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An instrument for automatic calibration of baroswitches

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ABSTRACT. The equipment described in this paper consists of an environmental testing chamber, and an automatic manometer coupled to several servo-controlled recorders for the mass calibration of baroswitches used in audio-frequency modulated radiosondes. A differential transformer with a soft iron float as its core follows the level of mercury in the manometer tube as the pressure falls or rises in the chamber. The chart drive in the recorders is synchronised with the motion of the differential transformer through servo links. When the aneroid pen moves over the commutator and makes a contact on a conducting segment, the recorder pen is deflected and the resulting trace indicates the pressure on the pre-printed chart. The pressure values corresponding to each contact are thus automatically recorded.

1. Introduction

The audio-frequency modulated radiosonde recently introduced in the national network of upper air stations in India, uses electrical sensors, *viz.*, a thermistor and hygristor for the measurement of temperature and humidity and a baroswitch for connecting the two sensors in sequence to the radiosonde telemetry circuit. The baroswitch — a pressure operated switching device — consists of an aneroid connected to a pen which moves over a commutator consisting of alternate conducting and insulating segments. When the pen rests on an insulating segment, temperature data are transmitted while either reference data or humidity data are transmitted when it rests on a conducting segment. Pressure is determined by the identification of the segment with which the pen makes a contact at any particular instant. Each baroswitch has to be calibrated before use. During calibration, the pressure at which the pen makes a contact with each segment of the commutator is determined.

The equipment described in this paper was designed for the automatic mass calibration of baroswitches. The automatic system not only reduces time and labour required for calibration, but also eliminates the personal errors inherent in a manual system.

2. Principle

The principle of the system is illustrated in Figs. 1 and 2. The baroswitches to be calibrated are kept in a test chamber, the pressure and temperature inside which can be varied. The chamber is connected to the cistern of a mercury manometer. A soft iron float resting on the top of the mercury column acts as a core for a differential transformer. When the float is in the centre of the differential transformer, its output is zero but when the float moves away from the central position, an error voltage is developed. This error voltage is amplified by a servo-amplifier and applied to the control winding of the manometer servomotor, which is a two-phase induction motor. The error voltage is either in phase or 180° out of phase with respect to the phase of the voltage in the primary winding of the differential transformer, depending on the direction in which the core is displaced from the centre of the differential transformer. The servo-motor rotates the lead screw which moves the differential transformer on the manometer tube, in a direction depending on the phase of the error voltage, in such a way that the error voltage is a minimum and the float is maintained in the central position. The level of mercury in the manometer tube is thus automatically tracked. The motion of the servo-motor which makes the transformer follow the column of mercury is transferred to recorders through another servo chain. This consists of the synchro transmitter driven by the manometer servo-motor, whose rotation is conveyed to the recorder servo-motor, through the control transformer and servo amplifier. The recorder chart roll thus moves in synchronisation with the mercury level in the manometer tube. This motion is so adjusted that the chart is advanced according to pre-printed pressure scale on the chart paper. When the pen attached to the aneroid in the baroswitch makes a contact with a conducting segment of the commutator, the pen on the recorder is deflected and the resulting trace indicates the pressure on the printed chart. The pressures corresponding to each contact are thus automatically recorded.

3. General description

The calibration equipment is shown in Fig. 3. Five trays, each containing five baroswitches can be kept in the test chamber, the pressure inside

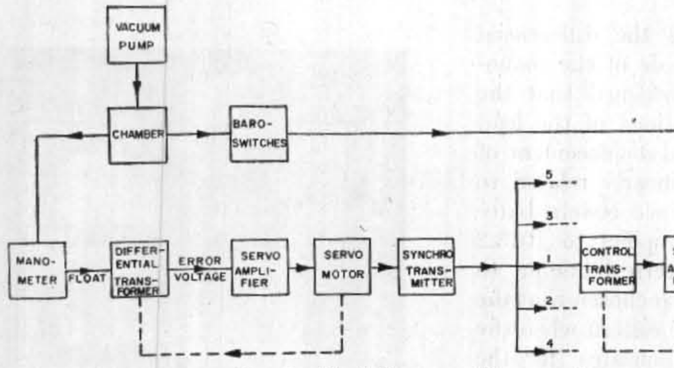


Fig. 1. Block diagram of Servo-system

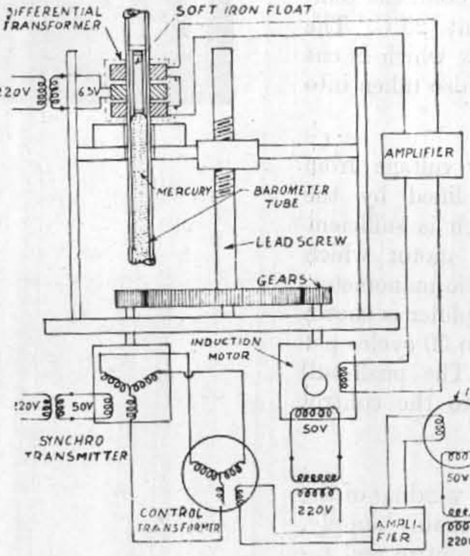


Fig. 2

which can be varied from 1050 to 2 mb. The chamber is connected to both the automatic and standard manometers. The baroswitch commutator has 150 conducting segments which are separately connected in a known sequence, *e g.*, all the conducting segments except every fifth segment upto 105 contacts are connected together, while every fifth contact is connected to a reference resistance. Besides providing check on the performance of the radiosonde during the sounding, these reference contacts serve to identify each segment. Calibration graphs for the five baroswitches in one tray are made on one recorder. Five recorders can be simultaneously driven by the automatic manometer enabling twentyfive baroswitches to be calibrated at a time. The complete cycle takes less than one hour.

3.1. *Automatic manometer* — The automatic manometer is illustrated in Fig. 4. The lower end of the manometer tube rests in the cistern while the upper end is connected to the test chamber. The soft iron float also serves as the index for the level of the mercury in the manometer tube. The differential transformer has three windings. The middle winding is the primary winding of the transformer and is energised from the mains supply through a 6V transformer. The two outer windings are the secondary windings. These are wound in opposition and connected in series. If the mercury level rises in the manometer tube, the core is displaced upwards from the middle position and a voltage in phase with the mains supply is developed in the output of the secondaries. The larger the displacement, the greater is the amplitude of the voltage. If the mercury level is lowered and the core displaced downwards from the middle position, the phase of the voltage developed in the secondaries is in opposition to that of the mains supply. The output of the differential transformer thus provides the error signal of the servo-system which maintains the core in its centre.

The lead screw which carries the differential transformer serves also as the scale of the manometer. The manometer is so designed that the scale is linear, *i.e.*, the revolutions of the lead screw and the consequent vertical displacement of the differential transformer are linearly related to the change in pressure. For a fixed cistern barometer, 760 mm of mercury correspond to 1013.2 mb at 0°C. The ratio of the cistern diameter to the manometer tube diameter is so chosen that the depression of mercury level in the cistern when the pressure is reduced exactly compensates for the thermal expansion of mercury in the manometer tube at the operating temperature. The instrument is kept in an air-conditioned room, the temperature of which is maintained at 25°C. The thermal expansion of the lead screw which is cut at a nearly constant temperature is also taken into account.

3.2. *Servo amplifier* — The error voltage from the differential transformer is amplified by the servo amplifier, the output of which is sufficient to drive the two-phase induction motor which turns the lead screw of the automatic manometer. The circuit diagram of the servo amplifier is shown in Fig. 5. The Twin-T filter tuned to 50 cycles per second forms the anti-hunt circuit. The push-pull output stage provides the power to the control winding of the motor.

3.3. *Servo-motor* — The reference winding of the servo-motor is excited from the mains supply. The phases of the voltages in the control and reference windings are adjusted to be 90° apart by the use of phase advance condensers. The motor thus rotates in either direction depending on the phase of the error signal. The revolution of the lead screw carries the differential transformer in the direction such that the error voltage is a minimum. The differential transformer thus maintains the float at its centre and follows the level of mercury and the revolutions of the lead-screw correspond to the change in pressure.

As a safety precaution, microswitches have been provided at both ends of the manometer. These cut off the supply to the reference winding of the motor when the carriage is driven beyond the safe limits.

3.4. *Recorder Servo chain* — The pressure data in the form of revolutions of the lead screw are transmitted to the recorder through this chain. It consists of the synchro transmitter, control transformer, servo amplifier, servo-motor and recorder.

3.4.1. *Synchro transmitter* — The servo-motor which drives the lead screw also rotates the synchro transmitter. The primary winding of the synchro transmitter is connected to the mains supply and the secondary windings are connected to the corresponding windings in the control transformers. The output of the transmitter is sufficient to operate five control transformers.

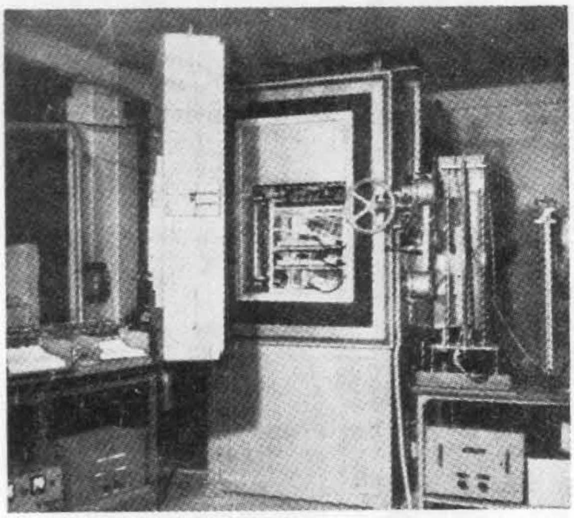


Fig. 3

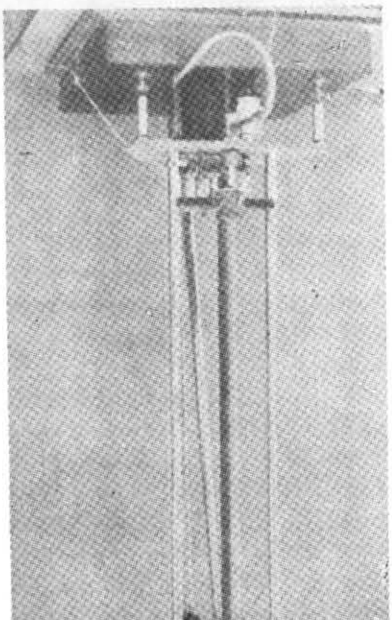
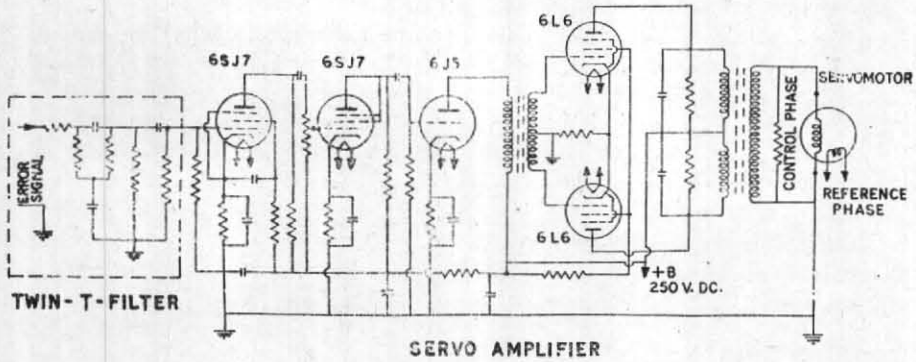


Fig. 4



SERVO AMPLIFIER

Fig. 5

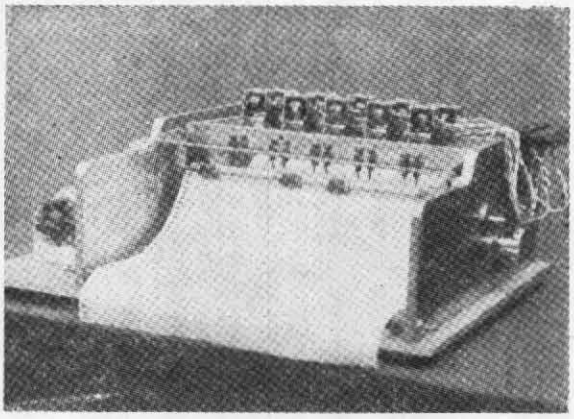


Fig. 6

3.4.2. *Control transformer* — In the null position, the shaft of the control transformer is aligned to that of the synchro transmitter. No voltage is then developed in the output of the control transformer. When the shaft of the synchro transmitter is rotated in a clockwise direction away from the null position, a voltage in phase with the supply is developed in the output. The amplitude of this voltage depends on the amount of rotation. Similarly, if the synchro transmitter shaft is rotated in a counter-clockwise direction from the null position, a voltage in antiphase with that of the mains supply is generated. The output of the control transformer is thus an error signal. This error voltage is amplified by the servo amplifier and applied to the recorder servo-motor. The amplifier and motor are similar to those used in the automatic manometer. The servo-motor drives the recorder chart roll and also rotates the shaft of the control transformer so as to bring it to the null position. The recorder chart drive is thus synchronised with the revolutions of the lead screw and with fall in pressure, the chart advances at a rate determined by the rate of change of pressure.

3.4.3. *Recorder* — The calibration chart recorder is illustrated in Fig. 6. The recorder pens, two per baroswitch, are directly actuated by 6V miniature radiosonde relays. The relay is operated when the aneroid pen makes a contact on the conducting segment of the commutator. One of the two relays is energised by one of the reference contacts and the other by remaining contacts. Every fifth contact is thus recorded separately making identification easy. The thick printed lines on the chart are one inch apart and correspond to 25 mb. Thin lines printed every 0·2 inch correspond to 5 mb. The accuracy of reading is 0·5 mb and continuous record of beginning, end and duration of each segment (whether conducting or insulating) in terms of pressure is available.

4. Performance of the instrument

The accuracy of the automatic calibration was checked by comparing it with a standard manometer which was also connected to the test chamber. The readings were taken every 50 mb during the calibration cycle and pressure values simultaneously read on the recorder chart. The differences were within the reading accuracy of 0.5 mb. To keep a check on the performance, the pressure readings are taken on the standard manometer both at the start and end of each calibration cycle during routine calibration and the record on the chart compared against these values. The gain and anti-hunt settings on the servo amplifier are made in such a way that the servo-motors run smoothly without any overshoot. The chart on the recorder is adjusted such that the first thick printed line corresponds to 1025 mb. This facilitates reading of pressure values on the record. During the calibration cycle, the temperature inside the chamber is reduced simultaneously with pressure to simulate actual flight conditions. Any errors in pressure measurement that may arise due to variation in temperature during the sounding are thereby kept to a minimum.

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