12. COMMISSION DE PHYSIQUE SOLAIRE

PRÉSIDENT: M. CHARLES E. ST JOHN, *Mount Wilson Observatory, California, U.S.A.*

MEMBRES: MM. Abbot, G. Abetti, J. A. Anderson, Bauer, de la Baume-Pluvinel, A. Bemporad, Bergstrand, Butler, Campbell, H. D. Curtis, Chapman, C. Davidson, Deslandres, Donitch, Duffield, Evershed, Favaro, A. Fowler, Hale, Jimenez, Lee, Lockyer, da Costa Lobo, Merfield, J. A. Miller, Milne, Minnaert, Mitchell, Nagaoka, Newall, Newton, S. B. Nicholson, Pannekoek, Rodés, Rowland, Royds, Sôtome, Störmer, Stratton, Wolfer.

At the meeting of the International Astronomical Union in Rome, 1922, centres for the compilation, discussion and publication of solar statistics were established and the number has since been increased by action of the Union.

The present centres are:

1. Sun-spots: Drawings. Visual. Stonyhurst.
2. Sun-spots: Positions and areas. Photographic. Greenwich.
3. Sun-spots: Polarities. Visual spectroscopic. Mount Wilson.
4. Sun-spot Numbers. Zurich.
5. Prominences: Areas at the limb. Visual and spectroscopic. Arcetri.
6. Prominences: Areas at the limb. Spectroheliographic. Kodaikanal.
7. Flocculi (calcium): Areas and motions. Spectroheliographic. Cambridge, England.
8. Flocculi and Prominences: Motions and forms combined with radial velocities. Meudon.
9. Solar Radiation. Smithsonian Institution, Washington.
10. Observations not closely allied to established centres. Mount Wilson.
11. Relationships between solar and terrestrial phenomena, suggested.
12. Eclipses: Cambridge, England.

SUGGESTED AGENDA

During the 1925 meeting at Cambridge three interesting and well-attended sessions of Commission No. 12 were held. In view of the increase in membership and in number of centres and of the consequent broadening of interests it is probable that more matters of interest will come up for consideration and discussion. To conserve time and still to get as much as possible from our conference it has seemed advisable to prepare a tentative programme and order of business.

I. Organisation. The President's Report and the consideration of recommendation No. 1.
II. Reports from the centres 1 to 10 and discussion.
III. Report of the Eclipse Centre.
IV. Relationships between Solar and Terrestrial Phenomena. Report of Index of Solar Activity.
V. Problems of the Solar Atmosphere theoretical and observational.
VI. Consideration of Recommendations and unfinished business.
VII. Individual Reports. Special Topics. Lantern slides showing interesting phenomena and new instruments.

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1. *Sun-spots: Drawings. Visual. Stonyhurst.* Rowland:

On the death of Father Cortie, in May 1925, the direction of the Observatory devolved provisionally on the writer till the appointment in December of the same year, of the present Director, Rev. E. D. O'Connor, S.J., who took over the Solar work of the Observatory.

The systematic observation of sun-spots and faculæ has been continued as heretofore, and the results of measurements of areas and positions of spot-groups have been published in the annual reports of the Observatory. Investigations of the relation of solar activity to terrestrial magnetic disturbances are being continued, but no papers have been published on this subject. A short note by the writer directing attention to an apparent double periodicity in a magnetic storm, was published in the Geophysical Supplement of *Monthly Notices, R.A.S.* (1, No. 7, June 1926).

As the eclipse of the sun on June 29, 1927, was total at Stonyhurst, extensive preparations were made for its observation, but these were unfortunately rendered nugatory by the cloudy conditions which prevailed at the time of the eclipse. Special quick runs on the magnetographs, however, which had been arranged at the request of the Gassiot Committee of the Royal Society, were quite successful, and showed that, under the quiet magnetic conditions which prevailed, the effect of the screening action of the moon was absolutely nil.

2. *Sun-spots: Positions and areas. Photographic. Greenwich.* Newton:

In co-operation with the Observatories at the Cape of Good Hope and Kodaikanal, an uninterrupted series of solar photographs has been secured since the last report. The work of measurement of spots and faculæ and the compilation of results have proceeded at Greenwich as usual. The Greenwich Photoheliographic Results have been published for the years 1923, 1924 and 1925, and those for 1926 will be in print before the meeting.

Tables giving the mean daily areas and heliographic latitudes of spots for each rotation of the sun together with a brief account of the sun-spot activity for each year are published in the *Monthly Notices of the Royal Astronomical Society* in advance of the *Greenwich Volume.* The results up to the end of 1926 have been communicated to members of Commission No. 12.

A determination of solar rotation from long-lived spots (1878–1923) is given in the *Greenwich Results* for 1924. The resulting formula for the daily sidereal motion is $\xi = 14^\circ{\cdot}37 - 2^\circ{\cdot}60 \sin \phi$.

The characteristic movements in longitude of sun-spots (especially of the leading spot of groups) have been investigated, and definitive results are given for these typical movements in the *Greenwich Results* for 1924 and in the *Monthly Notices of the Royal Astronomical Society*, April, 1925.

Addendum. Observations in areas and positions of spots are made at the U.S. Naval Observatory at Washington. For days lacking in the Washington series, the observations are supplemented through the co-operation of the Harvard, Yerkes and Mount Wilson Observatories. The compilations appear in the *Monthly Weather Review* of the corresponding calendar month.

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3. *Sun-spots: Polarities. Visual spectroscopic. Mount Wilson.* Nicholson:

At the 150-foot tower telescope visual observations of the magnetic polarity and field strength of all spots are made daily and also visual observations of the spectrum of active spot groups with special reference to the $H\alpha$ line. Visual observations have been made with the spectrohelioscope at the 60-foot tower telescope where a systematic study of activity in the neighbourhood of spots is to be undertaken.

The routine solar observations include direct photographs of the sun with a 175 mm. image, spectroheliograms with a 53 mm. image using the $H\alpha$ line of hydrogen and the K_2 line of calcium, and prominence spectroheliograms with the K_2 line of calcium.

Records of variations in the earth's magnetic field are made daily and are being compared with the observations of solar activity.

In co-operation with other observatories spectroheliograms of prominences and of the sun's disk are sent to the Kodaikanal Observatory as requested. Areas and positions of spots are furnished monthly to the Naval Observatory to supplement their observations for publication in the *Monthly Weather Review*.

The preparation of the magnetic observations of all sun-spots from 1917 to 1925 is nearly completed and will be published soon. A diagram of the sun each day with the polarity and field strength indicated for each spot will be reproduced. Nearly 1400 engravings giving the observations of about 2500 days have been completed.

4. *Sun-spot Numbers. Zurich.* Wolfer:

In April 1926 I resigned the directorship of the observatory, having reached the age limit. The observatory is now in charge of my successor, Professor W. Brunner. This change did not involve any discontinuity in our solar observations, and their organisation remains exactly the same as before with regard to instruments as well as to methods.

The observations of Professor Brunner were begun in April 1926 and parallel with them my own have been continued and will be carried on as long as possible. Through this arrangement the constancy of the traditional value of the "Wolf-Wolfer" relative numbers will be guaranteed for the future and the homogeneity of the long yearly series of these numbers will remain undisturbed.

The sun-spot numbers deduced from the observations from Zurich alone have been regularly published at the end of each quarter of a year in the *Meteor. Zeitschrift* and in *Terrestr. Magnetism* and lately in the *Monthly Weather Review* for those wishing to use them for comparison between solar and terrestrial phenomena. These are the "Provisional" spot-numbers; they are not quite complete throughout the year, but show some gaps here and there from lack of observations at Zurich.

The "final" sun-spot numbers are the result of the Zurich observations supplemented by a great number of foreign series, by which all the gaps in the former series are filled and the list made as complete as possible for every day of the year. These final numbers are published in the *Astronom. Mitteilungen* of this observatory, the last issue being that of 1926 edited by Professor Brunner.

5. *Prominences: Areas at the Limb. Visual and Spectroscopic. Arcetri.* Abetti:

Observations of prominences at the limb have been continued during the last three years at Arcetri, Catania, Madrid, Zô-Sè, and Zurich with increased activity. The summary of results to the end of 1926 has already been published in the *Publications of the Arcetri Observatory* and is in the press for 1927.

The height of the chromosphere has been measured continually at Arcetri, Catania, Madrid. The observations of Arcetri and Madrid are in good agreement and show changes as indicated in the publications of Arcetri and the *Rendiconti della R. Accademia dei Lincei.* It seems that it should prove interesting to find possibly a more precise method of determining the height of the chromosphere in order to follow better its variations.

The 4-metre spectroheliograph of the tower telescope has been in regular use, so far as weather and conditions of seeing have permitted, since May 1926. The photographs may be put at the disposal of the Kodaikanal, Cambridge or Meudon centres.

Researches on the motion of the vapour in the sun-spots and on the rotation of the chromosphere are in course at the sun-tower.

The subvention of £40 per year, for three years, together with some more financial help given by the Zurich and Arcetri Observatories, has been used here for the publication of the *Immagini spettroscopiche del bordo solare* for the three years 1922 (beginning of the present cycle), 1923, 1924, and have been sent to the most important institutions and observatories in the world.

The papers issued by this Observatory which deal with the above items are:

Rendiconti R. Accademia dei Lincei, **3**, **4**, **5**, **6**, 1926–27.

On the structure of $H\alpha$ in the sun-chromosphere.

Observations on the motion of metallic vapours on sun-spots.

On Evershed effect on sun-spots.

On the height of the sun-chromosphere.

On the relation between solar eruptions and the magnetic terrestrial storms.

Activity and height of the sun's chromosphere in 1926.

Observations of the partial eclipse, June 29, 1927, in Arcetri.

Publications of the Observatory in Arcetri, Fasc. 42–44.

Visual observations of prominences and of the chromosphere, 1925–27.

Description of the solar tower, Fasc. 43, 1926.

Spectroscopic images of the sun-limb for 1922–23 published under the auspices of the International Astronomical Union.

Idem for the years 1923–24 (in the press).

6. *Prominences: Areas at the Limb. Spectroheliographic. Kodaikanal.* Royds:

Spectroheliograms are being regularly received from the following observatories to complete the Kodaikanal series for statistics of areas of prominences and of $H\alpha$ dark markings:

Meudon	K_3 disc plates
,, ...	$H\alpha$ disc plates
Mount Wilson	K limb plates
,, ...	$H\alpha$ disc plates
Yerkes	K_2 limb plates
Pitch Hill	$H\alpha$ disc plates.

Now that experience has been gained of the character of plates which can be supplied by different observatories, half yearly statements from the co-operating observatories suffice instead of monthly statements as formerly. The Mt Wilson Observatory send their original plates which are later returned to them, but the other co-operating observatories send copies which are retained at Kodaikanal. In order to save the co-operating observatories unnecessary expense, the Director asks for the minimum number of plates which may be expected to give useful data beyond what is available in the Kodaikanal series.

The Director is of opinion that whereas formerly the data of prominences at the limb were more complete than those of $H\alpha$ dark markings, the situation is now reversed. Moreover, the correction for imperfect sky conditions (which is always an unsatisfactory and somewhat arbitrary correction) is more necessary for prominence plates than for $H\alpha$ dark markings plates. For instance in 1925, 352 days for which prominence plates were available were written down to 314 effective days, whereas 354 days of $H\alpha$ disc plates could be counted as 343 effective days. The prominence data would be more accurate than at present if at least one more observatory could include a K_{232} limb plate in its daily programme. The summaries are published for each half year in *Kodaikanal Observatory Bulletins*; that in the second half of the year 1926 in *Bulletin* No. LXXXI. The summaries show:

I. Areas and numbers north and south.
II. Distribution east and west of sun's axis.
III. Metallic prominences.
IV. Prominences projected on the disc as absorption markings.

7. *Flocculi (calcium): Areas and motions. Spectroheliographic. Cambridge.* Newall:

Spectroheliograms in K_{232} light have been obtained on 338 days and photographs of prominences on 280 days; 1004 spectroheliograms in K_{232} light for the years 1925 (April 1)–1928 (March 31) have been received from the Kodaikanal Observatory. By an agreement with the Astronomer Royal, prints of the Greenwich series of photoheliograms are now received for comparison with the daily spectroheliograms.

In continuation of the study of the inclination of elongated groups of calcium flocculi (*M.N., R.A.S.* **82**, 334) and of the life-history of bright solar calcium flocculi (*M.N., R.A.S.* **84**, 134), investigations are being carried on in order to find out the direction and magnitude of the proper motions of recognisable points on the boundary of such floccular masses as in their life-history change from compact (circular) form to the markedly elongated form assumed before the process of their gradual disintegration and dispersal has set in. It is hoped that the results of the research may be ready for publication before the meeting of the Union at Leiden in July 1928.

In the investigation of related sequences of outbursts of sun-spots upon which the Director has been engaged for some years past with the assistance of Mrs Beech, it was found desirable to plot all those groups which have been used for the determination of the proper motions of the sun-spots with reference to Carrington's graticule. This work was very nearly completed by the end of the year here reported upon and has since been wholly finished ready for discussion.

The records of Prominences, observed at Kodaikanal during the years 1925 and 1926 and received in manuscript through the kindness of the Director, Dr Royds, have been plotted by Mr Moss in continuation of the previous observations. The whole series 1904–1926 is now being examined with reference to discontinuities in the recurrences of localised prominences in an attempt to locate the origins of the disturbances.

A comprehensive table in order of wave-lengths in the spectral region 3905–7149 has been compiled by Mr Baxandall of all lines strengthened or weakened in the spectra of sun-spots as given in seven independent published records.

Independent estimates of the intensities of all the lines in the table in the region 4600–7149 have been made by Mr Baxandall from Hale's maps and the actual Fraunhofer line which has in each case been accepted is indicated. The origins of the sun-spot lines as given by Rowland for the corresponding Fraunhofer line have been revised from the manuscript copy of the recent Cambridge revision of Rowland's assigned origins.

The data provided by the table have been used for a search for possible correlation between the sun-spot effect and the data of King's temperature classification of the lines of various elements: and similarly with respect to the published records of the magnetic character of the lines. The results, for most of the elements whose lines are strongly affected in sun-spot spectra, show that almost all the greatly strengthened spot lines belong to King's low temperature classes, and the weakened lines to King's high temperature classes.

On the other hand, the greatly strengthened spot lines are not in general the lines showing the greatest magnetic separation.

The necessary data and comparisons have been completed and the results are being prepared for publication.

8. *Flocculi and Prominences: Motions and forms combined with radial velocities. Meudon.* Deslandres.

En ce qui concerne l'observatoire de Meudon, le travail de 1926 à 1928 peut être ainsi résumé:

"Le relevé des quatre couches de la surface et de l'atmosphère a été poursuivi avec les cinq appareils solaires et principalement avec le grand spectrohéliographe, confié à d'Azambuja. On fait chaque jour, autant que le temps le permet, une épreuve K_3, une épreuve K_1, une épreuve $H\alpha$ et deux épreuves de vitesse radiale, en suivant avec soin les indications du magnétographe, placé à côté, dont le papier sensible noircit sans développement. Le cylindre, sur lequel est enroulé le papier sensible, est dans la salle du grand spectrohéliographe, protégé par un verre jaune et un rideau. L'observateur solaire, en soulevant le rideau, a sous les yeux les variations de la déclinaison magnétique des dernières 24 heures. De plus, une sonnerie est mise en marche, lorsque la variation magnétique est grande.

On a pu ainsi plusieurs fois reconnaître un lien entre une variation solaire et une variation magnétique.

Une installation similaire est réalisée à l'Observatoire de Coïmbra (Portugal) qui travaille avec nous en liaison intime.

En premier lieu, ces épreuves solaires sont utilisées pour les cartes synoptiques de l'atmosphère solaire supérieure, dont l'observatoire a accepté la charge, avec une subvention annuelle de £100 accordée par l'Union Astronomique.

Des cartes similaires ont été publiées déjà en 1913, 1922 et 1927 avec les épreuves de Meudon. Or c'est seulement en 1926 que nous avons reçu les épreuves complémentaires de Kodaïkanal et de Mount Wilson, destinées à combler les lacunes de nos observations pour les années de 1919 à 1924. Nous avons dû refaire les premières cartes pour ajouter les détails nouveaux, et nous organiser pour un travail regulier et continu.

Bref nous présenterons à Leyde les cartes définitives de 1919, 1920 et 1921, avec les coordonnées des détails principaux; et notre intention est de régler le travail de manière à publier à la fin de chaque année les cartes de l'année précédente. Il sera nécessaire alors de combler rapidement la lacune de 1922 à 1926 inclus. Une dépense supplémentaire sera nécessaire; et je demanderai pour les années de 1929 à 1931 une subvention plus forte, de £125, au lieu de £100. La question sera d'ailleurs portée devant notre Commission solaire, qui devra donner son avis.

En même temps, M. d'Azambuja, qui a assumé la charge de la carte, a poursuivi des recherches originales sur la liaison des protubérances et des filaments, et aussi sur les images spéciales que donnent le centre et les ailes des raies du 'reversing layer' (raies de *Fe*, *Ca* neutre, *Sr* etc.). Cette dernière étude, fort intéressante, a été poursuivie avec le grand spectrohéliographe de 14^{m}, et a été publiée dans les *Comptes Rendus* de l'Académie.

D'autre part, j'ai étudié personnellement la loi de succession des orages magnétiques terrestres et les conséquences à en tirer sur la constitution du soleil.

En 1926, nous avons pu observer à Meudon plusieurs aurores boréales successives, accompagnées de beaux orages magnétiques, et mon attention a été appelée sur la succession de ces phénomènes. J'ai constaté que les pointes maxima des grands orages, représentées par la longitude du centre du soleil au moment de leur apparition sur la terre, sont séparées en longitude par des intervalles qui sont des multiples de 60°, 30° et 15°; et cette loi simple s'applique aussi aux petites pointes isolées dans les périodes de calme magnétique. Or les variations magnétiques sont dues à des corpuscules électrisés, émanés du soleil (Störmer), et les points d'émission dans le soleil sont de véritables volcans.

Tout se passe comme si le soleil offrait au-dessous de la surface une couche profonde qui tourne comme un corps solide; et cette couche a 24 brisures ou volcans (d'ailleurs intermittents) qui rejettent au dehors la matière fortement ionisée ou radioactive des couches intérieures. Ces volcans sont uniformément répartis autour de l'axe de rotation, cette division étant celle des corps à symétrie circulaire qui se refroidissent.

Le rayonnement corpusculaire des couches profondes, dû surtout à des corps radioactifs, est la cause principale de nos orages magnétiques; et j'ai émis l'idée qu'il était aussi la cause des principaux phénomènes observés sur la surface et les dépendances du soleil (taches, facules, protubérances, jets coronaux).

Si les volcans solaires rejettent des corps radioactifs, on explique aisément toutes les particularités des taches, et même du groupe bipolaire de taches à polarités opposées. On explique les champs magnétiques élevés et opposés des deux taches du groupe.

Finalement, le rayonnement corpusculaire qui, aux températures élevées, émet une quantité d'énergie plus grande que le rayonnement ondulatoire, s'annonce comme ayant une importance capitale dans le soleil. Voir les notes des *Comptes Rendus* de 1926 et de 1927.

Enfin je dois signaler les recherches très curieuses, poursuivies à Meudon et Paris par Mlle Maracineanu, doctoresse roumaine, sur l'influence exercée par le rayonnement solaire sur les propriétés radioactives des corps.

Telles sont les principales contributions de l'Observatoire de Paris-Meudon à l'étude du soleil pendant les trois dernières années.

9. *Solar Radiation. Washington.* Abbot:

So far as has come within my knowledge I would like to draw attention to the researches of Dobson, Pettit and the Smithsonian Institution, and to make one or two suggestions as to needed work.

Dr Dobson, having simplified the method of Fabry and Buisson for determining atmospheric ozone by substituting a special absorbent cell containing halogen gases instead of a sifting spectroscope, has continued at Oxford almost daily determinations of ozone. Aided by grants from the Royal Society, he has been able to prepare similar apparatus, and to institute similar measures at a number of European stations. Aided by a grant from the Smithsonian Institution, he has prepared such apparatus also for the Smithsonian Institution, which has been in nearly daily operation at Montezuma, Chile.

In general, Dr Dobson finds the atmospheric ozone decidedly variable at the British and European stations, with correlations to weather conditions and apparently too (as Clayton points out) to the solar activity. At Montezuma, Chile, however, the ozone appears to be constant. This curious result is still awaiting explanation, as far as I know, and may be of very great significance.

Dr Pettit, having perfected his method of measuring solar radiation in the region of the ultra-violet where silver is transparent, maintains two series of nearly daily measures, at Mount Wilson, California, and Tucson, Arizona. In accord with his expectation*, Dr Pettit finds large variations of the intensity of solar radiation outside the atmosphere in this ultra-violet region. In monthly means these range through at least 60 per cent. and in daily values much more. On comparing monthly mean values with variations of the solar constant, as reported by Smithsonian observers, there is found a high correlation, though the magnitudes of ranges have a disparity as between 60 and 1·5 per cent.

The increasing use of ultra-violet radiation for medical purposes, and the importance of it for all life, vegetable as well as animal, make these studies of Dobson and of Pettit of special interest. A great field for investigation in these lines is open.

The Smithsonian Institution continues to carry on its solar radiation station at Montezuma, Chile. The station formerly at Mount Harqua Hala, Arizona, was removed in November, 1925, to Table Mountain, California (Lat. 34° 22′ N, Long. 117° 41′ W, Altitude, 2460 metres). In December, 1926, observations were begun at Mount Brukkaros, South-west Africa (Lat. 25° 52′ S, Long. 17° 48′ E, Altitude, 1706 metres), under Smithsonian direction, at the expense of the National Geographic Society. At all three of these stations the solar constant of radiation is being observed on every favourable day. The fundamental method of Langley is used frequently as a test, but on every observing day from one to five values are obtained by the short methods devised by Smithsonian observers, in which a measurement of the humidity and brightness of the atmosphere serves to estimate its transparency.

The increased number of observations per day, and the independence of the results of gradual changes of transparency during the series of observations, which are both favourable features of the short method, have together greatly diminished the accidental error. Thus the range of variation formerly ascribed to solar change has been much reduced. But even in monthly mean values there still remains, as found in the nine-year period over which excellent results at

* See *Annals Smithsonian Astrophysical Observatory*, 4, 206, also *Smith. Coll.* 77, No. 5, p. 25.

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all seasons are now available, a range of solar constant values from 1·91 to 1·97 calories. Daily observations exhibit a total range still wider.

It appears that the monthly mean values march in general parallelism with sun-spot activity. Superposed on this variation is a strong regular periodicity of 25⅝ months. Besides these there are periodicities of lesser importance of about 15 and 11 months and there are found also harmonic overtone periods of these three regular periodicities. These results have held as from 1920 to 1926 inclusive. If continued indefinitely in the future they must have great interest*.

A new test method based on pyrheliometry alone has been developed by C. G. Abbot†. By the application of it important corrections and improvements in the solar constant determinations of Mount Wilson and Montezuma have been made. Greater attention than formerly is being paid to the elimination of sky radiation near the sun.

With the completion of several years of continuous observing under comparable conditions, it has become possible to revise the methods of reduction employed, and to determine systematic errors by statistical comparisons. This work is completed for the Montezuma station, and it is believed that present publications of the results of that station such as are now daily included in the weather map of the U.S. Weather Bureau, are definitive, and are given on the same scale as the results formerly published from Mount Wilson and Calama, Chile. Similar critical study is being carried to a completion for Table Mountain, California.

Dr Austin of the U.S. Bureau of Standards has published a comparison of sun-spot numbers, solar constant values, and intensities of transmission of long-range radio signals‡.

It appears that a high positive correlation persists between monthly mean values of the three variables.

10. *Observations not closely allied with established Centres are being carried on at several observatories.*

At Highbroom Evershed is taking photographs of prominence spectra in the *H* and *K* region with *Fe* and *Ca* arc comparison spectra for determining values of solar rotation at considerable heights above the chromosphere, and for new values of the Einstein gravitational effect given by the calcium lines in the prominences.

Determinations of the wave-lengths of selected lines in the solar spectrum are on the programmes at Allegheny and at Mount Wilson, and it is hoped that similar work will be undertaken at the Einsteinstiftung in Potsdam. There and at Mount Wilson and at Utrecht programmes for the quantitative determination of line intensities are in progress.

The study of absorbing vapours at great heights above the solar surface has been carried on at Meudon by d'Azambuja. There appears to be a close connection between these phenomena and prominences seen in projection on the sun's disc.

The Mount Wilson "Revision of Rowland's Preliminary Tables of Solar Spectrum Wave-lengths," to which much time has been given during the last year by Miss Charlotte E. Moore, Mr E. F. Adams and Mr St John, is about ready

* See *Smith. Misc. Coll.* **80**, No. 2, p. 8.

† *Ibid.* pp. 1–5.

‡ See publication last cited, p. 12.

for the printer and will appear before the Leiden meeting. The wave-lengths are given in the International System, the identifications have been checked and revised and many previously unidentified lines are assigned to their origin. Four columns are added to the table, giving respectively the intensities of the lines in spot spectra; temperature class from furnace spectra; the classification from the behaviour of lines under pressure in the explosive spark and in the high-current arc; and in the last column the excitation potential of all lines identified in series and multiplets. An addendum accompanies the table in which the type of term corresponding to each E.P. of each element is given. For example, in titanium E.P. 0·048 corresponds to the terms A^3F_4' etc. A short account of the Revision may be found in the *Proceedings of the National Academy of Sciences*, **13**, September 1927.

11. *Relationships between solar and terrestrial phenomena.*

It has been suggested that the Committee of the International Research Council set up to further the study of Relationships between solar and terrestrial phenomena hold its meetings in Leiden and that one joint meeting be held with the Solar Physics Commission. Professor Chapman, Chairman of the Research Council Committee, has been asked by the President to outline the present situation and to open the discussion which it is hoped will be general and result in some progressive action. His report follows:—

The recent progress in this subject will be dealt with in a Report which it is hoped will shortly be issued by the Committee appointed by the International Research Committee to further the study of Solar and Terrestrial Relationships. It will therefore suffice to indicate what appear to be the principal branches in which advance has recently been made, without detailed references.

The period since 1925 has been marked by considerable activity in observations bearing on this subject, both on lines previously well established, and in more novel directions. The Smithsonian work on solar radiation has recently been valuably supplemented by the regular observation of ultra-violet radiation now carried on at Mount Wilson and at Tucson (Arizona). Very large variations from day to day are found, which are likely in due course to afford important material for comparison with magnetic and other terrestrial data, including several phenomena of the earth's atmosphere, particularly in the upper layers. Great advances have been made recently in co-operative schemes of observation of the upper atmosphere, relating to the ozone-content, the luminosity of the night sky, and the temperature—as inferred from measurements of the transmission of sound over great distances. The latter work appears to confirm in a rather direct way the conclusion, previously drawn from meteoric evidence, that at 50 km. height and more the temperature of the atmosphere equals or exceeds that of the lowest layer; it appears probable that these temperatures are due to the absorption of ultra-violet solar radiation by the ozone layer in the upper atmosphere, and when more material has been accumulated it will be possible to test this hypothesis by comparing the variations of the ozone content and the ultra-violet radiation, in the region of the spectrum bordering on the ozone absorption bands. As yet the principal correlation of the ozone content of the upper air is with the distribution of atmospheric pressure in the troposphere, though there is evidence of smaller correlation with magnetic activity, and of an annual period. The luminosity of the night sky shows, besides irregular variations, an annual periodicity and strong indications of slower changes in phase with the solar cycle. There has been great activity in observing the changes, from time to time, in the transmissibility of radio-signals of different wave-lengths, travelling in different directions and regions of the earth; though opinion is divided on these questions, the general trend is towards associating the variations with changes in the ionization of the upper atmosphere, which reveal themselves also in other ways. Evidences of connections with magnetic variations have been found, but the investigations will need to be carried on for some years before definite conclusions, at least on many of the points raised, can be drawn. Less success has attended attempts to correlate the wireless variations with sun-spots, and this is doubtless for the same reason that has hindered progress in correlations of terrestrial magnetic and solar phenomena: magnetic storms are themselves not always associated with visible sun-spots, and the exact solar conditions which affect both the magnetic and wireless phenomena remain to be found.

It has been suggested that magnetic storms have a periodicity of recurrence at intervals which are simple fractions of the solar rotation period, indicating regularly spaced meridians of the sun, of special activity: but opinion is divided on the facts of the matter.

Recent laboratory researches leave little room for doubt that the green auroral line is due to oxygen, but further observational and laboratory work on the auroral spectrum is required for the elucidation of the nature and conditions of excitation of the molecules or ions to which the auroral light is due. There is need also for laboratory researches on the spectrum of the night sky, and on the formation of ozone by ultra-violet radiation, especially with reference to the possibility of ionization during the formation, or during subsequent absorption of further ultra-violet radiation; such work should throw light on the nature of the solar emissions, both radiative and corpuscular, which produce various phenomena of the upper atmosphere.

It has recently been found that the specially high auroral rays, extending up to several hundred kilometres, occur only (with a few doubtful exceptions) in situations within the unintercepted beam of sunlight passing beyond the circle dividing the dark and sunlit hemispheres of the earth. This remarkable observation has not yet been theoretically accounted for.

In spite of important recent progress in the theory of the solar atmosphere, comparatively little advance has been made recently in the explanation of solar and terrestrial correlations. In particular, the exact nature and conditions of emission of the corpuscular radiation which gives rise to auroræ and magnetic storms are still in doubt.

12. *Eclipses. Cambridge, England.* Stratton:

(*a*) *Introduction*

Recent investigations on the sun have shown the importance of solar eclipse observations and the need for further enquiry along fresh lines. The Eclipse Centre of the Solar Physics Commission was formed in order to facilitate the scientific observation of eclipse phenomena by securing co-operation between workers in various countries, by the collection and dissemination of meteorological data and other information useful for intending observers.

The first report of the newly formed eclipse centre deals with the approaching eclipses and the present position as to the more important eclipse problems. At

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the suggestion of several workers in the field a few notes and references on eclipse observational methods are given. Some resolutions are added for submission to the General Assembly of the Union.

(*b*) *Coming Eclipses*

(i) The eclipse of May 9, 1929, will be visible in Sumatra, Malay States, Siam, Cambodia and the Philippines. The maximum totality is 5 min. Arrangements were made in 1926 by the observers in Sumatra for meteorological observations round the hour and date of the eclipse to be made in Sumatra, Malaya and Siam during the years 1927, 1928, and the French and American authorities have also been asked to make suitable meteorological observations in 1928. Information as to suitable camp sites is also being sought.

(ii) The eclipse of April 28, 1930, annular over most of its path, will be total along a narrow belt, not more than half a mile wide, from just north of San Francisco across Nevada and Idaho to a point north of Virginia City in Montana. The longest duration of totality is 1·5 sec.

(iii) The eclipse of October 21–22, 1930, will be visible from the island of Niuafou in the Tonga Islands and, near sunset, in Chile and Patagonia. The maximum totality is 2 min. Mr A. Thomson, Director of the Apia Observatory, has kindly promised to supply information as to the meteorological and camping conditions at Niuafou. The Director of the Cordoba Observatory has been asked to obtain information about the South American conditions.

(iv) The eclipse of August 31, 1932, will be visible in a belt from Canada (Hudson Bay) to the Eastern States of the United States. Maximum totality 1·5 min. Prof. Slocum, Van Vleck Observatory, Middletown, Conn., U.S.A., has already organized meteorological observations for the next few years round about eclipse time along the totality belt in Canada and the United States.

It is hoped that the information referred to above will be sent in, in due course, to the director of the eclipse centre, who would offer it to the Astronomical Press for publication for the information of intending observers. (*Astronomische Nachrichten*, *Bulletin Astronomique*, *Journal des Observateurs*, *The Observatory*, *Popular Astronomy*, *Populär Astronomisk Tidskrift*.) Some details have already been published about the conditions for the 1929 eclipse: Siam, Brändli, *A.N.* **230**, 379, 1927; Philippines, Selga, *Pop. Astron.* April, 1927. It is thought that the eclipse centre may be of use to observing parties, if notice of intended expeditions could be sent in with details of proposed programme and site of camp as soon as these details are available. These could be circulated to others interested in the coming eclipse. It is not only the interchange of information between prospective expeditions that might prove useful but it may be helpful to those responsible for organizing expeditions, if early information was made available as to the success or failure of individual experiments or observations attempted at the last preceding eclipse. So little time is available and so many problems await solution that in the interest of economy of effort such information might with advantage be made available by an early date for intending observers by the co-operation of their colleagues. It may be particularly important to know that a problem has been attempted, but, for a particular reason, unsuccessfully, so that the next eclipse expedition can guard against a repetition of failure by taking the necessary steps in time.

(c) *Important Eclipse Problems*

(i) *The form of the corona.* At every eclipse it is important that the corona should be photographed so that the causes underlying its changes of form may ultimately be discovered. A programme with long and short exposures is desirable. Where possible, comparisons of photographs taken at distant stations at the same eclipse should be made for a study of rapid changes in the corona. For this work and for continuity of discussion it might be well to standardize the lens of a coronagraph and to get expeditions, whenever possible, to take equivalent photographs with a lens of long focal length. In addition, photographs with lenses of small *f* ratio for extensions might with advantage be taken. As far as possible it is desirable that photographs taken for coronal detail by different observing parties at the same eclipse should be photographically equivalent as to the kind of plates used, the exposure time and development. Prof. Miller of Swarthmore has suggested for the 1929 eclipse the use of plates as fast as Eastman Kodak No. 40 and for an instrument of 60-ft. focal length and 9 in. aperture a programme of exposures of 1, 2, 4, 14, 20, 10, 7, 2, 1 seconds—allowing 15 seconds for a change of plates—of which perhaps the most important exposures are 1 and 14 seconds.

In the publication of plates the orientation of the plate should be indicated as accurately as possible.

Comparisons might be made with advantage with objective-prism spectra obtained by the same or some other expedition and with the spectroheliograms so that the fullest information available as to the connections of coronal features with prominence and solar markings may be obtained.

(ii) *Brightness of the corona.* The total light and heat emitted by the corona needs to be measured at successive eclipses to correlate changes with changes of coronal form and extension. Recent determinations vary between 0·27* and 0·5† of the brightness of the moon.

Considerable confusion has arisen through a failure fully to recognize that the colour and total intensity are intimately connected. Results should be expressed when possible in terms of the intensity at some particular wave-length or over a certain range of spectrum and the ratio of such quantities should be measured to the same quantities for the full moon. Corrections to the measures are required for the portion of the corona obscured by the moon, for lunar augmentation and for differential atmospheric absorption. The intensities of the bright line coronal radiations at different heights is also worthy of careful study. At least one photograph of the corona should have standard squares printed on it with the same exposure as that of the plate.

The annular eclipse of the sun on April 28, 1930 would seem to offer an excellent opportunity to repeat Prof. Julius' examination of the total radiation from the solar atmosphere‡. In all the estimates of the total radiation from the corona the important part played by the varying condition of the atmosphere must not be overlooked and some check should be added if possible to the observations on the corona alone.

The law of intensity in terms of distance from the limb wants further elucidation by exact photometric methods. Laws so diverse as $I \propto r^{-2}$§ and $I \propto R^{-6}$‖

* Parkhurst, *Ap. J.* **64**, 273, 1926.
† Kunz and Stebbins, *Ap. J.* **62**, 114, 1925.
‡ *Ap. J.* **37**, 225, 1913.
§ *H.C.O. Circ.* **312**.
‖ Turner, *Proc. R.S.* **68**, 36.

have been found, r being the distance from the limb and R the distance from the centre.

The temperature of the corona is not settled. A tentative result (3000° K) was obtained in 1925 but not confirmed in 1926.

(iii) *Polarisation of the corona.* The polarisation of the coronal light at different heights and in different directions may be studied further with advantage*, in particular the relation of the observed polarisation to that of the sky in the immediate neighbourhood of the sun during the eclipse. The questions of coronal intensity and polarisation are intimately connected†. As scattering depends on wave-length, both visual and photographic observations should be made, but especially photographic observations, using colour filters of selective wave-length transmission.

(iv) *The coronal spectrum.* It is important to settle whether a number of lines which have only been measured at one eclipse belong to the coronal spectrum or not. High dispersions—say 3 prisms and a slit—are required, and unless the same observer can attack the problem at successive eclipses a standardized spectrograph for use at successive eclipses is desirable.

Increased accuracy of wave-length of the bright lines in the coronal spectrum is to be desired, especially to the red side of $H\delta$. For the strongest lines 5303, and, better, 3388, an interferometer method might be used to detect motion in the corona‡. Accurate photometric comparisons should be made between the lines as an aid to grouping those of like behaviour§ and ultimately perhaps to defining probable multiplet systems among them. The dark line spectrum in the outer corona should be examined carefully for divergencies in wave-length and width from the solar spectrum‖. Evidence has yet to be obtained for coronal rotation either from the bright line or the dark line spectra. The evidence from the dark lines for outward movement of the coronal matter needs verification.

The distribution of intensity of radiation in the continuous spectrum at different heights and in all regions of the spectrum needs to be studied, especially for the transition layers between the chromosphere and the corona. The most recent investigations have given different results. Ludendorff (*Sitz. der Preuss. Akad. d. Wiss.* 1925, 83) (*q.v.* for earlier observations), using very refined methods, got no difference from the solar continuous spectrum, while Davidson and Stratton (1927) from a small range of spectrum for a very low level in the corona confirmed the excess of radiation at longer wave-lengths found by Coblentz and Stetson in 1923 (*Ap. J.* **62**, 128).

(v) *Chromospheric spectrum.* For heights of lines, for low level chromospheric lines and for faint lines a grating without slit has proved the most successful instrument in the past but good focussing is essential and good seeing conditions. Large scale slit spectra of high dispersion are required to study variations of wave-length from the Rowland (or corrected Rowland) values. The work on changes from centre to limb of the sun's disc needs to be followed through the reversing layer into the low chromosphere. Observations made from near the edge of the totality belt would probably best provide the desired material (Evershed, *Phil. Trans.* 1903) or observations of the chromosphere at the cusp

* Young, *L.O.B.* **205**; Lewis, *L.O.B.* **318**.
† Newall, *M.N., R.A.S.* **66**, 480, 1906; Campbell, *L.O.B.* **346**, 1922.
‡ *M.N., R.A.S.* **87**, 683, 1927.
§ Campbell, *L.O.B.* **318**; Davidson and Stratton, *Mem., R.A.S.* **64**, 146.
‖ Ludendorff, *Sitz. d. Preuss. Akad. d. Wiss.*, Berlin, 1925.

with gratings of high dispersion. (Fowler, *M.N., R.A.S.* **72**, 541.) The central eclipse of April 28, 1930, offers an excellent opportunity of carrying out experiments along these lines.

Spectrophotometric work on the intensities of lines at different heights is very much needed now. The moving plate method should give good results under favourable conditions, *i.e.* at minimum solar activity when the chromosphere is most quiescent. The presence of a prominence would give false heights. Information of distribution of prominences on the limb broadcasted by wireless to eclipse expeditions might be helpful in this connection. A determination is required of the absolute and relative intensities at high and low levels in the chromosphere of the ionized calcium multiplets in the violet (H and K) and in the infra-red (8600 A)*. Extensions of observations towards the infra-red are becoming available and should be pressed as far as possible. Spectrophotometric work on the Balmer series, on the continuous spectrum at the head of the series, and on the continuous spectrum coming from prominences, may all lead to results of very considerable value. In particular the head of the Balmer series needs to be examined with higher dispersion to test the overlap by the hydrogen continuous spectrum. A determination of the relative intensities of lines of different excitation potential at different heights should also prove of interest. For this work to have its full value it is important that the distribution of the radiation in the continuous spectrum of the sun should be determined with greater accuracy (avoiding integration of absorption lines) and further into the ultra-violet than has been done at present.

Useful observations of the height of the chromosphere can be made by cinematograph observations† either by direct photography or with an objective prism or grating. Accurate time marks on the film should be arranged and if possible some simple photometric scale. The method in which photographs of the cusp taken during the partial phase are employed is worthy of attention. The intensity of the cusp image can be reduced by using screens of platinized glass—not by cutting down the aperture of the objective.

(vi) *The Einstein displacement.* Deviations from the Einstein law for the apparent displacement of stars near the sun have been suggested by previous results. (Dyson and others, 1919, 1″·98.) These should be checked by further observations under favourable conditions with such precautions as, if confirmed, will lead to explaining them in terms of coronal or terrestrial refraction or otherwise. It has been suggested that these plates might be used to test the opacity of the corona by precise determination of the magnitudes of the stars at the eclipse and on the field plates taken at another time.

(vii) *Time observations.* Despite the uncertainty of timing contacts, by reason of the ruggedness of the moon's limb, it may be possible by a fast moving plate spectrograph, an objective grating or prism cinema camera spectrograph employed at second and third contacts, to obtain useful information on the instant of mid-totality and on the boundary of the photosphere. Comparison of such determinations at several stations, at the same eclipse, based upon the same wireless time signals, may be of value from the point of view of the geodesist as well as of the lunar theorist. A tentative effort by Barton and by Captain Akkersdijk in Sumatra in 1926 indicated that the method might be usefully developed.

* See Davidson, *M.N., R.A.S.* **88**, 30, 1927, for work on these Ca^{+} lines outside total eclipse.

† See *M.N., R.A.S.* Dec. 1927.

(viii) *Meteorological data.* Measurement of solar radiation, true air temperature, atmospheric humidity, barometric pressure, strength and direction of wind, atmospheric electricity, potential gradient and conductivity, components of the Earth's magnetic field and the strength of wireless signals throughout the whole eclipse have all their own interest.

(*d*) *Observational Methods, Materials, Instruments and Apparatus*

(i) *Geodetic position and time service.* For any accurate time work the position of the station occupied should be carefully confirmed by observation, as charts and maps are not always to be relied upon. Chronometers may be rated and G.M.T. established by wireless signals.

Warning of the approach of totality can be obtained by observing the length of the disappearing crescent, calculated beforehand for 60^s and 30^s, say, before totality. The instant of totality can be called by an observer, watching for the reversal of the absorption spectrum through some objective grating. A metronome is a simple device for counting off the seconds of totality but the counter should be well rehearsed.

(ii) *The mounting of the instruments to counteract the earth's diurnal motion.* Short focus coronagraphs can be mounted equatorially on polar axes. With large cumbersome instruments and long focus coronagraphs, coelostats may be used. With long focus coronagraphs, the earth's diurnal motion may be counteracted by moving the plate or the lens during the exposure.

The coelostat. A very convenient instrument for use with large spectrographs or other physical apparatus. It saves considerable trouble and expense for long focus coronagraphs. Several instruments may be fed from the one coelostat, but it may prove more convenient to employ a number of mirrors attached to the same axis, or to drive several small mirrors, mounted on independent axes, according to the method introduced by the Cambridge Solar Physics Observatory Expedition 1927. (*M.N., R.A.S.* **87**, 677.) The coelostat is very easily adjusted (Turner, *M.N., R.A.S.* **56**, 406), but it introduces an extra and very sensitive optical surface—the mirror. In some designs the radius of the driving sector is too short, and, as the motion of the reflected beam is doubled, errors in the clock-drive become serious. The coelostat may, however, be worked with a long arm or quadrant in the same way as a polar axis.

If the coelostat available gives troublesome clock errors it is possible to fix the mirror and move the objective of the optical train through a small range. This method, due to Moll, has been used successfully by a Dutch eclipse expedition. The lens may be moved by a screw driven by an electromotor synchronized with a clock, with extreme resultant accuracy in driving.

Siderostat, or heliostat. The siderostat has a double motion and sends the horizontal beam to a fixed azimuth, south, but the sliding rod is against perfect following and at large low angles is impossible. A disadvantage of the siderostat is the rotation of the field.

Mirrors. Under eclipse conditions coelostat and siderostat mirrors seldom remain flat as they should do. The use of a mirror of pyrex glass should help to avoid trouble of this nature.

In a damp climate, mirrors should not be unpacked until a day or two at most before the eclipse. All the preliminary work should be done on an auxiliary mirror. The mirror should not be finally polished until the morning of the eclipse. In the unpolished state it is less likely to blister if moisture is deposited on it.

The polar axis. This form of mounting is best for small instruments where it is practicable. Except for quite small apparatus, the observatory equatorial is too cumbersome. The expeditionary axis, as developed by Lick observers and others, is best for medium sized apparatus, and has been used successfully for telescopes of 15 ft. focal length. It is particularly suited for low latitudes. The radius of the driving sector should be commensurate with the focal length of the telescope so as to minimize clock-driving errors. Several instruments may be mounted on one axis. But the operation of changing plates is likely to set up vibrations, and it would appear undesirable to mount a number of instruments on one polar axis. The objection, however, is more apparent than real, for it is possible to arrange the observing programme so that the plates are changed simultaneously on all instruments, or only at times when the disturbances will not interfere with the remaining instruments.

Schaeberle's method of moving the lens or plate during exposure. If the camera is pointed towards the eclipsed sun, the earth's diurnal motion can be counteracted by moving the lens or plate. When a fixed mirror is used with a horizontal camera, the motion may be compensated by moving either the lens or the plate. The moving plate Schaeberle tower telescope is suitable for lenses of great focal length and most convenient for use with a rather low sun. The tower supporting the lens must be screened from wind by an outer tower, covered with canvas. The plate is drawn by clockwork along suitably curved rails. The plate end of the telescope must be in a dark room in which the observer stands. Campbell (*L.O.B.* 131) discusses the relative merits of *Schaeberle and coelostat-fed coronagraphs.*

Driving clocks. Clocks having horizontal friction rings as part of the speed governor must be mounted with a governor spindle exactly perpendicular. The adjustment of the friction ring normal to the spindle is then carried out by means of screws provided for the purpose. Clocks of this type usually have two friction shoes of leather, wood or fibre mounted 180° apart. The shoes must subsequently be adjusted to exert the same amount of friction on the ring, when the clock is running at its proper speed. Weight-driven clocks are preferable, but spring-driven motors of the totally enclosed type, such as are used in high-class gramophones, can be employed where only a small amount of power is required. If overloaded they will not run steadily. Clocks regulated by a ball governor and a fan, that opens out and increases the air resistance when the speed increases, are excellent. This form of clock need not be mounted with the governor spindle strictly perpendicular.

(iii) *Lenses suitable for photography of the corona.* For extensions of the corona use lenses of comparatively short focus and large aperture. A single lens will give less scattered light than a doublet. A useful focal length is 75 cm. and upwards. For work in an aeroplane the largest possible aperture and shortest exposure, say 1/100 second, are necessary on the fastest plates. For the inner corona lenses up to 41 metres focus have been used; 12 m. focus gives probably the best average. A standard lens suggested as an alternative to the one mentioned in (*c*) (i) above is 10 cm. aperture, 6 m. focal length (*f*/60); using a special rapid plate (H and D 250) the exposure necessary for the full corona is 30 seconds, for the middle corona 5 seconds, for the inner corona 2 seconds. The considerable range of intensity in the corona makes it impossible to secure detail from the inner and outer corona from one exposure. Something can be done to meet this difficulty by suitable development, *e.g.* the well-known method of restraining density by removing the developer at an early stage and prolonging the development under water.

A tube between the lens and the plate holder is necessary; a light framework wrapped round with dark cloth has been found adequate. To meet tropical conditions a second covering, say palm thatch or white canvas, with sufficient air spaces in between is necessary and it may be desirable to ventilate the tube.

(iv) *Einstein cameras.* The lens used successfully in 1919 was 4-in. aperture, 19 feet focus, *i.e.* $f/57$. With this, 30 seconds exposure gave sixth magnitude stars without sky fog. But this was the most favourable field in the sky and will not occur for eclipses again in accessible regions for many years. Campbell at Wallal, 1922 (*L.O.B.* 346), used two lenses of 5-in. aperture, 15 feet focus ($f/36$); with an exposure of 120 seconds stars of $10^{m}\cdot5$ were shown on a darkened sky background, but inside 30′ from the limb stars fainter than $9^{m}\cdot5$ were lost in the denser corona.

Scale was determined from a check field taken at night. It would be better to take a check field during the eclipse by swinging the telescope to a near field of bright stars which would be photographed on the eclipse plate. This was done by Miller at Yerbaniz and Benkoelen. Apparently 120 seconds was the limit permissible for exposure at Wallal on account of the darkening of the background. This should be halved for the double exposure on the same plate. With a good scale field a multitude of stars is not necessary. Two or three stars near the sun are of more value than 200 or 300 at a distance.

(v) *Precautions for spectrophotometry.* Any plate to be used for spectrophotometric work should contain on itself (or on a separate plate cut from the same larger plate) the comparison spectrum used in its discussion. The two plates should be taken with the same time exposure, so far as possible, and as nearly as possible under the same conditions of moisture, temperature, etc. If the comparison spectrum is a solar spectrum it should be taken as soon as possible after the eclipse. Both spectra must be developed together.

The comparison spectra should be (*a*) a solar spectrum to be used in obtaining the sensitivity of the plate at different wave-lengths combined with the effect of the atmospheric absorption on the eclipse spectra and (*b*) a line spectrum, *e.g.* iron arc for the density intensity curve at separate wave-lengths. Both comparison spectra should be taken with a calibrated stepped wedge in front of a uniformly illuminated slit. Constancy of slit-width and freedom of the spectrograph from astigmatism are also essential in this work.

If possible, to allow results covering a large range of densities, several exposures of different duration should be made on the same spectrum. Otherwise it may be necessary to use a filter or some reflecting device (see *M.N., R.A.S.* **88**, 679, Carroll) for one part of the spectrum. The effect of this must be accurately allowed for. The principle and method of this spectrophotometric work is given by Ornstein in *Proc. Physical Soc.* (London), **37**, 334, 1925. He and Minnaert at Utrecht have offered to put themselves at the disposal of astronomers for the purpose of giving more detailed indications on the subject than can be given in this report.

(vi) *Focussing.* Focussing of a corona camera may be done on stars at night, but an autocollimating method is as good and perhaps better. If the camera is coelostat-fed its own mirror should be used for reflexion. If an illuminated source is put near the focal plane and the reflected image viewed through a suitable filter, the position of the focus may be determined with accuracy.

An objective prism should be focussed by means of a reflecting collimator with a slit.

The slit of the collimator must of course be first focussed to infinity and the focal lengths of the reflector and the spectrograph should be comparable.

Focussing on stars is an approximation on account of the changing temperature of the prism. The prism should be protected as much as possible from change of temperature.

The use of curved films with a single lens increases the field of sharp definition. The same applies to the concave grating.

(vii) *Colour filters*. The employment in coronal photography of selective colour filters, of known spectral energy transmission, has certain special advantages. With lenses having a large aperture to focal length ratio, the so-called Wratten monochromatic filters can be employed; while with those having a small aperture to focal length ratio, more transparent filters, such as Wratten tricolour, should be used. The filters should be of the cemented type, having good optically worked glass surfaces. It would be an advantage to make use of suitable stops with each filter, so that negatives of the same relative density would result from an exposure on some source of known spectral energy distribution like the sun.

(viii) *Prisms and gratings*. No general rule can be laid down for choice between these two types of instruments. It is mainly important to choose a problem within the optical reach of the instrument available for the observer, or, if a new instrument is being designed for eclipse work, to see that the optical details are as far as possible adequate for the work attempted. The *Objective Prism* is the spectrograph which gives most light, and, like the *Objective Grating*, it may be used for weak lines or for giving from the length of the chromospheric arcs the heights to which different gases rise. It may also show the relation between prominences and local intensification in the lower corona.

In 1926 in Sumatra a lens of 4-in. aperture and 39 feet focus, *i.e.* $f/117$, with a 45° prism before the lens, gave a good result.

With 10 secs. on a panchromatic plate, the coronal ring 5303 was shown in detail, the ring 6374 was also to be seen. Twenty secs. would have been better, and better still 5 secs. with standard $f/60$ lens. Concave gratings used as objectives without slit are best for determining the heights of the different gases of the chromosphere. The new gratings ruled by Anderson, Lyle and Merfield, in which a large percentage of light is concentrated in one order, are nearly, perhaps quite, as luminous as the objective prism, and for the red, much to be preferred.

For examining differences in the chromospheric spectrum at various heights, Campbell, and later Merfield and Kienle, used a moving plate spectrograph. A narrow slit was interposed between the spectrum and the plate, the slit running the length of the spectrum and normal to the chromospheric arcs at the point of contact. The plate was moved uniformly perpendicularly to the length of the spectrum, so that the spectrum was drawn out into lines gradually fading as the chromosphere was covered by the advancing moon.

Campbell used three 60° prisms before a 2-inches objective of 60 inches focus. The slit before the plate was 1/16 in. wide and the plate moved 1/16 in. per sec. The dispersion from $\lambda 3700$ to $\lambda 5300$ was 13 inches. The effective exposure was 1 sec. at $f/30$ and the resulting negative rather over exposed (*L.O.B.* 384).

Merfield used a similar device but with a concave diffraction grating ruled by Lyle and Merfield for the purpose with an aperture 6 cm., focus 100 cm., and 4250 lines to the cm. (10,795 per inch): 73 per cent. of the incident light fell into the 1st order spectrum on one side. The slit was $\frac{1}{8}$ mm. wide and the film moved at the rate of 1 mm. per sec. The effective exposure was $\frac{1}{8}$ sec. This at $f/17$ compares with Campbell's 1 sec. at $f/30$.

Slitless spectrograms are useful for studying the distribution of coronal matter relative to the prominences and also the connection between prominences and the continuous spectrum, but the *Slit Spectrograph* is necessary for accurate wave-lengths and accurate spectro-photometric work. The position of the slit relative to the cusps (if working on Fowler's plan) or its direction relative to the limb of the sun must be chosen to suit the problem under examination. Note that the lower chromosphere is only about $1''\cdot5$ deep, consequently 3 seconds is the maximum useful exposure with the slit tangent at the point of contact. Longer exposure can be made, possibly by working on the cusp and following the cusp with some rotating device.

Liquid prisms may be used with advantage. Carbon bisulphide is not suitable but aethylcinnamate can be used without fear of trouble from temperature differences.

In the *Infra-Red* Curtis reached 9000 A, using dicyanin stained plates and a concave grating 34 inches focus, ruled surface 5 × 3 in., 3609 lines to the inch, with exposure 1 second (*Pub. Allegh. Obs.* **6**, 6, *Ap. J.* **61**, 92).

Dicyanin is uncertain, and slow, and unsuitable for the tropics and should now be replaced by neocyanin for the infra-red (7700–8700, max. 8200–) (Kodak fine emulsion fast plates), and kryptocyanin for the extreme red (7000–8000, max. 7500).

For the *Ultra-Violet* a quartz spectrograph or metal grating must be used; silver mirrors fail to reflect below 3300. Lewis used a metal mirror and reached 3100 (*L.O.B.* **131**, 318). Stratton and Davidson in 1926 reached 3066, using a 4-prism quartz spectrograph with a speculum image-former (*Mem. R.A.S.* **64**, pt 4). The width of slit for a slit spectrograph is best determined by the diffractional method (Newall, *M.N., R.A.S.* **65**, 608).

With a low sun, the infra-red and ultra-violet of the chromosphere may not enter the slit when it is brought tangentially to a sharp visual image owing to atmospheric dispersion. This source of trouble can be mitigated by placing the slit radial at the point of contact. If an apochromat or parabolic mirror is not used to form the image when a tangential slit is employed, some parts of the spectrum may be lost altogether. The difficulty mentioned above may be partly overcome by examining a radial section. The disadvantage of placing the slit radial or examining a radial section by any other means (moving plate spectrograph) is that a prominence might be included. This trouble can be avoided by having some knowledge of the position of prominences and disturbed areas prior to totality. The focal ratio of the collimator of a slit spectrograph should be approximately the same as that of the image former. An increase of intensity may be secured by using a short focus camera lens in the spectrograph.

(ix) *Interferometer.* Attempts have been made at several eclipses to secure the wave-length of the coronal line 5303 and to detect motion in the corona by means of the method described by Fabry and Buisson (*Ap. J.* **40**, 241). These attempts have failed, possibly owing to the strength of the continuous spectrum (*Ap. J.* **61**, 95). The line 3388 might possibly offer a greater chance of success.

(x) *Polariscopes.* Double image prism, nicol prism, or reflecting polarigraph. Young (*L.O.B.* **205**) says "the reflecting polarigraph has much to recommend it in comparison with the double image camera: the focal length of the cameras may be made much longer, thus giving a larger image of the moon." Prof. Schuster has pointed out that for a range of several degrees near the polarizing angle the polarization is nearly complete.

In Young's instrument the reflectors are before the object glass. Turner suggests a cheaper arrangement by placing them just inside the focus at the proper angle. Here, with an aperture of *f*/20, light will converge at an angle of 3°, so polarization is not so perfect. Polariscopic apparatus should be fitted with colour filters. The following references will be of value:

NEWALL, "Nicol Prism and Savart Plates and Atmospheric Polarization." *Proc. Roy. Soc.* **67**, 362.
TURNER, "Reflection Polariser." *Proc. Roy. Soc.* **77**, 89.
NEWALL, "Polarising Spectroscope." *Proc. Roy. Soc.* **77**, 75.

(xi) *Photometers.* For measuring the total intensity of the coronal light the following instruments may be employed:

(*a*) *Photo-electric cell.* This instrument is difficult to work in tropical climates, on account of insulation troubles. It is a good instrument for the ultra-violet.

(*b*) *Selenium cell.* This instrument is valuable for measurements in the red, the visible and ultra-violet.

(*c*) *Thalophide cell.* Especially good for work in infra-red.

(*d*) *Thermopile and vacuum thermojunction.* Valuable for infra-red work. The results gain in value if the instruments are fitted with absorption cells or colour filters. If an image-forming lens or mirror is used, the measurements can be restricted to certain parts of the corona. It is objected that, unless certain precautions are adopted, the instruments register the integrated effect of the continuous and monochromatic radiations of the corona.

(xii) *Plates. The preparation and preservation of plates.* The choice of plates depends on the work for which they are to be utilized. If films are used, the celluloid should be stout and specially selected, so as to be as free as possible from drawing lines which generally run the length of the film. Panchromatic plates may be hypersensitized by bathing for five minutes in 1 per cent. solution of 0·880 NH_3 in borax, 1 : 250 by weight. The procedure is undesirable unless special speed is absolutely necessary. For the infra-red the neocyanin plates are best. On account of their low sensitivity they must be hypersensitized in ammonia. (Instructions are enclosed with the commercially supplied plates.) It is a desirable precaution to test a plate from the box it is intended to use in the eclipse. All coronal plates must be packed or double coated.

Expeditions should be equipped with an approved plate standardizing photometer so that the spectral sensitivity, the Schwarzschild index and other photometric data may be obtained under the eclipse conditions.

Stained plates may be preserved in the tropics by sensitizing in a spirit bath cooled with ice, and then drying in a large shallow air-tight box in the bottom of which is a layer of fresh quicklime. The box must be air-tight and preferably metal, but a well-made wooden box with a tight-fitting lid is quite satisfactory. The advantage of a metal box is that it can be placed in an ice chest to keep it cool if necessary. Immediately after staining, and before placing the plates in the drying box, they are drained of superfluous liquid and partly dried by whirling on a mechanical turn-table. Both exposed and unexposed plates may be preserved for a considerable time in a drying box of this description. The process was developed by Merfield in Mexico in 1923 and thoroughly tested by him at the Sumatra eclipse in 1926.

(xiii) *Exposures for eclipse spectra.*

Flash spectrum. The chromospheric spectrum is composite. It consists of bright lines superimposed on a continuous spectrum. The bright lines, however, are so intense, that no difficulty is experienced in getting sufficient contrast even when a low dispersion is used. With an objective prism working at $f/20$, $\frac{1}{4}$ sec. gave full exposure (Lockyer); with a grating, Mitchell gave 1 sec. With 3 prisms at $f/30$ Campbell gave 1 sec. With concave grating at $f/17$ Merfield gave 1/5 sec. As the chromosphere is $1''\cdot5$ deep, 3 sec. is the maximum useful exposure for the upper chromosphere.

It is the time to expose when the disappearing crescent breaks into beads. If the exposure is on the cusp the time may be prolonged by using an image rotator. With a 4-prism quartz spectrograph, slit-width $m = 2$, and collimator and camera aperture 3 in. and focal length 36 in., a 5-sec. exposure was given for the flash spectrum when the slit was tangential to the limb. The result was a full exposure for the ultra-violet.

Coronal spectrum. The coronal spectrum, like the flash spectrum, is composite, but the bright lines are very weak; therefore high dispersion is necessary to obtain contrast, while long exposures are required to obtain spectrograms of sufficient density. The outer coronal spectrum, so far as is known, shows no bright lines. It is simply a Fraunhofer Spectrum of very feeble intensity. A low dispersion must therefore be employed and a long exposure given.

At Benkoelen, with a 4-in. lens, focus 39 feet (*i.e.* $f/117$) and with a 45° prism, 10 sec. on special rapid plates showed 5303 A well and also 6374 A. This may be called a minimum exposure. Attempts have been made at various eclipses to reduce observational errors by employing shutters automatically controlled by means of clocks and pendulums. To obtain accurate data regarding exposures, chronographs might be used. These ideas are worthy of attention, especially when securing negatives for photometric purposes. Where the motion of a plate determines the effective exposure, as in the moving plate spectrograph, it is advisable to make use of some form of time marker.

(xiv) *Development of plates.* As photographic photometry is the foundation of an important part of most eclipse observations, the development and subsequent treatment of the plates is of the greatest importance. Space will not permit a discussion of the subject here, but a treatment of it will be found in Ch. IV of *Photography as a Scientific Implement*, a collective work, also in *Photographic Photometry* by Dobson. In the absence of distilled water, rain water may be employed in making up developing solutions. If the station is in a tropical climate a good supply of ice is essential. When electric power is available, a good supply of ice can be made with some of the small domestic refrigerating plants now commercially obtainable. A temporary dark room may be constructed from a frame hut covered with Willesden canvas and lined with black paper, but it is apt to be stuffy in tropical climates and for comfortable work such a room should be large and well ventilated. A splendid dark room can be made of three-ply wood or wood pulp building boards. Cracks may be stopped with cotton wool blackened over with paint. A good dead black for the interior of dark rooms, etc., may be made by adding lamp black to a thin solution of shellac in industrial spirits. A mixture containing turpentine is not recommended, as the vapour is apt to injure sensitive photographic materials.

(*e*) *Selection of Observing Stations and Camping Arrangements*

Details depend on local conditions. No general rules can be given, except:

(i) Protection from strong winds is important.

(ii) Electric power for lighting, charging batteries, working spark coils, comparison arcs, etc., is invaluable.

(iii) For protection of instruments, frame huts covered with canvas have proved very effective and convenient. Additional protection against heavy rains may be needed. Palm leaf shelters are easily constructed in most tropical places.

(iv) If time, labour and material are available, solid piers of concrete on which to mount the heavier instruments are desirable, especially for coelostats, etc. The meridian line must then be laid down as exactly as possible, and the precise position of the piers marked off.

(v) If the station is tropical a supply of ice is very desirable: failing this, cooling jars may be used.

(vi) The programme of observations should be well rehearsed in the days preceding the eclipse, and it is advisable to practise with dead plates in the holders, if large and heavy plates are to be used.

Resolutions. It is proposed to submit the following resolutions to the meeting at Leiden in 1928.

(i) That bodies responsible for organizing eclipse expeditions be urged to co-operate by circulating freely early information as to proposed plans and, after the eclipse, as to experiments that have not been successfully carried out.

(ii) That such bodies be urged to employ the eclipse centre's standard lenses and procedure for coronal photography.

(iii) That with a view to spectrophotometry of eclipse spectra in the ultra-violet, Commission 12 be urged to take steps to ascertain the distribution of the sun's radiation as far as possible towards the ultra-violet.

Installations for Solar Research put in productive use since the last Meeting of the Union

La Torre Solare at Arcetri is described and illustrated in Fasc. No. 48, *Osservazioni e Memorie del R. Osservatorio Astrofisico di Arcetri*, 1926, Dr Giorgio Abetti.

The Einsteinturm at Potsdam with its equipment is described by Dr E. Freundlich in *Das Turmteleskop der Einsteinstiftung*, Berlin, J. Springer, 1927.

The solar laboratory of the Mount Wilson Observatory in Pasadena with its equipment is described in *Nature*, **118**, 1–8, supplement, 1926. Although the expense was in great part borne by Dr Hale, the solar laboratory now forms an integral part of the Observatory. In accord with the original purpose of the laboratory, namely to develop new methods of attack, he has given much time and effort to developing the spectrohelioscope to the point where it can be produced at minimum cost and in such form that it will lend itself to the use of both the professional and amateur astronomer. The instrument will be used in widely distributed stations favourably situated for solar observations, as it promises to be of great value in the observation of evanescent phenomena and as an adjunct to spectroheliographs now in use in a half-score of observatories. Preliminary arrangements are for installations in Italy, Syria, Australia, Hawaii, Samoa, Japan and England.

The spectroheliograph at Coïmbra modelled on the Meudon instrument is now working regularly.

Evershed's observatory at Ewhurst, England, is equipped with a 15-in. coelostat, a 6-in. objective of 20 ft. 9 in. focus and a combined autocollimating spectroheliograph and spectrograph placed 10 ft. underground and auxiliary apparatus, now in daily use.

The solar radiation station of the Smithsonian Institution at Harqua Hala, Arizona, has been moved to Table Mountain in Southern California and a fourth station has been located at Brukkaros in South Africa.

Progress along lines recommended in 1925

Pursuant to the action taken at Cambridge on recommendation VIII (7) from the committee of the International Research Council on Relationships between Solar and Terrestrial Phenomena that consideration be given to the question of defining numerically an index of solar activity, the President obtained suggestions from several members of this Commission. These were referred to Dr S. B. Nicholson of Mount Wilson Observatory and he was requested to prepare a report to serve as a basis of discussion at the meeting in Leiden. The report follows:

On the choice of an Index of Solar Activity

The determination of the best index of solar activity depends on the use which is to be made of it. The problems for the study of which such an index is desirable may be put into three general groups. *First*, the problem of the sun itself, the study of the processes by which its temperature is maintained, and the variability of its emitted radiation. *Second*, the effect which changes in the solar radiation have on climatic and other conditions relating to life on the earth. *Third*, the effect of solar activity on the magnetic field of the earth and other related phenomena.

For the first two problems the rate of solar radiation is of prime importance. The determination of the absolute value of the solar constant by Abbot and his associates has reached a high degree of precision but the variations are not yet certain to within a few per cent. of their values. Differential measures of the ultra-violet light are being made by Dr Pettit, and these furnish valuable criteria of the changes in solar radiation. Sun-spots give evidence of changing conditions on the sun and may furnish a sensitive test of the state of solar activity. Faculæ and prominences, while varying in general with the spots, cannot be observed equally well all over the sun's visible surface and are, therefore, less satisfactory than spots as an index of solar activity. The bright calcium flocculi, on the other hand, can be observed anywhere on the solar disc and are closely related to both faculæ and spots. They furnish, therefore, a very valuable index of solar activity, which combines the advantages of both spots and faculæ. A long series of measures of the areas of these flocculi is available from the observatory at Ebro. The extremely long record of "Wolf-Wolfer" relative spot-numbers makes that index of exceptional value in studying solar activity over a long period of time. The "Wolf-Wolfer" numbers are a very satisfactory criterion of spot activity, possibly even more representative of the activity over the sun than the areas of the spots. There are reasons for believing that changes in solar radiation, associated with the presence of sun-spots take place over areas around the spot groups. If this is the case their effect on

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the earth would be more closely related to the projection of such areas on the visible disc than to their actual areas on the sun. For this reason the projection areas of spots, faculæ, or flocculi, rather than their actual areas on the sun, should be used in studying terrestrial conditions. In the study of the sun and of sun-spots themselves their actual areas are of course more desirable.

The relation of variations in the earth's magnetic field to solar activity presents a somewhat different problem. The diurnal and seasonal variations in the earth's magnetic field give good evidence that they are closely related to solar activity. Variations in the earth's magnetic field are large on the average when sun-spots are present but these changes are not directly related to the number of spots. Certain types of spot groups which are characterized as very active seem to be closely associated with great activity in the earth's magnetic field, but such activity sometimes occurs when no spots are present. The solar activity which produces magnetic storms seems to come from a rather limited area which is usually, but not always, occupied by an active spot group. Such regions may be in the solar hemisphere toward the earth without a storm taking place and a storm may commence when the active region is in any heliographic longitude, but the probability that a magnetic disturbance will occur is greater if such a region is near the centre of the solar disc. Spectroheliograms with the $H\alpha$ line of hydrogen sometimes show very bright areas usually within an active spot group and there is some evidence that these regions are usually, if not always, present when a magnetic storm begins. In this connection more systematic visual observations with the spectroscope, such as those made as Kodaikanal and Stonyhurst, or better yet with the spectrohelioscope as worked out by Hale, are very desirable.

Summary. The areas of calcium flocculi are suggested for an index of solar activity to supplement the "Wolf-Wolfer" relative spot-numbers. They are a definite quantity closely related to spots and faculæ and can be observed wherever they are on the solar disc. Around active groups their areas are extended, while around old stable spots their areas are generally less in proportion to the size of the spot, thus giving a better indication of the actual activity than does the area of the spot. A fairly long series of measured areas exists and additional calcium spectroheliograms are available for measures if desired.

For the study of solar activity as affecting the earth, the projected areas of flocculi or spots should be used instead of those corrected for foreshortening. In the study of terrestrial magnetism a special index may be desirable which gives great weight to active groups, especially when near the centre of the solar disc, and which gives additional consideration to regions of great activity, marked by abnormal intensity or displacement of the spectral lines, especially those of hydrogen.

In reference to recommendation X (3) from the same committee concerning the measurement of ozone in the upper atmosphere, it is encouraging to report that such observations are now regularly made in Oxford, England, Montezuma, Chile, and at several other stations under the initiative of Dr Dobson aided by grants from the Royal Society. Under a subvention from La Société des Observatoires du Mont Blanc, observations have been carried out at high altitudes by Chalonge, Dejardin and Lambert.

In reference to recommendation VIII (6) the President reports that registering magnetic variometers have been installed on Mount Wilson for use in connection with the spectroheliograph work as at Meudon and Ebro.

In appendix (3) Professor Fabry called attention to the importance of the study of the ultra-violet radiation from the sun. This is now done regularly on Mount Wilson, California and at Tucson, Arizona, under the direction of Dr Pettit and with equipment designed by him and described in *Proceedings of the National Academy of Sciences*, **13**, 380, 1927.

Suggestions and Recommendations

1. The growth in the membership of the Commission de Physique Solaire and in the number of centres suggests some reorganization among the centres and the desirability of a small advisory committee with whom the President may confer. The membership exceeds forty, and the centres, active and suggested, number twelve; consequently the interests are widened and the programme for the meetings of the full Commission have assumed increased importance. The authorization of an advisory committee of three or five members is proposed for consideration at the meeting of Commission No. 12 in Leiden.

2. The interest in theoretical problems of the solar atmosphere evidenced by recent important papers on radiative equilibrium, selective radiation-pressure, theory of sun-spots, the production of Fraunhofer lines and other related subjects suggests the advisability of a centre concerned directly with such questions. A centre, "The Solar Atmosphere," is therefore suggested for consideration. A fuller co-operation between theoretical researches and observations should prove of advantage to both and be mutually stimulating. Professor Milne has been asked to prepare a brief review of the situation to open the way for discussion.

3. In 1925 Commission No. 12 authorized the appointment of a centre to take up the scheme of defining an index of solar activity. For this purpose among others a new centre, "Relationships between Solar and Terrestrial Phenomena," is proposed to serve as a liaison between Commission No. 12 and the corresponding Committee of the International Research Council.

Concerning this Dr Abetti says, "I agree with you that a corresponding centre of our Commission should take up the whole matter."

4. Two resolutions are proposed by the Eclipse Centre:

(1) That bodies responsible for organizing eclipse expeditions be urged to co-operate by circulating freely early information as to proposed plans and after the eclipse as to experiments that have not been successfully carried out and that such bodies be urged to employ the eclipse centre's standard lenses and procedure for coronal photography.

(2) That with a view to spectrophotometry of eclipse spectra in the ultra-violet, Commission No. 12 be urged to take steps to ascertain the distribution of the sun's continuous radiation as far as possible towards the ultra-violet.

5. It is desirable that every plate have impressed upon it standard squares for photometric purposes. (John A. Miller.)

6. The rare earth elements are of growing astrophysical importance. They are at low level in the sun, their lines are strong in certain types of stars; and in eclipse spectra do not reverse suddenly at the limb to the absorption spectrum like neutral atoms nor fade rapidly into the continuous background like *Ti* and *Sc* but still show in emission far in on the solar disc. (Menzel.)

Though behaving like enhanced lines in the sun, stars and spots they are generally stronger in the arc than in the spark, quite opposite in behaviour to that of typical lines from an ionized atom. The accurate measurement of their spectra and a study of the conditions of excitation is recommended to Commission No. 14. (St John.)

7. It is suggested that the attention of solar observers be called to the desirability for solar observations for furnishing new or better data for theoretical astrophysical investigations and for comparison with theoretical deductions. (St John.)

8. A subvention is asked for by Dr Abetti, and the request is seconded by Professor Wolfer, for continuing the publication of the *Immagini Spettroscopiche del bordo Solare* for three years. If the subvention be increased from the original £40 a year to £60, it will be possible to publish the *Immagini* not only for 1925–27 but also to begin the publication of the period 1912–21 which is still missing from the series begun in 1869. The request has been forwarded to the General Secretary as requested by him for transmission to the Executive Committee with the approval of the President.

C. E. ST JOHN
President of the Commission

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