551·508(540)

Progress of Meteorological Instrumentation in India*

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(*Received 29 January 1968*)

1. Introduction

1.1. Perhaps there can be no better proof of the proverb : 'Necessity is the Mother of Invention ' than the development of meteorological instrumentation in the India Meteorological Department. With the growing need for meteorological data for various scientific disciplines and other applied fields, it became necessary to extend our meteorological observing net-work on a country-wide basis and also equip our observatories with more and more sophisticated instruments. In the context of limited financial resources, particularly in terms of foreign exchange, there was no other alternative but to take up the manufacture of instruments in the department itself. A start was made first in the early thirties of this century by setting up two small repair and maintenance units at Agra and Poona in regard to upper air and surface meteorological instruments respectively. In course of time these two small units became the centres of design, development and production of routine meteorological instruments.

1·2. By 1938, the workshop organisation at Agra became a fairly well established manufacturing unit and started production of self-recording meteorographs and other simple meteorological instruments, for the exploration of the upper atmosphere from a few selected stations in India. Similarly, the meteorological workshop at Poona started manufacturing the routine surface meteorological instruments, such as, raingauges and anemometers. In the year 1941, the workshop at Agra was moved to the new site of the Upper Air Office at New Delhi. Progress was made here on the development of a suitable radiosonde for Indian conditions, which could be easily fabricated from components and materials locally available and employing a simple technique so that the then available scientific staff could handle the instruments without much difficulty. In order to expedite the development of such an instrument, the two units at New Delhi and Poona were encouraged to evolve a suitable radiosonde on a competitive basis. This proved to be a very efficacious method for the quick development of the instrument. By 1942, both the centres evolved two different types of radiosondes one using a clock-work called the C-Type Radiosonde and the other using a fan called the F-Type Radoisonde.

1·3 During World War II, need arose for getting upper air temperature and humidity data from a number of stations in India and these two centres helped in setting up 13 to 14 radiosonde stations within a few years. The two types of radiosonde instruments are still in use at sixteen stations in India. These are, however, on the verge of replacemment by audio-frequency modulated radiosondes in which the meteorological parameters change the electrical property of the sensor which is made to frequency-modulate an audio signal. The extent of audio-modulation determines the value of meteorological parameter in question. This development also came as a matter of necessity. The previous sondes were of the mechanical type and therefore subject to errors due to zero-shift and hysteresis. These sondes placed serious limitations on the accuracy of measurement and the maximum height of observation. The advent of jet aircraft in the post-war period and supersonic aircraft of the future have made the need far more pressing for probing the atmosphere to very high levels. A programme of reorganising and expanding our workshops has been made to meet the needs of the time.

1·4. Besides the production of the conventional meteorological instruments both for surface and upper air observations, the department also produces a very large number of specialised instruments in the field of geophysics, agricultural meteorology and other allied branches. In the subsequent paragraphs a brief account is given of some of these instruments.

2. Departmental Workshops

Each one of the workshops at New Delhi and Poona has three main divisions, *viz.*, (*i*) Machine-shop, (*ii*) Assembly-shop and (*iii*) Design and Development-shop.

*Presented at the UNESCO Seminar on "Instrumentation" organised by Central Scientific Instruments Organisation (CSIO) and held at Chandigarh from 12 to 16 November 1967

Fig.1. Machine-Shop at New Delhi

Fig. 2. Machine-Shop at Poona

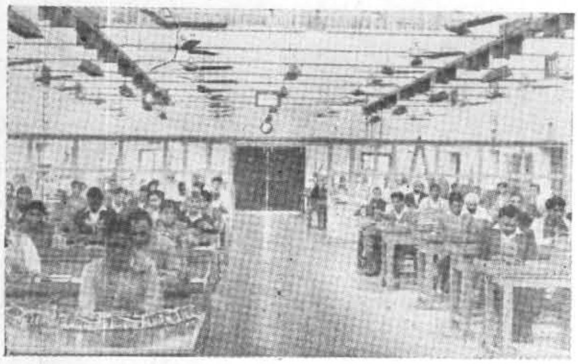

Fig. 3. Assembly-Shop, New Delhi

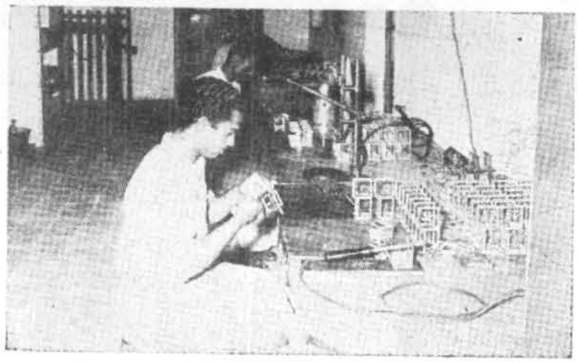

Fig. 4. Assembly-Shop, Poona

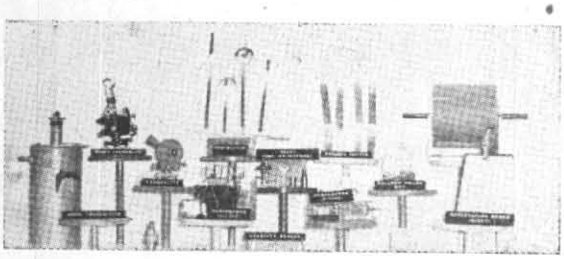

Fig. 5. Routine Upper-air instruments

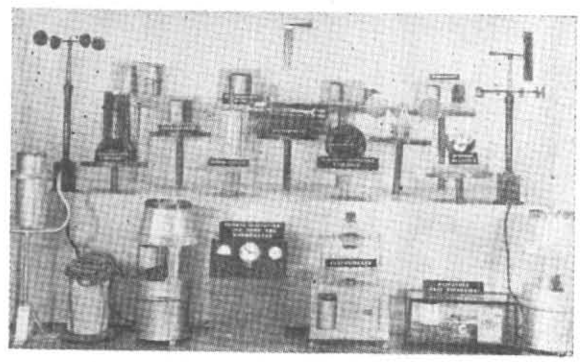

Fig. 6. Routine Surface instruments

Figs. 1 to 4 show these shops at New Delhi and Poona.

3. Production of Upper Air and Surface Instruments

3·1. Practically all the instruments and equipment require for running an upper air station are manufactured in the meteorological workshops at New Delhi and these include (*i*) Pilot Balloon Theodolite, (*ii*) Protractors and Direction measurers, (*iii*) Observation boards, (*iv*) Balloon releasing and following accessories, (*v*) Low pressure Hydrogen Generators and (*vi*) Radiosondes. A number cf these routine upper air instruments can be seen in Fig. 5.

3·2. As in the case of an upper air observatory so also for a surface meteorological station, all the instruments are manufactured at Poona. These include a wide range of instruments from the most simple to the most sophisticated one. The list is a long one and mention may be made of a few instruments only, such as (*i*) Barometer and Barograph, (*ii*) Psychrometers and Hygrographs, (*iii*) Anemometers and Anemographs, (*iv*) Raingauges—ordinary and self-recording, (*v*) Evaporimeters and Evaporigraphs, (*vi*) Thermographs and (*vii*) a large number of other instruments including anemometers and windvanes. A general view of the range of routine meteorological instruments can be seen in Fig. 6.

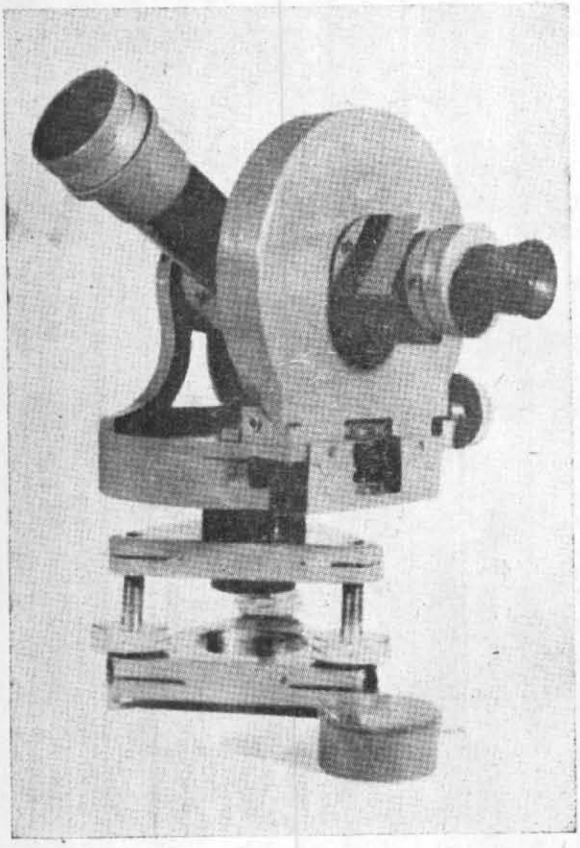

Fig. 7. Pilot Balloon Theodolite

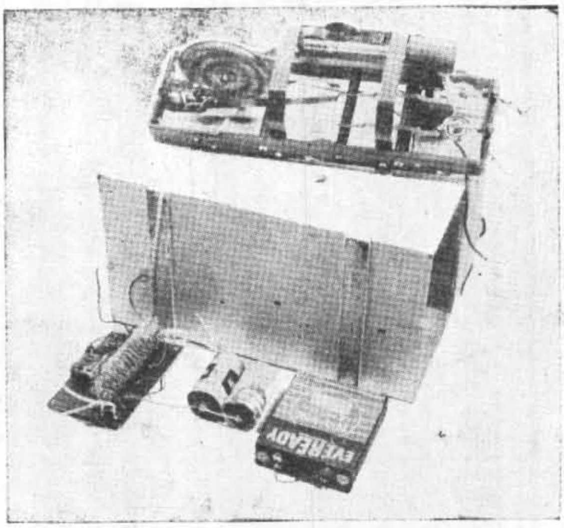

Fig. 8. C-Type Radiosonde

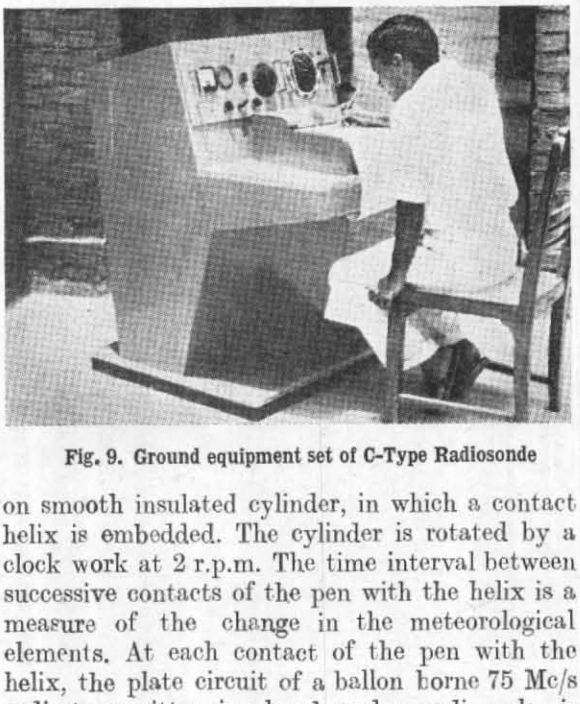

Fig. 9. Ground equipment set of C-Type Radiosonde

3.3. For the manufacture of the pilot balloon theodolite; (Fig. 7), the optics are imported.

No attemt has been made so far to get the optical components manufacturd in the country as the number of these instruments required is very small. If and when the number of these instruments increases, it may be desirable to take the help of CSIO for manufacturing the optical components of these theodolites in India. This may not also be required in view of the fact that observations from pilot balloons are restricted in height due to the limitations placed by the visibility conditions and cloud ceiling resulting in the gradual replacement of the optical theodolite by the radio-theodolite.

4. Manufacture of Radiosondes

4·1. C-Type Radiosondes.

4·1·1. As mentioned earlier, the department uses two different types of radiosondes known as C and F-Types. The C-Type is the clock-operated radiosonde and works on "Olland" principle in which each of the meteorologically sensitive elements actuates mechanically pen arm resting on smooth insulated cylinder, in which a contact helix is embedded. The cylinder is rotated by a clock work at 2 r.p.m. The time interval between successive contacts of the pen with the helix is a measure of the change in the meteorological elements. At each contact of the pen with the helix, the plate circuit of a ballon borne 75 Mc/s radio-transmitter is closed and a radio-pulse is received in the radio-receiver of the ground equipment . Each received-pulse actuates a relay in the recorder and produces a short mark on a chart paper roll corresponding to pressure, temperature humidity and a refernce pen. Each instrument is individually calibrated up to a temperature of —60° to—80° C in a low temperature calibration equipment. A photograph of the radiosonde together with the meteorograph transmitter and its batteries can be seen in Fig. 8.

The radiosonde ground equipment for obtaining the flight record of the instrument is shown in Fig. 9.

Fig. 10. F-Type Radiosonde

Fig. 11. Ground equipment of F-Type Radiosonde

Fig. 12. Audio-modulated Radiosonde

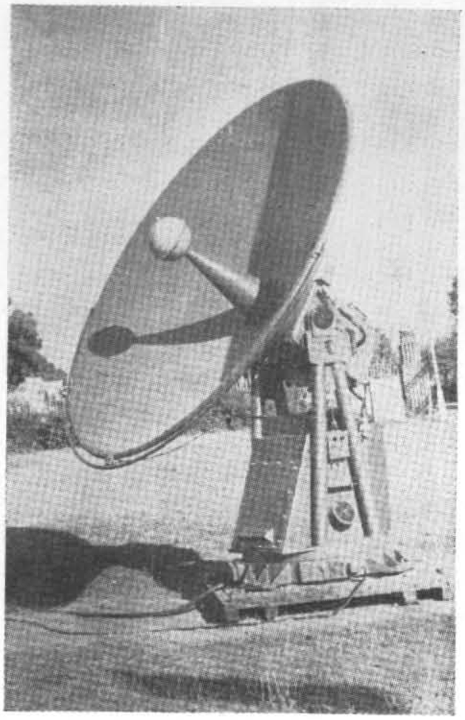

Fig. 13. WBRT Radio-theodolite

Fig. 14. Ground equipment of 1680 Mc/s Radiosonde

The ground equipment employs a super regenerative receiver of high sensitivity and can be seen on top left of the ground equipment.

4·2. F-Type Radiosonde

4·2·1. The F-Type radiosonde of the meteorological department is manufactured in the workshops at Poona. A photograph of the radiosonde can be seen in Fig. 10.

In this instrument also, 'Olland' principle is utilised. The signals from the balloon-borne transmitter are sent out in the form of pulses which are recorded on a paper tape and the number of pulses between the reference marker and the pulse due to either temperature, pressure or humidity determine the value of the element in question. The ground equipment set complete with receiver and the paper tape recorder is shown in Fig. 11.

These instruments are individually calibrated upto about $-60°C$ in a suitable deep-freeze chamber and each instrument is supplied with its own calibration graph.

4·3. New Radiosonde.

4·3·1. As already indicated, the C and F-Type radiosondes are about to be replaced by the new audio-modulated type radiosonde. The following

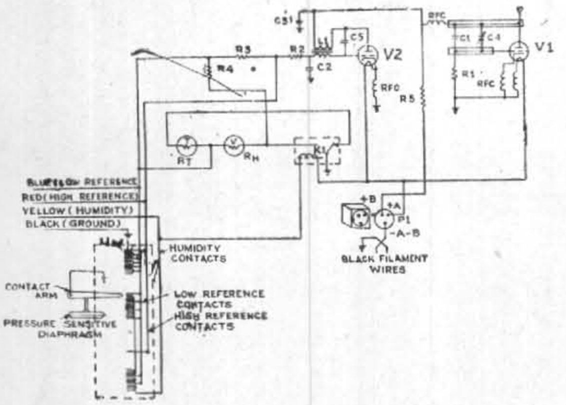

Fig. 15. 401 Mc/s Blocking Oscillator-Transmitter circuit diagram

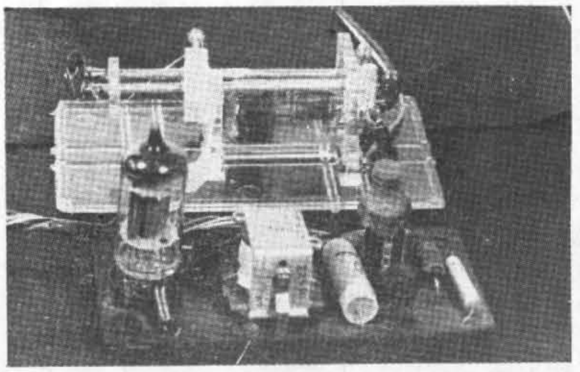

Fig. 16. 401 Mc/s Blocking Oscillator

paragraphs describe the new radiosonde and its associated ground equipment.

4·3·2. Audio-modulated radiosonde (1680 Mc/s) as shown in Fig. 12, is a precision, balloon-borne telemetering instrument which measures pressure, temperature and relative humidity of the upper atmosphere. Thermistors and hygristors are used for temperature and humidity measurements respectively.

4·4. WBRT Ground Equipment.

4·4·1. This is U. S. Weather Bureau type radiotheodolite with a ranging attachment. It can track a balloon-borne transmitter having an output of only 50 m.w. at a frequency of 1680 Mc/s, upto horizontal distances of 160 km or more.

The spatial position of radiosonde in terms of elevation, azimuth angles and slant range is automatically recorded periodically. Upper wind are computed from these data. Simultaneously this radio-theodolite receives the radiosonde data in the form of audio signals and feeds them to a radiosonde recorder described below.

4·5. Ground Recorder for 1680 Mc/s Radiosonde.

4·5·1. The radiosonde signal from the WBRT receiver is in the form of audio frequencies varying between 0 and 200 cycles per second. The frequency converter, which uses a magmeter, accurately converts these frequencies into a D.C. voltage suitable for operating a strip-chart recorder.

The recorder which is used in the ground equipment is a true rectilinear recorder operating on the null balancing potentiometer principle.

4·6. 401 Mc/s Transmitter.

4·6·1. This is a miniature, light weight, one valve UHF transmitter designed by IMD and is being manufactured at BEL, Bangalore for the department. The transmitter operates at 401 Mc/s and uses all indigenous components. A circuit diagram of the blocking oscillator-transmitter is given in Fig. 15.

The printed circuit blocking oscillator audio modulates the carrier at a rate determined by the meteorological sensor.

4·6·2. The circuit (Fig. 15) consists of a tube 6C4 acting as a self-blocking oscillator and a tube type EC 81 acting as a carrier oscillator. The tuned circuit of EC 81 is a transmitter, frequency of which can be adjusted by a screw attached to the grid lecher rod. The resistance in the grid circuit of 6C4 determines the blocking rate at which carrier is modulated. The resistance may be the thermistor, hygristor or the reference resistor depending on the position of the pressure operated switch.

4·6·3. The commutator switch consists of insulating and conducting segments and is operated by the aneroid capsule in conjunction with the 6V miniature relay. During the flight, the blocking audio rate associated with the temperature and humidity elements may vary from 8 to 185 c.p.s. A photograph of the 401 Mc/s blocking oscillator is shown in Fig. 16.

4·7. Metox Radio-theodolite.

4·7·1. It is radio direction finding equipment used for mesurement of wind direction and speed in the atmosphere. The optical theodolite which it replaces has the limitation that it cannot be used in case of poor visibility and low cloud ceiling. The radio-theodolite (Fig. 17) consists of a directional antenna, an antenna phasing switch for changing antenna lobes and 401 Mc/s receiver with an oscilloscope indicator.

This theodolite provides a means for an operator to locate the position of the balloon-borne radiosonde transmitter in space at any moment. When the four pips on the oscilloscope are of equal heights the radio-theodolite is on the 'bearing

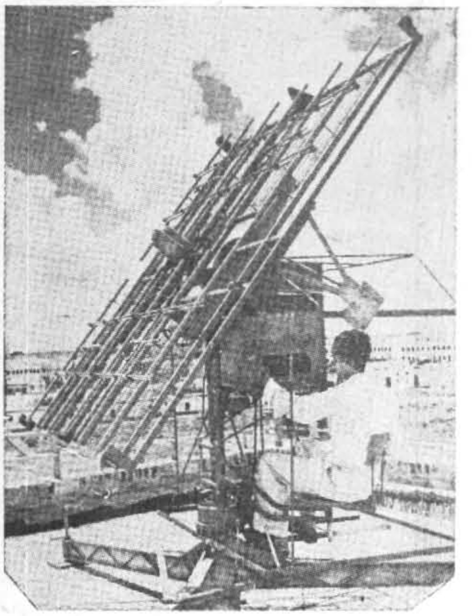

Fig. 17. Metox Radio-theodolite

Fig. 18. Selenia Radar Antenna System

5. Selenia Radar

5·1. It is a dual purpose X-band radar which can be used either for storm detection or for the determination of upper winds. It has a peak power output of 200 KW and effective range of 400 km. To determine upper wind characteristics, the radar automatically tracks a corner reflector carried by a balloon. Fig. 18 shows the antenna system of the radar.

5·2. Selenia Ground Installation.

5.2.1. The various units that comprise a typical Selenia ground installation are shown in Fig. 19. The indicator unit consists of a 16″ CRT, on which PPI, RHI or REI displays are presented. In RHI presentation, the target height is plotted against ground ranges on the screen. In REI presentation, the target elevation is plotted against the range. Iso-echo contour circuit enables detection of strong cells within the storm aera. The auxiliary indicator consists of an A/R scope which presents the target echo amplitude against range.

Provision is made for closer examination of the target echo by the use of R-scope. The *transmitter console* consists of transmitter and receiver. 0·5 μ sec pulses are used at short range and 3 μ sec pulses for long range detection. The *tracking unit* provides a double scale system for accurate target range measurements, automatic range tracking of the target and determination of angular errors in pointing. The information is fed to antenna servos. The *data presentation unit* presents continuous display of azimuth and elevation data concerning the antenna position and the range information received from the automatic range tracking unit.

5·3. Radiosonde data from Selenia Radar.

5·3·1. The antenna assembly of the radar consists of a reflector with r.f. feed assembly and drive mechanisms. The reflector is a paraboloid of 2-metre diameter for the X-band radar system. The property of the radar to keep the reflector pointed towards the balloon-borne target during upper wind measurements is utilised simultaneously to obtain meteorological information from a 401 Mc/s audio-modulated radiosonde, carried by the same balloon, through the two Yagi arrays mounted on the two sides of the radar reflector shown in Fig. 18.

6. Special Sondes

6·1. Besides, pressure, temperature and humidity there are many other important meteorological parameters which are required to be measured at different levels in the upper atmosphere. The instruments which are used for measuring these elements by telemetering, are special types of sondes such as radiometersondes, ozonesondes, etc each bearing the name of the element to be measured.

6·2. Radiometersonde.

6·2·1. It is one of these special types of sondes which measures the upward and downward radiation flux. It has two black surfaces one facing upwards and the other downwards. In each of these surfaces is embodied a thermistor which measures the radiation temperature on the surface. Knowing the temperatures of these two surfaces, the outgoing and incoming radiation due to emission from earth's surface and from clouds and other particulate matter can be easily computed. The radiation flux can also be calculated theoretically by assuming the physical properties of water vapour and carbon dioxide. It has

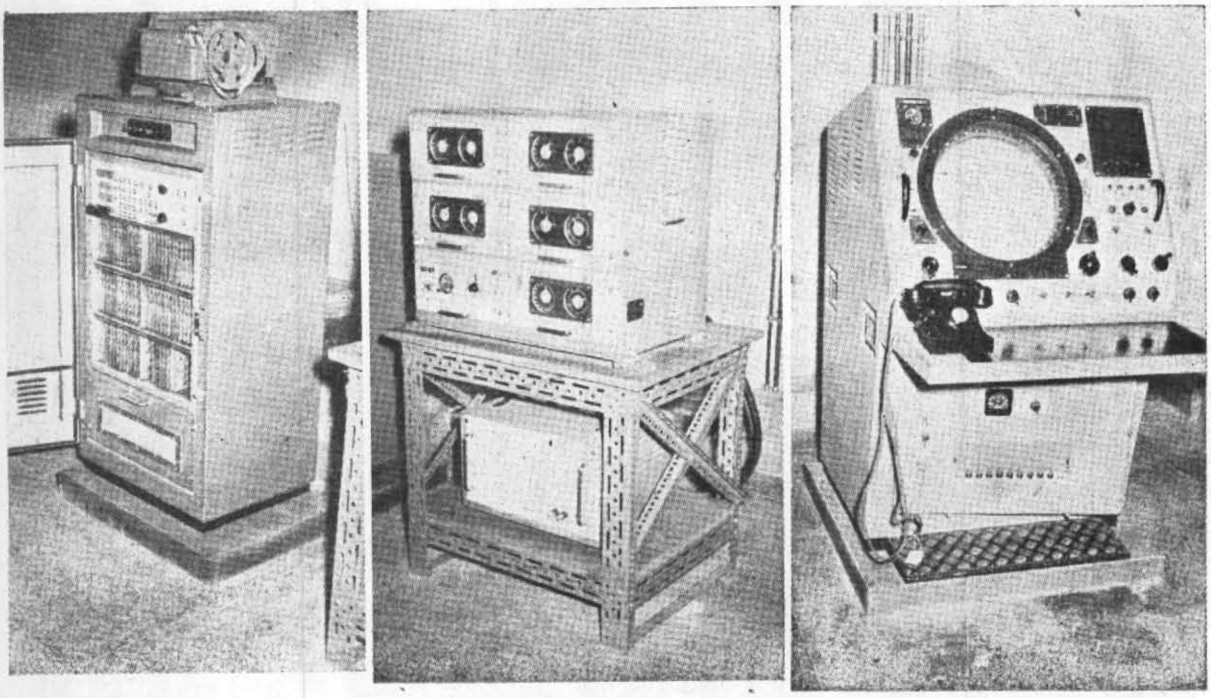

Fig. 19. Selenia Radar Ground Display

been found in radiometersonde ascents over north India that there is a considerable difference between the values computed on the basis of absorption of water vapour and carbon dioxide and the values observed with the help of a radiometersonde. This is attributable to radiation attenuation by a fairly deep layer of dust which prevails over this region especially during summer months.

6·2·2. This radiometersonde was originally developed by Suomi and Kuhn at the University of Wisconsin, U.S.A. and has been adopted for use with the audio-modulated radiosonde already described in the preceding paragraphs. Fig. 20 shows a picture of the radiometersonde.

6·3. Ozonesonde.

6·3·1. The ozone sensor in this special type of sonde is an electrochemical cell of the Brewer type called the "Bubbler" and it makes use of the reduction of a solution of potassium iodide in the bubbler by ozone itself. The surrounding air is pumped at a steady rate of about 200 c.c. per minute into the bubbler by a miniature pump operated by a miniature motor. The arrangement is shown in Fig. 21.

Every molecule of ozone liberates two electrons which flow through the external circuit. For the amounts of ozone found in the atmosphere, currents upto 5 μA are obtaniable.

6·3·2. The telemetering system consists of a temperature controlled transistorised D.C. amplifier modulator and UHF transmitter. The bubbler current output from the D. C. amplifier modulates the 72 Mc/s carrier in the range 0—200 cycles. The ozonesonde transmits in addition to the ozone reading, the pumping rate, the D. C. amplifier zero, the atmospheric pressure and the temperature of the pump. The entire system is housed in a thermocole (expanded polystyrene) housing of 100 mm wall thickness to prevent the potassium iodide solution from freezing. The signals from the sonde are received on a 72 Mc/s receiver and recorded on a 300 mm chart as in the case of ordinary audio-modulated radiosonde.

7. Special applications of Electronics in meterological instrumentation

7·1. The instruments described so far are more or less of conventional type which are in routine use in all meteorological services with some difference in their design. In the India Meteorological Department a few special applications of electronics to meteorological instrumentation have been made which are quite unique. Some of these are described below.

7·2. Calibration of C-Type Radiosonde.

7·2·1. The calibration of radiosondes requires that we subject the instruments to the same pressure and temperature varations as are met with in actual flight of the balloon in the atmosphere. For this purpose a refrigeration chamber is used

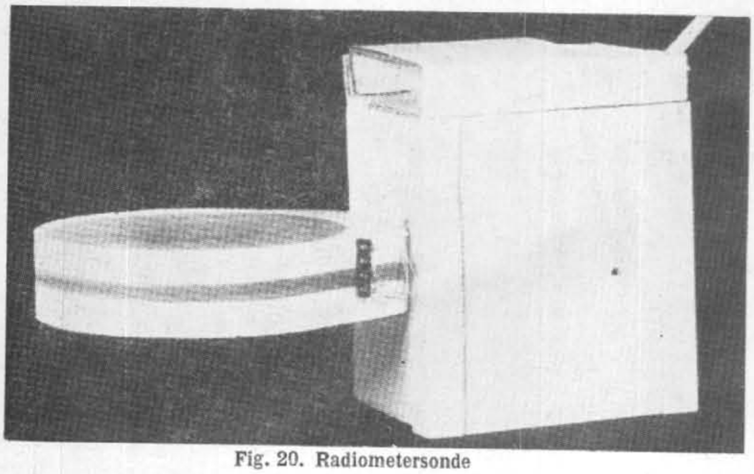

Fig. 20. Radiometersonde

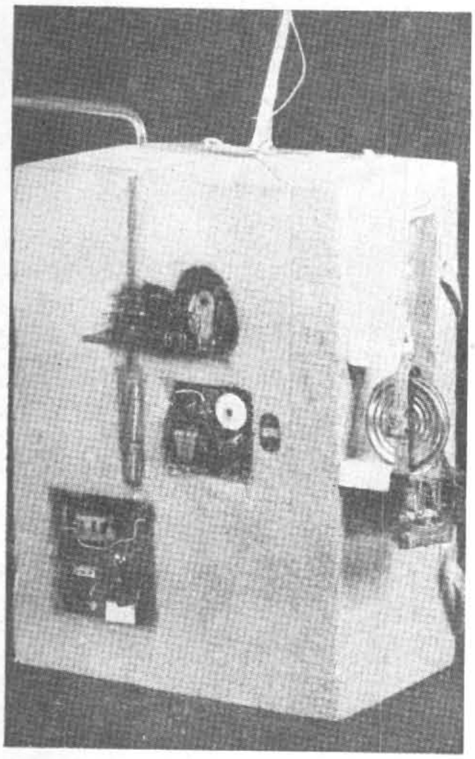

Fig. 21. Electro-Chemical Ozonesonde

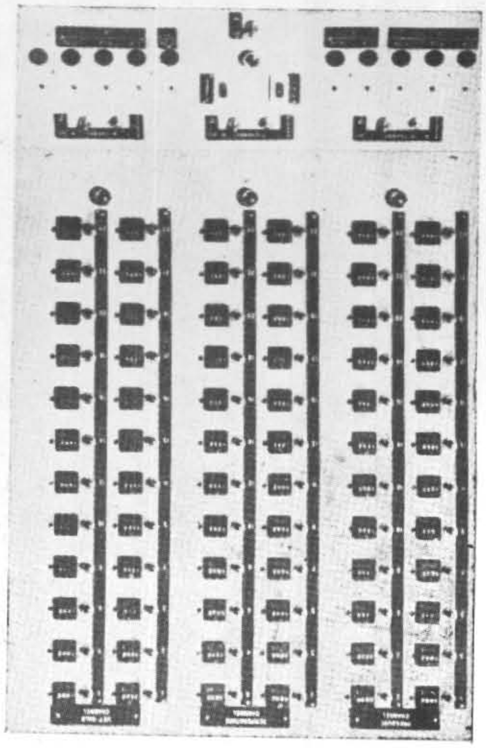

Fig. 22. Front Panel of the equipment

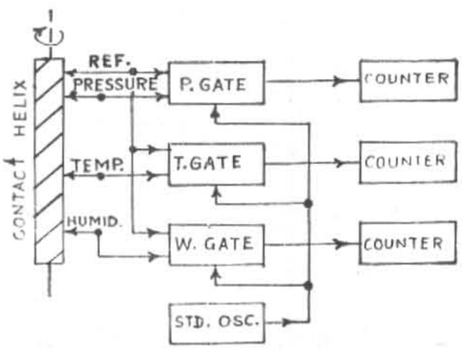

Fig. 23. Block diagram of the principle of electronic calibration of radiosondes

in which both pressure and temperature are reduced at a rate which simulates the near atmosphere conditions. In the calibration technique a special electronic principle is used.

7·2·2. The main principle underlying the electronic calibration is that instead of measuring the time interval or linear displacement of various marks from the reference mark of the radiosonde, the number of oscillations from a standard oscillator is counted in each cycle from the time the reference contact is made. The pulses from the standard oscillator are fed to low speed frequency counters and if the counting is done at a uniform rate, the number of counts in the desired interval would be proportional to the corresponding displacements, thus enabling one to draw calibration curves for each element after obtaining the time-intervals from the number of counts. To measure the time-interval between the reference pen and the sensor pen contacts, three electronic gates are employed. The reference contact opens all the three gates for pressure, temperature and humidity simultaneously and the three low speed mechanical counters start counting the pulses from the standard oscillator. Contacts from

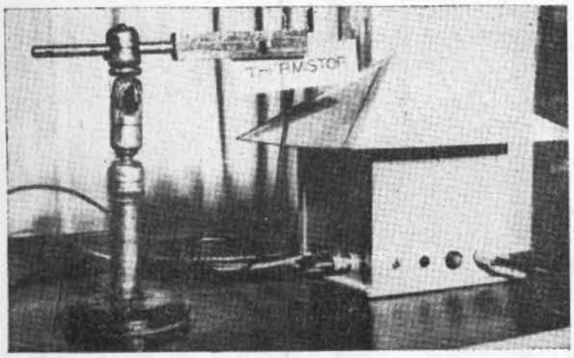

Fig. 24. Remote Temperature Sensor Unit

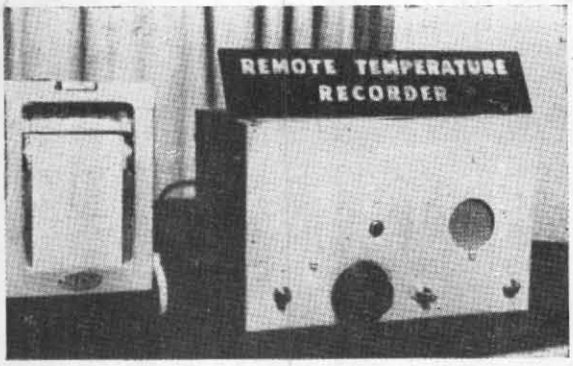

Fig. 25. Remote Temperature Recorder Unit

the other elements close the respective gates. The operation is shown in the block diagram in Fig. 23.

The whole equipment has been constructed on a sub-assembly basis, keeping in view ease of replacement and servicing. All the counters along with the reset switch and neon indicators of the gate circuit are arranged in a front panel (Fig. 22) in six columns, two each for pressure, temperature and wet bulb.

7·3. Remote Indicating Instruments.

7·3·1. Temperature.

7·3·1·1. For remote indication of temperature, thermistors are generally used as temperature sensors in a phase-shift oscillator. The changes in temperature cause variations in the resistance of the thermistor. The oscillator output can be transmitted by means of a cable to the recording head. The instrument can give a continuous record of temperature with an accuracy of $\pm 0 \cdot 5$°C.

7·3·1·2. The instrument consists of three different parts, *viz.*, (*i*) transmitter, (*ii*) frequency meter and (*iii*) recorder. While the transmitter comprises the sensing-head, the frequency meter and the recorder make up the receiving end. These are shown in Figs. 24 and 25.

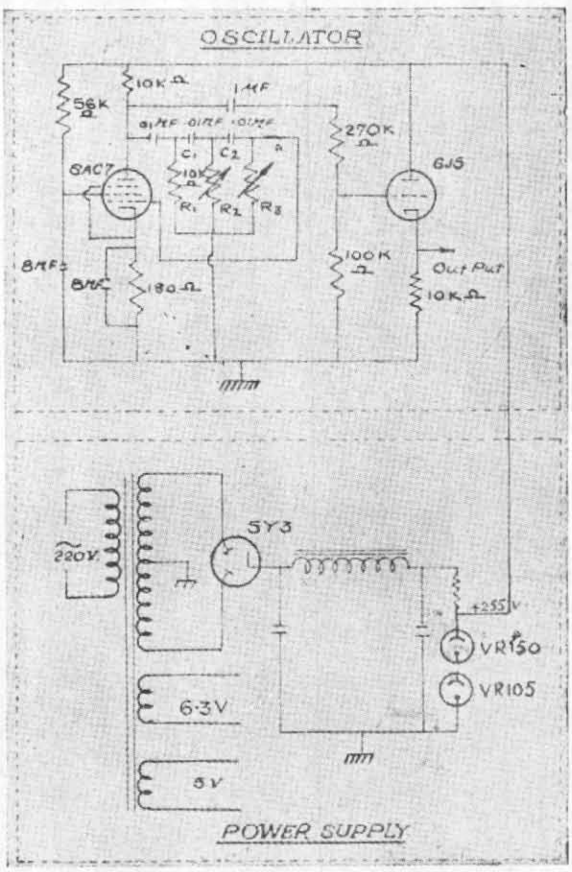

Fig. 26. Circuit of Transmitter of Remote Temperature Indicator

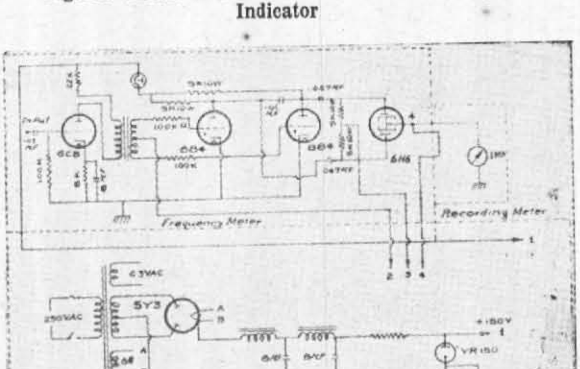

Fig. 27. Circuit of Receiver of Remote Temperature Indicator

7.3.1.3. The electronic circuit of the transmitter portion and the circuit of the receiver are shown in Figs. 26 and 27 respectively.

The transmitter consists of a phase shift oscillator, a cathode follower and a power supply system

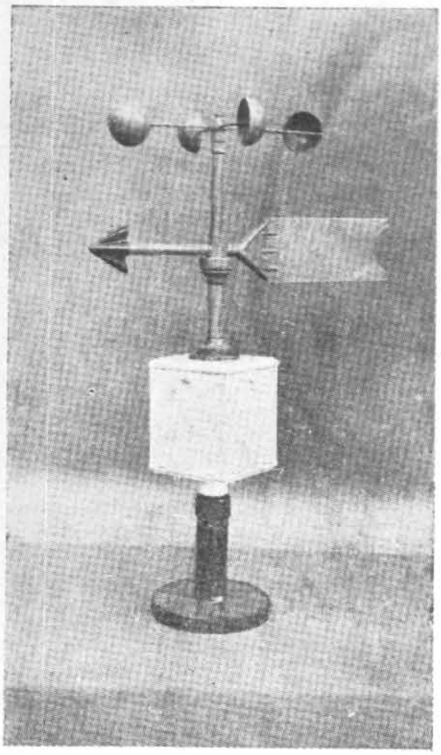

Fig. 28. Anemovane Head

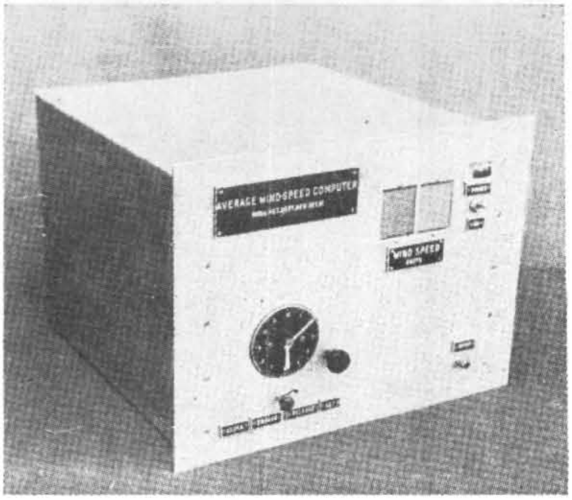

Fig. 29. Display unit for Anemovane

(Fig. 26). The oscillator uses a 6AC7 valve. At the frequency of oscillation (72 Mc/s), the phase shifting network (consisting of resistances R_1 R_2 and R_3) produces a phase shift of 180° of the plate voltage of the oscillator tube and thus the feedback to its grid is in phase with the input voltage because a phase change of 180° already exists between grid and plate voltage of the tube. Thus the variation in the value of the thermistors at R_2 and R_3 are used to create the phase shift in the carrier frequency.

7·3·1·4. The receiving equipment (Fig. 27) is a standard frequency metre and utilizes a recording type D.C. milliameter for giving a record of the measured temperature. The instrument has three ranges (—5 to 25°C, —15 to 45°C and 20 to 50° C), any of which can be selected by a switch on the panel.

7·3·2. Photo Anemovane.

7·3·2·1. For aviation purposes, there is a need for givig the average wind speed over a period of ten minutes. While the continuous indication of wind speed and direction is not difficult, the *continuous averaging* of wind direction and speed requires a little complicated instrumentation. Fig. 28 shows a photo anemovane designed for this purpose.

7·3·2·2. The average wind speed is computed by transistor binaries from the pulses received from a photo-transistor anemometer during each ten-minute interval and is registered on transistor decade units. Diode decoders transfer this figure to digital display tubes. The display on the indicating tubes is held through relays. The average wind speed is thus continuously displayed.

7·3·2·3. In order that the average wind speed remains displayed on the indicating tubes during the computation of the next ten-minute average, a transfer unit and a memory unit have to be incorporated between the registering and displaying units. These units have been combined in a simple relay circuit which is operated by momentary pulses. Fig. 29 shows the display unit.

7·3·2·4. Measurement of wind direction involves determining the angle at which wind vane is positioned with respect to north. The average value of this angle over the preceding ten-minute interval has to be computed to obtain the average wind direction. This requires that we have a switch giving the position of north and a switch giving position of the windvane. Values of these positions are to be monitored a number of times during the ten-minute interval and then averaged for presentation. In the photo anemovane phototransistors with pilot lamps placed across perforated discs provide the switching action while the rotating anemometer enables these perforated discs to move a number of times during the ten-minute period thus giving sufficient number of readings

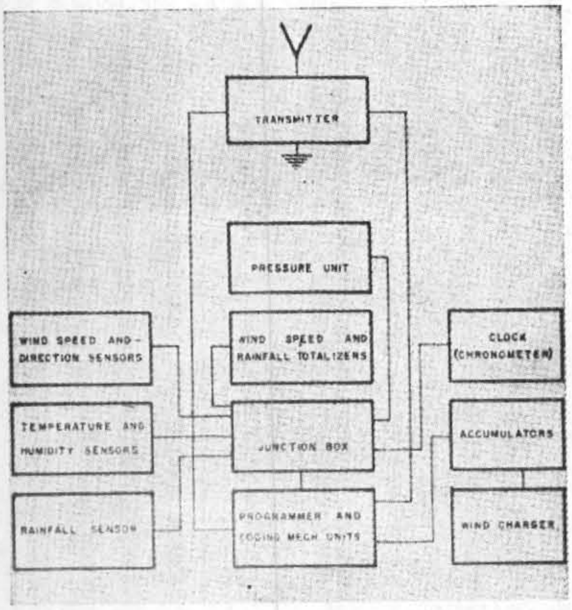

Fig. 30. Block diagram of Automatic Weather Station

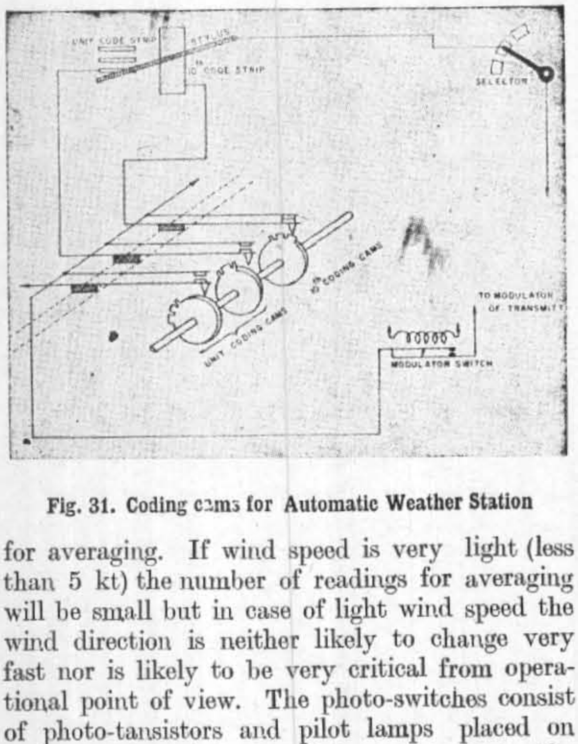

Fig. 31. Coding cams for Automatic Weather Station

for averaging. If wind speed is very light (less than 5 kt) the number of readings for averaging will be small but in case of light wind speed the wind direction is neither likely to change very fast nor is likely to be very critical from operational point of view. The photo-switches consist of photo-tansistors and pilot lamps placed on opposite side of discs which are rotated by the anemometer. One of the pilot lamps rotates with the windvane while another is fixed in the direction corresponding to north. The interval between these two switches, therefore, corresponds to the angle subtended by the windvane. For digital presentation, the values of the angle are computed as a fraction of 360°.

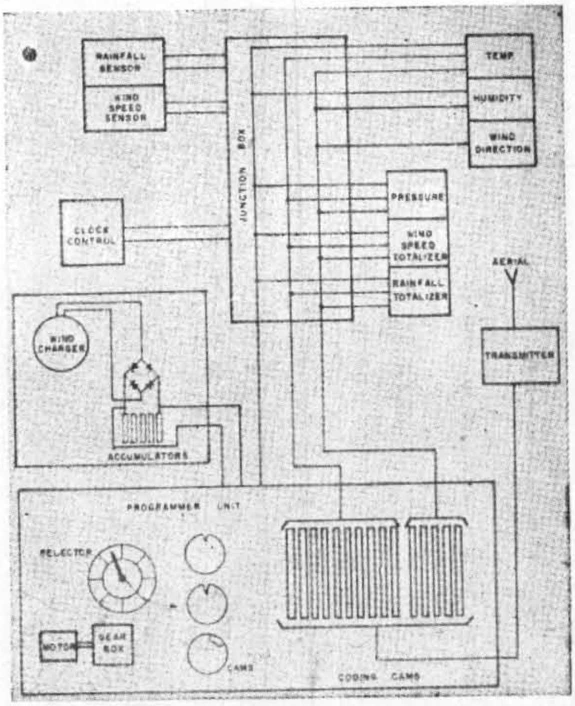

Fig. 32. Inter-connections with sub-units

7·4. Automatic Weather Station.

7·4·1. An Automatic Weather Station has been developed in the India Meteorological Department. The station measures and transmits at regular intervals data on pressure, temperature, humidity, wind direction, wind speed and rainfall. A special coding system enables the transmission of all data in Morse Code. The temperature, humidity and pressure values are converted by their respective coding units from analogue to digital form. The wind speed and rainfall values are coded after totalizing the pulses generated by their sensors while the information regarding the wind direction is coded through direct contacts operated by windvane. The system uses a 4 to 6 Mc/s h.f. transmitter, aerial, receiver and a 24-volt power supply. Fig. 30 shows the block diagram of the system.

Fig. 31 shows the schematic diagram of the principle of connections of one unit with coding cams and transmitter. As will be seen from the figure, there will be a programmer connecting each met. element in a sequence. At that time the position of the coding stylus on the 10″ code strip with a number of contacts (arranged in thickness according to Morse Code) determines the particular duration (long or short) of the signal to b emitted by the transmitter. These long or short duration pulses correspond to the dashes or dots of the Morse Code.

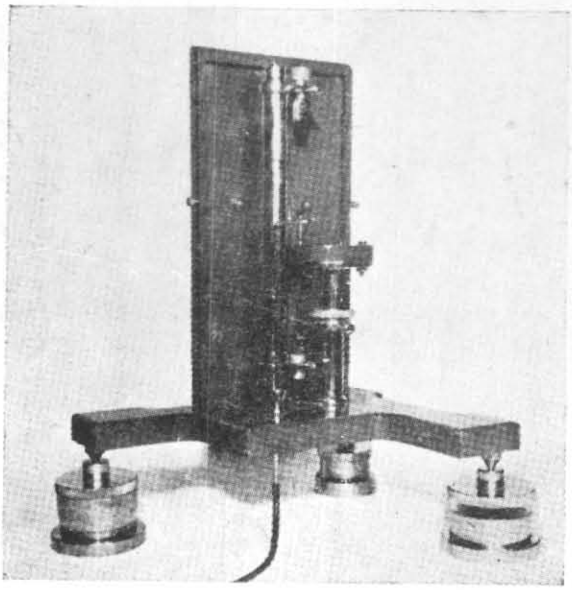

Fig. 33. Wood-Anderson Seismograph

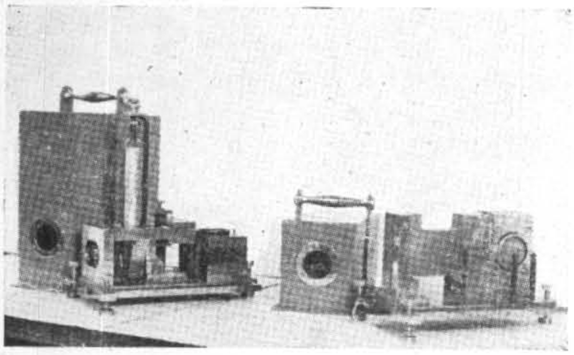

Fig. 34. Electromagnetic Seismograph

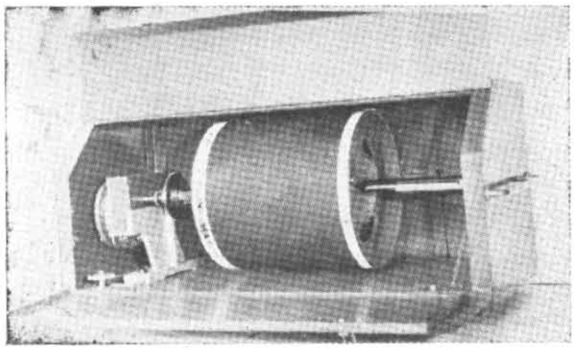

Fig. 35. Seismograph Recorder

Fig. 32 shows the block diagram of the system. This block diagram shows the various parameters measured and the inter-relationship of the various sub-units of the system.

8. Seismological Instruments

8·1. With the increase in the number of dams for our hydro-electric and irrigation projecis the demand for seismological instruments also increased considerably. It was impossible to import all these instruments and therefore India Meteorological Department undertook the development and construction of different types of seismographs. These instruments have already been installed in a large number of seismological observatoires set up in different parts of our country. A few of these seismographs are described here.

8·2. Wood-Anderson Seismograph.

8·2·1. Fig 33 shows the photograph of wood-Anderson's seismograph with its cover removed. This type of seismograph is a demountable model of Wood-Anderson seismograph. It has a fine suspension wire of tungsten or phosphor-bronze (1—50 mm in diameter). A cylinder of copper 3·8 cm long and 0·266 cm in diameter is attached to the middle of the suspension. A small mirror is attached to the copper cylinder whose rotation can be recorded on any photographic recording unit. Damping is brought about and adjusted by placing the copper cylinder between the pole pieces of an Alnico magnet. The period is adjusted between 0·5 to 6 sec.

8.2.2. With a period of 0·8 sec and critical damping the instrument can give earthquake magnitudes directly. The static magnification can be adjusted between 1000 to 2000.

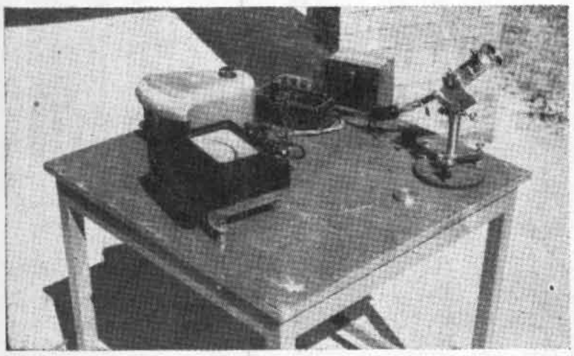

Fig. 36. Angstrom Pyrheliometer

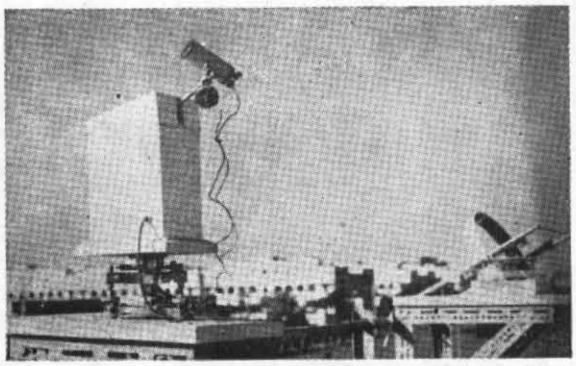

Fig. 37. Actinograph

8·3. Short period Electromagnetic Siesmographs.

8·3·1. These seismographs which are also manufactured in our workshop are used for recording both horizontal and vertical components of earth's displacement. One such set of instruments can be seen in Fig. 34. These are of moving coil type and are used both for tele-seismic and regional studies. They are portable and suitable for mobile observatories. The period can be adjusted between 1 and 2 sec with the help of hinges. The magnification can be adjusted from 2 to 4000. A sensitive galvanometer is employed in conjunction with these instruments.

8·4. Seismograph Recorder.

8·4·1. The recorder employs a conventional type photopaper of size 30 × 92 cm and is used for recording the mirror vibrations of the seismographs. Fig. 35 shows the recorder in its housing. The peripehreal speed is adjusted to either 30 mm/min or 60 mm/min. There are arrangements to adjust the spacing between the recording traces to either 2·5 mm or 5 mm. It is rotated by either a 220 volts 50 cycles synchronous motor or a clock-work. A cylindrical lens is also provided with the help of which sharp focus of the light spot is obtained on the drum. The length is such that records of all the three components can be obtained on the same photographic paper.

9. Radiation Instruments

9·1. Angstrom Compensation Pyrheliometer.

9·1·1. The instument is shown in Fig. 36. It measures the instantaneous values of solar radiation at normal incidence. A thin blackened shaded manganin strip is heated electrically until it is at the same temperature as a similar strip which is exposed to the solar radiation. The energy used for heating is equal to the absorbed solar energy. Thermo-couples on the back of each strip connected in opposition to a sensitive galvanometer are used to test the quality of temperature data. This instrument is used as standard for calibrating other radiation instruments.

9·2 Actinograph

9·2·1. For continuous recording of radiation energy a Pyrheliograph (or Actinograph) of Moll —Thermopile type mounted on ecliptical clock work (Heliocentric arrangement) is used. This instrument can be seen in Fig. 37. But for this difference that it is made to rotate so as to be able to follow the sun's apparent motion, this instrument has the same construction as the pyrheliometer described in the preceding paragraph.

9·3. Moll-Gorezynski Solarimeter.

9·3·1. This solarimeter measures the global radiation. This instrument shown in Fig. 38 consists of seven pairs of manganin-constantan thermo-couples mounted on a small copper pillar and electrically insulated. The sensor is covered with two concentric glass hemispherical domes for cutting off long radiation. When the sensor is shaded from direct sunlight, the record gives the diffuse (sky) radiation.

9·4. Angstrom Pyrgeometer.

9·4·1. It measures the effective long wave outgoing radiation from the earth and the atmosphere. This net terrestrial radiation can be measured only in the absence of solar radiation, *i.e.*, during night. The instrument (Fig. 39) consists essentially of two pairs of blackened and gilded strips of manganin below which are attached the sensitive thermojunctions. On exposure to space, the black strips cool more rapidly than the gilded ones. The black strips are heated electrically to the temperature of the gilded one and a measure of the net out-going radiation is thus obtained.

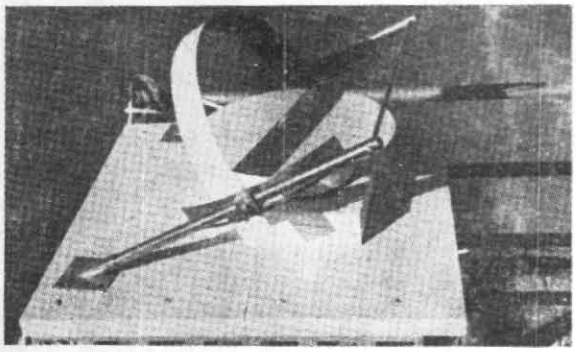

Fig. 38. Moll-Gorezynski Solarimeter

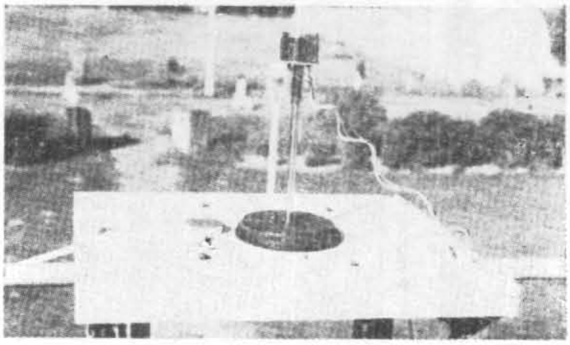

Fig. 39. Angstrom Pyrgeometer

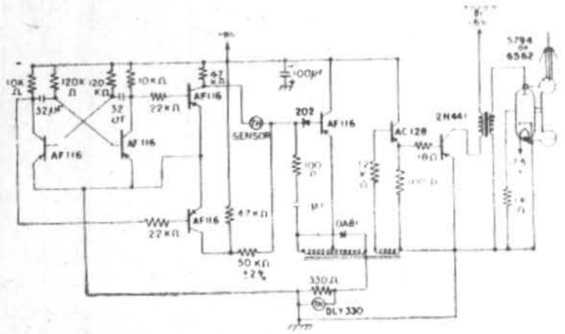

Fig. 40. Circuit diagram of Met. Rocket payload

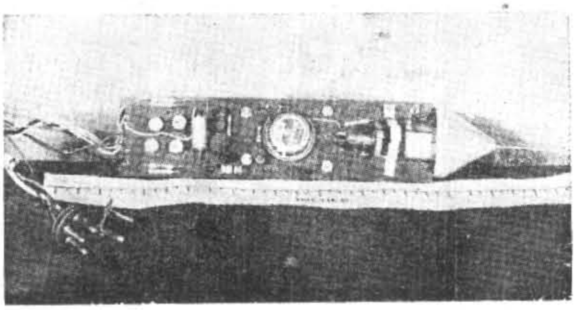

Fig. 41. Met. Rocket payload

10. Pulse-modulated Rocketsonde telemetry package

10·1. A telemetry package working on 1680 Mc/s frequency has been designed in the New Delhi laboratories for telemetering temperature data from meteorological sounding rockets. The package is completely transistorised except for the final transmitting stage which uses a sub-miniature tube. However, the circuit is so designed that no h.t. battery is needed for this tube. The change in resistance of a head thermistor, due to variations in temperature, changes the pulse-repetition frequency of the modulator over the range 10—200 pulse/sec. This instrument now awaits ground tests for various vigorous conditions it will be subjected to during actual use.

10·2. The basic package consists of three units *viz.*, (1) a switching circuit, (2) a sensor modulator and buffer amplifier and (3) a power driver and r.f. oscillator stage. The chief charactristics of the device can be summed up as follows—

(*a*) Mode of transmission	: Pulse modulated
(*b*) Modulation frequency	: 10—200 c/s
(*c*) Pulse width	: 200 μ-see
(*d*) Carrier frequency	: 1680 Mc/s
(*e*) Peak Power output	: About 4 W
(*f*) Battery consumption	: 1·2 W
(*g*) Volume without battery	: 625 c.c.
(*h*) Weight without battery	: 175 gm.

10·3. Figs. 40 and 41 show the circuit diagram and the picture of the instrument rocketsonde transmitter respectively.

11. Difficulties experienced and ingenuity required in the design and fabrication of instruments

11·1. The above is a brief description of some of the instruments designed and manufactured in the departmental workshops. This account is by no means complete as an attempt has been made here to bring out the salient features of some special instruments only. This article will not be complete if some of the difficulties experienced in this pioneering attempt by a government department to be self-sufficient with regard to its instrument requirements are not brought out. These difficulties mostly relate to—

(*i*) Non-availability of technical personnel and consequent attempts to train raw hands, (*ii*) Procurements of raw materials and special components at non-standardisation of the available stores,

(*iii*) Storage, indenting and replacement of special technical stores,

(*iv*) Problems relating to tooling mass production of gadgets and templates,

(*v*) Quality control, testing and calibration to maintain required standards of accuracy in meteorological measurements and

(*vi*) Trade Union spirit of workers and loss of production output due to lack of worker's interest.

Each one of the above aspects could be the subject matter of a separate article but for want of space and time, only a few salient features are pointed out.

11·2. In the early days, it was impossible to get trained mechanical staff for employment in workshops. Occasionally, one could find an experienced old hand who proved more a handicap than help on account of his conservatism in accepting new ideas of working to a given measurement with the use of modern measuring tools. The department had, therefore, no other alternative but to recruit raw young hands and train them gradually in the particular item of work required to be done by them. This proved to be an asset for the organisation in many ways, *e.g.*, the training in specialised job only avoided the drift of workers to other organisations. It brought a number of children of our own employees in the appropriate age-group, on whom it was easier to exercise disciplinary control than outsiders. Though lack of trained hands slowed down rapid expansion it resulted in the establishment of a stable instrument manufacturing organisation. These difficulties were considerably reduced in post-war years due to a large number of qualified technical staff coming out of the newly established industrial training centres in the country.

11·3. Difficulties due to non-availability of standardised raw materials were enormous to begin with and continue to be so even after so much of industrialisation of the country. Often the design of the instrument and components had to be modified to suit the available material. Inspite of standards set by Indian Standard Institute and the products supplied, conforming to these specifications, the materials were found to differ greatly in compositional, dimensional and other physical characteristics. It is to be hoped that in years to come, all these troubles will be over.

11·4. A good number of raw materials had to be stored in sufficient quantitites for keeping up the supplies of instruments to the observatories. For some of the stores indented from abroad, it takes more than two years to procure them. The foreign exchange stringency placed new difficulties in procurement of special raw materials. Every attempt was, therefore, made to use indigenous materials and components, as far as practicable, but for some items it was not possible to get an indigenous substitute. The workshop organisations had therefore to be backed by well provisioned stores, suitably categorised and a keen watch kept on stock minimum and stock maximum. In this connection it may be mentioned that a large stock of materials due to the procurement difficulties results in the blocking of capital and therefore, is to be avoided for economic reasons.

11·5. It may be of interest to other organisations to know that in the tooling of meteorological instruments, workshop management has shown a good deal of ingenuity in using local products or components obtained from junk shops in designing gadgets and templates for easy fabrication on a mass production basis. A number of instrances of this kind of ingenuity can be cited which, for want of space, is not possible to enumerate here. But if an organisation has to thrive, the design engineer has to be realistic in his approach to the problem and make the best of what is available in the country and on the shop floor. Quite often, the design of the new instrument can be influenced a great deal by dies and punches already available for fabricating certain other instruments. In the meteorological workshops, this praticular principle has been one of the major factors in designing the instruments.

11·6. For delicate and intricate instruments requiring precision measurements, it is absolutely essential to have a proper quality control. At every stage of component, sub-assembly and final instrument production, a great amount of vigilance is to be made and rigid controls have to be exercised in order to have the production of comparable performance. The standardisation has to be carried out to such a degree that even components can be replaced whenever required, without having to send a complete instrument to the outstation. This is by no means an easy problem.

11·7. In these days of trade unionism every worker feels that unless he can find fault with the organisation, he is not an effective member of the union. Very often the grievances put forth are unnecessary or are absolutely uncalled for which workers try to do merely to assert their role as trade union workers. In the India Meteorological Department, we have, however, been extremely fortunate that our workmen have shown keen interest to their work and great consideration to their supervisors and officers which is largely due to better communications between the employees and employers and more human approach to their problems.

12. Conclusion

In a country like ours which has set its goal for a quick industrialisation, instruments production plays a very important role. The import of instruments from outside, both for industry and for scientific departments and institutions, takes a very large share of the commodities imported from abroad. It is of great national importance that the manufacture of instruments should be one of the greatest concern of the nation. The role of the Central Scientific Instruments Organisation, the All India Instruments Manufacturers Association, the large number of instuments manufactuing firms, the Indian Standard Institutions and the National Laboratories cannot be over-emphasised. We all have to work together to attain self-sufficiency in instruments production in the country.