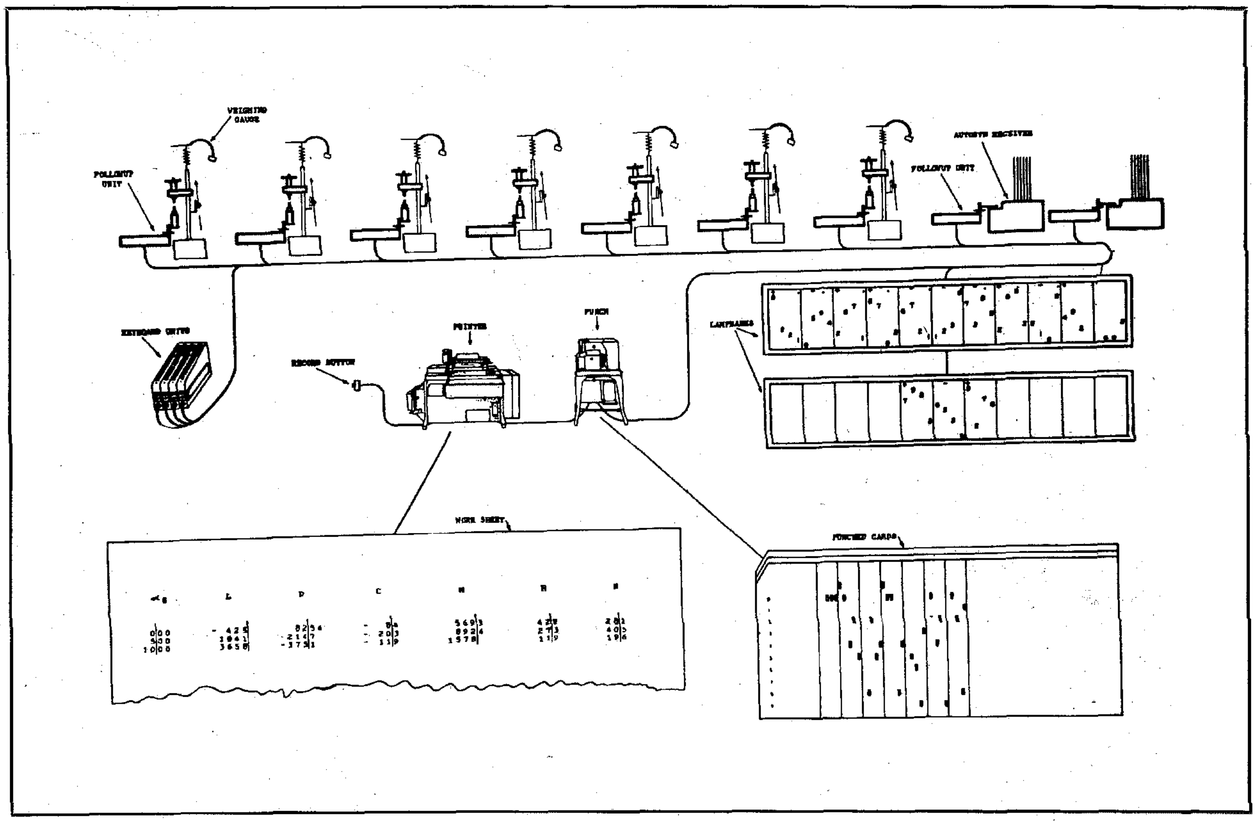


FIG. 31. Line drawing showing I.B.M. measuring and recording system.

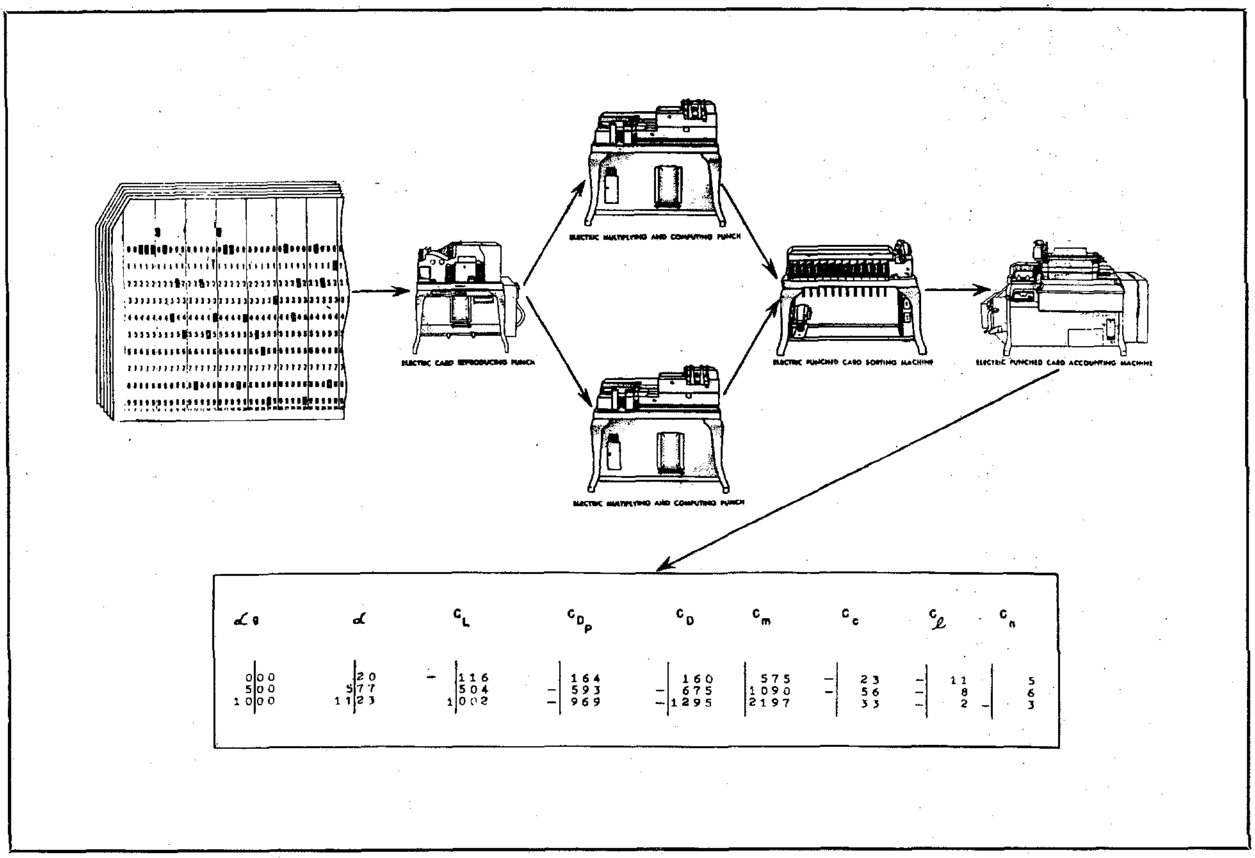
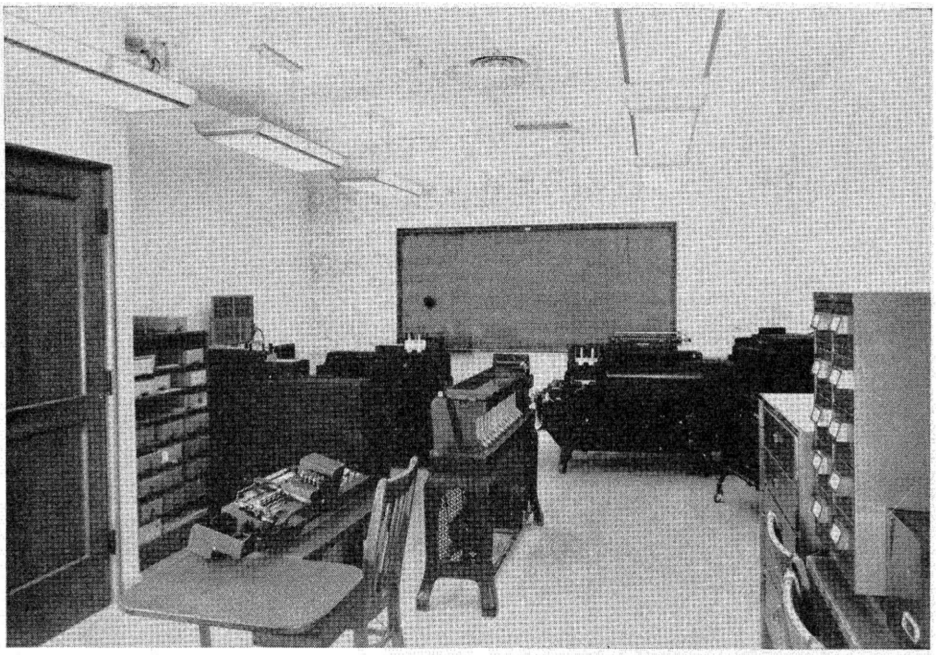


FIG. 32. Line drawings of I.B.M. computing equipment used in the measuring and recording system.



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.