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Nr. 1

THE AURORAL OBSERVATORY AT TROMSØ

BY

THE EXECUTIVE COMMITTEE

1 9 3 2

A.S JOHN GRIEGS BOKTRYKKERI, BERGEN

THE AURORAL OBSERVATORY AT TROMSØ.

($\varphi = 69° 39'.8$, $\lambda = 18° 56'.9$ E Gr.)

By

The Executive Committee.

Foundation and Organisation.

In 1926 The International Education Board, founded by Rockefeller, granted the sum of 75 000 dollars, to cover the cost of the buildings and the equipment of a new observatory in Northern Norway for the study of the Aurora Borealis, atmospheric electricity, terrestrial magnetism and allied phenomena.

The expenses connected with the annual running of the observatory were guaranteed by the Norwegian Government and Storting.

A "Magnetic Bureau" was erected at Bergen, the object of which is to take part in the treatment and publication of magnetic observations and to assist in the performance of magnetic work in our country.

The Tromsø Observatory and the Magnetic Bureau are both included in the name Det Norske Institut for Kosmisk Fysikk ("The Norwegian Institute of Cosmical Physics") which, according to statutes approved by the Government, is conducted by an executive committee consisting of the Directors of the Tromsø Observatory and the Magnetic Bureau and three other members appointed by the Government.

At the present time the members of the executive committee are:

L. Vegard, President, Professor, Oslo.
C. Størmer, Vice-President, Professor, Oslo.
S. Sæland, Professor, Oslo.
O. Krogness, Professor, Director of the Magnetic Bureau, Bergen.
L. Harang, Director of the Auroral Observatory, Tromsø.

The Programme of Work.

In 1926 — during the negotiations with the International Education Board — the field of work was drawn up in the following way:

„The object of the auroral institute is to obtain systematic and continuous observational data for the study of: 1) Aurora Borealis, 2) Terrestrial Magnetism, 3) Earth Currents and 4) Atmospheric Electricity. The main purpose is first of all to find out the true nature of these phenomena, their mutual relations and their relations to solar activity and the physical properties of the atmosphere.

*

1. With regard to the auroral studies the plan includes:
   a) Securing as far as circumstances permit continual observations of the appearance, developments, forms and colours of the aurorae with the aim of securing data for statistical treatment of the periodicities of these phenomena.
   b) Photographic determination of position and height of various auroral forms to the extent which is found necessary, so as to get material covering different times of the day, year and period of solar activity.
   c) An intimate study of the auroral spectrum.

   It will be of special interest to obtain more exact values of the very weak lines which are detected, and to develop suitable methods for the study of the variations of the auroral spectrum. We know that differences exist for different auroral forms and displays, and it is also a problem of great importance to find out how the spectrum varies with altitude. For the solution of these problems it is necessary to have spectral observations combined with height measurements.

   The interpretation of these spectra will ultimately involve a pretty definite knowledge of the higher strata of the atmosphere and the nature of the agency (electric rays) which produces the auroral spectrum.

   It might, therefore, also be considered worth while to undertake certain measurements of the ordinary radiation of the sun, partly for the purpose of making clear the influence of the atmosphere.

2. With regard to the observations of terrestrial magnetism they should be conducted on the same lines as are usual at permanent magnetic observatories and should consist in:
   a) Continuous diurnal records of the three components (H, D, V).
   b) Absolute determinations undertaken as often as considered necessary (every 10 or 14 days).
   c) It is also intended to keep reserve sets of registering instruments for investigations which might require a special speed or sensitiveness.
   d) Determination of sudden variations of the vertical component by registering the electric currents induced in a horizontal closed circuit.

3. Continuous records of earth currents in two horizontal lines perpendicular to one another.

4. Observations on atmospheric electricity intended to include:
   a) Observations (possibly continuous records) of potential gradient.
   b) Measurements of the ionisation of the air, and occasionally measurements of the "penetrating radiation".
   c) Measurements of the vertical electric current of the atmosphere.

In general the object is to take such observations of atmospheric electricity as further developments may indicate the importance of undertaking in this locality.

The scientific staff of the observatory will have to carry out the observations in accordance with plans and instructions given by a commission, which at the present time consists of the following members:

Director O. Krogness, Geophysical Institute, Tromsø.
Professor C. Størmer, University, Oslo.
Professor S. Sæland, University, Oslo.
Professor L. Vegard, University, Oslo.

It is intended that the various subjects of research shall be divided between the members of the committee in a way which pays due regard to the special subject in which each member is most interested and has the greatest experience.

At present Professors Størmer and Vegard will be specially responsible for the *auroral* observations and their further treatment. Størmer is going to conduct

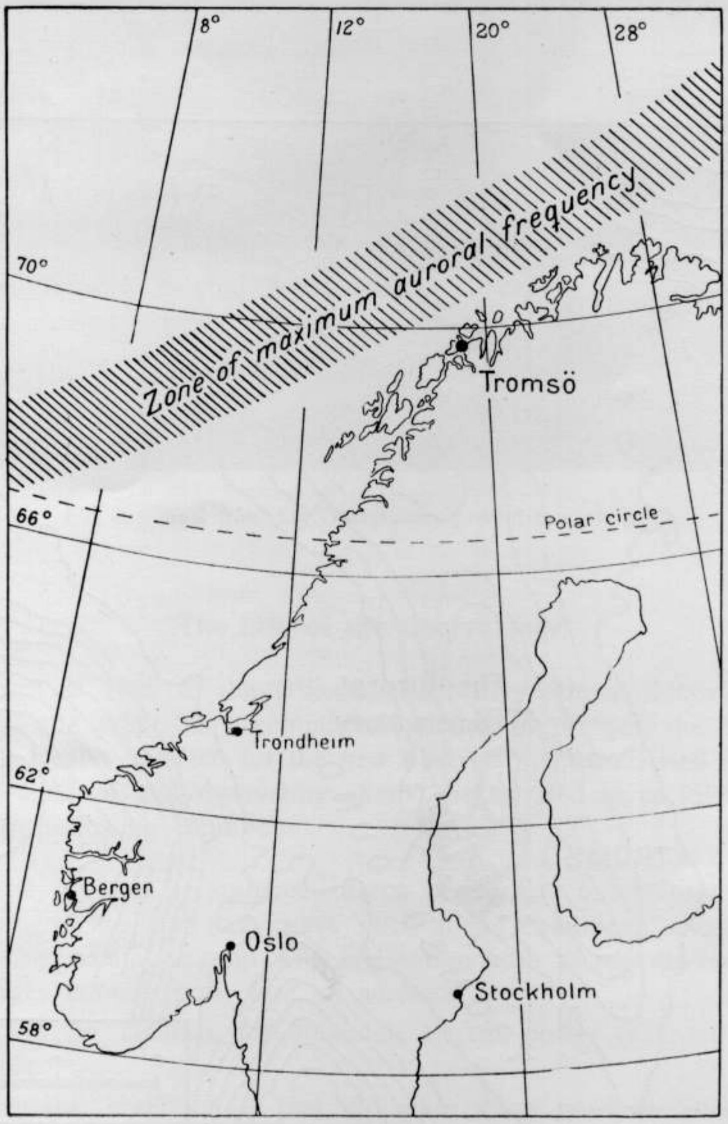

Fig. 1.

the observations relating to the determinations of the position of the aurorae and their treatment and publication. Vegard will attend to the spectral observations, their further treatment and the publication of the results. Director Krogness and Professor Sæland will be responsible for the conduct of the observations of magnetism, earth currents and atmospheric electricity.

The material relating to terrestrial magnetism, earth currents and atmospheric electricity will be worked out according to international rules at a separate bureau.

The joint committee will draw up a plan of work, which will secure a harmonic interaction between the various branches of observations.

As the starting of the different branches of observations above mentioned, takes some time, it is understood that the plan must to a certain extent be developed gradually. We intend first of all to start with terrestrial magnetism and auroral observations and then, as soon as circumstances permit, to take up observations of earth currents and atmospheric electricity."

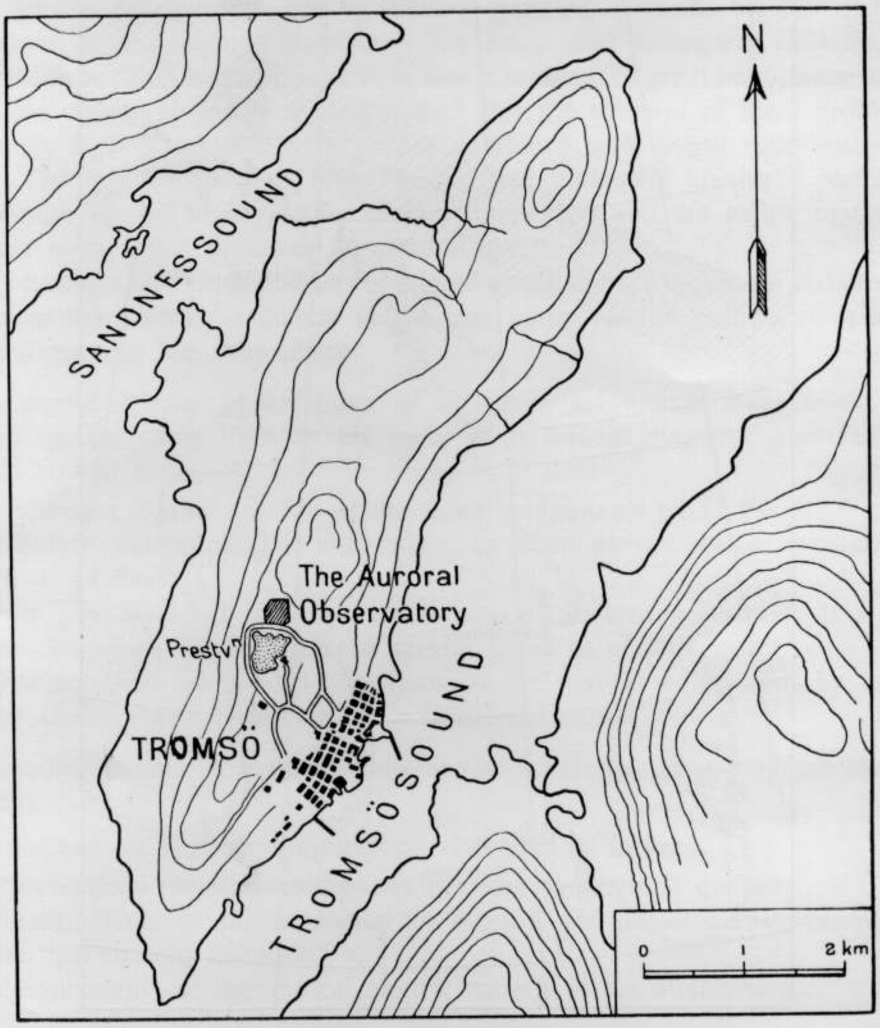

Fig. 2. The Tromsø Island.

Fig. 3. View from the Observatory ground towards south.

The Site of the Observatory.

In a report of 1926 to the Officers of the International Education Board from the members of the preliminary commission already mentioned, the conditions to be fulfilled by the locality selected for the new observatory, were stated in the following way: "The location of the observatory should be selected so as to fulfil in the best possible way the following conditions:

1. It is of the greatest importance that a permanent observatory should have a position where the staff may have good living conditions, and where they can stand in easy communication with civilisation both as regards ordinary transport and messages through post, wire, or wireless.
2. There should be facilities for obtaining electric power (alternating current) and water supply.
3. An indispensable condition is that the place gives good facilities for the observations, and for our purpose the most important conditions are:
   a) That the stations should be as near to the auroral zone as possible.
   b) The auroral observations require a free horizon and a clear sky and facilities for arranging a second basis station for height measurements.
   c) Magnetic observations require that the ground does not cause abnormal magnetic values, and that the spot on which the observations are performed is free from local magnetic disturbances with a period so large that they are able to effect the readings of the instruments. The most dangerous source of such disturbances are direct electric currents and variations in the iron tube system in the vicinity of the magnetic huts.

d) For the work on atmospheric electricity it is advantageous to have clear and dry air, and ordinarily the observations should be undertaken on fairly even ground."

After having inspected those localities in Northern Norway which might possibly be taken into consideration as sites for the new observatory, we finally decided on a place near the town of Tromsø. Before selecting this place a careful study was made of the weather conditions, the probability of a clear sky and the local magnetic variations at the various places. As it was found that the ground at Tromsø gave in this respect as good conditions as the other places inspected, we decided to place

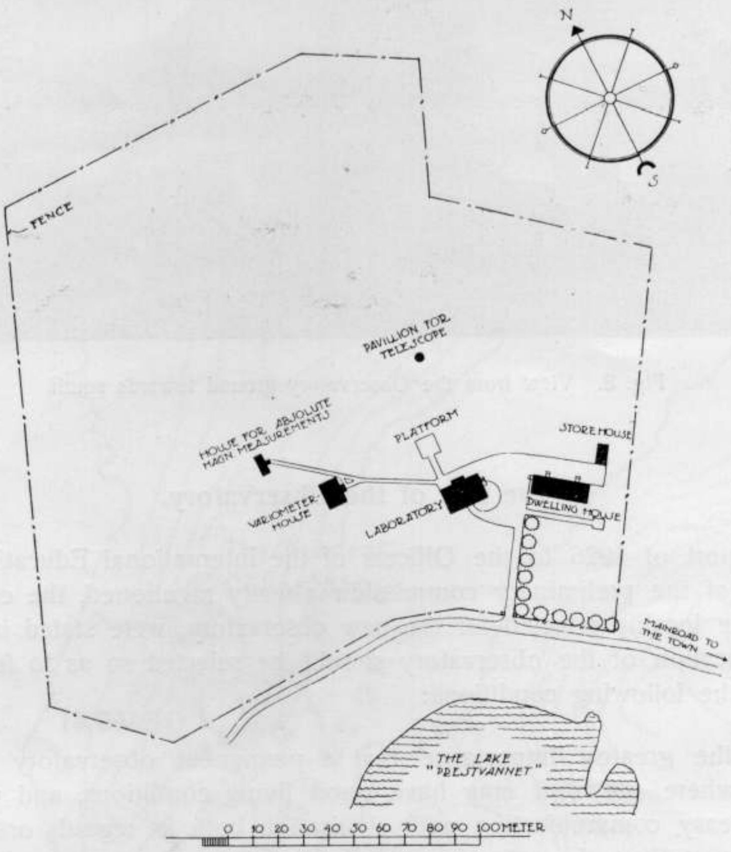

Fig. 4. Observatory ground showing the position of the buildings.

the observatory on the top of the Tromsø Island to the north of the lake "Prestvannet" at a distance of about 2 km from the centre of the town and at about 112 m above sea level. The position of the observatory will be seen from Fig. 1 and Fig. 2. Fig. 3 shows the picturesque view from the observatory grounds.

That Tromsø is a town with about 11 000 inhabitants, and the administrative centre of Northern Norway, will in many ways facilitate the conditions of living and scientific work. Water and electricity (230 Volt alternating current) could be got from the town's supply, and as will be seen from the map (Fig. 1) Tromsø has a suitable position relative to the auroral zone which passes close to the north of the town from SW—NE.

The necessary ground — covering about 51 000 m^2 — was granted by the town of Tromsø and the municipality of Tromsøysund.

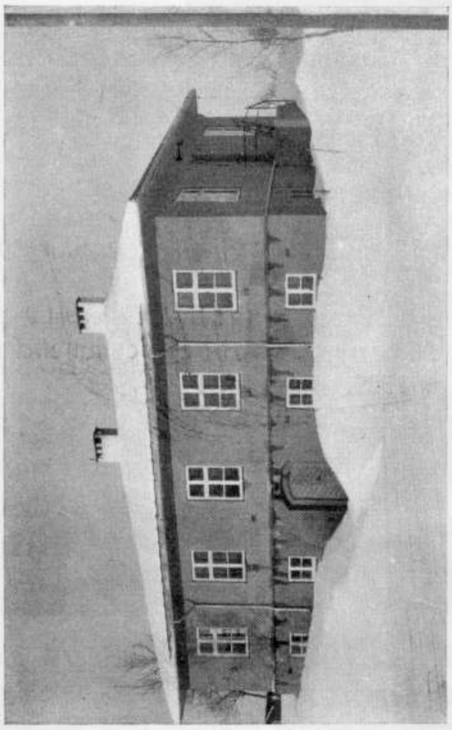

Fig. 5 *a*. The main observatory building from S—E.

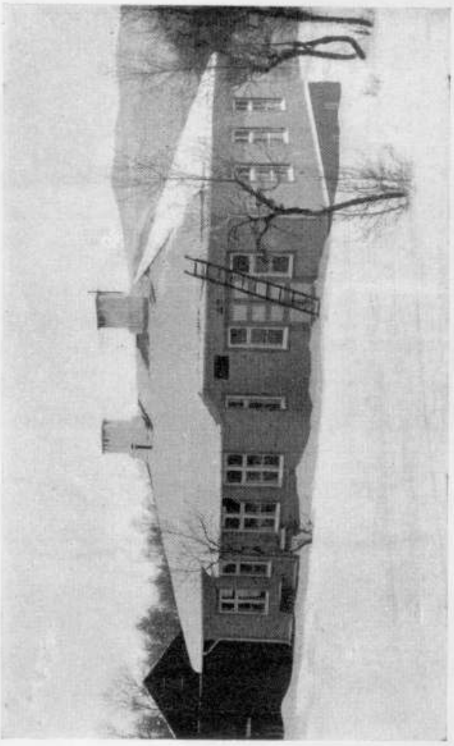

Fig. 5 *b*. The main observatory building from north.

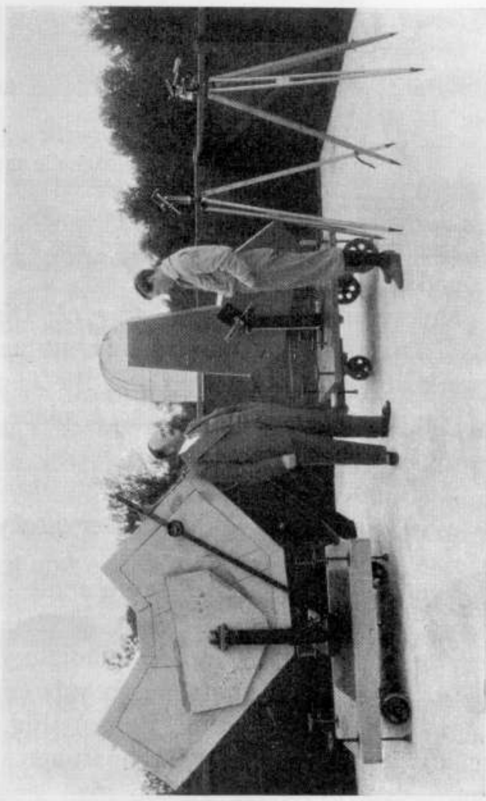

Fig. 6 *a*. The big glass spectrograph (left), the quartz spectrograph and auroral cameras on the platform. The telescope pavilion is seen behind.

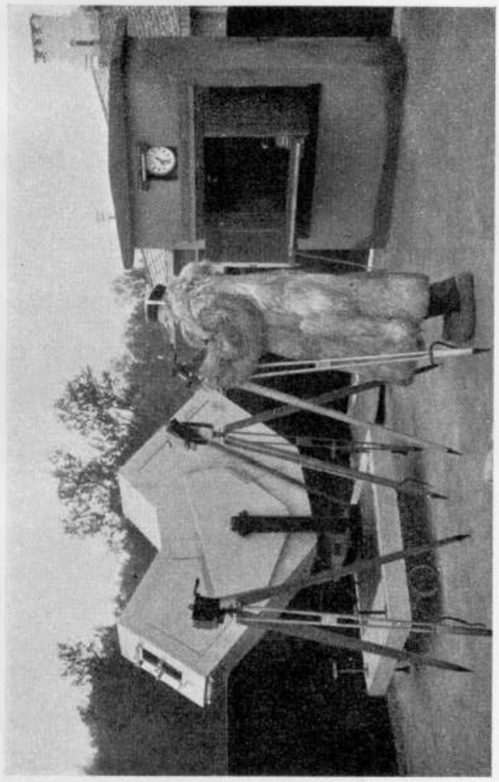

Fig. 6 *b*. Picture of the observation platform showing stand with clock, auroral cameras and big glass spectrograph.

General Plan of the building Work.

The planning and erection of the various observatory buildings was conducted by a building committee consisting of:

Mr. Crawfurd-Jensen, State Architect.
„ O. Krogness.
„ C. Størmer.
„ S. Sæland.
„ L. Vegard (chairman).

Detailed plans and drawings were worked out by the State Architect Mr. Crawfurd-Jensen assisted by Mr. Sigurd Trøim (architect). The building work on the spot was conducted by Mr. Chr. Knudtzon. The building committee also recived most valuable assistance from the Borough Surveyor of Tromsø Mr. P. A. Amundsen.

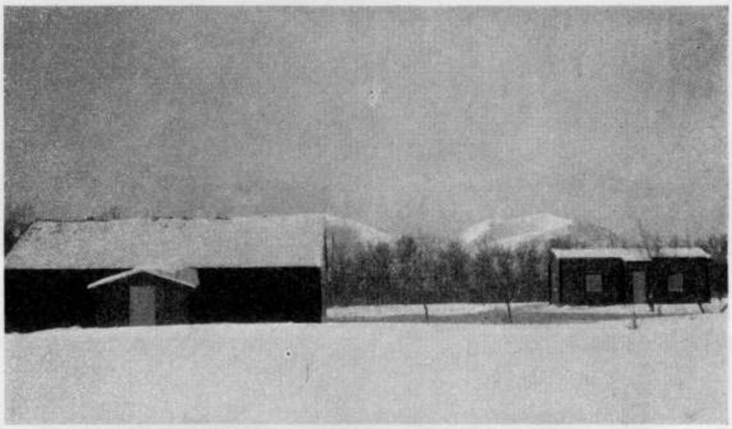

Fig. 7. House for magnetic registrerings (left) and for absolute magnetic measurements.

The work was commenced in the autumn of 1927 and the buildings were finished at the end of 1928.

The scientific staff, consisting of: Director Leiv Harang, the first assistent Mr. Einar Tønsberg and the instrument-maker Mr. Magnus Jacobsen, commenced their work at the end of 1928 and the beginning of 1929.

The official inauguration took place on August the 7th, 1930.

Observatory Buildings.

The following houses were built on the Observatory ground, as will appear from Fig. 4:

The principal Institute or Laboratory with an observation-platform outside, (Figs. 5 and 6), a house for magnetic records (Variometer House), and one for absolute magnetic measurements (Absolute House) (Fig. 7), a small telescope pavilion (Fig. 6), and a dwelling house (Fig. 8) with apartments for the director, the first assistent and the instrument-maker. A fairly good road leads from the town to the observatory. A tall fence has been put up round the observatory-grounds.

Fig. 8. The main observatory and dwelling house. View from S—W.

The principal Institute.

Previous work on the auroral and kindred phenomena, especially investigations on the auroral spectrum, had shown the importance of having good facilities for experimental work on the spot of observations. Accordingly the principal building was planned as a small physical institute. The house, which is solidly built of concrete, has a basement and one floor.

The basement (Fig. 9) contains one fairly large laboratory room, provided with switch-boards for the electric distribution and an electric DC.generator to be used for charging the storage battery and for other purposes, a room for storage battery, a room for registrations of earth currents and atmospheric electricity, a second room for registrations of various kinds, a small store room and rooms for fuel and the central heating furnace.

The ground floor (Fig. 10) contains: —A workroom and library containing writing and drawing-tables, typewriters and calculating machines. A laboratory room which through a wide door communicates directly with the observation platform outside (compare Fig. 5 b). The bigger instruments are placed on supports with rubber wheels and may easily be wheeled into the laboratory if wanted. A second laboratory room is provided with windows towards the north, west and east, and is used as an auroral lookout room. The ground floor also accommodates a photographic dark-room, a workshop, and two rooms for visitors who might wish to stay at the observatory for scientific purposes.

The observation platform (Figs. 6 and 11) has a concrete floor with a network of wires, through which the floor may be heated by electric currents. At one side of the platform is placed a stand (shown on Fig. 11) containing all necessary electrical terminals, for telephones, for electric signals to the various parts of the observatory, for

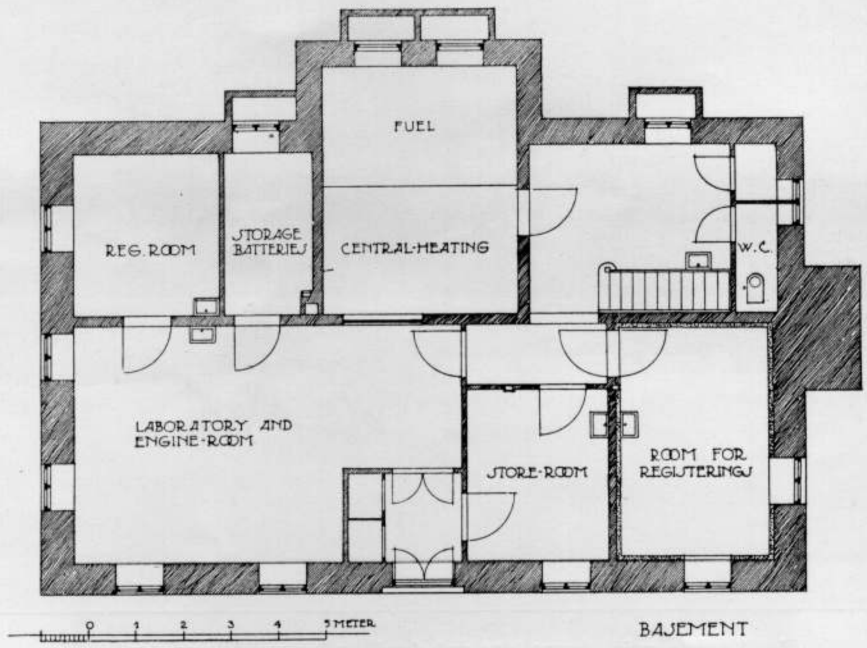
FUEL
REG. ROOM
STORAGE BATTERIES
CENTRAL-HEATING
W.C.
LABORATORY AND ENGINE-ROOM
STORE-ROOM
ROOM FOR REGISTERINGS
0 1 2 3 4 5 METER
BAJEMENT

Fig. 9.

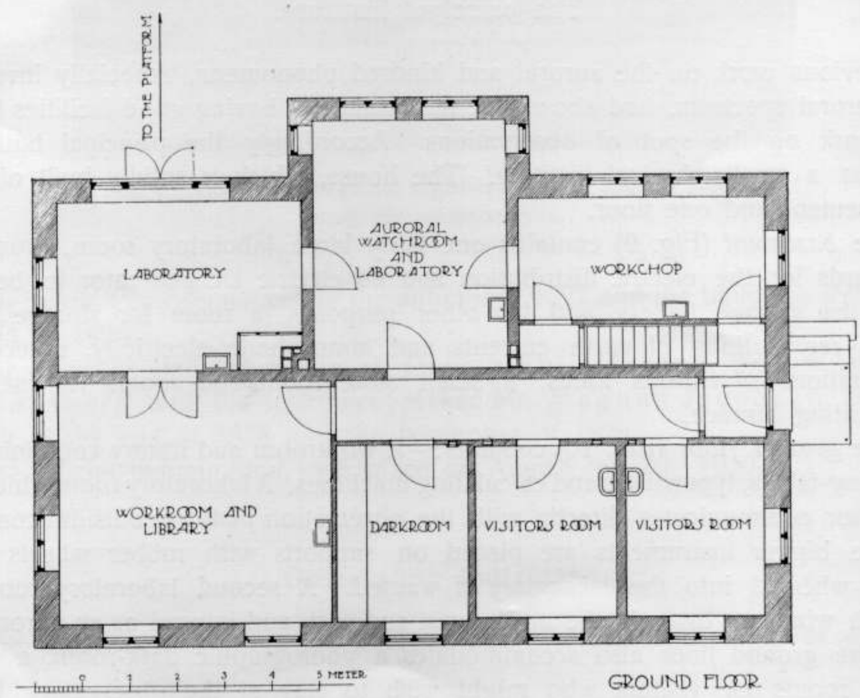
TO THE PLATFORM
LABORATORY
AURORAL WATCHROOM AND LABORATORY
WORKCHOP
WORKROOM AND LIBRARY
DARKROOM
VISITORS ROOM
VISITORS ROOM
0 1 2 3 4 5 METER
GROUND FLOOR

Fig. 10.

the ordinary alternating current and for the storage batteries, while on the top of the stand (not shown in the fig.) are terminals for high tension current, which may be generated in the laboratory. The stand is also provided with an electrically driven clock which may be illuminated by an electric lamp inside the stand.

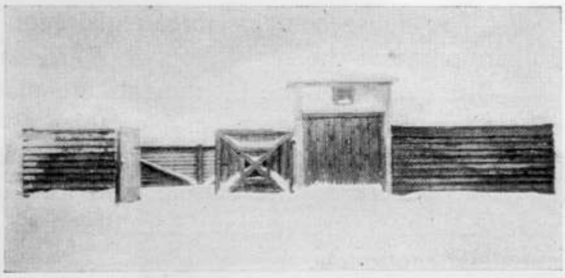

Fig. 11. Observation platform with stand.

The platform is surrounded by a wooden fence, which mainly serves as a shelter against the cold wind and snowstorms. The platform with stand and fence is illustrated in Fig. 6 and 11.

The House for magnetic Registrations.

The house for continuous magnetic registrations is situated 40 m from the Laboratory and — as will be seen from Fig. 12 — consists of two buildings, one inside the other. The inner part is a wooden construction, and the outer one a wooden frame, which according to recommendation by Sæland is filled with bricks of turf. The inner house is separated from the outer one by a corridor where the air can circulate freely. In this way all parts of the inner house are kept at nearly the same temperature, and the registration rooms only show very slow temperature changes. The diurnal variation of the temperature is thus quite negligible.

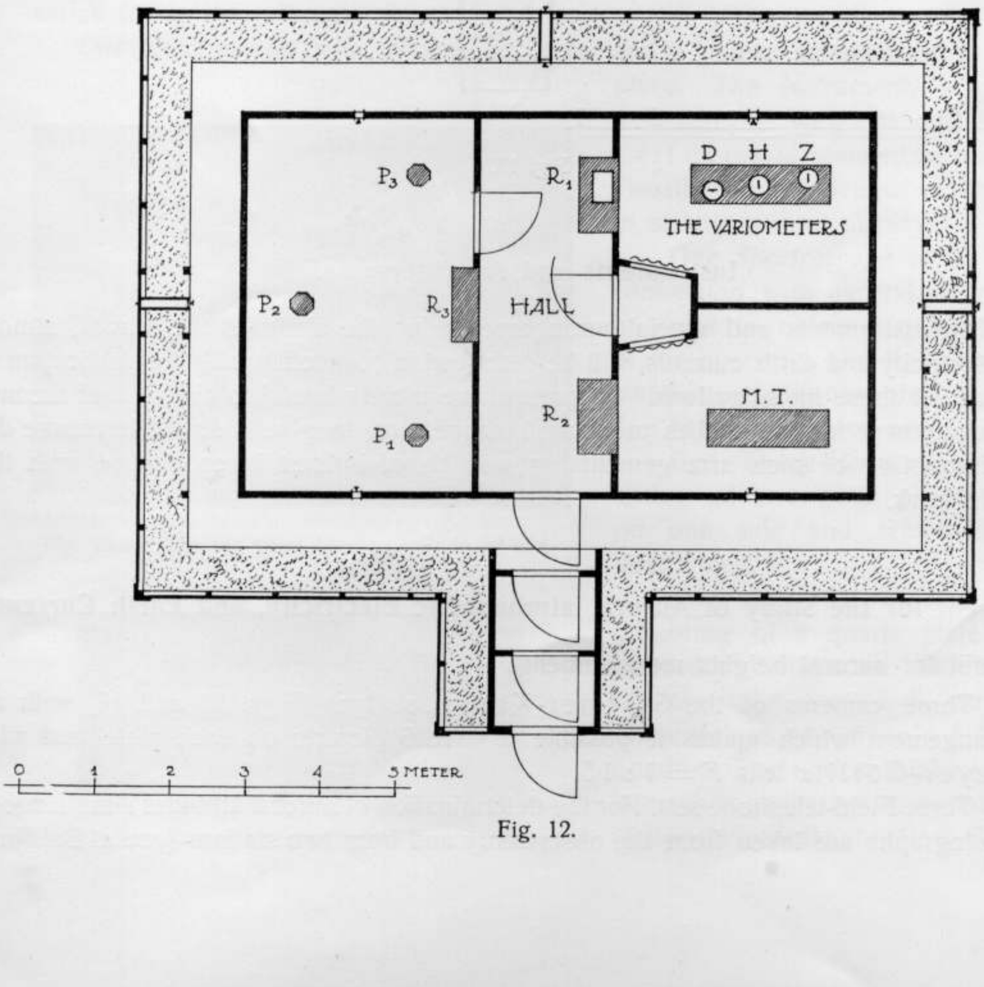

Fig. 12.

The house contains three registration chambers situated on both sides of a central hall from which the registrators R_1 R_2 R_3 can be attended to.

In one room the instruments are placed on marble pillars (P_1 P_2 P_3); in the two others they are placed on marble tables.

The greatest care was taken to see that the magnetic houses were built of non-magnetic material. The marble used for the pillars was selected from specimens which were collected from various localities and which were carefully tested with regard to magnetic properties.

The House of Absolute Magnetic Measurements

is built of wood and has only one room with the necessary marble pillars for the instruments (Figs. 7 and 13). Care was taken to see that the pillars were firmly fixed to the rock by means of iron-free concrete and that they did not touch the wooden floor of the chamber.—

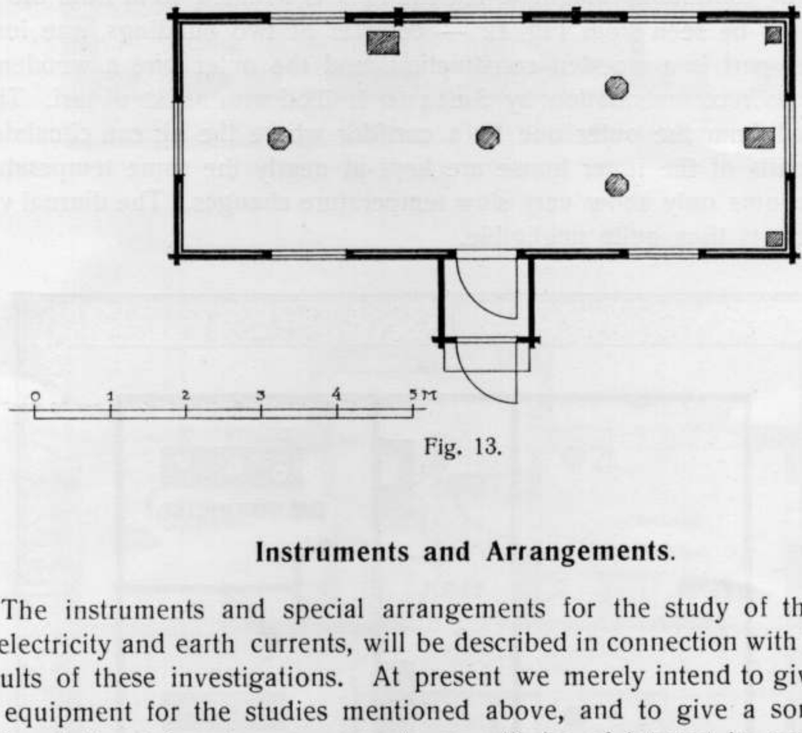

Fig. 13.

Instruments and Arrangements.

The instruments and special arrangements for the study of the aurora, atmospheric electricity and earth currents, will be described in connection with the publication of the results of these investigations. At present we merely intend to give a brief account of our equipment for the studies mentioned above, and to give a somewhat more detailed description of such arrangements as will be of interest in connection with the magnetic work.

Equipment for the Study of Aurora, atmospheric Electricity, and Earth Currents.

A. Outfit for auroral heights measurements.

Three cameras of the Størmer-Krogness type (Figs. 14 and 16) with an arrangement which makes it possible to take 6 pictures on each plate and with Meyer-Görlitz lens $F = 1 : 1{\cdot}5$.

Three Field-telephone sets. For the determination of auroral altitudes simultaneous photographs are taken from the observatory and from two stations (one at Balsfjord

43 km to the south, the other at Torsvåg Lighthouse, 68 km to the north ofTromsø). The observatory has also some cameras with great light-power for special investigations.—

B. For the study of the auroral spectrum a number of spectrographs were designed by Vegard and at present the observatory possesses the following spectral apparatusses.

One big glass-spectrograph (Fig. 15 *a*) with two prisms and of high light-power. The optical parts were made by Zeiss; all mechanical parts at Oslo.

One Quartz spectrograph with two big Cornu prisms. The optical parts were made by Carl Leiss, Berlin, and the mechanical parts were made at Oslo.

Four smaller glass-spectrographs with very great light-power and of various designs.— These somewhat smaller instruments are specially built for the study of the intensity variations in the auroral spectrum, and are also intended to be used in connection with the Fabry-Perot etalons, mentioned below (Fig. 15 *b*).

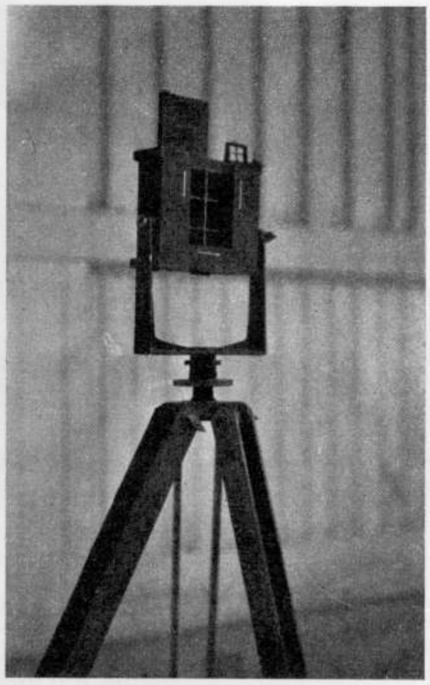

Fig. 14. Auroral Camera of the Störmer—Krogness type.

Two of these small spectrographs have a camera lens consisting of one piece of glass $F\ 1:1$, and two 30 degree prisms, one of which has a spherical surface which forms the callimator lens.

One Spectrometer with micrometer screw and a pointer-arrangement in the eye piece. The instrument, which was designed by Vegard and built by Carl Leiss, is intended for measuring visually the wavelength of lines seen in strong auroral displays.

One Spectroscope to be used in connection with auroral observations in order to obtain a quick estimate of the spectrum and thus make sure whether a luminous phenomenon is due to an aurora or not.

One Fabry-Perot etalon consisting of two glass plates silvered on one side and separated by a quartz ring.

Two Fabry-Perot etalons each consisting of a quartz plate lightly silvered on both sides. One is about 2·5 mm, the second 5 mm thick. These etalons were made by A. Hilger, London. The optical thickness of the two quartz plates was measured by The National Physical Laboratory, England.

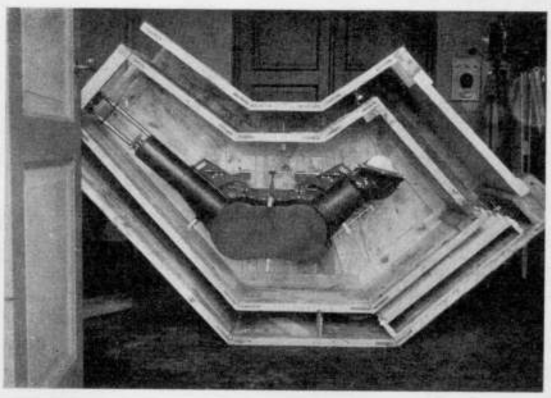

Fig. 15 *a*. The big glass spectrograph in ist box.

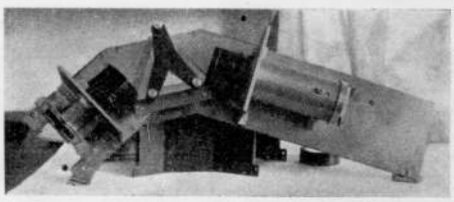

Fig. 15 *b*. One of the small glass spectrographs.

Fig. 16. The Russeltvedt Collector in position.

The big spectrographs to be used for long exposures are put into well isolated wooden boxes (compare Figs 6 and 15 *a*), placed on a suitable stand, so that the whole box may be turned round a horizontal and vertical axis. The box is heated by electric current and the temperature regulated automatically.

The interferometer, being very sensitive to temperature-changes, is carefully protected in a well isolated box, where the temperature is kept as constant as possible and accurately measured.

C. One small spectrograph designed by Harang which automatically takes one photograph of the auroral spectrum. This instrument is intended to record the intensity of the aurora every hour.

D. *Instruments for atmospheric electricity.*

A recorder for the potential gradient with a mechanical collector of the Russeltvedt-type Fig. 16, a quadrant electrometer Fig. 17, and a registrator. One Kolhørster apparatus for measuring the cosmic, penetrating radiation. It is intended to make arrangements for continuous records of the intensity of this radiation.

E. *Radio-work.*

A radio-aerial has been put up, and in particular the observatory intends to make records of the intensity of radio-waves transmitted across the auroral zone. For this purpose the Norwegian Telegraph Office has kindly placed at our disposal two receivers (one for long and one for short waves), and we intend to cooperate with the Norwegian stations at Svalbard, East Greenland and Jan Mayen.

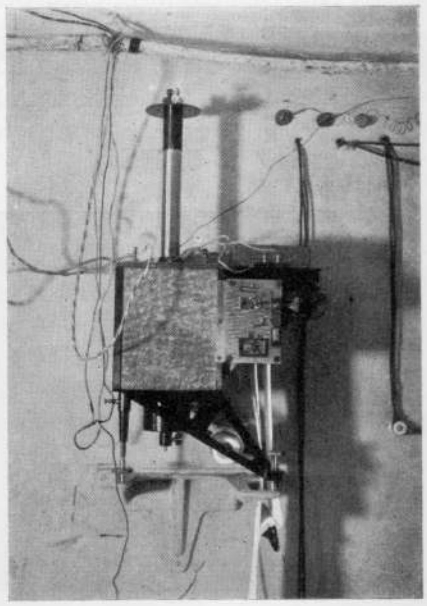

Fig. 17. Electrometer for recording of the potential gradient.

F. *Earth currents.*

By means of two galvanometers of ordinary type earth-currents are recorded in two horizontal straight cables, one E—W and one N—S. Large resistances are put in series in each of the two lines, and the said instruments act as volt-meters. The numerical data for the two horizontal cables are shown on the following page.

The variations of the vertical magnetic component are recorded by a galvanometer in a horizontal circuit. The length of the cable is 805 m, the effective current-area is 32 200 m². The scale value of the galvanometer is $1{\cdot}92 \times 10^{-8} \frac{\text{amp.}}{\text{mm}}$. The total resistance of the circuit is 124·6 Ω, which gives a scale value of the electromotive force $2{\cdot}39 \times 10^{-6} \frac{\text{volt}}{\text{mm}}$.

	Length	Total resistance	Scale value of galvanometer
E—W cable	170 m.	395 400 Ω	$1.37 \times 10^{-8} \frac{\text{amp.}}{\text{mm}} \sim 32 \times 10^{-3} \frac{\text{volt}}{\text{km}}$
N—S cable	175 m.	292 000 Ω	$1.74 \times 10^{-8} \frac{\text{amp.}}{\text{mm}} \sim 29 \times 10^{-3} \frac{\text{volt}}{\text{km}}$

Clock and Time Marking Scheme.

A most important part of the general equipment are the clock-arrangements and the scheme for obtaining suitable time-marking on the various photographic records.

All time-signals and time-markings and some secondary electrically driven clocks are operated by a primary precision clock (Fig. 18), placed in the outlook room on a pillar resting directly on the concrete basement floor. The primary and secondary clocks, as well as the relays to be used for operating the time-marking, were delivered through the firm Elektrisk Bureau, Oslo, according to a given specification. The clocks were made by C. Bohmeyer, Halle.

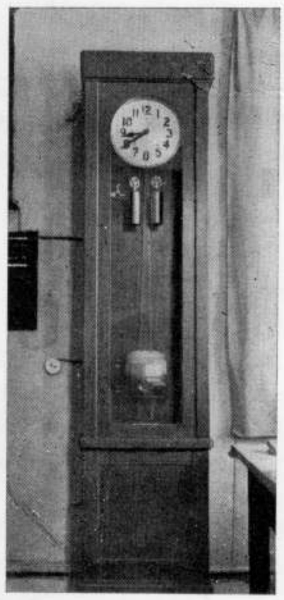

Fig. 18. The central clock.

The primary clock has a Riefler pendulum Cl. II, an electrically driven automatic winding up arrangement and is provided with contact-mechanism for secondary clocks and for electrical impulses for the time-marking. For the latter purpose contacts are made every minute and every half hour.

The secondary clock on the observation platform has a second pointer and receives impulses every second, the other secondary clocks receiving impulses only once a minute.

The special arrangement for the time-marking on photographic records was worked out by Vegard and is indicated in Fig. 19.

All lamps used for registering purposes are made for a tension of 6 volts. Ordinarily we use alternating current from the town supply, transformed down to 24 volts by means of the transformer *T*. The tension for the lamps (6 volts) was taken out by a potentiometer arrangement. If for some reason alternating current should fail a double relay *(C) (D)* is automatically operated and connects the terminals *(ab)* leading to the lamps with a 24 volt storage-battery. One of the terminals *(a)* branches off at *P* into two, and one of them passes through the relay *A* which is operated by the contact mechanism of the central clock and receives an impulse once a minute. The second main terminal *(b)* branches off at Q, passes through the relay *(B)* and at Q_2 through the resistance R_1. Ordinarily the connection through the relay *(B)* is broken and the current passes the resistance R_1, but every half-hour the relay is operated by the central clock by the circuit II, and it short-circuits the resistance R_1. In consequence of this the lamp connected to this terminal (1) is intensified.

The relays—one of which is shown in fig. 20—mainly consist of a small evacuated glasstube containing some mercury which produces contacts and breaks.

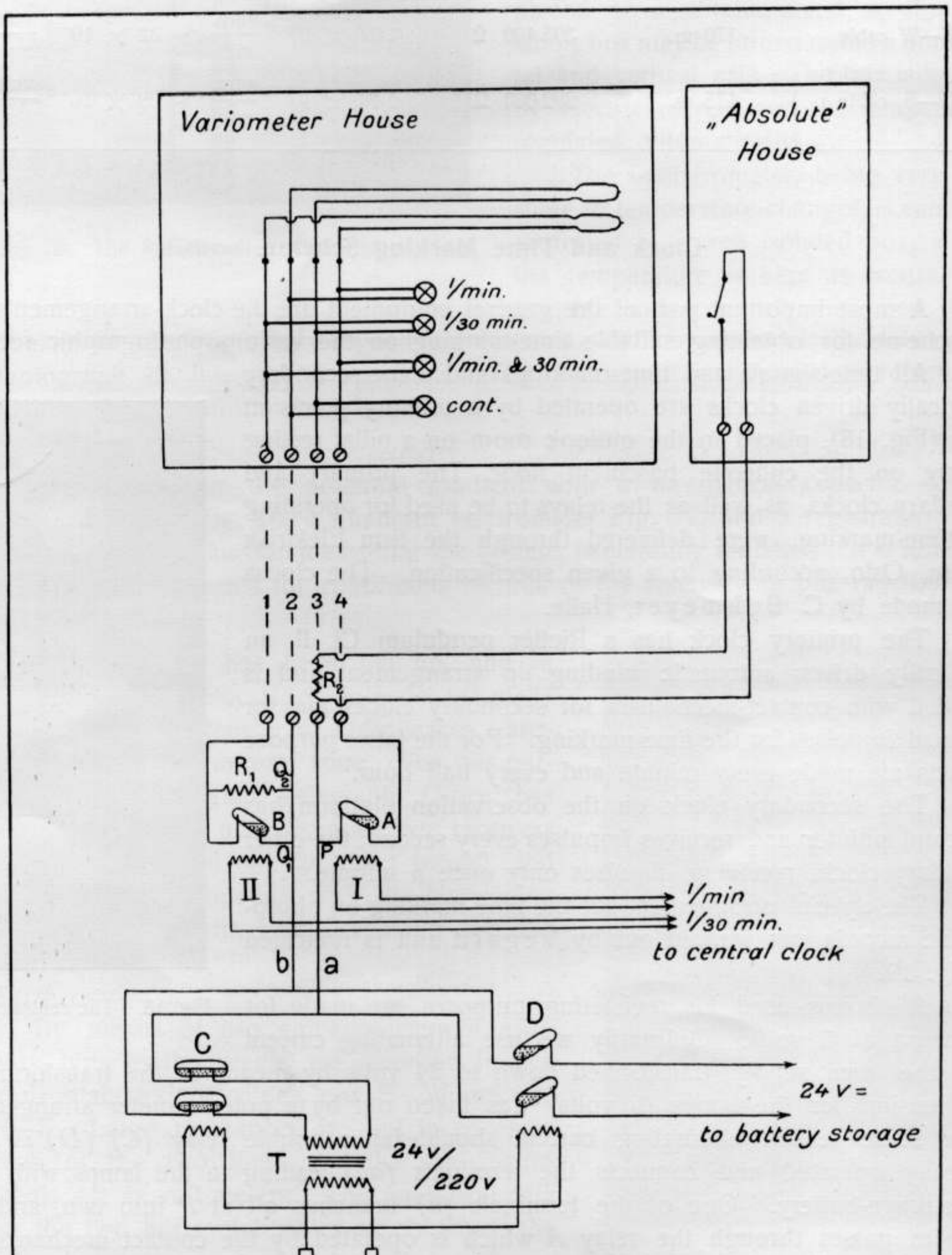
Variometer House
„Absolute" House
1/min.
1/30 min.
1/min. & 30 min.
cont.
1 2 3 4
R2
R1
Q2
B
A
Q1
P
II
I
1/min
1/30 min.
to central clock
b
a
C
D
24 V =
to battery storage
T
24 v/220 v
220 v

Fig. 19.

In this way we obtain four contact screws and corresponding terminals (1, 2, 3, 4) Fig. 19, which may be combined in four different ways as follows:

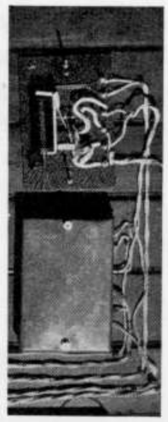

Fig. 20.

Combination of 2 and 3 gives constant tension and current.
" " 1 " 3 " continuous current, but intensified every 30 min.
" " 2 " 4 " a light flash every minute lasting 1·8 sec.
" " 1 " 4 " a light flash every minute and intensified every 30 min.

Fig. 19 also illustrates the connection for the registration lamps used for the magnetic variometers.

For the absolute magnetic measurements we have found it necessary to find a method by which the exact moment when a reading of an instrument is taken can be marked off on the variometer curves. This is done in the way indicated in Fig. 19, by means of a resistance R_2 which is short-circuited by pressing a contact-button in the "absolute house". In this same way all lamps connected to the terminal 3 may be intensified and short-circuited from the lookout-room in the laboratory and from the stand on the observation platform.

Magnetic Registration Instruments.

It is intended to have three sets of magnetic variometers, one set in each of the three rooms of the variometer house. The principal set is intended to give the continuous 24 hours' records. Another set is intended to give 24 hours' records with reduced sensitiveness; and in the third room we intend to have a set to be more freely used for experimental purposes. Thus it is our plan to make rapid records e. g. in connection with auroral displays. Arrangements will be made which will render it possible to start or stop the records by relays operated from the observational platform.

At present two sets of magnetic registering apparatus have been put up, the principal set for the ordinary 24 hours, records and another for continuous registrations with smaller sensitiveness.

The principal set (with high sensivitiveness) consists of one *H*-variometer and one *D*-variometer, of a modernized Eschenhagen type, made by Carl Bamberg, Berlin. For these instruments the magnets are suspended in the usual way:—in the *D*-variometer by a nearly torsion-free quartz-fibre so that the magnetic axes of the magnet will at any moment give the direction of the horizontal component *H*, while in the *H*-variometer the axis of the magnet is held in a position nearly perpendicular to the magnetic meridian by means of the torsion of the quartz-fibre.

The variometer for the vertical intensity *(V)* is a balance constructed by la Cour[1]) and made at Copenhagen under his supervision.

The three variometers are placed behind each other on the same marble plate resting on a concrete pillar as indicated in Fig.s 21 *a* and 21 *b*. Two lamps with linear filaments are used for the registrations, so that we get two curves for each component. One of the lamps is connected to the terminals 1 and 4 (Fig. 19). It lights up for 1·8 seconds once a minute and is intensified every half hour.

[1]) la Cour: Publikasjoner fra det Danske Meteorologiske Institut, Communications Magnetiques, No. 8, 1930.

The second lamp is connected with terminals 1 and 3 and burns continuously, but is intensified every half hour. In order to get the two curves as close to each other as possible we use an arrangement due to la Cour, which is shown in Fig. 22. Two 45° prisms are placed so that their edges nearly meet in front of the broad slitt in the screens, which protects the instruments from the direct light from the lamps.

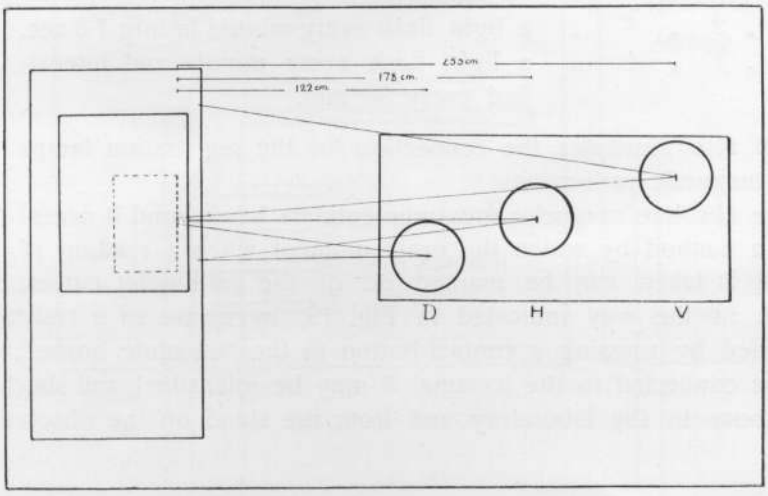

Fig. 21 *a*.

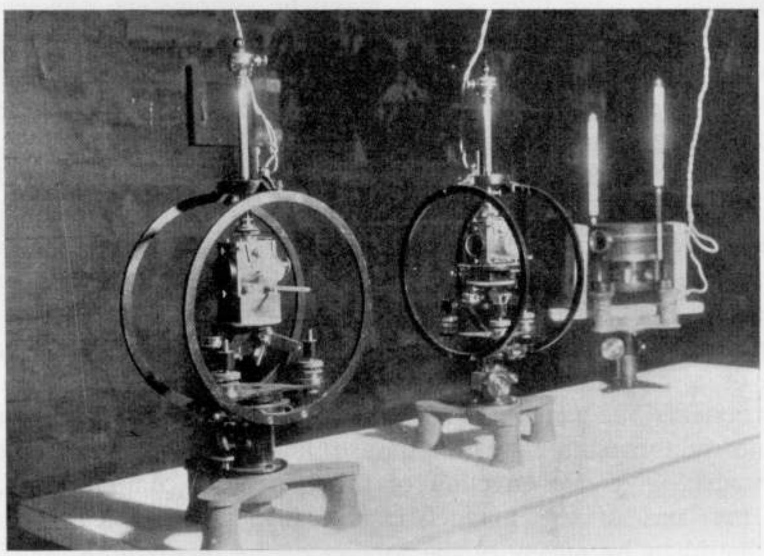

Fig. 21 *b*. The magnetic variometers in position.

All three magnetic elements with base lines are recorded on the same paper, together with temperature curves. Part of a magnetogram covering 12 hours is shown in Fig. 23. We notice that one set of curves is composed of dots, which enable us to fix the time to a fraction of a minute. To the right of the diagram we notice the marks corresponding to an absolute determination of the magnetic elements.

For the determination of the scale value each variometer is provided with a Helmholtz-Gauguin coil, through which may be sent an electric current of known strength. The current is operated from the laboratory. The arrangement is illustrated in Fig. 24 *a*. The current from a 24 volt storage-battery may be regulated by the resistance R_1 reversed by the arrangement *T* and measured with the amperemeter *A*. By means of the movable contact-wire *c* the current may be made to pass the coils of the *H—D* and *V*-variometers respectively. This arrangement is put up in the laboratory and a picture of it is shown in Fig. 24 *b*.

The Instruments for Absolute Measurements.

The Theodolite for absolute determinations of *H* and *D* is from Carl Bamberg, Berlin. Fig. 25 shows the instrument placed on its pillar in the "absolute" house. *H* is determined by oscillations and deflections. The constants of the two magnets used for *H*-measurements were determined by O. Krogness at the Danish Observatory "Rude Skov" during a stay there in October 1928.

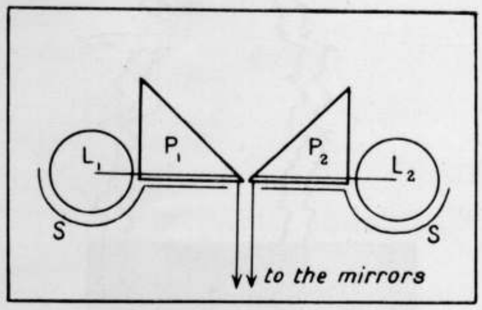

Fig. 22.

The temperature coefficient α was determined by observing the deflection angle produced by the magnet when placed in hot and cold water.

The induction coefficient was determined by the deflection method.

For the sake of control, simultaneous readings on the standard instruments of the observatory were taken and we were thus able to reduce every reading to standard values of *H* and *D*.

By the calculation Krogness has used the following procedure.

In accordance with Lamont the magnetic moment *M* is expressed by the formula:

$$\text{a)} \qquad M = M_o\,(1 - \alpha t)\,(1 + \frac{6}{7}\,\varkappa\,H')$$

$$\text{b)} \qquad M = M_o\,(1 - \alpha t)\,(1 - \frac{8}{7}\,\varkappa\,H')$$

H' is the component of the magnetic field parallel to the axis of the magnet. Formulas a) and b) are to be used according as *M* is increased or diminished by the field, hence *H'* is always regarded as positive.

The Lamont formula for the horizontal intensity *H* may be put in the well-known form:

$$H = \frac{C}{T\sqrt{\sin\varphi}}$$

T is the time of oscillation, reduced for torsion, to standard temperature and infinitely small arcs, corresponding to a certain moment of inertia *I* of the oscillation system. φ is the deflection angle, corresponding to a standard distance, reduced to standard temperature and corrected for "the difference of the distance W and E".

The theodolite-constant *C*, may be put in the following form:

$$C = \sqrt{\frac{2\,\pi^2 I_o}{r_o^3}\,k_d \cdot k_i}$$

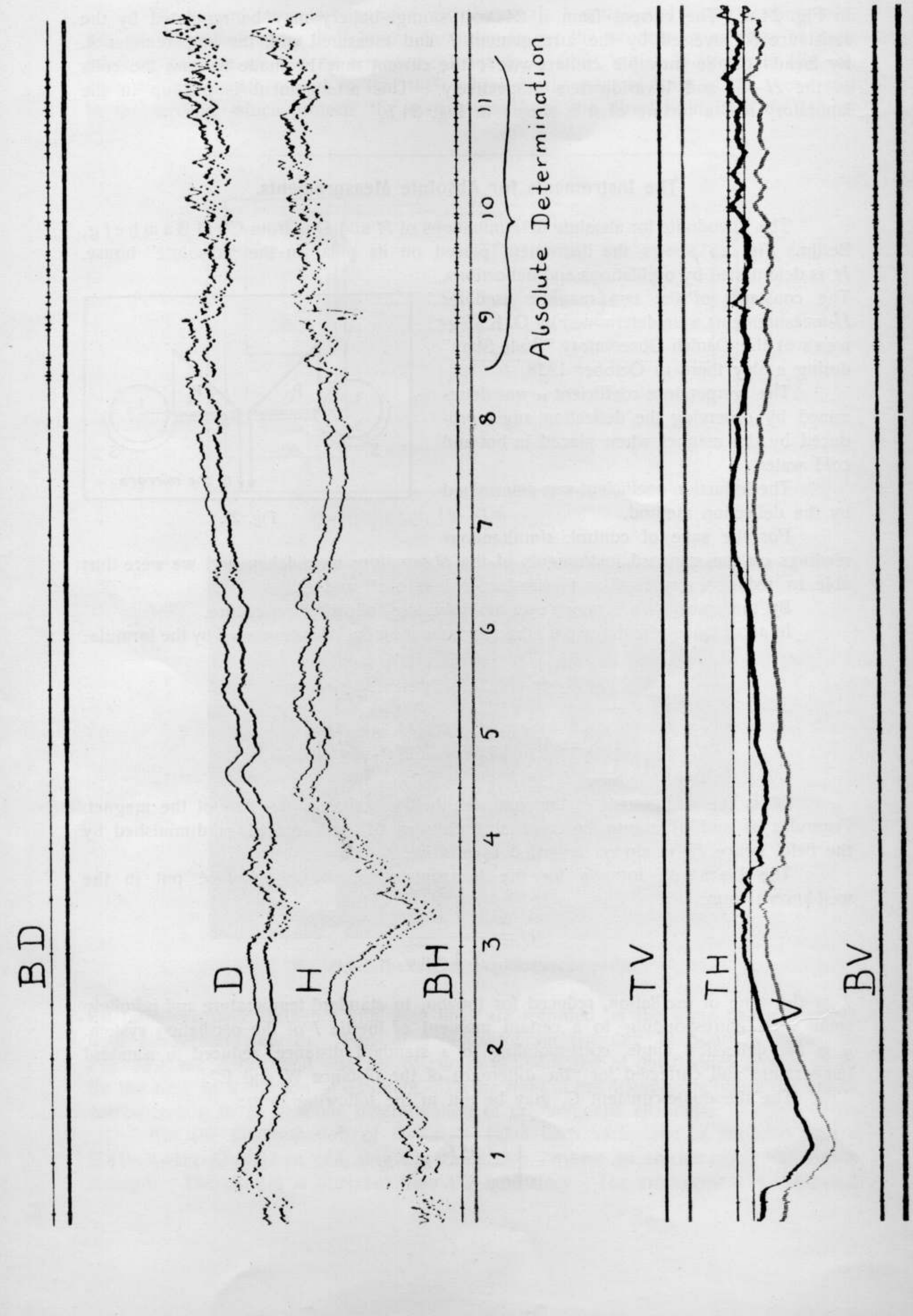

Fig. 23.

I_o is the moment of inertia of the magnet with suspension, and r_o the standard distance by the deflection, both at 0° C.

"The distribution-factor" k_d and the "induction-factor", k_i may be expressed in the following way:

$$k_d = 1 + \frac{P}{r^2} + \frac{Q}{r^4} \quad \text{and} \quad k_i = (1 - \frac{3}{7} \varkappa H) (1 + \frac{4}{7} \varkappa H \sin \varphi)$$

As regards the determination of the "distribution-function"

$$k_d = 1 + \frac{P}{r^2} + \frac{Q}{r^4}$$

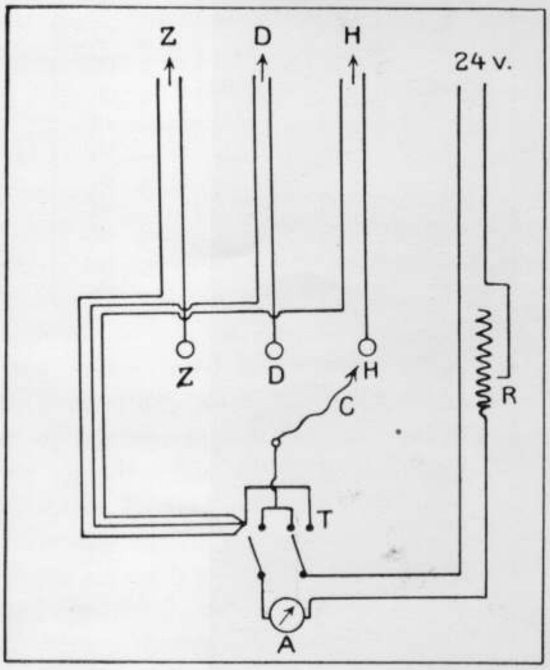

Fig. 24 *a*.

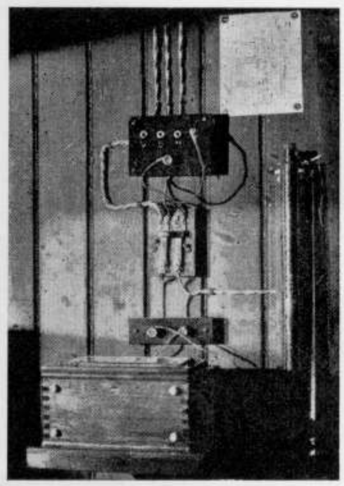

Fig. 24 *b*.

the following remarks may perhaps be of interest. The determination of this function is, as is well known, a somewhat delicate operation. Ordinarily, the two coefficients P and Q are determined by taking deflection measurements at three distances. In order to get trustworthy results a series of measurements is required. Krogness used the following method:

The deflection bar has a series of holes, one for each cm. between $r = 20$ cm and $r = 37$ cm. Deflection observations were made at all these distances. From these measurements a curve for the function

$$M \cdot k_d = \frac{H r^3 \sin \varphi}{2}$$

is drawn on a large scale. From this curve we are able to eliminate the errors of observation by simply smoothing the curve graphically.

On the smoothed curve (Fig. 26) we choose 3 points, which are convenient for the calculation of the constants P, Q and M. By varying the choice of the 3 points we get values that may differ slightly from each other. More points could of course be selected and the three constants could be determined by the method of the least squares. We have not, however, found such a method necessary, the first and simpler method giving results which are sufficiently accurate for the purpose. This will be seen from Table I and the curves. (Fig. 26).

For Magnet II it was not necessary to make use of a special smoothed curve, as no noticeable errors were found.

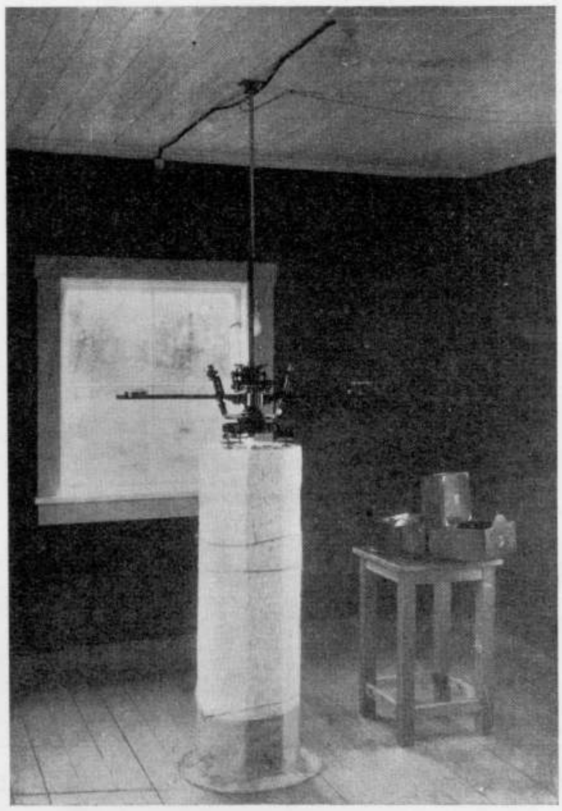

Fig. 25. The magnetic theodolite on its pillar.

The values given in Table II correspond to the "standard distances 28 and 37, marked on the deflection bar, and to the present average values of H and $H \sin \varphi$ at Tromsø. The factors k_d and k_i only show small variations mainly due to changes of the horizontal intensity and of the magnetic moment of the magnets. The necessary correction may at any time be calculated from the data given in the table.

For the determination of D a mire consisting of a concrete pillar of suitable form was put up near the lake "Prestvannet" at a distance of about 250 m to the south of the "absolute house". The Azimuth of the mire was determined in the usual way.

Determinations of D with our Bamberg Theodolite have been carried out at "Rude Skov" by Krogness and Harang, who got a fairly constant difference of 40″ from the values found at the observatory. Earlier, preliminary measurements

Table I.

Distance	Magnet I			Magnet II	
	k_d			k_d	
	Obs.	Smoothed Curve	Calc.	Obs.	Calc.
20 cm.				1·12106	1·12106
21 „				1·10833	1·10888
22 „	1·10159	1·10164	1·10162	1·09818	1·09848
23 „	1·09267	1·09257	1·09230	1·08963	1·08951
24 „	1·08260	1·08446	1·08424	1·08162	1·08173
25 „	1·07735	1·07719	1·07719	1·07523	1·07494
26 „	1·07063	1·07086	1·07101	1·06868	1·06897
27 „	1·06571	1·06543	1·06555	1·06386	1·06369
28 „	1·06089	1·06073	1·06071	1·05907	1·05901
29 „	1·05646	1·05631	1·05638	1·05477	1·05483
30 „	1·05264	1·05252	1·05251	1·05113	1·05108
31 „	1·04925	1·04911	1·04904	1·04773	1·04771
32 „	1·04584	1·04589	1·04590	1·04473	1·04466
33 „	1·04329	1·04314	1·04305	1·04218	1·04191
34 „	1·04050	1·04052	1·04045	1·03961	1·03939
35 „	1·03852	1·03828	1·03810	1·03718	1·03711
36 „	1·03465	1·03596	1·03595	1·03500	1·03501
37 „	1·03396	1·03398	1·03396	1·03330	1·03303

with the same instruments carried out by Sæland at "Rude Skov" gave similar results. Hence we assume that this difference is real, and we have therefore introduced this correction for D at Tromsø.

For the determination of the inclination I, we have an earth inductor from Schultze, Potsdam, provided with a sensitive galvanometer. More accurate values of I and the vertical intensity should be obtained by measuring V (or Z) directly by some accurate method. For this purpose we intend to use the intensiometer constructed by la Cour.[1])

The precision compensation apparatus to be used was obtained directly from Otto Wolf, Berlin. The reversing coil arrangement and the other parts necessary for these measurements were kindly furnished by the Meteorological Office at Copenhagen, where the instrument-work was controlled and the apparatus finally tested by la Cour and his collaborators.

The la Cour apparatus also measures H and in this way we have always a method of

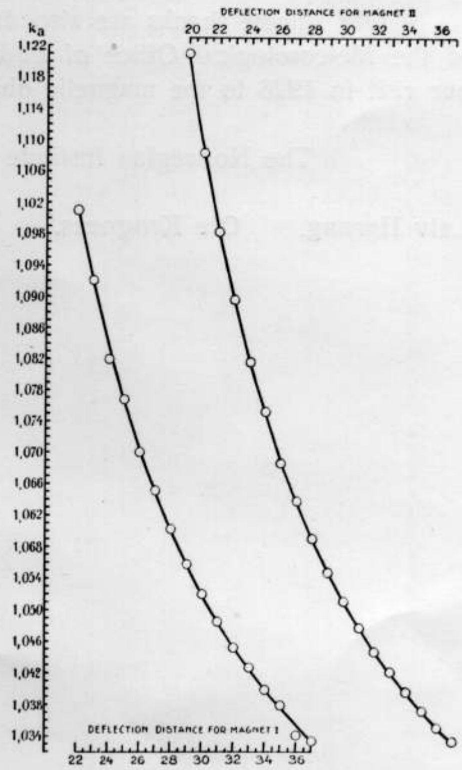

Fig. 26.

1) la Cour, Terr. magn., s. 153, 1926.

Table II.

	Magnet I	Magnet II
Length	11·9 cm	11·9 cm
Weight	30·1 gr	30·1 gr
Moment M_0 (Oct. 1928)	709·4 C. G. S.	558·2 C. G. S.
Moment of Inertia I_0	385·5	381·1
Temperature coefficient α	0·00313	0·00100
Mean induction coefficient $\varkappa$	0·0114	0·0081
Distribution coefficients P	45·03	44·01
Distribution coefficients Q	2009·8	1765·4
Theodolite constant for Tromsø, C $r = 28$ cm	0·60574	0·60202
Theodolite constant for Tromsø, C $r = 37$ „	~~0·38758~~ 0.39381	0·39150

estimating the correctness of the results obtained by the la Cour method for the vertical component.

The apparatuses for measuring I and V were not taken into use until the beginning of 1931.

In conclusion we wish to express our indebtedness to Director D. la Cour of the Meteorological Office of Copenhagen for giving us the privilege of making comparison measurements at the magnetic observatory at Rude Skov and for his valuable help and advice in connection with the equipment for the magnetic work.

We also wish to thank Mr. J. Egedal for his kind and most valuable assistance by the measurements at "Rude Skov".

Our sincere thanks are also due to Director G. Melander and Dr. J. Keränen of the Meteorological Office of Finland for their kind helpfulness in connection with our visit in 1926 to the magnetic observatory at Sodankylä.

The Norwegian Institute of Cosmical Physics, February 1932.

Leiv Harang. Ole Krogness. Carl Størmer. Sem Sæland. Lars Vegard.