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A RADIATION RECORDING SYSTEM

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ABSTRACT

The instrument described prints, at hourly intervals, continuously integrated totals of six main radiation quantities and also of sunshine duration. It incorporates a strip chart recorder which provides an analogue record, but the integrating system is independent of the operation of the recorder.

1. INTRODUCTION

Continuous records of solar and terrestrial radiation quantities are made for studies of radiation climatology and also for agrometeorological and other research projects. For these purposes readings are usually required in the form of hourly integrated totals, and the equipment here described has been designed to supply these, together with a continuous analogue record. Six main radiation quantities - global, diffuse, direct, positive net, negative net, and ultra violet radiation - are accommodated as well as sunshine duration.

To record hourly values of seven quantities requires an annual total of just over 60,000 readings. However, during the hours of darkness all values will be zero, except negative net radiation, and this reduces the total number of effective readings to 35,000. Three digits for each reading will give sufficient precision for hourly totals, but manual compilation of such a record, even if the integration is carried out automatically, is laborious, and the system described has been designed to take advantage of the computer facilities available and minimise manual labour.

2. GENERAL ARRANGEMENT

The output from each of the radiation sensors is in the form of a small direct emf. These can be conveniently integrated by sensitive dc integrating motors, the rate of rotation of which is directly proportional to the applied voltage. These are available commercially, fitted with amplifiers to operate in the range of a few millivolts. For convenience units with a sensitivity of 0-10 mV were used for each circuit so that a single integrator could serve as a spare for any channel. To compensate for the variation in sensor output, each signal was fed through an appropriate resistive attenuator.

This arrangement with one continuously operating integrator for each parameter is more accurate than any in which values of the integrals are sampled at intervals and summed, as for instance, from the movement of the balancing mechanism of a multipoint potentiometric recorder.

A photo-electric interrupter circuit operated by each dc motor produces pulses at a rate corresponding to its rate of rotation, and the sum of the pulses occurring is printed at hourly intervals by a multi-channel printing counter. These totals are then manually edited and transferred to punched cards for presentation to the computer at monthly intervals, together with the appropriate calibration constants. The radiation values are then computed and printed in the form of totals for each hour of the month, with daily totals and monthly means for each hour. The process could have been completely automated by feeding the integrator outputs to a tape punch rather than a printing counter, but it has been found that the manual editing, which is normally carried out daily, serves to detect any anomalies or instrumental failures, which might go unnoticed until the end of the month with consequent loss of record.

In parallel with the integrating system, a multipoint potentiometric recorder produces an analogue record of all the quantities except duration of sunshine. The complete instrument which operates from a 230 Volt 50 hertz mains supply, is seen in Fig. 1. Details of the major proprietary items used in the recording system are listed in Appendix 1.

3. CIRCUIT DETAILS

(a) Global radiation and diffuse radiation

Global radiation is measured by a pyranometer with a Moll-Gorczynski thermopile as the sensing element, which is electrically compensated for variation of sensitivity with ambient temperature (Collins and Walton 1967). The sensitivity of the pyranometer is about 0.1mV per mW cm^{-2} of radiation flux and therefore the output is in the range 0-15mV. The signal is fed to the dc integrating motor via its attenuator network, and the pulse output operates one channel of the printing counter via a suitable transistorized pulse shaping circuit.

Diffuse, or sky, radiation is measured by a similar pyranometer, but the direct solar beam is occulted by a small shading disc driven by a suitably geared synchronous electric motor (Sumner 1968). With a pyranometer of similar sensitivity to the global instrument the output is in the range 0-5 mV, and this signal is applied to another channel of the printing counter after integration.

(b) Direct radiation

An Eppley temperature compensated pyrheliometer is used for measuring the intensity of direct solar radiation at normal incidence. It has a narrow angle of view, and must be continually adjusted in azimuth and elevation to follow the apparent movement of the sun. This is done with a sun-tracking device made in the C.S.I.R.O. laboratory - a description of which will be published later. Its output, in the range 0-5 mV, is integrated and printed as for the global and diffuse instruments. The relationship between global radiation (G), diffuse (D) and direct radiation (I),

$$G = D + I \sin h$$

where h is the sun's angle of elevation, provides a useful check on the correctness of the readings of each quantity.

(c) Net radiation

Net radiation or radiation balance, including both long and short wave components, is measured by a polythene shielded net pyrradiometer as described by Funk (1959). The radiation balance measured over grass is positive during the day, and generally becomes negative a little before sunset and positive again a little after sunrise. In order to integrate the positive and negative totals separately, two dc integrating motors are used and a sensitive transistorised discriminating circuit switches the appropriate one into circuit. The maximum output from the net pyrradiometer, which has a sensitivity of about 0.4 mV per mW cm^{-2}, is about 35 mV by day and 5 mV by night.

(d) Ultraviolet radiation

The method of measuring ultraviolet radiation is similar to that used by Marchgraber and Armstrong (1962). A pyranometer with a Moll-Gorczynski thermopile is fitted with a hemispherical glass filter which transmits ultraviolet radiation in the wavelength range 290 to 375 millimicrons. As, however, the filter also has a small pass band in the near infrared, a second pyranometer of identical sensitivity is fitted with an ultraviolet filter and an infrared filter. This instrument, which will then respond only to the infrared portion transmitted by the ultraviolet filter, is connected in series opposition to the first one, and the resultant signal is then proportional to the ultraviolet radiation. The output in this case is much smaller, and has a maximum value of only 0.5 mV. A pre-amplifier, temperature stabilised in a crystal oven, is therefore used. This is based on a micro-circuit amplifier (Fairchild type μA 709c)

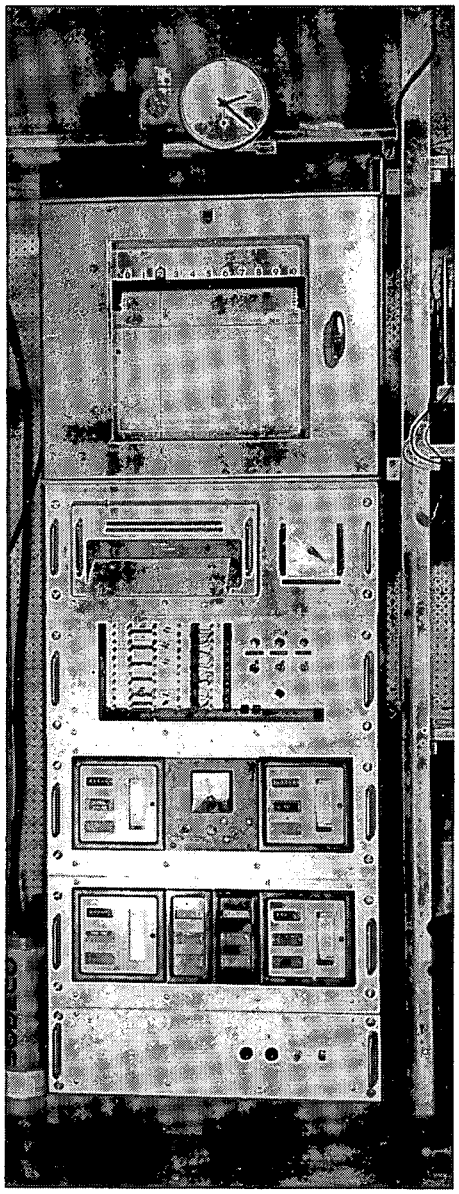

Fig. 1 Radiation recording system.

with associated circuits, and the voltage gain is 20. This brings the signal into the range 0-10 mV, and it is integrated identically to those from the global and diffuse radiation sensors.

(e) Duration of sunshine

Duration of sunshine is commonly measured by a Campbell-Stokes sunshine recorder, and to maintain continuity of record a modified Campbell-Stokes instrument is used (Collins 1968). In the latter the recording card is replaced by a thermopile which produces a direct emf of 7.5 mV when the direct radiation reaches an intensity equal to that needed to start burning the normal card. A transistorised sensing circuit switches on a synchronous motor when this level is reached, and it generates pulses at the rate of 50 per hour which are fed to one channel of the printing counter. The latter thus prints, at hourly intervals, the duration of sunshine in fiftieths of an hour. It is preferable to record in fiftieths of an hour rather than minutes, as daily totals are customarily presented in decimal form.

4. TIMING AND PRINTING

Totals are printed at hourly intervals, the print initiating pulse being derived from a battery operated clock. In the case of mains failure, recording will cease for the period of failure, but when the supply is resumed the print timing will still be correct. Immediately after printing all counters are returned to zero by a resetting circuit. During the printing and resetting period the counting circuit is interrupted, and the incoming counts are stored until the circuit is restored so that there is no loss of record. The print interval can be varied if required.

Radiation records are normally made with respect to Local Apparent Time. The conversion from clock time takes into account both longitude and equation of time. The latter varies continuously through the year and, if adjustment to the time clock is made in units of one minute, two or at most three adjustments per week will be needed when the equation of time correction has its most rapid rate of change. If the alterations to the clock are made early in the day when radiation quantities are small, the error of 1.7 percent in the totals in the hour in which the adjustment is made can be neglected. The recording system can, of course, be operated on Standard Time or Local Mean Time if desired.

Accuracy

Within the range 1/10th full scale to full scale, the integration error of the dc integrating motor and its associated amplifier is stated by the makers to lie between +0.7 percent and -1.7 percent. There is also a possible error of ± 1 on the printing counter. This represents ± 0.15 mW cm^{-2} on the global and net radiation channels and less on the others. In tests carried out at regular intervals, a known direct voltage is injected into each channel for a number of hours, and channel sensitivities determined. Short period accuracy has been found to be considerably better than the figures given above, and any long period drift can be corrected by adjusting the calibration constant before the monthly data are fed into the computer.

5. ANALOGUE RECORD

The multipoint potentiometric recorder, used to give the continuous analogue record, has a sensitivity of 10 mV full scale. Suitable series and shunt resistors are used as voltage dividers on the channels on which the sensor output is in excess of this. For the net radiation channel an offset zero is used so that the negative night signal can be recorded.

With the present arrangement, adequate definition is given by recording a point on each channel every three minutes, but this printing interval is variable. A 24-hour record covers about half a metre of chart.

The recorder and integrating systems are independent of each other, and failure in one does not affect the other, except in the case of ultraviolet radiation, where the pre-amplifier is common to both the integrator and recorder. In the event of failure in an integrator, the hourly total can be obtained by manual integration of the analogue record.

6. CONCLUSION

According to the World Meteorological Organization's Regulations, the observing programme at principal radiation stations should include continuous recording and publication of hourly totals of global solar radiation and diffuse radiation, as well as regular measurements of direct solar radiation and records of sunshine duration. The recording system described is suitable for such a programme, and in addition provides hourly totals of net and ultraviolet radiation.

REFERENCES

Collins, B.G. 1968 A modified Campbell-Stokes sunshine recorder. Met. Mag., London, 97, pp. 16-19.

Collins, B.G. and Walton, E.W. 1967 Temperature compensation of the Moll-Gorczynski pyranometer. Met. Mag., London, 96, pp. 225-228.

Funk, J.P. 1959 Improved polythene-shielded net radiometer. J. Sci. Instrum., 36 (6), pp. 267-270.

Marchgraber, R.M. and Armstrong, R.W. 1962 Solar and sky ultraviolet and recording equipment. United States Army Signal Research and Development Laboratory Technical Report 2290.

Sumner, C.J. 1968 A solarimeter stand with motorized occulting disc. J. Appl. Meteor., 7, pp. 145-7.

APPENDIX 1

The major proprietary items which were used in the recording system were:

PYRANOMETERS by Kipp & Zonen, Delft, Holland; with temperature compensation added in our own laboratory.

PYRHELIOMETER by Eppley, Rhode Island, U.S.A.; with suntracker made in our own laboratory.

CAMPBELL-STOKES SUNSHINE RECORDER by Casella, London, U.K.; with modifications made in our own laboratory.

NET PYRRADIOMETER by Middleton, Eastern Street, South Melbourne, Australia. 3205.

DC INTEGRATING MOTORS with amplifier (MESSMOTORS) by Fernsteuergeräte, West Berlin, Germany.

MONODECADE PRINTING COUNTER (20 digit) by Sodeco, Geneva, Switzerland.

MULTIPOINT POTENTIOMETRIC RECORDER by Philips, Sturt Street, South Melbourne, Australia. 3205.

The total cost of the components for the system, excluding the radiation sensors, was about $A4,500.

The labour involved in construction was assessed at about $A1,500.