PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

# The Total Solar Eclipse of August 9, 1896. Report on the Expedition to Kio Island

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# I. *The Total Solar Eclipse of August 9, 1896.—Report on the Expedition to Kiö Island.*

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*Presented by the Joint Permanent Eclipse Committee.*

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Contents.



## I. Preparations for the Eclipse.

Although this expedition failed in its main objects, because of unfavourable weather, I think it desirable to place on record an account of the arrangements which had been made to secure observations, more especially as a new feature was introduced in the training of a large number of observers.

The weather chances in Japan and elsewhere, from accounts which I had received, were not very promising, and it was determined, therefore, to occupy a station in Lapland, where the chances were certainly better. One of the most convenient places of observation was Vadsö, but as another section of the expedition had selected this station, it seemed desirable to observe from some other point, so as to multiply the chances of obtaining results. I accordingly made representations to this effect to the Admiralty, and H.M.S. "Volage" was placed at my disposal, with instructions

to select a station on the south side of the Varanger Fjord. The final choice of a place for observation was to depend upon examinations of suitable sites near the central line of eclipse, which as a result of local inquiries seemed to show the greatest probability of a fine morning on August 9th.

The Norwegian Government readily granted permission to land, and instructed the authorities at Vadsö to render assistance.

The party consisted of Mr. Fowler, Dr. W. J. S. Lockyer, and myself. Being a delegate to the International Conference on Bibliography, I could not leave London before July 22nd. Mr. Fowler and Dr. Lockyer, therefore, went on in advance, and joined H.M.S. "Volage" at Hammerfest on July 22nd.

## *Objects of Expedition.*

The success which attended the use of the large scale prismatic camera during the total eclipse of 1893, indicated that spectroscopes of this form were the most important instruments which could be employed on an eclipsed sun. In the report on the results obtained in 1893* I have given a full account of the appearances shown on photographs taken with prismatic cameras, and have indicated the special points to be considered in interpreting them. It may be remarked, however, that among the special services rendered by the instrument are (1) the separation of the true coronal spectrum from the apparent one produced by reflected chromospheric light when a slit spectroscope is employed; (2) localisation of the different radiations, so that we get a complete separation of coronal from chromospheric light, and information relating to the distribution of any particular radiation; (3) the special facilities for photographing the phenomena in the lower parts of the sun's atmosphere, in the region of the so-called "reversing layer."

Profiting by previous experience, prismatic cameras of the highest available power formed the chief part of the instrumental equipment. These were the 6-inch prismatic camera employed in Africa in 1893, and a 9-inch which had recently been purchased for the Solar Physics Observatory. The work of each of these instruments was arranged to supplement that of the other in as many particulars as possible.

As long ago as 1871 I had occasion to lay stress upon the importance of securing a record of the integrated spectrum of the light proceeding from every part of the eclipsed sun. The use of an integrating spectroscope is now more necessary than ever, for the reason that the prismatic cameras define what part of the total light proceeds from the chromosphere and prominences, so that a simple subtraction gives us the spectrum of the corona. A large spectroscope, which will be described later, was accordingly prepared as an integrating spectroscope for use during the eclipse.

* 'Phil. Trans.,' A, 1896, vol. 187, pp. 551–618.

Another observation, which it was very important to make, was to note the presence or absence of indications of carbon and other substances in the corona. For this observation a 6-inch telescope, giving a small bright image, and a spectroscope with a silvered glass grating, were provided.

To supplement the work of the photographic spectroscopes, a number of prisms and small slit spectroscopes were taken out for use by such assistants as might be available.

When it was ascertained that an almost unlimited number of helpers was forthcoming, the programme of the expedition was extended so as to include records of as many as possible of the attendant phenomena, and sketches of the corona, with or without the disks introduced by Professor NEWCOMB in 1878 to protect the eye from the glare of the inner corona.

*Selection of a Station.*

Leaving Hammerfest on July 23rd, the "Volage" proceeded to the Varanger Fjord, and, after twelve hours' delay on account of fog, arrived off Kiö Island on the evening of July 24th. The observers, and a surveying party of officers and men under the command of Lieut. MARTIN, R.N., were landed here, with tents and other requisites for camping out, while the ship went on to Vadsö for mails and provisions, and to make inquiries of the Governor as to the local meteorological conditions.

The exploring party first landed on an island in Bras Havn. On July 25th the weather was so bad that little progress was made, but towards evening the island of Kiö was visited and several possible sites were marked out. On the following morning another visit to Kiö Island resulted in the final selection of a site, and the places for the various instruments were provisionally prepared.

H.M.S. "Volage" returned on the evening of July 26th, and operations were seriously commenced on the following morning, leaving very nearly a clear fortnight for preparations.

The island of Kiö lies nearly north of Bras Havn, at a distance of about a mile and a quarter. It is but small, and consists chiefly of *moutonnéed* gneiss rocks, which are in many places covered with peat to the average depth of a foot. With the willing help of bluejackets, the actual site was levelled and covered with pebbles from the beach, to minimise the ill effects of the soddened peat.

There was a perfectly clear horizon in all necessary directions, and a sea horizon to the north of east, where the eclipsed sun would be visible.

The nearest safe anchorage for the ship was Bras Havn, so that the observers and working parties had to travel by boats between Bras Havn and Kiö Island every day. The inconvenience of this was greatly reduced by the tents which had been lent by the War Department, in which the observers could rest and take their meals as occasion required.

The latitude of the observing station was 69° 54′ 55″ N., and the longitude

29° 46′ 10″ E., so that it was a little less than five miles south-east of the nearest part of the central line of eclipse.

## *Local Conditions of Eclipse.*

The apparent semi-diameters of the sun and moon at the time of eclipse were respectively 15′ 48·4″ and 16′ 17·8″, while the duration of totality was 105 seconds. Assuming the chromosphere to be 10″ deep, a portion of it would thus be visible for 18 seconds after the commencement of totality, and another portion for 18 seconds before the end of totality.

The sun's altitude at the time of totality was a little over 14°, and its amplitude about 7° N. of E.

The calculated Greenwich time of the commencement of the total eclipse was August 8d. 15h. 57m. 42s. First contact took place at the approximate position angle 70° west of the north point, and the last at 111° east of the north point.

## *Erection of Huts and Instruments.*

To secure proper foundations for each of the instruments, the surface peat was removed, and concrete bases laid down on the solid rock. The wood framing for the huts had been brought out from England, each piece carefully marked so that no time was lost in erecting them. The large hut for the 6-inch prismatic camera, as well as that for the siderostat, were almost completed and covered with Willesden canvas at the end of the first day, owing to the zeal of the chief carpenter, Mr. Martin, and his assistants.

July 28th, like the preceding day, was fortunately fine, and the huts were then completed and made to safely withstand the violent wind experienced. The photographic dark-room was also finished.

The following two days were wet and cold, but the huts being erected, it was possible to continue the erection and adjustments of the instruments, unpack and attend to various small matters. A tent, consisting of spars and sail cloth, was also fitted up as a shelter for the large integrating spectroscope.

During the next few days all the instruments brought from England by the "Volage" were completely mounted, and by the time of my arrival on August 2nd, they were in adjustment and ready for the eclipse.

The remaining instruments which I took out with me on the s.s. "Garonne" were also put in position without delay, so that almost a whole week was available for rehearsals and general training of those members of the ship's company who volunteered their assistance.

Trial photographs with all three instruments, taken on August 6th, at the same

time in the morning as the eclipse would occur, showed all to be in perfect readiness and adjustment.

### *Organisation of "Volage" Observers.*

In response to a general call for volunteers made by Captain KING HALL, R.N., officers and men to the number of 74 volunteered their assistance for securing observations of the eclipse. To utilize this help to the best advantage, demonstrations and lectures were given by Mr. FOWLER and myself in the Captain's cabin, which was willingly placed at my disposal for the purpose, and on deck. As a result of these, selections were made for the different branches of observations. All the volunteers were well prepared for the eclipse, and fully capable of using the instruments entrusted to them, assisting with the large instruments, or recording the phenomena for which they were told off.

The complete muster roll of observers and their division into parties was drawn up and handed to me by the Rev. E. J. VAUGHAN as follows :—

*Personal Assistant to* Mr. Norman Lockyer.
Mr. Hugh B. Mulleneux, Midshipman.

1. *6-inch Prismatic Camera.*
Mr. Fowler.
Lieut. Beal.
Geo. Roberts, A.B.
Private Fras. Huskisson, R.M.L.I.
Private Joseph Briggs, R.M.L.I.

2. *9-inch Prismatic Camera.*
Dr. Lockyer.
Mr. Fitzwilliams, Mid.
Mr. Bruce, Mid.
Patrick Sullivan, Lg. Shipwrt.
Harry Froud, A.B.
Alfred Woollard, A.B.

3. *Integrating Spectroscope.*
Lieut. Martin.
Mr. Silvertop, Mid.
Mr. Brendon, Mid.
Mr. Woodbridge, Mid.

4. *Disks 3′ and 5′.*
Capt. King Hall. } 3′ Eclipse Island.
Mr. Parker, Mid. }
Fredk. Hesch, P.O. 2 Cl. } 3′ Signal Island.
William Bowden, P.O. 1 Cl. }
Thos. Bridgeman, P.O. 2 Cl. } 5′ Eclipse Island
John Hilyard, Qual. Sig. }

5. *Sketches of Corona.*
Mr. Constable, Mid.
Mr. Greene, Mid.
Mr. Warton, Mid.
Thos. Sutherland, S. Corpl.
Archd. Wright, 2 Yeo. Sig.
Edwd. Marshall, Boy 1 Cl.
Robert Roberts, Boy 1 Cl.
William Hicks, Qual. Sig.
Chas. Miles, P.O. 1 Class.
Chas. Bennett, S.B. Attendant.
Edward Miller, P.O. 1 Class.
James Biss, Boy 1 Class.
Willm. Barton, Ord.
Joseph Gale, P.O. 1 Class.
Edward Pegler, Lg. Sig.
Cuthbert Davis, Lg. Sea.

6. *Colours of Landscape.*
Lieut. Sinclair. On board "Volage."
Staff Surgeon Whelan. Signal Island.
Lieut. Yelverton. }
Harry Beresford, Yeo. Sigs. }
Harry White, Ch. Stoker. } Eclipse
Geo. Bennett, Lg. Seaman. } Island.
Herbert Gambler, A.B. }
James Harding, Stoker. }

7. *Shadow Phenomena.*
Private Geo. Allen, R.M.L.I.
Private Frank Blanchard, R.M.L.I.
Private Thos. Gauntlett, R.M.L.I.
Richard Collings, Blacksmith.

8. *6-inch Equatorial with grating.*
Mr. Fowler. } First and last
Lieut. Clinton Brown. } contacts.
Mr. Norman Lockyer. }
Lieut. Clinton Brown. } During totality.
Mr. Brooks, Asst. Paymr. }
Rodney Munday, Sig. Boy. }

9. *$3\frac{3}{4}$-inch Telescope.*
Mr. Norman Lockyer.
Lieut. Hodges.
Henry Lewis, 3rd Writer.

10. *Slit Spectroscopes.*
Lieut. Law. }
Chas. Smith, Boy Writer. }
Thos. Makepeace, Ch.E.R.A.
Willm. Westacott, Sig.

11. *Prisms for Rings.*
Alex. Duncan, E.R.A.
Thomas Brown, E.R.A.

12. *Timekeepers.*
William Smith, P.O. 1 Cl.
Alfred Saunders, P.O. 1 Cl.
Mr. C. E. Lloyd Thomas, Mid. (Chronometer).

13. *Contacts.*
1–4. Staff Paymaster Ramsay. } Signal
Staff Engineer Underhill. } Island.
1–4. Mr. Fowler. } Eclipse Island.
Lieut. Clinton Brown. }
2nd. Mr. Norman Lockyer.
3rd. Mr. Norman Lockyer.

14. *Polariscope.*
Rev. E. J. Vaughan, M.A., Chaplain.
Rowland Allison, Armourer's Crew.

15. *Meteorology* (Thermometers).
John Yardley, P.O. 2 Cl. }
Chas. Symes, P.O. 1 Cl. } Eclipse Island.
Fred Faizell, Stoker. }
Willm. Thripp, Stoker. }
Ernest Hurst, P.O. 1 Cl. } Signal Island.
T. Cannon, Lg. Sig. }

16. *Stars.*
Rev. E. J. Vaughan, M.A.
Lieut. B. Yelverton (Dup.).
Lieut. Hugh F. Sinclair (Dup.).

17. *Landscape Camera.*
Marquis of Graham. Eclipse Island.

18. *Observations of Shadow Bands.*
Staff Surgeon Whelan, M.D. Signal Island.

The following were the intructions to the observers :—

"One volunteer in each subject to collect results and see that everything is signed. Also these must see Mr. LOCKYER in the course of this morning (August 9) to report all ready, &c."

*Disks* (F. HESCH, P.O., 2nd Cl., to report).

Disk observers, besides dictating what they see, should afterwards give a sketch if possible (small sun).

*Sketches of Corona* (Mid. CONSTABLE to report).

Sketchers, besides making drawings, should hand in a written statement of what they have seen. Both this and the sketches should be signed.

*Colours of Landscapes* (H. BERESFORD, Yeo. Sig., to report).

Besides filling up the form, each observer should hand in a signed statement of his impressions.

*Shadow Phenomena* (Private G. ALLEN, and R. COLLINGS, Blacksmith, to report).

(1.) Note shadow approaching from westward.
(2.) Give an idea of the apparent velocity.
(3.) Give an idea of the effects on colours, &c.
(4.) Give an idea of the effects on birds, &c.
(5.) How long visible before totality ?

*Slit Spectroscopes* (Lieut. LAW, and T. MAKEPEACE, Ch.E.R.A., to report).

(1.) What was the nature of the spectrum ?
(2.) Was it a continuous, or a bright line one ?
(3.) What were the colours of the bright lines ?
(4.) What were the colours of the brightest lines ?
(5.) General remarks.

*Prisms for Observations of Rings* (A. DUNCAN, E.R.A., to report).

(1.) Were there any bright rings ?
(2.) If so, what colours were they ?
(3.) Which ring was brightest ?
(4.) Which ring was broadest ?
(5.) General remarks.

*Timekeepers* (Mid. THOMAS to take charge of Admiralty chronometer).

(1.) Warn Mr. LOCKYER 5 minutes before G.M.T. of first contact.
(2.) Note times of first and last contacts as called by Mr. FOWLER.
(3.) Warn Mr. LOCKYER 10 minutes before G.M.T. of commencement of totality.

(4.) Note the time when Mr. Lockyer calls "180°," and call "1 minute" after the lapse of 6 m. 50 s.

(5.) Note the times of beginning and end of totality, as signalled by Mr. Lockyer.

W. Smith and A. Saunders (1st Cl. P.O.'s) to take charge of stop-watch.

(1.) At signal "go" from Mr. Lockyer, Smith, with back to the sun, to announce "105 seconds" and afterwards give the time remaining every 5 seconds by such calls as "95 seconds more."

Saunders meanwhile to observe general phenomena.

(2.) At "65 seconds more," Saunders to turn his attention to stop-watch and to call "60" simultaneously with Smith, afterwards continuing the calls every 5 seconds. During the last 45 seconds Smith to note the general appearances.

*Contact Observations* (Staff Paymaster Ramsay, and Staff Engineer Underhill).

(1.) Select coloured glasses to enable you to comfortably observe the sun before the eclipse begins.

(2.) Note time of first contact, as indicated by the chronometer provided.

(3.) Similarly note times of 2nd, 3rd, and 4th contacts.

(4.) Compare chronometer with ship's chronometers.

(5.) Note general impressions of phenomena.

*Thermometers* (C. Symes, P.O., 1st Cl., to report).

(1.) Prepare forms for entering observations.

(2.) Set up screens 3 ft. 6 in. high to shield thermometers from direct rays of sun, the thermometer to be 3 ft. from the ground and 1 ft. from screen.

(3.) Begin readings at first contact.

(4.) End readings at last contact.

(5.) Read every 5 minutes, or oftener, if rapid changes are noted.

*Observations of Stars* (Rev. E. J. Vaughan to report).

(1.) Give list of first magnitude stars seen close to sun.

(2.) State whether any second or third magnitude stars were seen.

(3.) Was the number of stars about equal to that usually seen at full moon, or was it darker and more stars visible?

*Landscape Camera* (The Marquis of Graham).

(1.) Before totality, see that the sun's image is near the centre of the plate.

(2.) Expose a plate for 1 second when the timekeeper calls "95 seconds left."

(3.) Expose a plate for 5 seconds when "55 seconds" is called.

(4.) Note your general impressions of the phenomena.



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*The 6-inch Prismatic Camera.*

The 6-inch prismatic camera, intrusted to Mr. FOWLER, was essentially the same instrument as that employed for the Eclipse of April 16th, 1893, in West Africa.* Instead of the mounting of my 6-inch Cooke telescope, however, the equatorial head of a Dallmeyer photoheliograph was adapted for the occasion, this resting upon a wooden stand which was afterwards filled up with concrete. The wooden tube of the instrument was square in section and was firmly attached to the declination axis by a strong iron plate. A consideration of the position angles of the points of contact indicated that dispersion in an east and west direction would better show the chromospheric arcs, and the prism was placed accordingly.

In 1893, ten dark slides, each holding three dry plates, were provided. The experience then gained showed that narrower plates would meet all requirements, so five compartments were made to replace the three in each slide, and in this way fifty plates became available.

Guided by the results obtained in 1893, the following table of exposures was drawn up for this instrument :—

* 'Phil. Trans.,' A, 1896, vol. 187, p. 559.

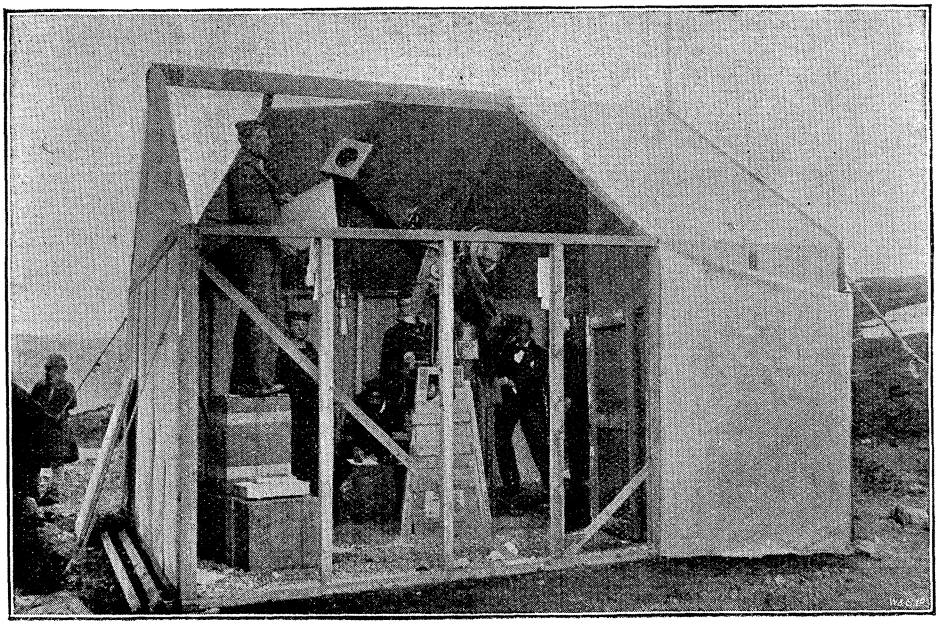
## Exposures for 6-inch Prismatic Camera.

| Number. | Exposure. | Time. | Remarks. |
|---|---|---|---|
| 1 | Instantaneous | .. | 1 minute before totality |
| 2 | ,, | .. | 40 seconds ,, ,, |
| 3 | ,, | .. | 30 ,, ,, ,, |
| 4 | ,, | .. | 20 ,, ,, ,, |
| 5 | ,, | .. | 10 ,, ,, ,, |
| 6 | ,, | 105 | Totality begins. Wait signal |
| 7 | ,, | 103 | |
| 8 | ,, | 101 | |
| 9 | ,, | 99 | |
| 10 | ,, | 97 | |
| 11 | ,, | 92 | |
| 12 | ,, | 90 | |
| 13 | ,, | 88 | |
| 14 | ,, | 86 | |
| 15 | ,, | 84 | Chromosphere disappears |
| 16 | 20 seconds | 79–59 | |
| 17 | 12 ,, | 57–45 | |
| 18 | 30 ,, | 43–13 | Chromosphere reappears |
| 19 | Instantaneous | 11 | |
| 20 | ,, | 9 | |
| 21 | ,, | 4 | |
| 22 | ,, | 2 | |
| 23 | ,, | 0 | Totality ends |
| 24 | ,, | .. | 2 seconds after totality |
| 25 | ,, | .. | 4 ,, ,, ,, |
| 26 | ,, | .. | 9 ,, ,, ,, |
| 27 | ,, | .. | 11 ,, ,, ,, |
| 28 | ,, | .. | 13 ,, ,, ,, |
| 29 | ,, | .. | 15 ,, ,, ,, |
| 30 | ,, | .. | 17 ,, ,, ,, |
| 31 | ,, | .. | 22 ,, ,, ,, |
| 32 | ,, | .. | 24 ,, ,, ,, |
| 33 | ,, | .. | 26 ,, ,, ,, |
| 34 | ,, | .. | 28 ,, ,, ,, |
| 35 | ,, | .. | 30 ,, ,, ,, |
| 36 | ,, | .. | 35 ,, ,, ,, |
| 37 | ,, | .. | 37 ,, ,, ,, |
| 38 | ,, | .. | 39 ,, ,, ,, |
| 39 | ,, | .. | 41 ,, ,, ,, |
| 40 | ,, | .. | 43 ,, ,, ,, |
| 41 | ,, | .. | 48 ,, ,, ,, |
| 42 | ,, | .. | 50 ,, ,, ,, |
| 43 | ,, | .. | 52 ,, ,, ,, |
| 44 | ,, | .. | 54 ,, ,, ,, |
| 45 | ,, | .. | 56 ,, ,, ,, |
| 46 | ,, | .. | 61 ,, ,, ,, |
| 47 | ,, | .. | 63 ,, ,, ,, |
| 48 | ,, | .. | 65 ,, ,, ,, |
| 49 | ,, | .. | 67 ,, ,, ,, |
| 50 | ,, | .. | 69 ,, ,, ,, |

Edwards's Isochromatic plates were employed throughout.

The method of working the instrument was that adopted by Mr. FOWLER in 1893. He himself being stationed at the camera, 2nd Class Petty Officer G. M. ROBERTS made the exposures by withdrawing a card from the front of the prism, while Sub-Lieutenant BEAL made careful records of the times at which each plate was exposed, and warned Mr. FOWLER of the termination of the three long exposures. Privates J. BRIGGS and F. HUSKISSON stood one on each side and respectively handed the slides to and received them from Mr. FOWLER.

Fig. 1.



The 6-inch Hut, showing Mr. FOWLER and his Assistants at drill.

Actual rehearsals with the splendid assistance thus available showed that the programme could be thoroughly carried out; in fact a few seconds were saved, so that the attempt to secure a photograph exactly at the end of totality was the more likely to be successful.

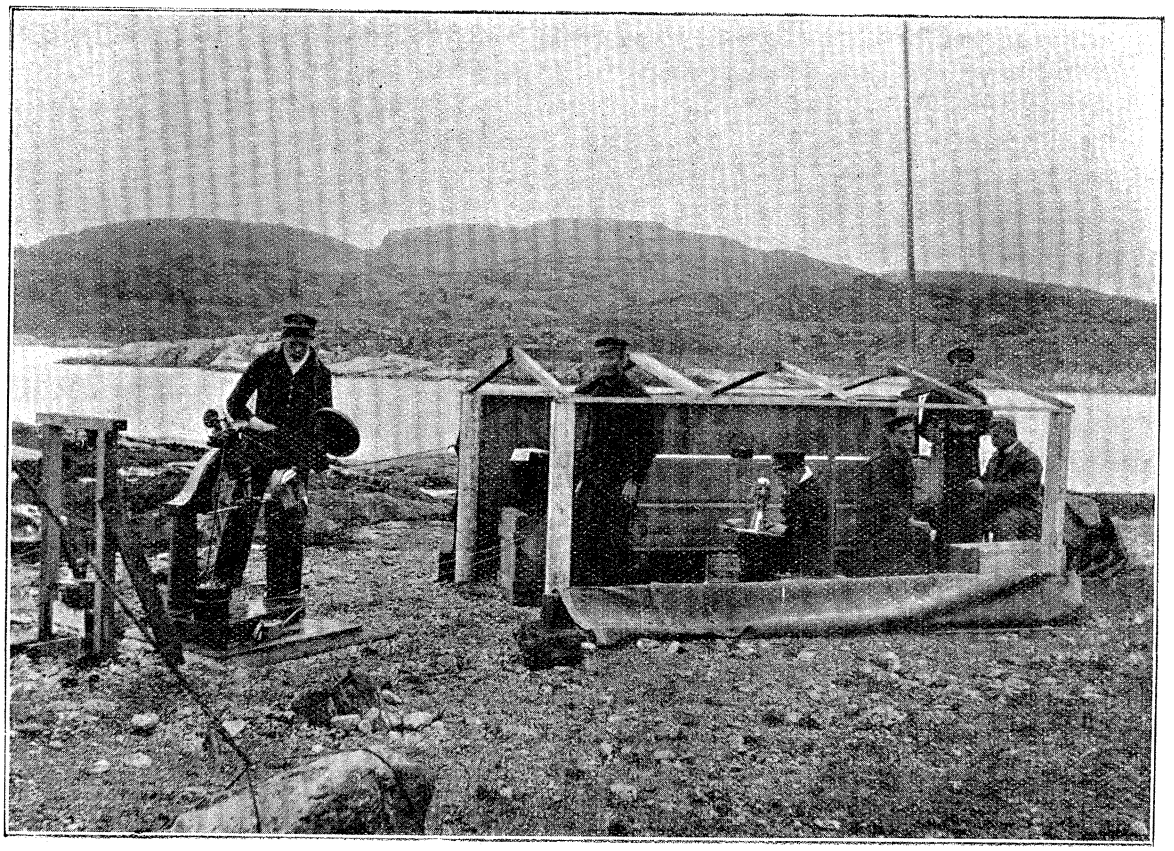
### *The 9-inch Prismatic Camera.*

This instrument was intrusted to Dr. W. J. S. LOCKYER.

The tube carrying the prism, lens, and camera of the 9-inch prismatic camera was fixed horizontally on loaded packing cases resting on concrete foundations, and the sun's rays were reflected into it by the mirror of a 12-inch siderostat. Three dark slides, each holding three plates, were provided, the change from one plate to the next in each slide being made by a rack and pinion. An additional slide, carrying a plate $8\frac{1}{2}'' \times 6\frac{1}{2}''$, was so arranged that the light passing through a narrow slit running the whole length of the spectrum was exposed at any instant. The position

of this slit was adjusted so as to fall at the point where the photosphere would reappear after the end of totality. This "dropping plate" was intended to be exposed from as near as possible ten seconds before the end of totality, to 15 seconds after, the spectrum being moved slowly in the direction at right angles to the length of the spectrum.

Fig. 2.



The 9-inch Prismatic Camera.

With this instrument the exposures were intended to be longer than with the 6-inch, so that there might be a greater chance of obtaining impressions of the fainter coronal rings. The complete scheme of exposures was as follows :—



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EXPOSURES for 9-inch Prismatic Camera.

| Number. | Exposure. | Time. | Remarks. |
|---|---|---|---|
| 1 | Instantaneous | 10 seconds before totality | |
| 2 | „ | 105 | Totality begins. Wait signal. |
| 3 | 10 seconds | 103–93 | |
| 4 | 5 „ | 88–83 | Chromosphere disappears. |
| 5 | 10 „ | 81–71 | |
| 6 | 30 „ | 69–39 | |
| 7 | 5 „ | 34–29 | |
| 8 | 10 „ | 27–17 | |
| | | | Chromosphere reappears. |
| 9 | Instantaneous | 15 | |
| 10 | 25 seconds | 10 seconds before totality to 15 seconds after | Dropping plate. |

In working the instrument Dr. LOCKYER had five assistants. Midshipman FITZWILLIAMS was in charge of the siderostat, to attend to clock-winding, &c.; Midshipman BRUCE acted as special timekeeper to note the times by a deck watch at which each plate was exposed and to announce the termination of the longer exposures; Shipwright P. SULLIVAN stood by the prism to remove the cap at a signal from Dr. LOCKYER and to replace it when Midshipman BRUCE gave the signal "over"; Able Seamen H. FROUD and A. WOOLLARD respectively handed the dark slides to Dr. LOCKYER and replaced them in the box from which they had been taken.

### *The Integrating Spectroscope.*

This instrument was intrusted to Lieutenant MARTIN, R.N.

The dispersive parts of the integrating spectroscope consisted of two dense flint glass prisms of 60°, having an effective aperture of very nearly 3 inches. As collimator, a 4-inch Cooke object-glass (TAYLOR'S patent triplet) of 72 inches focus was employed, while the camera was fitted with a portrait lens of 19 inches focus. The optical parts were mounted on a board 7 feet by 2 feet 6 inches. This was hinged to another board of the same size, which was to serve as a base, and the boards could be inclined at an angle equal to the sun's altitude by the use of blocks.

The base rested upon loaded packing cases which were carefully levelled with cement upon a solid rocky foundation. As a siderostat was not available for use with this instrument, a simple arrangement was provided for keeping the collimator approximately directed to the centre of the dark moon during totality. A 2-inch object-glass of 30 inches focus was fixed to the inclined board so as to throw an image of the sun on the centre of a small screen when the collimator was pointed at the sun. The whole spectroscope could be moved in azimuth by means of a milled headed

driving screw, 4 inches in length, which was turned by hand, and in this way the sun's image could be kept sufficiently near to the centre of the screen to ensure a large proportion of the direct rays of the corona entering the collimator.

The instrument was housed in a tent made of spars and sails, loaded with rocks to prevent it being blown away by the wind. The only opening was towards the east, in the direction of the eclipse, but on the morning of the eclipse one side was removed in order that the workers might be able to view the phenomena as opportunity offered.

Three plates were exposed during totality with the following exposures, but no results were obtained :—

| Number. | Exposure. | Time. | Remarks. |
|---|---|---|---|
| 1 | 15 seconds | 105–90 | |
| 2 | 65 ,, | 85–20 | |
| 3 | 10 ,, | 15– 5 | 5 seconds allowed to prevent over-running |

The times indicated in the table are, as before, those announced by the general timekeepers as measuring the number of the remaining seconds of totality.

Lieutenant Martin, R.N., was assisted by Midshipman Silvertop as exposer, Midshipman Brendon as special timekeeper, while Midshipman Wooderidge attended to the screw for keeping the collimator directed to the sun.

### *The 3¾-Inch Refractor.*

The 3¾ inch Cooke telescope was mounted on a small equatorial head without clamps or adjustments. In this case the tripod stand was dispensed with, and the head was screwed to the top of a loaded packing-case. A diagonal eyepiece, which could be rapidly changed, by a simple operation, from total deflection at a silvered surface to reflection from plane glass, was provided.

With this instrument it was my intention to observe the times of commencement and ending of totality, and the structure of the inner corona. Observations of the corona were also to be made by Lieutenant Hodges during the time I was engaged with other instruments, H. Lewis, 3rd Writer, was to act as recorder. It was calculated by Dr. Lockyer, that 7 minutes 50 seconds before totality the visible crescent would extend over 180°, and I hoped to utilise this fact as a check on the accuracy of the chronometers.

### *Sketches of Corona.*

As no photographic telescope was available for the work at Kiö Island, I had to rely upon sketches to indicate the general appearance of the corona. Experience has shown that although drawings usually represent the feebler extensions more

clearly than photographs, the drawings made by different observers frequently have little resemblance to each other. An experiment I had made during the passage outwards on s.s. "Garonne," however, convinced me that these large differences could be almost entirely eliminated after a little practice in sketching from photographs projected upon a screen by a magic-lantern, and that drawings made under good conditions might be very valuable.

The form which the rehearsals took was as follows :—

Each observer was supplied with the necessary drawing-paper, Morris-tube targets being found to serve this purpose capitally.

By means of a magic-lantern, enlarged views of several different coronas were thrown on a screen for inspection, and attention was drawn to the dissimilarity between any two of these. Instruction was then given as to the important features to be noted and recorded, special stress being laid on noting accurately the exact orientation of the features in question. This was facilitated to a great extent by the concentric circles and radial lines surrounding the bullseye, and passing through the centre respectively. It was suggested, also, to those making these drawings to consider the image of the corona on the screen, or the actual eclipsed sun in the sky as an ordinary compass card, with the north at the top and the east on the right-hand side. The question of the orientation of any point was by this means an easy matter to determine.

After these preliminary trials the coronas were withdrawn, and a previously unseen one substituted. This corona was then exhibited on the screen for 105 seconds, this being the duration in time of the approaching eclipse. The time was called out in exactly the same manner as was adopted during the actual eclipse. Commencing with 105, the number of seconds remaining was called out every 10 seconds until the final 10 seconds were left, when each second was counted. The image of the corona was then immediately withdrawn from the screen, the observers were allowed 15 minutes, to fill in any extra details which they had observed and not had time to record, and to make any notes of the phenomena in general.

A subsequent examination of the drawings thus made showed a remarkable similarity, and by means of a few rehearsals, the observers became quite expert in inserting most of the details shown on the screen, both as regards form and colour.

During the competition that took place nearly every evening, marks were awarded, 10 being allowed for form and 10 for colour. In most cases the marks given were high, 18 marks out of 20 was by no means uncommon.

The selection of the sketching party was accordingly based upon the results of these competitions.

For the actual eclipse, each observer was provided with a piece of drawing-paper, 12 inches square, in the centre of which was a blackened disc representing the dark moon ; passing through the centre of the disc were lines at angles of 45°, which were taken to represent points of the compass.

Some of the observers were provided with wooden disks to cut off the light of the lower corona, so that the long extensions might be the better visible. Two of the disks were arranged to cover the corona to a distance of 3 feet from the moon's limb, and one to a distance of 5 feet.

Lieutenant MARTIN, R.N., very kindly superintended the setting up of the disks. The disks themselves were of thin wood, about 5 inches in diameter, and were attached by iron rods to long spars standing vertically. The place for the eye was determined, in the first instance, with the aid of a theodolite and measuring tape, the altitude and azimuth of the sun at the time of eclipse, and the proper distance of the disk from the eye having been previously calculated.

To guard against error, the pointers indicating the position of the eye were provided with horizontal and vertical movements. A horizontal bar was supported between two uprights about 18 inches apart, and from this was suspended a piece of wood about 10 inches long, which could slide along it. A piece of brass, the end of which marked the place of the eye, was free to slide up and down the vertical piece.

Ten minutes before totality the disk observers were to be blindfolded, and, meanwhile, an amanuensis was to keep the pointer in the proper place; at the commencement of totality the observer would take his place and dictate the directions and lengths in diameters of the most conspicuous streamers.

## II. RESULTS OBTAINED.

Forty-five plates were exposed in the 6-inch prismatic camera, and three in the integrating spectroscope, but no images were obtained in consequence of the thick clouds. There was no opportunity of adjusting the 9-inch, so that the plates were not even exposed.

Lord GRAHAM secured during totality an excellent photograph with the $7\frac{1}{2}'' \times 5''$ camera, which showed that the sun was completely blotted out from view by the dense clouds at the time the exposure was made.

The only other observations were those secured by the "Volage" observers. These are appended.

### *Meteorology* (*Temperatures*).

As already stated, six observers were told off to take thermometer readings at intervals of five minutes throughout the entire eclipse. Two observers were stationed at each thermometer, one to take the readings and another to note the times.

The thermometer on Bras Havn was graduated on Fahrenheit's scale and was fully exposed. Those on Kiö Island were Centigrade thermometers, and they were supported at a height of 3 feet from the ground, at a distance of a foot from a piece of sail cloth, which shielded them from the direct rays of the sun.

The readings observed are shown in the following table :—

TEMPERATURE Observations During Eclipse.

| Time. | Thermometer in open. Island in Bras Havn. Petty Officer, 1st Class, E. W. Hurst; Leading Signalman, T. Cannon. | | Shielded thermometer, No. 1. Kiö Island. Petty Officer, 1st Class, C. Symes; Petty Officer, 2nd Class, J. Yardley. | | Shielded thermometer, No. 2. Kiö Island. Stokers, F. Faizell and W. Thripp. | | Remarks. |
|---|---|---|---|---|---|---|---|
| A.M. | ° F. | ° C. | ° F. | ° C. | ° F. | ° C. | |
| 5. 0 | 52 | 11·1 | 46·4 | 8 | 47·3 | 8·5 | 1st contact |
| 3 | 50 | 10 | | | | | |
| 5 | 49·75 | 9·9 | 46·4 | 8 | 47·3 | 8·5 | |
| 7 | 48·75 | 9·3 | | | | | |
| 8 | 48 | 8·9 | | | | | |
| 10 | 47 | 8·3 | 46·4 | 8 | 47·3 | 8·5 | |
| 15 | 46·5 | 8 | 46·4 | 8 | 47·3 | 8·5 | |
| 20 | 46 | 7·8 | 46·4 | 8 | 47·3 | 8·5 | |
| 25 | 46 | 7·8 | 46·4 | 8 | 47·3 | 8·5 | |
| 30 | 46 | 7·8 | 46·4 | 8 | 47·3 | 8·5 | |
| 35 | 46 | 7·8 | 46·4 | 8 | 47·3 | 8·5 | |
| 40 | 46 | 7·8 | 46·4 | 8 | 47·3 | 8·5 | |
| 45 | 45·75 | 7·6 | 45·95 | 7·75 | 46·85 | 8·25 | |
| 50 | 45·75 | 7·6 | 45·95 | 7·75 | 46·85 | 8·25 | |
| | | | | | | | Totality |
| 55 | 45·5 | 7·5 | 45·5 | 7·5 | 46·4 | 8 | |
| 6. 0 | 45·5 | 7·5 | 45·5 | 7·5 | 46·4 | 8 | |
| 5 | 45·5 | 7·5 | 45·95 | 7·75 | 46·4 | 8 | |
| 10 | 45·5 | 7·5 | 45·95 | 7·75 | 46·85 | 8·25 | |
| 15 | 45·5 | 7·5 | 45·95 | 7·75 | 46·85 | 8·25 | |
| 20 | 45·5 | 7·5 | 46·4 | 8 | 47·3 | 8·5 | |
| 25 | 45·5 | 7·5 | 46·4 | 8 | 47·3 | 8·5 | |
| 30 | 46 | 7·8 | 46·4 | 8 | 47·3 | 8·5 | |
| 35 | 47 | 8·3 | 46·4 | 8 | 47·3 | 8·5 | |
| 40 | 47 | 8·3 | | | | | |
| 45 | 47 | 8·3 | | | | | |
| 50 | 47 | 8·3 | | | | | |
| 55 | 47 | 8·3 | | | | | |
| | | | | | | | Last contact |
| 7. 0 | 47 | 8·3 | | | | | |
| | Temperature remained at 45°·5 F. (7°·5 C.) during totality. | | | | | | |

It will be seen from the foregoing that the exposed thermometer fell $6\frac{1}{2}$° F. between first contact and totality, but only rose $1\frac{1}{2}$° F. from totality to near the time of last contact.

The variations of the two shielded thermometers on Kiö Island were exactly equal, although the actual readings differed by half a degree Centigrade. From first contact to totality the fall of temperature was 0°·5 C. (0°·9 F.), while there was an equal rise of 0°·5 C. from totality to near the end of the eclipse.

*Landscape Colours.*

The observations of the colours of sky, clouds, land, and water before, during, and after totality, are indicated in the following table, and by the additional remarks appended :—

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## Landscape Colours, &c.

| Direction. | Sky. | | | Clouds. | | | Land. | | | Water. | | | Observer. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Before totality. | During totality. | After totality. | Before totality. | During totality. | After totality. | Before totality. | During totality. | After totality. | Before totality. | During totality. | After totality. | |
| East | Streaks of light in horizon. A little blue sky | ... | ... | Heavy, in bands | ... | ... | ... | ... | ... | Grey; green | ... | ... | Lieut. Yelverton, R.N. |
| | ... | ... | ... | Dull grey, slate | ... | ... | ... | Black | ... | ... | ... | ... | Chief Stoker H. E. White. |
| | Blue | Violet | Blue | Dirty grey | Dark | Grey | Black | Blue black | ... | Blue | Yellowish brown | ... | Leading Signalman G. A. Bennett. |
| | ... | ... | ... | Dark, with bright streak | ... | ... | ... | ... | ... | ... | Dirty | Blue | Yeoman of Signals H. Beresford. |
| | ... | Purple blue | ... | ... | Sepia | ... | ... | Black | ... | ... | Light streaks | ... | H. Gambler, A.B. |
| | Blue | Blue | ... | Dark slate | Slate | ... | Grey | Dark brown | ... | Dirty | Dirty | ... | J. Harding, Stoker. |
| South | Light near horizon. Greenish tinge | ... | ... | Heavy and black | ... | ... | ... | ... | ... | ... | ... | ... | Lieut. Yelverton, R.N. |
| | ... | ... | ... | ... | ... | ... | ... | Black | ... | ... | ... | ... | Chief Stoker H. E. White. |
| | Blue | Light blue | Grey | Grey | Dark | Dark | Violet | Bluish | ... | Brownish | Light blue | ... | Leading Signalman G. A. Bennett. |
| | Grey | Grey | Grey, with red streaks | Grey, with bluish tip | Dark | ... | ... | Dark | ... | ... | Dirty | Blue | Yeoman of Signals H. Beresford. |
| | ... | Blue | ... | Dark | Dark and light | ... | Brown | Brown | ... | Dirty | Dirty | ... | J. Harding, Stoker. |

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## Landscape Colours, &c. (continued).

| Direction. | Sky. | | | Clouds. | | | Land. | | | Water. | | | Observer. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Before totality. | During totality. | After totality. | Before totality. | During totality. | After totality. | Before totality. | During totality. | After totality. | Before totality. | During totality. | After totality. | |
| West . | A little blue sky | ... | ... | Neutral and dark | ... | ... | Greys and green | ... | ... | Dark grey | ... | ... | Lieut. Yelverton, R.N. |
| | ... | ... | ... | Slate blue | ... | ... | ... | Black | ... | ... | ... | ... | Chief Stoker H. E. White. |
| | Dark and light blue, streaky | ... | ... | Grey | ... | ... | Dark | ... | ... | Yellowish | ... | ... | Leading Signalman G. A. Bennett. |
| | Small patch of blue | ... | ... | ... | ... | ... | ... | Dark | ... | ... | Dirty | Blue | Yeoman of Signals H. Beresford. |
| | Light sepia streaked with greyish blue | ... | ... | Dirty white | ... | ... | Natural | ... | ... | Grey | ... | ... | H. Gambler, A.B. |
| | Blue | ... | ... | Slate | Light | ... | Brown | ... | ... | Dirty | ... | ... | J. Harding, Stoker. |
| North . | Heavy clouds | Light; very little blue green | ... | Grey | Dark and heavy | ... | Band of reddish light on hill, slate blue elsewhere | ... | ... | Dark grey | ... | ... | Lieut. Yelverton, R.N. |
| | ... | ... | ... | ... | Black, streaked with yellow | ... | ... | Black | ... | ... | Streak of light colour | ... | Chief Stoker H. E. White. |
| | Blue | ... | ... | Grey | ... | ... | Dark | ... | ... | Black | ... | ... | Leading Signalman G. A. Bennett. |
| | Grey and blue capped with white | Grey blue, capped with white | Dark blue, with reddish streaks | Grey, with silver tops | ... | ... | ... | Dark | ... | ... | Dirty | Pale streak from E. to W. | Yeoman of Signals H. Beresford |
| | Dark sepia | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | H. Gambler, A.B. |
| | Blue | ... | ... | Dark | ... | ... | Brown | ... | ... | Dirty | ... | ... | J. Harding, Stoker. |

Additional notes of colours, &c. were as follows :—

*Chief Stoker* H. E. WHITE :—"Before totality there was hardly any change from usual colours. During totality the land went black, streaks in clouds assumed a reddish-yellow tint, and a streak of light colour appeared on the sea towards the north, otherwise no change."

*Yeoman of Signals* H. BERESFORD :—"Before totality the sun was shining only on a patch of land to the westward of Vadsö, which appeared like a sandhill with a reddish tint; no change noted elsewhere, either in land, sky, or water. During totality the land and water appeared to be of an inky blackness; no change was observed in the sky; the air seemed to go suddenly cold. Directly after the total eclipse a slight change appeared in sky to the south; the land came back to its ordinary colour, the sun shining on the same place as before total eclipse; the water underwent a slight change, to the northward a pale blue streak running from east to west, and the air seemed to feel a little warmer."

## *General Observations.*

After the eclipse the following notes as to the general phenomena observed were received from the officers named :—

*Staff-Surgeon* J. H. WHELAN, M.D. :—"The sudden rush of darkness at totality caused a feeling of dread; an instinctive feeling of fright lest the source of our being had gradually been extinguished, it seemed to me.

"The gulls started a discordant calling which seemed to distinctly change to one of rejoicing when the light began to increase again.

"During totality, the sky being nearly entirely overcast by clouds, a brightness appeared to the north, and another to the south, west of the horizon, as if the sun had set there, tingeing the clouds."

*Lieutenant* YELVERTON, R.N., noted the bleating of sheep and screaming of gulls during the darkness of totality.

*Lieutenant* W. H. B. LAW, R.N. :—"For 20 minutes before totality the sky darkened appreciably. The clouds to the south took an ashy grey colour, the land also took a dark grey tint, and looked, if possible, even more desolate and barren than before. In fact, the whole appearance of land and sky to the south looked as if a heavy thunderstorm was imminent.

"About 4 seconds before the signal for totality was given, a rift in the clouds allowed the sun to be seen. The moon had covered all except a thin crescent at the left hand bottom corner; the inner edge of the crescent through binoculars appeared somewhat rough; then the clouds came over again.

"Suddenly it became much darker—somewhat like the darkness of a London fog (medium); the moon's shadow swept across the earth and sea, moving in a north by westerly direction. The air became appreciably colder to the feelings, and the sea

birds began screaming. A few seconds before mid-totality a faint glare or reflection became visible on the clouds about the sun's position, lasting several seconds.

"Just about 5 seconds before the end of totality, the sky became clearer, the shadow could be seen sweeping across the fjord, looking like a huge catspaw moving rapidly to leeward.

"Directly after totality was over, land, sea, and sky gradually regained their normal appearances, the lightening process being much quicker than the darkening."

T. MAKEPIECE (*Chief Engine-room Artificer*):—"The left limb of the sun was visible for the space of 5 seconds (before totality). At '75 seconds left,' a luminous body was visible, having at the right upper side a smaller body of the same nature, both appearing as through a haze.

"At '35 seconds left' there occurred a great commotion among the sea birds settled on the surrounding rocks."

Mr. MAKEPIECE afterwards expressed the opinion that the larger of the bright cloudy patches was in the position of the sun, and appeared as if it were the sun seen through several thicknesses of muslin. It may be remarked that the two patches in question are very distinctly shown in a photograph taken by Lord GRAHAM during totality with the $7\frac{1}{2}'' \times 5''$ camera.

A. DUNCAN *and* T. BROWN (*Engine-room Artificers*):—"At 5.52 the left limb of the sun was visible for 5 seconds; colour, very faint white. At '35 seconds to go,' birds fly off screaming."

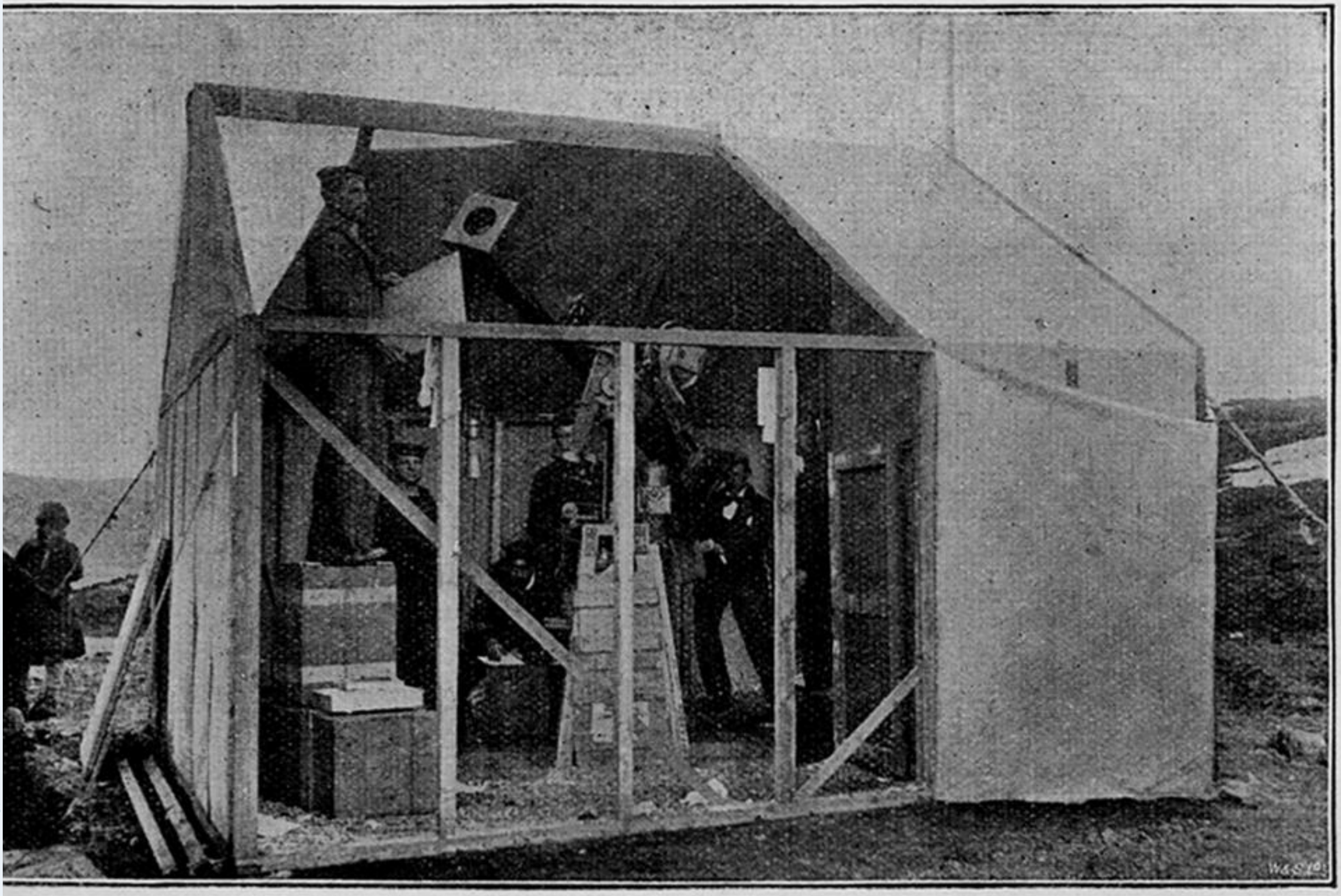
A. WRIGHT (*Second Yeoman of Signals*):—"Observed a silvery-white crescent from about N. by W. to S. by W., with a horn pointing in a direction S.E. on the S.W. part of dark moon. The part of the crescent visible was about one-eighth the diameter of the dark moon."

Immediately on my return to England, as the "Volage" was practically going out of commission, I reported to the Royal Society that the arrangements made by the Admiralty to assist the observing party had been carried out in the most admirable manner, and I suggested that the President and Council of the Society should mark its appreciation of the attempt on the part of a large ship's company to further the cause of science. I am glad to say that a letter of thanks was sent by the Society to the Admiralty, and another by the Admiralty to the officers and men of H.M.S. "Volage."

In the erection of the huts and instruments, no one could have wished for more help than was given. Everyone in the ship showed the keenest interest in the work, and help was afforded in every possible manner. Had the weather been fine, I am convinced that the results obtained by the "Volage" observers would have been far more complete than any previously obtained by a single party.

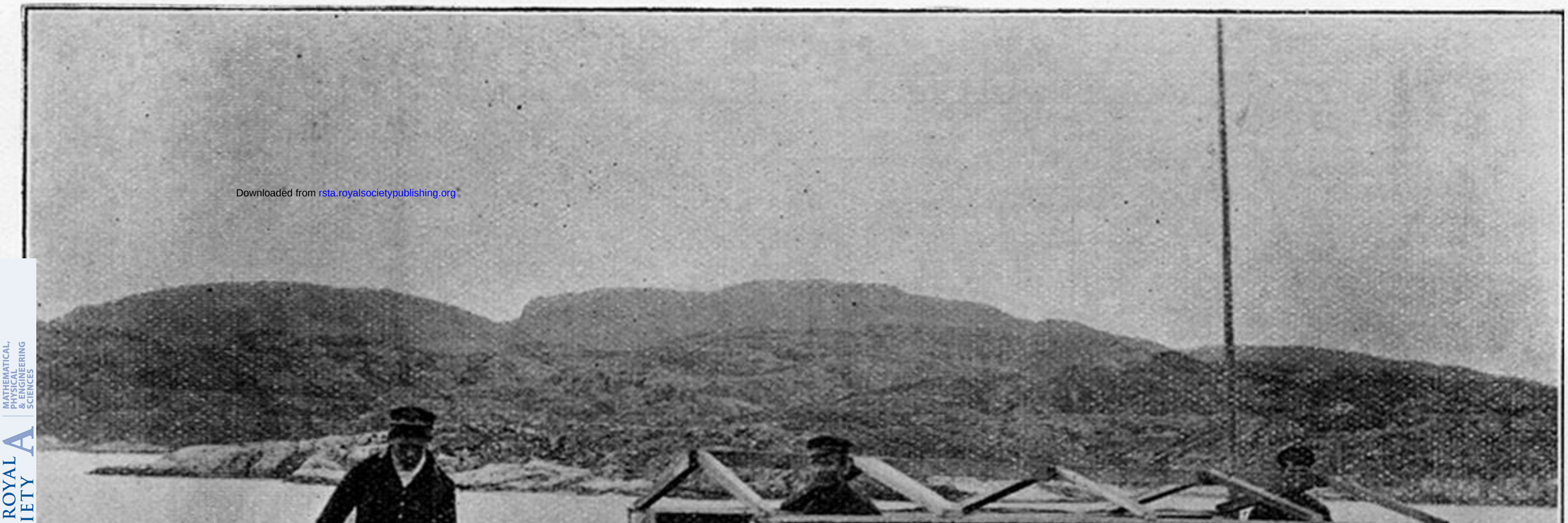
I am anxious, also, to state my entire satisfaction with the manner in which Mr. FOWLER and Dr. LOCKYER conducted the operations before my arrival.

Fig. 1.



The 6-inch Hut, showing Mr. FOWLER and his Assistants at drill.

Fig. 2.







PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

The 9-inch Prismatic Camera.