by Minnaert in 1927. If a long range of wave-lengths is to be studied, the image ought to be formed by a mirror. For investigation of low levels of the chromosphere, observations should be made from a position not far inside the belt of totality, so that the layers may be observable for a relatively long time.

It is a pleasure to acknowledge assistance received from the Canadian Pacific, and from the Canadian National Railways. We are indebted to Dr. R. M. Stewart, Director of the Dominion Observatory, Ottawa, who visited Parent and gave information as to the possibility of the site. He also made arrangements with the Canadian Customs authorities, who allowed all the instruments to pass through the customs unexamined. At Parent the observers were hospitably welcomed, and they received the greatest kindness and assistance from everyone with whom they came in contact.

TOTAL SOLAR ECLIPSE, 1932 AUGUST 31: REPORT OF THE EXPEDITION FROM THE SOLAR PHYSICS OBSERVATORY, CAMBRIDGE.

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An expedition to observe the total solar eclipse of 1932 August 31 was arranged under the joint auspices of the Joint Permanent Eclipse Committee and the Solar Physics Observatory, Cambridge. The original party consisted of Professor F. J. M. Stratton, Professor J. A. Carroll, Dr. R. O. Redman and Mr. C. P. Butler. Owing to the meeting of the International Astronomical Union at Harvard early in September and to the accessibility of the belt of totality in Canada, an unusual amount of skilled volunteer help was available for the day of the eclipse itself and for a few days preceding it. It was decided that this provided an opportunity for carrying out a large programme of observation at little extra expense, save for the time involved in preparation in England. All available instruments were therefore pressed into service, and special arrangements were made to feed extra beams from auxiliary mirrors driven along with the main cœlostats. These mirrors were a source of anxiety in the preparatory stages and never very satisfactory. When possible, mirrors independently controlled should be used for eclipse work.

Dean Eve of McGill University, Montreal, very kindly offered to assist the expedition in every way, and with the kind co-operation of the authorities of the Hermitage Country Club, Magog, selected a very suitable site for the eclipse camp between two fairways of the local golf-course. The eclipse occurred in the afternoon, and there was a good view to the south-west over ground sloping down to Lake Memphremagog. By the kindness of the Canadian Minister of Defence, tents to shelter the instruments were provided without charge by the Canadian Defence Force, and when a number of these tents were damaged badly by a line squall, which struck the camp, they were all very speedily replaced.

The programme consisted of the following main groups of experiments :—

(*a*) Spectrophotometric study of the flash and the corona.
(*b*) Spectroscopic observations in the infra-red.
(*c*) Interferometric studies of coronal and chromospheric lines.
(*d*) Polarisation effects in the corona.
(*e*) Coronal photographs.
(*f*) Rotation of the corona.
(*g*) Air temperature and humidity changes.

(a) *Spectrophotometry.* (i) *Moving-plate Camera.*—This was an objective spectrograph with a 6-inch plane grating and a 6-inch Cooke photovisual lens of 20 feet focal length ; it was fed from an auxiliary mirror mounted on the polar axis of the Cambridge 16-inch cœlostat. The slit in the focal plane was 1 mm. wide, and the plate was driven under gravity past this slit at 1·5 mm./sec. by means of a steel wire running off a drum driven by a gramophone motor. Time-marks were made on the plate by light signals controlled by chronometer contacts. The slit was horizontal, and was normal to the Sun and 9° from the points of contact. Exposure requirements being uncertain, two plates of different speeds were used for the two contacts—Imperial Eclipse Ortho 850, and Imperial Special Rapid, both backed. The effective exposure was $\frac{2}{3}$ second. The other halves of the plates were calibrated in an auxiliary spectrograph. The region of spectrum to be examined was the ordinary photographic region $H\beta - H\delta$. Focusing was done by an auxiliary collimator equipped with a concave mirror of $6\frac{1}{4}$ feet focal length. Dr. R. O. Redman was in charge of this instrument.

(ii) *The 21-foot Rowland Concave Grating.*—A beam from the 21-inch siderostat, kindly lent by Sir Francis McClean, was fed on to a Lassell $7\frac{1}{4}$-inch mirror of 85 inches focal length. An image of the Sun was formed on the slit of a collimator with a 12-inch mirror (Oliver) of 97 inches focal length. The parallel beam from this mirror fell on the Rowland concave grating and the photographic plate was placed at the principal focus, where the images being stigmatic were suitable for photometric work. The plates used were curved and backed, the spectrum reaching from λ 4900 to λ 3000. The region of the spectrum to which special attention was paid was from the head of the Balmer series λ 3646 towards the ultra-violet. The direction of dispersion was parallel to the line of contacts, and for that the instrument had to be tilted on its concrete pillars 14° from the horizontal.

Comparison spectra to be used for photometric work were to be obtained from out-of-focus images of the Sun taken immediately after the eclipse through the same optical train, but with the Lassell mirror moved to 14 feet 6 inches from the slit of the collimator and with a calibrated wedge (platinum sputtered on quartz by Professor Carroll at Aberdeen) over the slit. To provide for exposures of different length on the flash and the corona the solar comparisons were taken with and without a quartz diffuser in the beam. Further comparisons were to be made on a tungsten filament lamp calibrated with a fixed current at the National Physical Laboratory. The somewhat heavy set of batteries required to give 16 amp. D.C. for the lamp were kindly lent by the Hart Company of Canada, and a petrol-charging set for these batteries and for running D.C. arcs was lent by the Canadian Defence Force.

Mr. Butler was in charge of the setting up of this instrument, and at the eclipse was in general control, with Mr. J. Murray at the camera and Mr. Lang at the siderostat.

(iii) *The Hills 4-prism Quartz Spectrograph.*—This instrument was to be used for the continuous spectrum at the head of the Balmer series, and to repeat with different dispersion from the Rowland grating the spectrophotometric study of the lines of the Balmer series at different levels in the Sun. The continuous spectrum of the corona in the ultra-violet was also to be studied. The calibration programme was similar to that of the Rowland concave grating. The image of the Sun on the slit of the spectroscope was formed by a 9-inch Herschel speculum mirror of 10 feet focal length, fed by a 9-inch speculum flat, kindly lent by Dr. Steavenson and the Royal Observatory, Greenwich, respectively. The flat was mounted on a base linked to and driven with the Cambridge 16-inch cœlostat.* Process films were used. The instrument was worked by Dr. W. L. Webster and Dr. C. S. Beals.

(iv) *The 20-inch Common Reflector.*—The short focal length of this instrument (45 inches), and its large light-gathering power, made it suitable for a study of radiation from an extended source. A 1-prism slit spectroscope, working at $f/3$ with two Aldis anastigmat lenses of 12-inch focus, was built for use with this telescope, which was mounted equatorially. A study of the distribution of the continuous radiation in the corona at different levels and the absorption lines at higher levels was intended. The programme of exposures (1 second, 8 seconds and 60 seconds) was chosen to link up with the programme of the Greenwich expedition, where an instrument of larger focal ratio was available. Ilford Special Panchromatic plates were used. Mr. E. G. Williams, with the help of Mr. G. Murray, was in charge of the instrument.

(b) *Spectroscopic Observations in the Infra-red.*—Two regions were especially studied for new coronal lines and for the flash spectrum. As several other expeditions nearby were known to be working on the spectral region sensitive to the mesocyanine dye (maximum 7500 A.), it was decided to allot the instrument which gave the better optical performance to the region centred at 9600 A., for which the plates (Eastman Infra-red Sensitive B) were stained with xenocyanine. These plates were not available in England for trial before the expedition left for Canada, but Professor G. H. Henderson of Dalhousie University, Halifax, kindly undertook to experiment with these plates before joining the eclipse camp, and he subsequently took charge of the whole of the infra-red work and the hyper-sensitising of the special plates.

The two instruments used were both fed with beams from the 21-inch siderostat. For the xenocyanine plates the beam was diverted by a 12-inch

* *M.N.*, 87, 677, 1927.

flat (belonging to the Hills siderostat) on to a 9-inch concave speculum mirror of 10 feet focal length, kindly lent by the Science Museum. The spectrograph used was a Hills slit spectrograph, with a 4-inch Anderson grating having a very bright first-order spectrum. An argon tube was used for a comparison spectrum. Professor Henderson, with the help of Mr. L. Lefèvre, took charge of this instrument. The beam for the other spectrograph was diverted by a 5-inch right-angled prism on to a 5-inch Rowland flat grating used objectively. The image of the flash spectrum was formed by a 6-inch Henry lens of 90 inches focal length. Professor J. Satterly took charge of this instrument.

(c) *Interferometric Studies of Coronal and Chromospheric Lines.*—The instruments from Aberdeen brought by Professor J. A. Carroll consisted of two objective interferometers as follows :—

(i) A large interferometer fed from the 16-inch Oxford cœlostat (kindly lent by Professor H. H. Plaskett), with a pyrex mirror 12 inches in diameter ; the optical train consisted of two 45° prisms 6 inches in height, followed by a Fabry-Perot étalon, and a single lens of 13·5 cm. aperture and focal length 15 cm. The étalon consisted of a pair of plates 13 cm. in diameter, silvered by cathode deposition *in vacuo* so that each plate reflected about 70 per cent. of green light falling on it near normal incidence. They were mounted in a specially designed carrier separated by $\frac{3}{64}$ of an inch, and tilted about an axis in the plane of dispersion so that the angle of incidence was between 20° and 30°. It will be seen that this instrument was of very great light-gathering power, and, used with special plates prepared by Messrs. Ilford, Ltd., and the *H* emulsions by the Eastern Kodak Co., it is thought that ample exposure would have been secured in less than half a minute. Two exposures were planned—one of 10 seconds with a fast, coarse-grained plate, and one of 50 seconds with a slow, fine-grained plate. The resolving power of the interferometer is, of course, scarcely more than could be obtained with any good spectroscope; but naturally the use of the instrument objectively in this manner yields information which a slit spectroscope cannot give without the use of the method of the spectro-heliograph. The objective interferometer yields a picture of the corona in its own monochromatic radiation crossed by the Fabry-Perot fringes whose shape, width and intensity can be measured at all points of the image. The isolation of the monochromatic image of the corona in the green light (5303 A.) was much facilitated by the special plates employed, which had a sharp maximum of sensitivity at just this wave-length. The plates were standardised by means of comparison fringes from a high-voltage thallium arc. It is expected that full details for the construction of this instrument will be published separately in the near future. Thanks are very specially due to Mr. C. G. Fraser, of the Department of Natural Philosophy, Aberdeen, for much care and thought over the design of this instrument, and the very beautiful workmanship displayed in its construction. Professor Carroll took charge of this instrument, Captain W. M. Lindley being in control of the cœlostat.

(ii) A small interferometer fed from the same pyrex mirror consisted of an étalon of plates 64 mm. in diameter, somewhat more heavily silvered, and separated by $\frac{3}{32}$ of an inch and with a dispersion train of two 60° light flint prisms. The camera lens was a 21-inch focus Ross Process Xpres of exceptionally fine performance. Messrs. Ross very courteously sent lenses to Professor Carroll to test, from which this one was selected. This instrument was designed for measurements of the profiles of the chromospheric lines by providing a flash spectrum of crescents in the usual manner, crossed by the interference fringes formed by the etalon (which was tilted at about 30° to the line of sight). The instrument was set to cover the whole of the visible spectrum, but the exposures were planned so that the stronger chromospheric lines only would be photographed, to avoid too great confusion with the moderate scale of dispersion employed. Exposures were also planned with this instrument on the coronal green line during the greater part of totality in the same manner as with a large interferometer. The exposures on the flash, of course, were to be made in the few seconds after second contact and preceding third contact, consisting of one of 1 second and one of about 5 seconds. Dr. J. L. Johnstone was in charge of this instrument.

All the photographic plates used in both instruments were calibrated for photometric measurements.

(d) *Polarisation Effects in the Corona.*—The double-tube camera with a large Nicol prism (kindly lent by Professor Newall) in front of one lens, as taken out to the eclipses of 1927 and 1929, was set up for a study of the distribution of polarisation in the corona. Four exposures of 10 seconds, each with the axis of the prism in positions displaced each time by 45°, were to be taken. The photometric calibration was done by a tube photometer and skylight. The instrument was in the charge of Mr. S. Stratton and Mr. G. Dodd.

The beams for the above camera came from the Cambridge 16-inch cœlostat. Another beam from the same cœlostat fed a double-image slit spectrograph designed for the study of the polarisation of the corona in different wave-lengths. The image of the Sun was formed by a Hilger lens of focal length $28\frac{1}{4}$ inches, working at $f/8{\cdot}4$. The slit of the spectrograph was placed diametrically across the Sun's image. The two polarised images were formed by a prism of fluorspar placed between the dispersing image of the spectrograph and the camera lens. The direction of separation of the images was at right angles to the dispersion and parallel to the axis of the Nicol prism of the double-tube camera in its initial position. The comparison spectra for the photometric study were taken with a calibrating spectrograph. Exposures of 15 seconds and 60 seconds were to be made for the study of the lower and higher corona. Professor Stratton took charge of this instrument.

The fluorspar prism used in this spectrograph was lent by Professor Newall, as was also a Savart prism through which Dr. Aston was to examine the sky in the immediate neighbourhood of the Sun for evidence of polarised light scattered into the coronal beam by the Earth's atmosphere, as noticed by Professor Newall at Guelma in 1905.*

* *M.N.*, **66**, 476, 1906.

(e) *Coronagraphs.*—The Greenwich 19-foot coronagraph used as at Benkoelen in 1926, with the 4-inch lens and the 8-inch Dublin cœlostat (both kindly lent by the Royal Irish Academy), was the main instrument used for direct photography of the corona. Calibrated plates for photometric purposes were taken with a tube photometer and skylight with the same exposures, namely, 2, 5 and 15 seconds. A 4-inch direct-vision prism (kindly lent by the Royal Observatory, Edinburgh) was to be placed in front of the object-glass for the flash spectrum at second and third contacts. Dr. Knox-Shaw, with the help of the Master of Gonville and Caius College, Mr. J. F. Cameron, was in charge of the instrument. A spare beam from the cœlostat was used for two cine-cameras and a stationary camera worked by Mr. G. Cohen.

In addition to Dr. Hall's two cameras, to be described below, Dr. Lockyer provided a coronagraph of 4 inches aperture and 20 inches focal length, which he worked himself. This was provided with a beam from the Oxford cœlostat, with an auxiliary flat supplied by Professor Carroll.

(f) *Rotation of the Corona.*—The Newall 4-prism spectrograph mounted on a polar heliostat was arranged for a study of the rotation of the corona. The instrument was mounted as used by Professor Newall at Pulgaon in 1898,* save that, instead of two slits being used, one slit was used and set diametrically across the Sun at the two ends of the equator. A comparison spectrum from an arc of calcium and manganese was to be put on the plate immediately after totality. The instrument was in the charge of Dr. J. L. Haughton, assisted by Mr. G. Stratton.

(g) *Air Temperature and Humidity Changes.*—Dr. Haughton carried out measures of air temperature by means of a multiple thermocouple and a potentiometer. The couple was made from twelve pairs of iron-constantan wires, soldered in series, the "cold junctions" being in glass tubes passing through the cork of a 1-quart thermos flask. The thermos was buried up to its neck in the ground and filled with crushed ice. The thermocouples were arranged radially round the flask, being parallel to the ground for about 6 inches and then bending up for about 4 inches, so that the junctions lay in a rough circle of about 15 inches in diameter and about 6 inches above the ground. A canvas sheet screened the couples from direct sunshine. This screen was fixed about 6 feet above the ground on the N.E. side and about 1 foot on the S.W. side.

The apparatus was calibrated by comparing the readings obtained on the potentiometer with those of a standard mercury thermometer mounted in the same plane as the couple junctions. Neglecting one reading which lies exactly 1° C. off the curve, and which is probably a mistaken reading of the thermometer, there was no observation more than 0°·2 C. away from the curve, and the majority were within 0°·1 C. of it. In view of the fact that the potentiometer readings were definitely unsteady when there was a breeze, oscillating over about 0·1 or 0·2 millivolts, the calibration can be considered very satisfactory. If this method is used in a future eclipse, it might be well to shelter the couple from direct draught, so as to render its reading a little more steady.

* *M.N.*, **58**, App. [55], 1898.

Readings of the potentiometer were taken at intervals of approximately 20 minutes for about 4 hours before first contact, and then more frequently. The results obtained in the neighbourhood of totality are shown in fig. 1.

Between 15^h and 18^h 30^m G.C.T. the temperature tended upwards, presumably due to the clearing of the sky. After this, as the clouds returned, the temperature fell steadily. The rate of fall did not appear to increase after first contact, until totality was approaching, when an acceleration does seem to have occurred, a sharp drop of about $0^\circ\cdot5$ C. taking place during totality. It is not, however, certain that this $0^\circ\cdot5$ C. fall was due to the eclipse, as departures from a smooth curve of twice this amount can be seen on other parts of the record. The total fall in temperature between the first and third contacts was of the order of $3^\circ\cdot5$ C. This may be compared

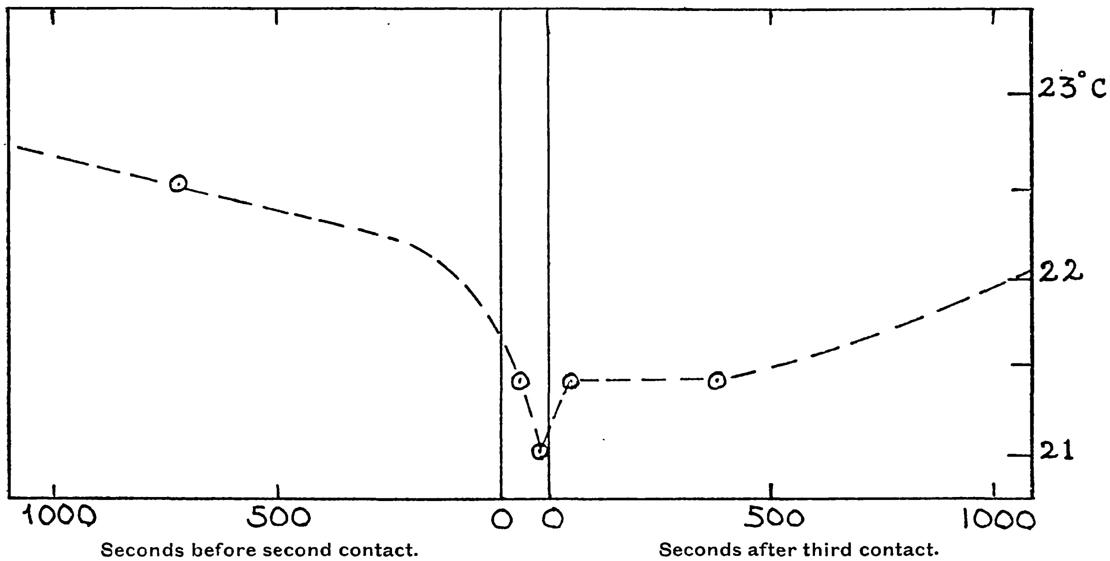

FIG. 1.—*Air Temperature during Eclipse.*

with the fall of about 1° C. observed at Penhill during the eclipse of 1927.* In this latter case, however, the fall was superimposed on a rising temperature, while at Magog the temperature was already falling.

The only safe deduction to make from these results is that during a cloudy eclipse the fall of temperature is very slight, and may readily be masked by changes in cloud conditions.

Professor A. N. Shaw carried out observations of air temperature, humidity, katathermometer readings and pressure. A drop of over 5° F. in air temperature was accompanied by an increase of relative humidity from 66·8 to 82 per cent., the absolute humidity remaining nearly constant (see fig. 2). A further drop of temperature of 6°, or a higher relative humidity at the time of first contact, might easily have led to a general deposit of dew. Professor Shaw from a study of the observations calculates that if the Sun had not been obscured by cloud the total fall of temperature would have been between 12° and 15° F. The need to protect eclipse apparatus of small thermal capacity from cooling is emphasised by these

* *M.N.*, 87, 692, 1927.

results. The velocity of the wind was determined from katathermometer readings. The wind, which varied in direction between S.W. and S., fell from 7·0 m.p.h. at first contact to 0·74 m.p.h. a little before totality. During totality it had an average of 1·7 m.p.h., falling to 0·56 m.p.h. just after. The barometer during the time of eclipse slowly fell 0·05 inch. Miss M. Dodd helped Professor Shaw in recording the observations.

Dr. Hall's Apparatus.—Dr. Wilfred Hall joined the Magog eclipse camp,

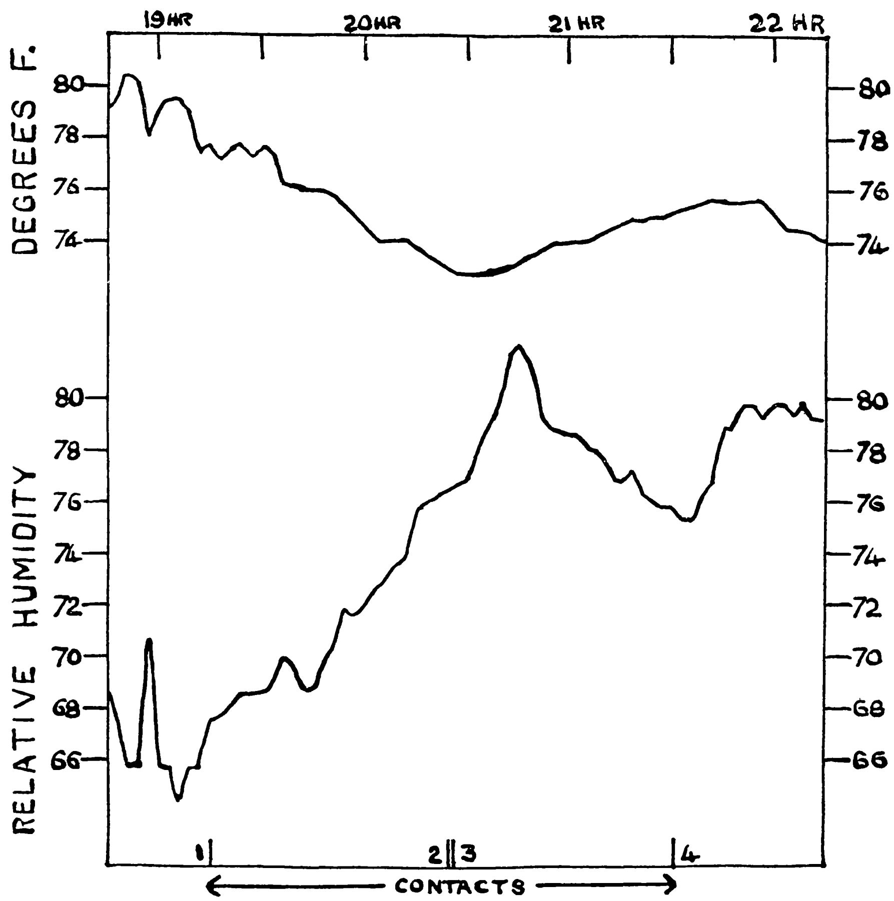

FIG. 2.—*Humidity and Temperature.*

bringing his own coronagraphs and spectrographs. His programme was arranged to fit in with the main work of the expedition.

(1) *Coronagraphs.*—These were a camera with a Cooke P.V. lens of 5 inches aperture and a focal length of 100 inches, fed by a Grubb cœlostat, and a small camera mounted equatorially, having a W.D. aeroplane lens of $19\frac{1}{2}$ inches focal length working at f/5·8. With the former it was intended to photograph the corona without any screen, also by light transmitted through a green filter as well as through a cell containing a solution of æsculin. A photometric scale for comparison of densities would have been taken with the tube photometer if results had been obtained. With the small camera it was hoped to photograph the outer corona with the special object of determining the extent of any coronal extensions—a long exposure