GEODÆTISK INSTITUT
DANMARK

THE SEISMOLOGICAL STATIONS
KØBENHAVN
AND
SCORESBY-SUND

PUBLISHED BY THE
GEODETIC INSTITUTE
COPENHAGEN · DENMARK
1930

The Seismological Station København.

The seismological station København was established by the Danish Geodetic Survey which later became part of the Geodetic Institute. For several years the lack of a Danish seismological station had been felt, and we are greatly indebted to the Carlsbergfond for generously providing funds to purchase the seismological instruments, thus making it possible to establish a station near Copenhagen. After much searching, a place suitable for the erection of the instruments was found, the State placing at our disposal two caponieres of the old fortifications of Copenhagen.

After preliminary work of a varied kind the instruments were installed during the autumn of 1926, and the station was opened in November of that year.

Site of Station.

The two buildings containing the seismological station form part of the old fortifications whose walls and moats surround Copenhagen (see plate I). They are at a distance of about 6 km. from the outskirts of the city, the most southerly being rather more than a kilometre from the highroad to Roskilde, which is the nearest road with heavy traffic. The two caponieres are about 600 m. apart.

The fortifications are still under the control of the Danish War Office, and the public is not allowed to enter, so that the place for the instruments, although comparatively near the town, is to an unusual extent shielded from disturbances of non-seismic origin. The delicate instruments are thus able to record to their full advantage, and the disturbances sometimes shown in the records are insignificant.

The two buildings, caponieres XIII and XIV, are exactly alike; they are similarly placed in the fortifications and are equally orientated. They are built into the ramparts of the fortifications and the north-eastern wall is the only external one. They are situated close up to the moat, the floor being about one metre above the level of the water. The buildings have a fine, well-protected situation between the overgrown ramparts, as shown in fig. 1.

The buildings are of heavy concrete, and stones are placed round them for further protection. The thickest wall in the rampart is about 3 m. through. The rampart above the roof is drained for surface water. The floor is cast in concrete which rests directly on the ground.

The Rooms.

Plate II shows the plan of cap. XIII which contains most of the instruments.

In front of the original close fitting iron entrance door *D* a small building has been placed. It is divided into two parts one of which serves as a passage to

Fig. 1. Caponière XIII.

the inner rooms and is fitted with a second door in front of the iron door. Between the doors is a woollen curtain, and so the entrance is well protected.

In the big front room *S* the roof is supported by three concrete columns (*B* in plate II). The ceiling is boarded. The funnel-shaped spaces *A* in the wall are crenelles which have been bricked up, both inside and outside. Some air-holes in the ceiling have been filled in with wooden plugs.

The long room *L* with a vaulted ceiling (see fig. 3) has an area of about 21 m^2. In front of the door leading to *S* is a woollen curtain. An iron-door leads to the small room *I*. The original windows *E* of *L* and *I* are bricked up.

The room *V* has an area of about 9 m^2. In the square part of the room, to the right of the entrance door, is a vault made of hollow bricks. The entrance is protected by a curtain.

In the small room *R*, to which a passage leads from *S*, the original window has been bricked up. As the room was formerly used for the working of search lights, there is an aperture in the ceiling, and this aperture has not been bricked up.

Cap. XIV has been preserved in its original condition. No building has been added, and windows and crenelles have not been bricked up; they are, however, all shut by tight iron shutters. For the present it has been considered unnecessary to close the rooms more completely as only the rooms *L* and *V* are used.

Temperature and Humidity.

In closing cap. XIII so tightly it was intended to try to avoid great changes of temperature, to keep humidity out of the rooms, and to shield the instruments against draught; in all these respects the measures adopted have proved effective.

The records seem undisturbed by air-currents. It may also be stated that no direct influence of strong wind on the building has been traced; the half underground situation and the thickness of the outer walls seem to render sufficient protection against this.

The temperature of the building, which is not heated, is quite satisfactory. Daily changes of temperature are unknown, and the yearly changes are small. In room *V* which is the best protected, being situated right in the ramparts with no outer walls, the range of variation of temperature from the autumn of 1926 until the autumn of 1929 has been 5.7°; a maximum temperature of 10.9° was reached in the autumn of 1927 and a minimum temperature of 5.2° after the very severe winter of 1929. The smallest variation of temperature occurs in room *V*, but the temperature only varies a few degrees more in the other rooms, with the exception of room *R* into which the outside air enters directly; in this room a minimum temperature of ÷ 1° and a maximum temperature of 15° were observed.

The humidity has not given much trouble except just after the erection of the station. The degree of humidity is about 70 % and is kept low by means of chloride of calcium placed in bowls on the floor and in sacks of a loosely woven material suspended from the ceiling; under the sacks pails are suspended to receive the drops of liquid chloride of calcium. A special drying apparatus, which is very effective, is also used; a ventilator sucks up the air over perforated trays filled with chloride of calcium. When the degree of humidity rises, it can be reduced several degrees per cent if the drying apparatus is kept working during a day and a night. Rather large quantities of chloride of calcium are used, but the humidity is kept so low that it has no bad influence on the instruments.

Cap. XIV has not been used long enough for us to be able to tell whether a a satisfactory temperature and humidity can be obtained without taking more extensive measures. Room *V* seems, however, to be sufficiently protected. In the winter of 1929 the minimum temperature has been 6.1°. The temperature has thus kept higher than in the corresponding room of cap. XIII owing to the fact that it is very rarely that anybody enters it. In room *S* the temperature fell to 2°.

In cap. XIII there is so little access of fresh air that it is sometimes necessary to let oxygen into the rooms.

Light.

Electric light has been installed in all rooms both in cap. XIII and cap. XIV. Current is conducted to the station from the public works, giving an alternating current of 220 volts. This voltage is used for ordinary light; but for the photographic registration 6 volt lamps are used, and therefore a transformer to 6 volts has been fitted. In the room *S* of cap. XIII there are, besides two ordinary lights, two ceiling lights with spherical reflectors, one above the Wiechert horizontal seismograph, the other over the column *P*. In room *L* and in the small room *I*, where photographic registration is employed, there are amber lamps, which give more light than the usual red lamps without affecting the photographic films. In *L* there is also a lower hanging white lamp which has special ignition and which is used when work has to be done on the apparatus.

During work with the apparatus it may be necessary to have the separate parts brightly lighted, and so the station has been fitted with two 6 volt Zeiss "search lamps", mounted as standing lamps. The lamps can be turned on their stands so that the light, which is very intense but of limited field, can be directed to a fixed point.

There is also an ordinary hand lamp for 220 volts. In the different rooms there are several plug-connections on the high voltage and on the low voltage. A Phillip rectifier, which gives a current of either 3 or 6 ampères, is used to charge up the accumulators.

All leads, both for the high voltage and for the low, are placed in leaden tubes as a protection against moisture.

Then Istruments and their Mounting.

The station possesses the following apparatus:

1 Wiechert 1000 kg. horizontal seismograph.
1 » 1300 kg. vertical seismograph.
3 component Galitzin pendulums.
2 » Milne-Shaw seismographs.
2 » Wood-Anderson torsion seismometers.

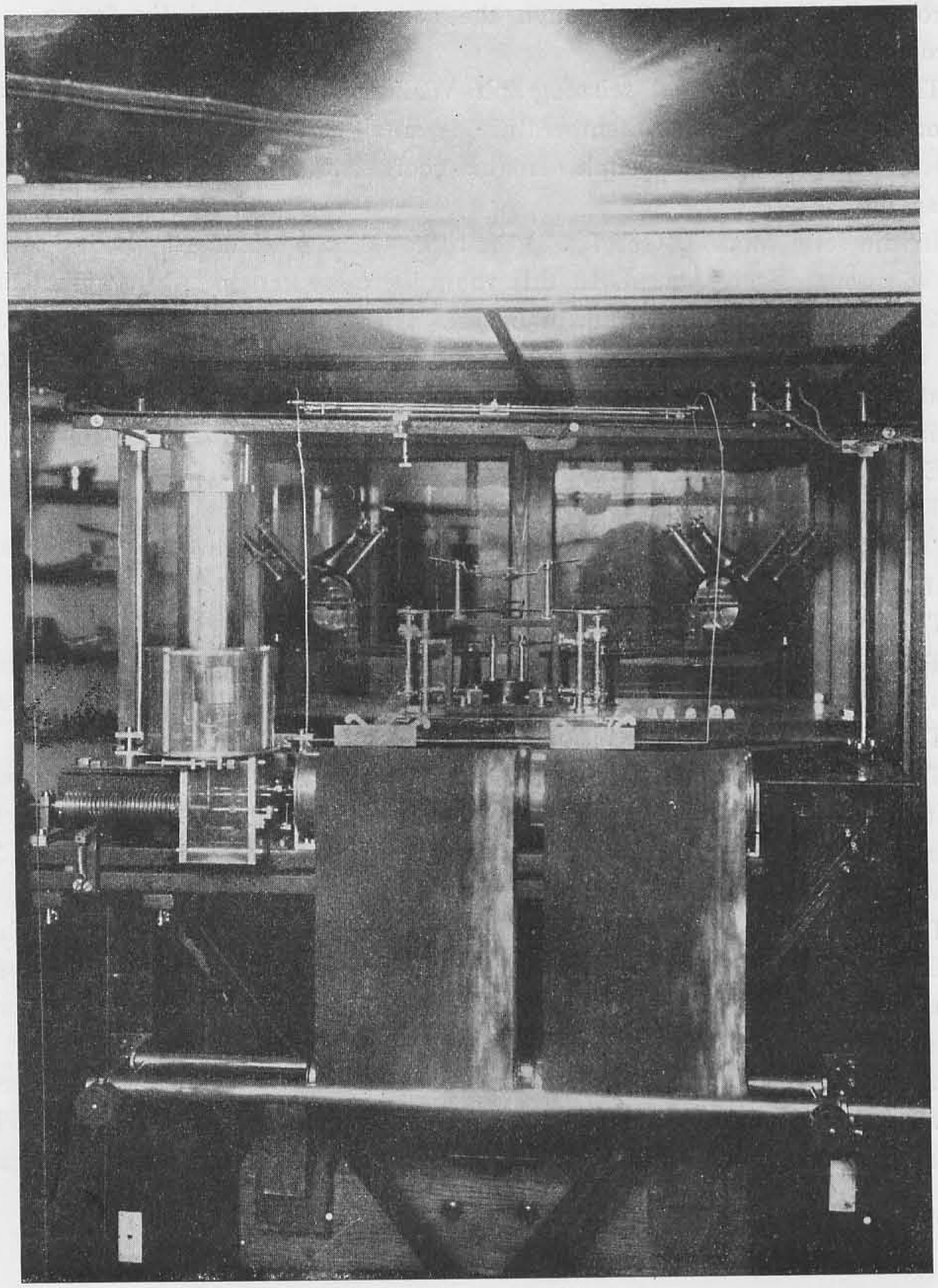


Fig. 2. Wiechert horizontal Seismograph.

All the instruments, except the torsion seismometers which are placed in cap. XIV, are in cap. XIII. Their places are marked in plate II.

The Wiechert horizontal seismograph W.-H. (see fig. 2) is placed in the big front-room *S*. Holes are cut through the concrete floor, and the frame is set in the ground.

The Wiechert vertical seismograph W.-Z. is erected in room *V*. As already mentioned, the variation of temperature is small in this room so that it is well suited for a vertical seismograph. In this room two of the clocks *C* of the station are also hung.

In the long room *L* (see fig. 3) the three Galitzin seismographs and one Milne-Shaw seismograph are placed. In this room there are two long brick piers, the back one 72 cm., the front one 65 cm. in height. The pendulums and the galvanometers stand on the back one, and on the front one are the three pieces of recording apparatus of the Galitzin seismographs and their lamps. The recording apparatus of the Milne-Shaw seismograph is on a table.

Each of the Galitzin pendulums rests on three iron plugs cemented in the pier. The Milne-Shaw seismograph is placed on a slate slab, which is laid on the top of the brick pier. The galvanometers, lamps and recording apparatus also stand on slate slabs laid on the piers.

The second Milne-Shaw seismograph is in room *I*.

Time signals are received by means of a wireless apparatus in *S*, and here there is an extra pier which can be used for experimenting with the apparatus.

The accumulators are placed in *R*.

The room next to the entrance is used for preparing the smoked paper.

In cap. XIV the American torsion seismometers stand on two piers in room *L*. The recording and auxiliary apparatus is on tables. In the rooms *V* and *S* there are two clocks, and the accumulators are in *R*.

The piers for the apparatus are built of brick and rest directly on the concrete floors of the buildings, and the Wiechert instruments are in immediate connection with the floor. This has the drawback that the records are visibly disturbed when somebody enters the station, but it was feared that the subsoil water would penetrate if the piers were built into the ground and did not join up with the floor. In most of the instruments the disturbance is slight; it shows mostly on the Wiechert horizontal seismograph, which is often passed during the daily work in the station.

The separate Instruments.

The 1000 kg. Wiechert horizontal seismograph supplied by Bartels in Göttingen is of the usual pattern.

The proper period is about 9 sec. for each component. The magnification is

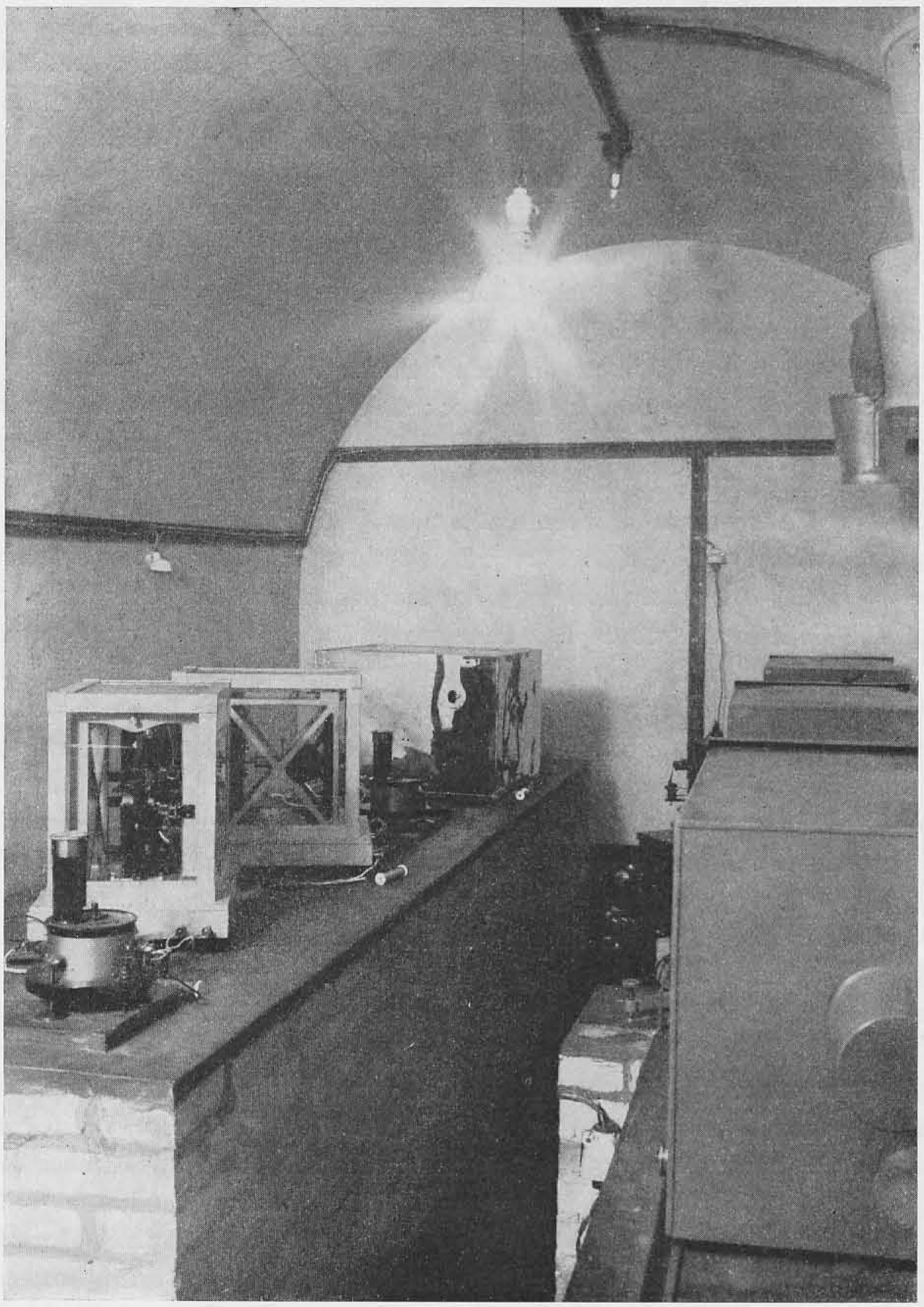


Fig. 3. The long Room.

about 200, the damping ratio about 4 and the coefficient of friction about 0.5. The constants have not altered much since the instruments were mounted.

The recording speed is about 12.5 mm/min. It is not quite constant, but varies periodically between 12.2 and 12.8 during a revolution of the drum; this is owing to a somewhat excentric placing of the drum against the clock-work.

The 1300 kg. Wiechert vertical seismograph was supplied by Spindler and Hoyer in Göttingen. Its period is about 6 sec., the magnification about 165, the damping ratio about 5 and the coefficient of friction about 0.2.

The recording speed is about 10 mm/min; but in this apparatus there is also a considerable periodical variation.

At first it proved difficult to get the regulating pendulums of both the Wiechert horizontal and vertical seismographs to work satisfactorily. Both pendulums were of the same construction; they were suspended on a metal point resting in an agate cup. The movement was irregular; they "beat", and the cup was worn by the point. After some small alterations had been made, the regulating pendulum of the horizontal seismograph worked well. In the vertical seismograph the original suspension was replaced by a Cardan suspension in 4 flat springs as used in the recording apparatus of the Galitzin seismographs. This suspension has proved very satisfactory.

The compensation for temperature of the vertical seismograph is very carefully adjusted, and as in addition the room is not exposed to sudden changes of temperature the seismograph works excellently; since it was put into working order, it has functioned well and the lines have not crossed.

Some care has been given to the smoking of the paper used for the mechanical recording, and a smoking apparatus has been constructed the cylinder of which is rotated very quickly by means of cog-wheels. The apparatus is placed in a box from which there is an outlet through a bent tube carried through the ceiling of the smoking room; on the top is a ventilator which is kept working while the smoking takes place. The paraffin used is mixed with a little camphor.

The Galitzin pendulums and their recording apparatus were constructed by Masing, formerly mechanic to the Russian Court; he worked for Prince Galitzin, and he has now a work-shop in Dorpat in Esthonia. There Professor Wilip continues his work on the improvement of the Galitzin pendulums, and the instruments erected in the Station København are of a new type. The horizontal pendulums have been described by Wilip in his paper: "On New Precision Seismographs", Dorpat 1926.

They differ in particular from the older pendulums by being suspended in flat springs. They are covered by glass cases fitting to the floor of the frame so as to be air-tight, and, as mentioned, they are erected on three plugs cast into the pier. The set of horizontal component pendulums, first erected in the station København, were sent to Scoresby-Sund in July 1927 (see the description of this station). In December 1927 they were replaced by another set of the same construction; but in these instruments thinner plate-springs have been used for the suspension. They have been furnished with scales which make it possible to adjust to a fixed zero position.

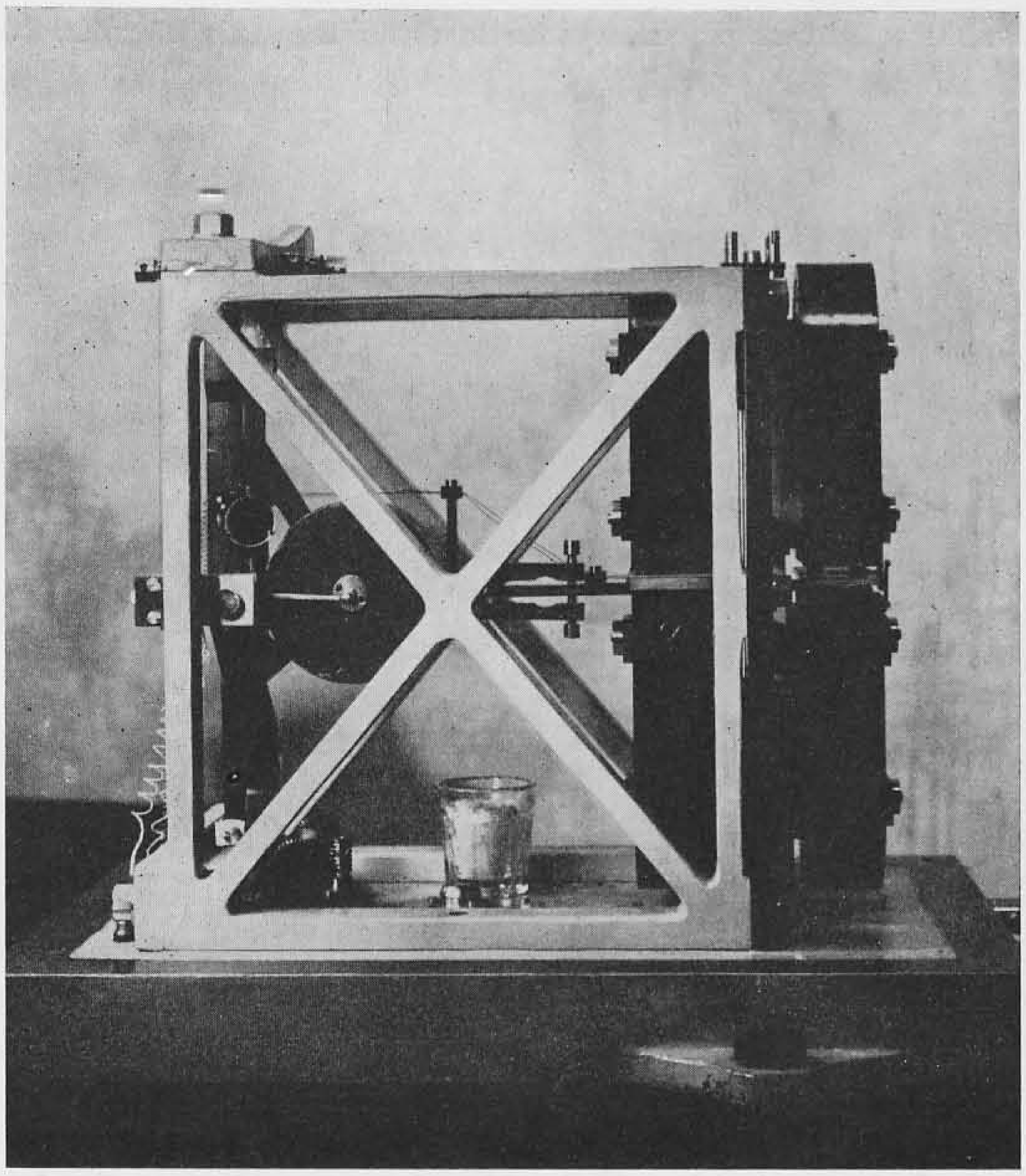


Fig. 4. Galitzin horizontal component Pendulum.

The horizontal component pendulums are adjusted for a proper period of oscillation of about 12.5 sec., and their galvanometers have this proper period. On account of the suspension of the pendulums, it is not possible to increase the proper period much above this value, and if it is attempted they become unstable. The transmission factor of both pendulums is about 100, and they have critical damping.

The vertical component pendulum (see fig. 5) is somewhat smaller than the original apparatus of Galitzin.

The oscillating frame is suspended by two sets of plate-springs and is held in position by two spiral springs. It is furnished with an adjustable compensation for variation of temperature in the form of a double spiral made of two metal bands soldered to each other along the edges and possessing different expansion coefficients. This spiral is fastened to the oscillating frame, and its free end, on which a movable weight is placed, points towards the axis of rotation. A rise of

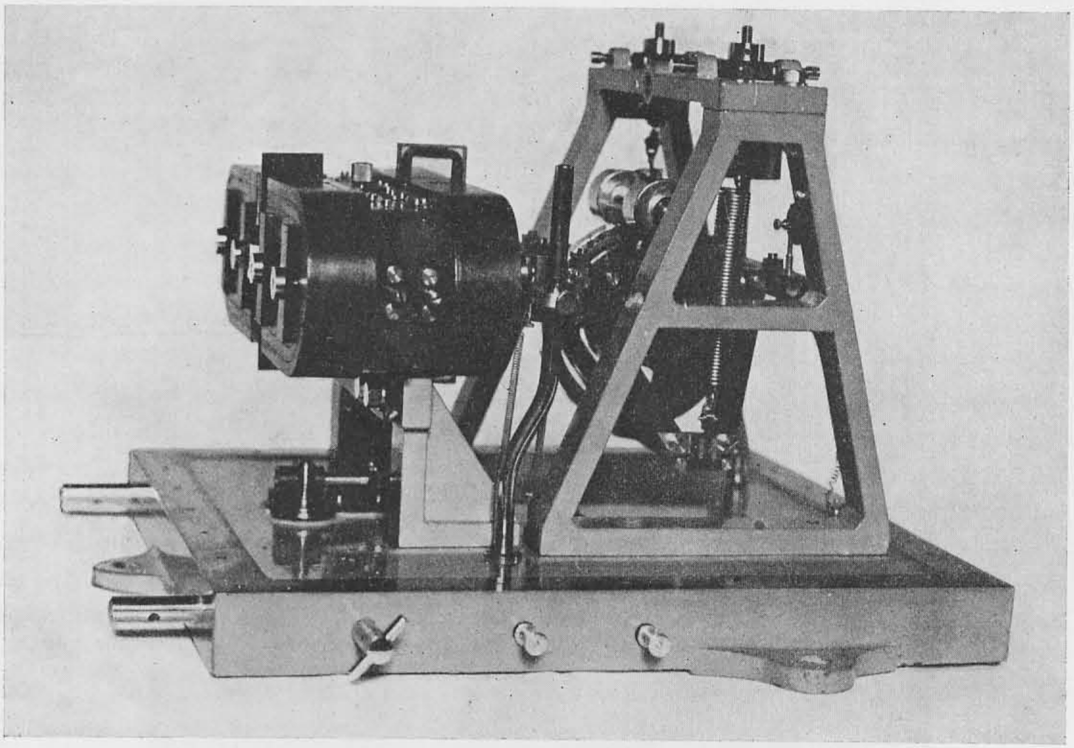


Fig. 5. Galitzin vertical component Pendulum.

temperature which, by prolonging the spiral springs, would cause the frame to sink, will, at the same time, bend the compensating spiral so as to let the weight advance towards the axis of rotation, and thus the equilibrium is preserved.

The compensation becomes stronger or weaker according as the weight is placed nearer or further from the end of the spiral, since its displacement depends on the length of spiral which contributes to it.

As the vertical seismograph is in the same room as the other seismographs and the recording apparatus, it is exposed to changes of temperature when the daily changing of paper takes place and when work with the other apparatus is carried out. As it was to be feared that the compensation would not suffice to exclude the effect of these changes, a double copper box has been placed round the glass case of the instrument, the two plates of the copper box being completely insulated from one another by cork. The outside of the box is nickelplated in order to absorb as little heat as possible. In the front and the back of the box there are panes of optical glass, which make visible both the mirror, used when the constants are determined, and the scale, used for adjusting the zero position. The key used for the adjustment is carried through the side of the box.

The vertical seismograph has worked satisfactorily. It has, however, been necessary to limit its proper period to about 10 sec. instead of increasing it to 11.5 sec., which is the proper period of the corresponding galvanometer. It has the usual drawback of the Galitzin vertical seismographs that its proper period varies much with its zero position. Besides, its construction is such that critical damping can only just be obtained and the transmission factor can not be made to exceed 100.

The Galitzin pendulums have electromagnetic damping, but instead of a pure copper plate, a plate is used consisting of two copper plates with an aluminium plate inserted between them. This is done in order to avoid the changing of the proper period by introducing the damping (See O. Somville: »Constantes des Sismographes Galitzine«, Ann. Obs. R. de Belgique, Série 3, I. 1922).

Each of the three seismographs has its own recording apparatus. They are worked by a clock-work with a spring and provided with a regulating pendulum in Cardan suspension.

The drum has at one end a projecting rim resting on two cylinders. At the other end there is, in prolongation of the axis of the drum, a screw-cut rod resting in a bearing formed by two easily moved wheels. The clock-work turns one cylinder; this cylinder works the drum, and the lengthways motion is brought about at the same time, the wheels following the groove of the screw-cut shaft. The recording works are delicately made, and as the movement from the clock-work is transferred to the circumference of the drum, the variation of the recording speed is small. The recording speed is 15 or 30 mm/min; it can be altered by the changing of a cog-wheel. With a speed of 30 mm/min the drum is carried its full length in 24 hours, with a speed of 15 mm/min it is only carried half-way, and then the paper can be used for the records of 48 hours, or 2 seismographs can record on the same film for 24 hours. This is made use of occasionally, e. g. during repairs.

6 volt tube lamps with a single luminous wire are used for recording lamps.

The two Milne-Shaw seismographs have been supplied by J. J. Shaw, West Bromwich, and are of the standard type which is now so widely used. They are adjusted for a proper period of 12 sec. and a damping ratio of about 20. The magnification is about 300. For an extended description see J. J. Shaw: »The Milne-Shaw Seismograph«.

The Wood-Anderson torsion seismometers erected in cap. XIV have a pure torsion period of 6 sec., but have been adjusted for a proper period of about 10 sec. For their description see Anderson and Wood: »Description and Theory of the Torsion Seismometer«, Bull. Seism. Soc. America XV, 1. 1925. The seismographs and their recording apparatus have been supplied by Henson Co., Pasadena, California.

The recording apparatus is worked by electricity. The recording speed is 30 or 60 mm/min. The spacing of the lines is only $2^1/_2$ mm.

Time-marking.

The time-marking is worked electromagnetically and is controlled by 3 pendulum clocks, furnished with minute-contacts.

On the photographic recording apparatus an electromagnet draws a plate in front of the light of the recording lamp; on the Galitzin and Milne-Shaw apparatus the plate is opaque, so that the light is interrupted whilst the minute-contact lasts. On the torsion seismometers the plate is a piece of thick glass inclined to the direction of the light, which is therefore refracted. The time-mark then appears as a hook on the line. The advantage of this is that no part of the record is lost; but it may be difficult to trace the marks in an earthquake diagram. On the Wiechert apparatus the pen is lifted by means of a frame, moved by an electromagnet.

The circuits of the electro-magnets pass through the pendulum clocks, and into these minute-contacts of a special design have been built (see fig. 6).

On the counting wheel arbor are two small discs *A*; their circumference is spiral, the outer winding of the spiral falling abruptly towards the inner one. The levers *B* and *C* pivoted at *b* and *c* carry two agate pins which rest one against each disc. To the levers contact pieces are fastened, a plate *n* to *C*, and, vertically above this, a pin *m* to *B*.

At every second-beat the spirals move underneath the agate pins. The spirals are similarly placed, but the agate pin on the lever *B* is a little in front of the one on *C*, and therefore, when, at a certain second, *B* falls from the outer winding of the spiral to the inner one, a contact is made which lasts until *C* falls a few seconds later.

The distance of the agate pins, and thus the length of the minute-contact, can be regulated. *C* is carried by the lever *E*, pivoted at *e* and held in position against the screw S by the spring F. When the screw is turned the position of E is altered so that the agate pin of C is moved forward or backward on the disc.

The position of E has been adjusted so as to give a minute-contact of 3 se-

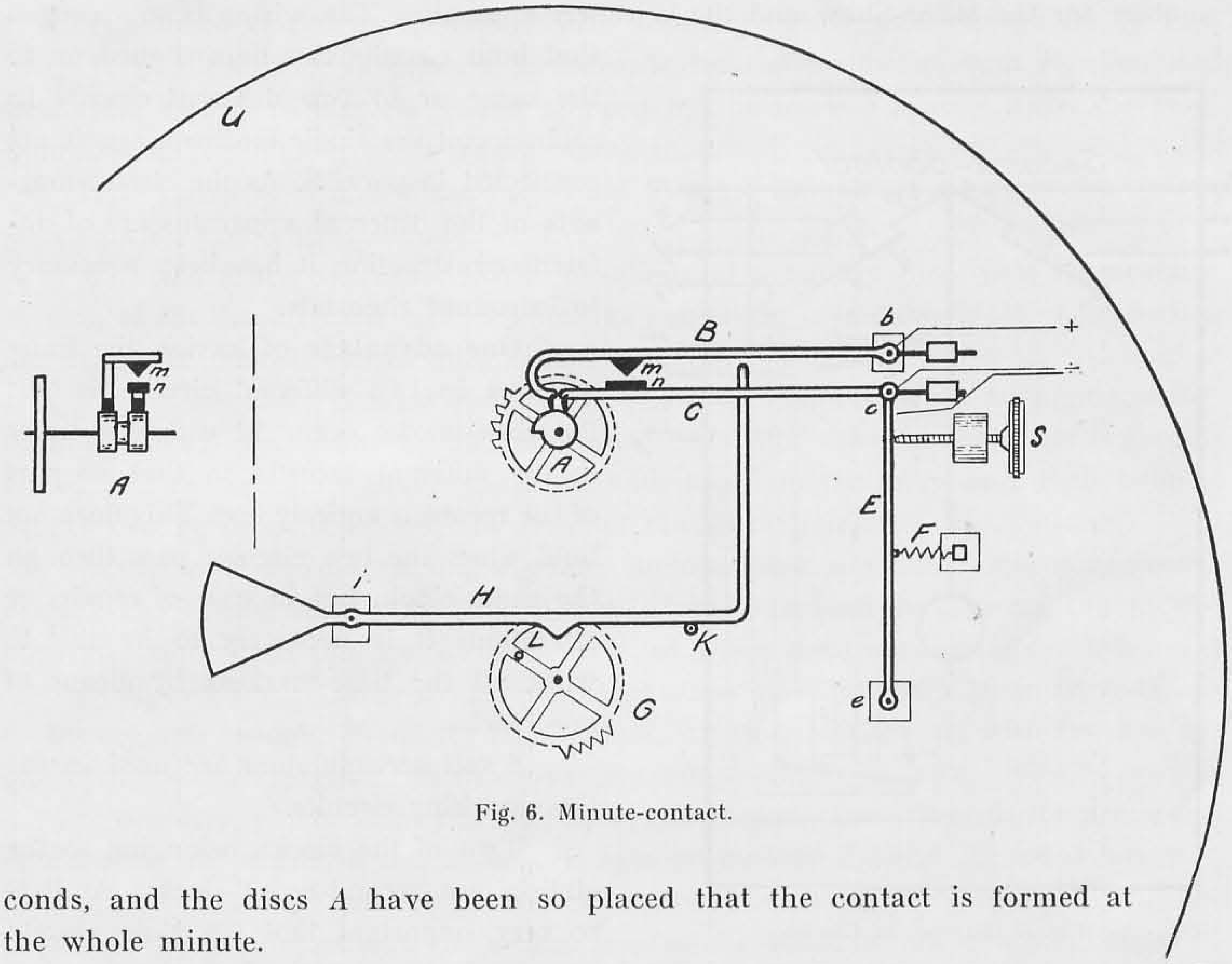


Fig. 6. Minute-contact.

conds, and the discs A have been so placed that the contact is formed at the whole minute.

The minute hand wheel has a pin L projecting from its face. At every full hour it raises the lever H to meet B, which is thus prevented from falling. Therefore no contact is formed at the full hour and the time-mark is left out in the diagrams.

In addition to the primary minute-contact described above, a secondary minute-contact has been introduced into the clocks by means of a relay (see fig. 7). The circuit of the primary minute-contact is conducted through the solenoid wire of the electro-magnet of the relay and when the armature is attracted a contact is formed.

One clock, therefore, can control two time-marking circuits. One circuit can be connected to the primary minute-contact by m_1 and m_2, the other to the secondary one by m_3 and P_1 as shown in the figure.

Cap. XIII has two clocks provided with minute-contacts, cap. XIV has one. One of the clocks of cap. XIII is manufactured by Max Richter and its rate is very satisfactory.

In cap. XIII there are two time-marking circuits, one for the Galitzin and another for the Milne-Shaw and the Wiechert apparatus. The wiring is so arranged that both circuits can be switched on to the same or to two different clocks. In each circuit the single electro-magnets are connected in parallel. As the electro-magnets of the different apparatus are of different construction it has been necessary to introduce rheostats.

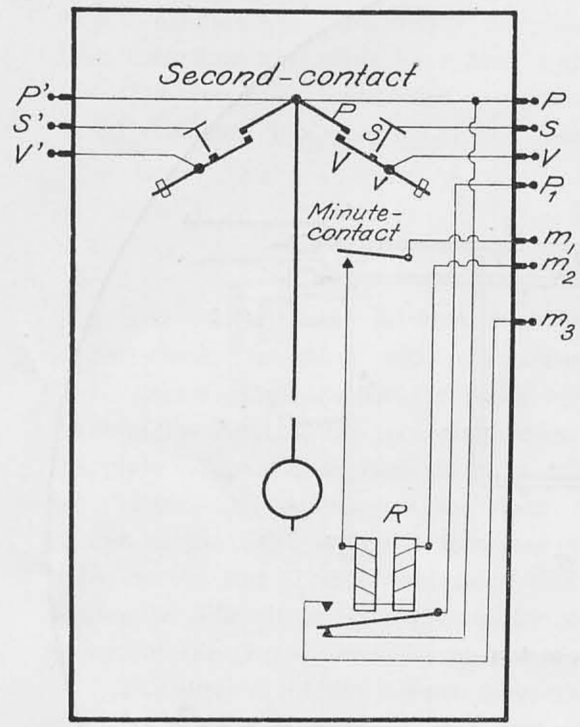


Fig. 7. Diagram of Clock.

One advantage of having the time-markers in two different circuits is that the time-marks occur at different times in the different records so that no part of the record is entirely lost. This does not hold when the two circuits pass through the same clock, but in case of repairs or alterations it is necessary to be able to work all the time-markers by means of one clock.

6 volt accumulators are used in the time-marking circuits.

Two of the clocks belonging to the station are second-order clocks. As it is so very important that the time should be accurately determined, the station has been provided with a Riefler clock in a dust-proof case with automatic winding, and the two second-order clocks have been synchronised with the Riefler clock. This has been hung in the in-most room, *V*, in cap. XIV. The room is entered very rarely and therefore the clock hangs undisturbed at an almost constant temperature.

Three leads passing through the air join the 2 caponieres and serve for the synchronisation and the time-comparison of the clocks.

Time Service.

The rate of the Max Richter clock is determined daily by means of the scientific time-signals from Nauen or from Tour Eiffel and the other clocks are compared with this clock by means of a chronograph.

The three clocks are provided with ordinary lever contacts, see fig. 7. The lever *V*, pivoted at *v*, is pressed downwards by the pendulum arm *P* when the pendulum swings to the left, and is stopped by the screw *S* exactly when the pendulum is in the middle of its swing to the right.

If *P* and *V* or *S* and *V* are connected to the terminals of a battery the circuit is completed every other second.

If *P* and *S* are connected to the terminals of a battery there is a momentary closing of the circuit each second when the pendulum is in the middle of the swing and the lever makes contact with both *P* and *S*.

This momentary closing of the circuit is made audible in the telephone of the radio-apparatus by means of an inductance coil. When the second-beats thus obtained and the scientific time-signals are both heard in the telephone, their coincidences can be determined and the error of the clock found.

As the radio-apparatus and the Max Richter clock are not in the same room, a slave clock worked by the Max Richter clock has been hung over the radio-apparatus, and from this the seconds are read when the time-signals are taken.

For purposes of comparison, the clocks are made to mark their seconds on a chronograph record. *P* and *V*, for instance, are put into circuit with the coil of one of the electro-magnets which move the pens.

P, however, is not connected directly to the chronograph; through the armature of the relay *R*, previously mentioned, it is connected to P_1, and P_1 and *V* are put into circuit with the chronograph coil. The circuit is closed every second when the pendulum forms contact with the lever, except at the whole minute while the minute-contact lasts and the armature is attracted; then there is no longer a connection from *P* to P_1. The chronograph thus marks every other second with the exception of the one occurring at the whole minute, and it is made possible to number the seconds on the chronograph record.

The second-contacts (P_1 and *V*) and the secondary minute-contacts (P_1 and m_3) of the various clocks are connected to a panel fixed near the chronograph, and on this they can be connected by plugs to the two pens of the chronograph.

If the seconds of the Max Richter clock are marked by one pen, and those of another clock by the other pen, the error of the clock can be determined, and, by repeated determinations, the rate of the clock.

It is necessary to know also the error of the minute-contact of a clock, since it is the minute-contact which marks the time on the seismographic records, and the minute-contact does not necessarily occur exactly on a whole second. This error may be found by means of the chronograph if one pen is put into circuit with the minute-contact, the other with the second-contact of the same or another clock.

As two pens are used for comparison of the clocks, their parallax must be known. Therefore it is so arranged that the pens can be connected in parallel in one and the same circuit and moved simultaneously by means of a switch. Then their parallax can be measured on the record.

The Care of the Station.

As the station is about 13 km. from the Institute the daily duties are left to a caretaker who lives near the station.

The station is as a rule only visited once a day. The films and the smoked papers are changed; the clock-works are wound, and the zero positions of the pendulums are examined and altered if necessary. The temperature and the degree of humidity are read in all the rooms. The outside minimum and maximum temperatures of the night and day are read on a thermometer placed by the entrance door. The barometer is read and the wind-force is noted.

The bowls and bags containing chloride of calcium are inspected and refilled if necessary. If the degree of humidity tends to rise the drying apparatus is started.

At 9.30 or 12.00 G.M.T. the scientific time signal is taken and the daily comparison of the time-marking clocks is made.

The smoked paper is fixed, fresh paper is smoked and the films are developed.

All notes of temperature, degree of humidity, time-signals etc. are entered on a form and sent, together with the records, to the Institute.

On entering the station the caretaker marks the time on the seismographic records by means of a hand-connector; three 10 sec. breaks at intervals of 10 seconds are made, beginning at the full minute; a note is made of the time of the minute. When the work at the station is finished, the time is marked with a break of half a minute beginning at a full minute.

At the innermost entrance door in cap. XIII there is a contact which completes one of the time-marking circuits of the seismographs when the door is opened, thus causing a break in the records. In this way it is possible to check each entrance to the station and to avoid confusing the disturbance produced with seismic movements.

The constants of the Wiechert instruments are determined once a month, and the caretaker has been taught to carry out the instrumental part of the determination. The constants of the other instruments are determined by scientific assistants. In the beginning the constants of the Galitzin seismographs were determined frequently but, when it was found that the constants did not vary much, a determination was only made about once every second month. The disposition of the instruments required for the determination of the constants is somewhat difficult as the seismographs and the recording apparatus are so close. The telescopes for the reading of the galvanometers must stand between the piers, but the pendulums are all so placed that from room *S* their mirrors can be sighted at a distance of 5 m. In one of the horizontal pendulums the mirror is on one side of the axis. A Löbner stop-watch to 0.01 sec. is used for the determination of the period of oscillation.

The Reading of the Records.

The reading of the records and the calculation of the constants and the time-determinations is done in the office of the Geodetic Institute in Copenhagen.

The constants of the Galitzin seismographs are calculated by means of Somville's formulae.

In the determination of the coefficient of friction for the Wiechert instruments, account is taken of the residual damping which remains when the proper damping has been removed; then the values obtained for the coefficient of friction are less variable.

The measurement of time in the records is done by means of converging glass scales made by the mechanic Læssøe-Müller in Copenhagen. The length of the minute is divided into intervals corresponding to 5 seconds and every other line is dotted. The lines are fine and drawn in red, so as to show clearly also on the smoked paper. A so-called "Messschieber", constructed by Lutz and manufactured by Edelmann und Sohn, München, is also at hand; it is used for the measurement of particularly well marked phases.

The records are read as soon as the films have been developed and dried. The readings of large earthquakes are sent to the international bureau in Strasbourg and to Professor Turner in Oxford.

The records of all the seismographs are used, but, in the bulletins, the phases are given without reference being made to the seismographs on which they have been recorded, as it would be impracticable to publish the readings of the individual records.

All clearly marked phases are read whether they can be identified or not.

The maxima are, as a rule, only measured on the Galitzin records, but if these are missing, the measurement is done on the Wiechert records. The time for the maxima are given correct to $^{1}/_{10}{}^{th}$ minute and no correction for retardation is introduced.

Not only the records of the station København but also those from the two Greenland stations, Scoresby-Sund and Ivigtut, are read in the Geodetic Institute. In addition to this, according to an agreement with the Astronomical Observatory in Lund, the records of its 1000 kg. Wiechert horizontal seismograph are read.

The records of the different seismographs of the station København have been found to supplement each other excellently.

The Galitzin instruments are superior to the others owing to their high power of magnification, and their exactly determined constants give greater value to the records when the determination of the azimuth of the epicentre, the angle of emergence, the true earth movement in the maxima, etc. are concerned. They are, however, a good deal disturbed by microseismic movement, especially in winter; the horizontal seismographs, having a proper period of 12.5 sec., have their highest power of magnification for earth-movements with a period of 7.2 sec. and the most frequent periods in the ordinary microseismic movement come near to this.

The low recording speed of the Milne-Shaw instruments, which hinders exact measurement, makes the phases more conspicuous, and often the interpretation of a diagram can be made with greater certainty from a Milne-Shaw record than from any of the others.

The Wiechert instruments give details in short periodic motion which the others are incapable of rendering. Also, in very strong earthquakes, when the Galitzin records become confused and difficult to disentangle, the Wiechert records render good service.

The Wood-Anderson torsion seismometers with a period of ca. 10 sec. have a power of magnification lying between that of the Galitzin and the Milne-Shaw instruments; they are being altered into short periodic seismographs intended for near earthquakes. When this has been done the station will be well equipped for the recording of both near and distant earthquakes.

The Seismological Station Scoresby-Sund.

For a long time seismologists had desired to have a station erected in the far north at a great distance from other stations, since such a station would be of great scientific value. Therefore, in 1925, the Director of the Geodetic Institute applied to the Board of the Carlsberg Foundation for a grant towards the expenses of erecting such a station. The Board granted the necessary funds and in the summer of 1926 an expedition went to reconnoitre in order to find a suitable place for the station. After various places had been tried, Scoresby-Sund, a recently formed colony on the east-coast of Greenland, was determined upon (see plate III). Near the colony, which is situated at Rosenvinges Bay, a suitable plateau was found, 69 m. above the sea level; here the bed-rock in many places extended to the surface.

The proposition was looked upon favourably by Mr. Daugaard-Jensen, Chief of the Administration of Greenland, who gave it valuable assistance. In 1927 Mr. Daugaard-Jensen applied for and obtained permission from Parliament to erect a wireless station in Scoresby-Sund which was to be combined with the seismological station and established at the same time. The Carlsberg Foundation and the state have jointly borne the expenses of the combined station.

A steamer calls at the colony of Scoresby-Sund only once a year. Therefore it was necessary in the planning of the station to lay stress on making everything as perfect and reliable as possible and at the same time simple enough to need the attention of one man only.

First of all, it was important to find means of erecting the seismographs in such a way that they were well protected against inclement weather. Heavy storms are very frequent in this latitude, and the variations of temperature are great; dangerous floods may occur in spring. It was found to be most appropriate to blast a cellar in the rock, and to cover it with a low isolating building.

For the station, which was to be established as a first order station, Galitzin pendulums were chosen. It influenced the decision that these instruments are so small that they do not require much room for their erection. The recording apparatus, not needing so much protection, was to be placed in the wireless station building, which was to be erected at a distance of about 50 m. from the cellar.

Dr. Nøkkentved of the engineering firm Nøkkentved & Friis Jespersen took great pains and rendered very valuable assistance in the planning of the buildings for the station.

The Ministry of the Navy has in different ways rendered assistance to the carrying out of the work by granting first the use of the patrol boat "Fylla" for the reconnoitring, and secondly a years leave to Mr. Janus Sørensen, to whom was allotted the responsibility of erecting the station. The Institute wishes to express its best thanks to the Board of the Carlsberg Foundation, to the Ministry of the Navy and to Mr. Daugaard Jensen, without whose valuable help it would have been impossible to accomplish the enterprise.

On July 23rd 1927 Mr. Janus Sørensen, with 2 assistants, set off to Scoresby Sund in the boat "Gustav Holm" and arrived on August 3rd.

When the unloading was completed and all the instruments and fine material had been stored temporarily in the house where the men were to live, the erection of the station on the chosen site, east of the colony, was begun. This was about the middle of August.

The schedule of the work which had to be completed before the middle of October, when winter would begin, was: transportation of timber, wood and other accessories for the 2 buildings, and 46 barrels of concrete, as well as the boards for the scaffolding; further transport of 25 m^3 of sand for moulding which was to be fetched by boat from a place about 5 km. away from the colony and carried up the rest of the way to the site of the station; the erection of the building for the wireless station and the recording apparatus and its external completion; the blasting of a cellar in the rock and its lining with concrete, and the erection of the building over the cellar.

Although the assistance of the Eskimoes was rather limited, and was used chiefly for transport, favoured by fine weather the men succeeded in carrying through the project.

After the alignment and marking out of the positions of the buildings had been done, the work was begun. The men were divided into 2 gangs, the one undertaking the erection of the building for the station, the other the boring and blasting of the cellar.

The Station-House.

The station-house (see plate IV) measures externally 4,46 × 15,01 m. and is erected on a concrete foundation cast directly on the rock; the concrete is made in the proportion 1:4:6.

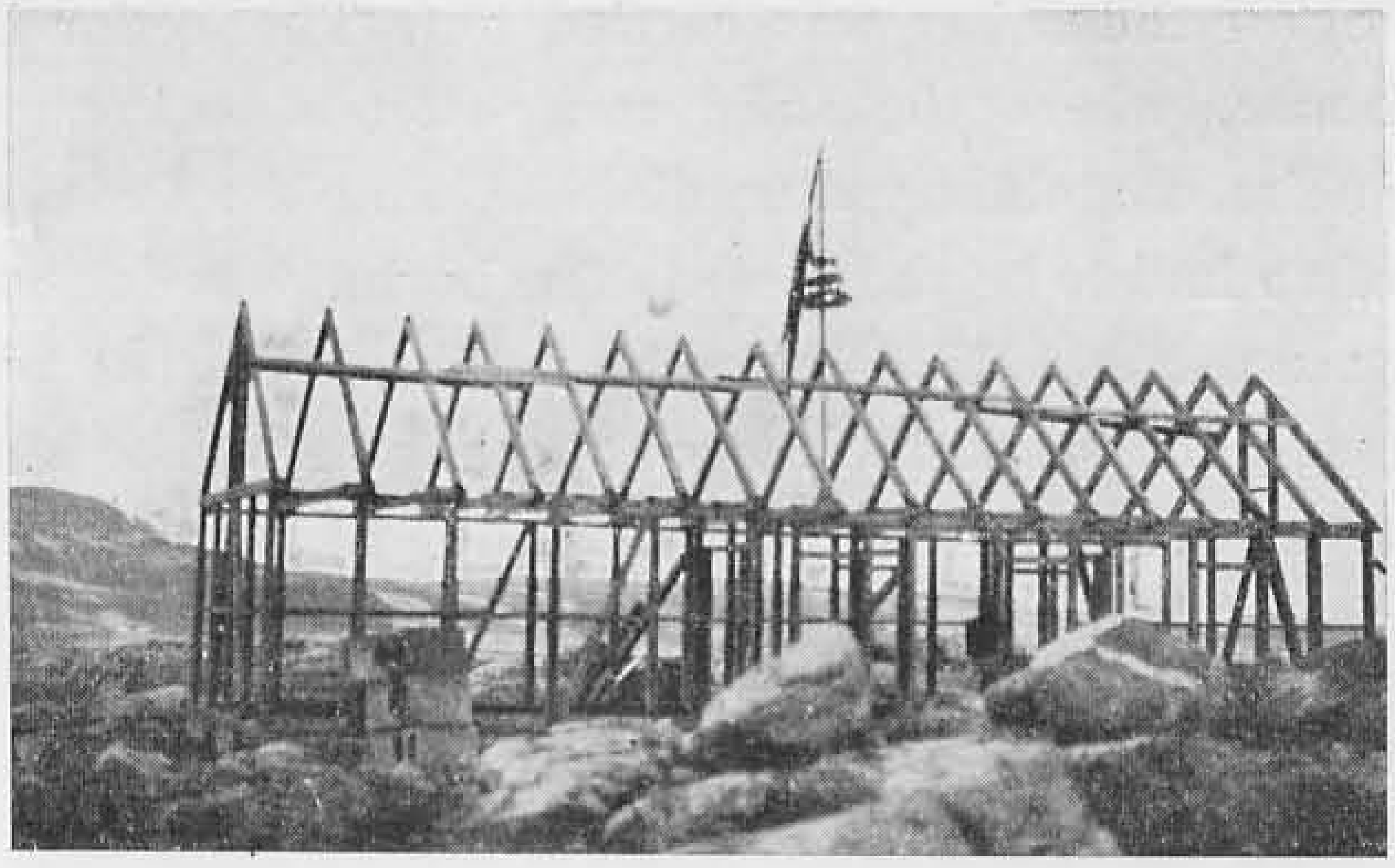


Fig. 8. Station-House under Erection.

The half-timber construction consists of 4″ × 4″ plane timber and 2″ × 4″ horizontal boards all joined together with wooden nails. It was made in Copenhagen, and the house as well as the building for the pendulum cellar was erected on trial before the departure.

The lower wooden frame is bolted to the foundation by means of several pieces of round iron cast into the concrete. The upper frame is also joined to the roof beams by iron bolts.

As shown in plate IV, the walls of the house have three boardings, the space between the two innermost being filled with wood-shavings. The outside of the middle boarding is covered with asphalt paper and 2″ × 2″ wooden lists are nailed to it; on these lists the outer boarding has been nailed and its joints have been covered by wooden lists.

The partitions of the house have two boardings with wood-shavings between them, and the walls in the recording- and the transmitter-room have been covered with Swedish compoboard. The space between the ceiling-boards and the attic floor is also filled with wood-shavings.

As the rooms are so very well insulated it has been possible during the winter to keep a suitable temperature by means of a continually burning stove with a comparatively small consumption of coal, viz. about 300 kg. a month.


Fig. 9. Station-House.

The roof has a single wooden boarding covered by asphalt-paper "Icopal B" on wooden lists.

On August 27th the half-timber construction was erected and on October 13th the outside of the building was finished so that the indoor work was secured for the winter.

The Pendulum Cellar.

Simultaneously with the erection of the station-house the blasting of the cellar was carried out. The cellar is placed 50 m. north of the station-house, where the solid rock extends to the surface. The bedrock here consists of gneiss containing some diabase, and it was very hard to work, so that the stonedrill often had to be sharpened. The boring was done with a rose-drill (no mechanical power was used) until a suitable depth had been reached, when the blasting was done.

The work took about 25 days and the stone-refuse was about 22 m^3. The dimensions of the cellar after the casting of the concrete were to be 2,10 $\times$ 3,55 m. and the depth 2 m. (see plates V and VI).

Fig. 10. Building over Pendulum Cellar under Erection.

After the cellar had been blasted, the base of the pendulums was cast up to the level of the floor. Then the scaffolding was put up, and walls and bottom were faced with rough concrete in proportion 1:4:8; to this was added a layer to insulate against the moisture. For this purpose "sealit", a pitch-like material, was used, applied to a thickness corresponding to a consumption of $2^1/_2$—3 kg. per m^2. In order to prevent the moisture from permeating round the pendulum-base a groove was made round it in the casting, and this was filled afterwards with sealit.

A coating 10 cm. thick was cast on the walls and the bottom in the proportion $1:2^1/_2:3^1/_2$, cross armoured with 7 mm. round-iron, and then the pier for the pendulums was built of bricks to a height of 20 cm. above the floor.

A roof of reinforced concrete, 20 cm. thick, was cast above the cellar, and in this a solid wooden frame was placed for the trap-door.

Over the cellar a low wooden building was built of half-timber construction with three boardings like the station-house, the only difference being that in this case the roof has three boardings like the rest of the building; the space between the two lower boardings has been stuffed with wood-shavings (see plate VI).

The dimensions of the building are 5,17 $\times$ 6,62 m., and the ridge of the roof is only 2,20 m. above the rock.

The entrance to the building is through an iron trap-door with a rubber frame and turn-buckles for fastening; it is placed in one gable, and from here a corridor leads to the trap-door of the cellar. It is necessary to crawl to pass through the corridor, which is 75 cm. wide and 90 cm. high at the lower side; the sloping roof forms the ceiling. To militate against changes of temperature when the cellar is entered the corridor has two doors.

As shown in plates V—VII the rest of the building is almost filled with stones. About 80 tons of stones were used, and they cover an area which extends about 1 m. over the outline of the cellar. The space between the toplayer of the stones and the ceiling is filled with wood-shavings.

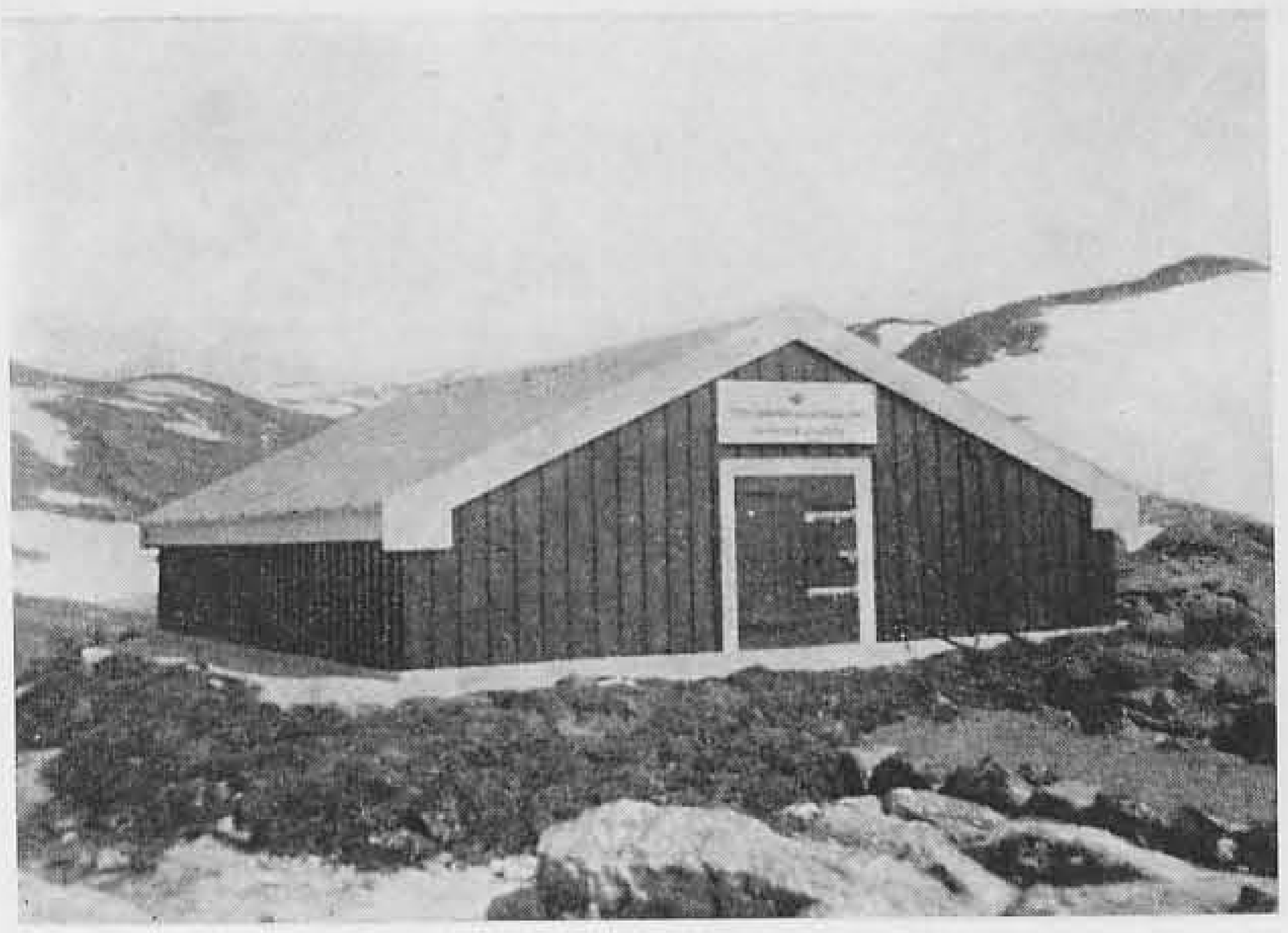


Fig. 11. Pendulum Cellar.

As the casting was not finished until Sept. 25th, when the rock had already begun to freeze, it was very difficult to dry the cellar. Walls and ceiling were covered with a coat of hoar frost a couple of centimeters thick which had to be scraped off. After this the drying was chiefly done by means of a kerosene stove, and by directing the flames of a powerful blow-lamp to the concrete; later on, a drying apparatus as described on page 5 was also used.

In December, after this slow drying process, the cellar was treated with ceresit, a chalk-like material which, mixed with liquid concrete, penetrates into the pores of the concrete and prevents the moisture from percolating. The walls and the ceiling were then covered with ekspanko-sheets (cork) 3 cm. thick. After this the electric wiring was fitted.

The use of the kerosene stove for the drying of the cellar was continued until June 1928, and therefore it was not possible in the first year to ascertain whether the stone isolation was effective. But in the month of July the temperature remained almost constant, i. e. at 2° C. while the variation of the outside temperature amounted to 15—20°.

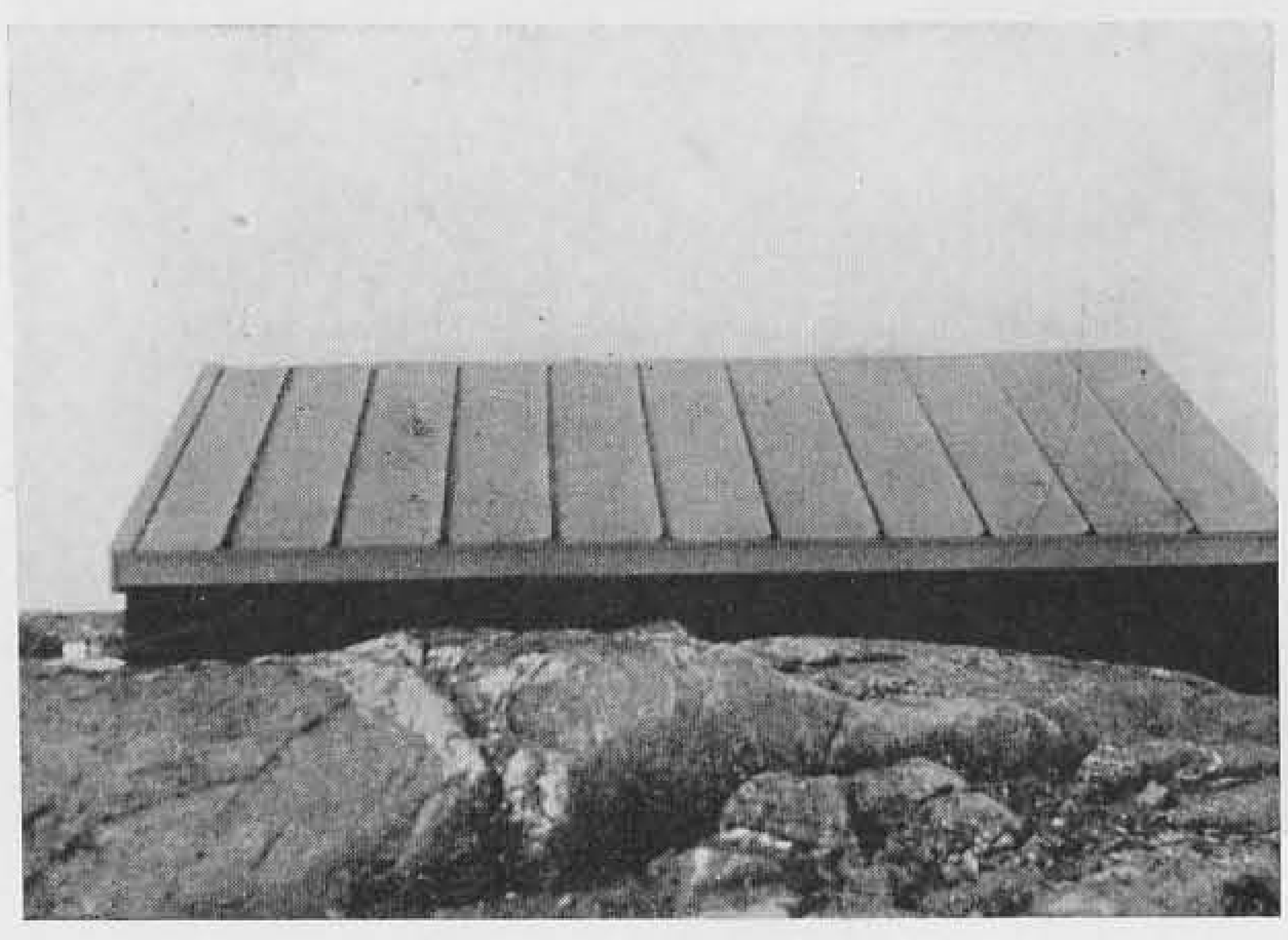


Fig. 12. Pendulum Cellar. Side View.

The Radio Plant.

In the autumn, when the casting of the pendulum cellar had been finished, the work of fitting the inside of the station-house was continued.

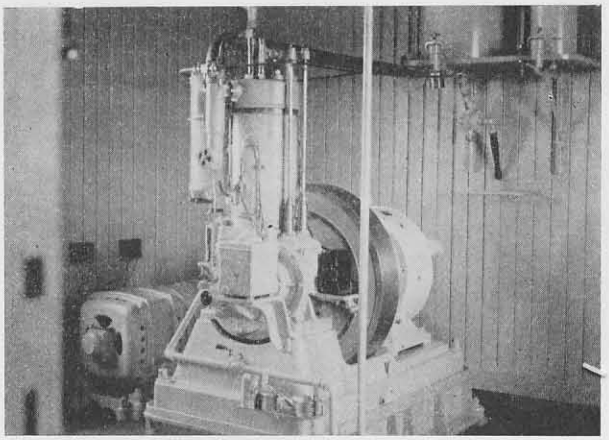


Fig. 13. Motor.

The house has three rooms, one for the primary power plant and the converter, one for the receiver and the transmitter, and a third for the recording apparatus of the seismographs. The rooms were boarded inside and the wirings for the seismic plant, the radio plant and the electric lighting were mounted. In the middle of October the converter and the heavy motor-dynamo, weighing 1100 kg., were carried to the station by dog-sledges. When the transmitter and the power-plant had been fitted, connection was established with Reykjavik and Angmagsalik (about 65° 37′ N. 37° 33′ W.).

Because of the isolated and inaccessible position of the colony, instead of one of the more sensitive valve transmitters, it was thought advisable to fit a common spark-transmitter, in which repairs and possible exchanges of separate parts are easier to carry out than in the more complicated valve-transmitters.

The output of the transmitter is 2 kw. with a maximum antenna current of 15 ampères.

The primary power-plant consists of an 8 hp. one cylinder, 4-stroke kerosene motor, to which is connected a 5 kw. 110 volt direct current compound dynamo. The consumption of kerosene is very small, being only about 300 gr. per eff. hp. per hr. The converter consists of a 6 hp. direct current shunt motor, 100 volts × 50 ampères, directly connected to a 3 kw. 500 cycles alternating current generator, 200 volts × 15 ampères.

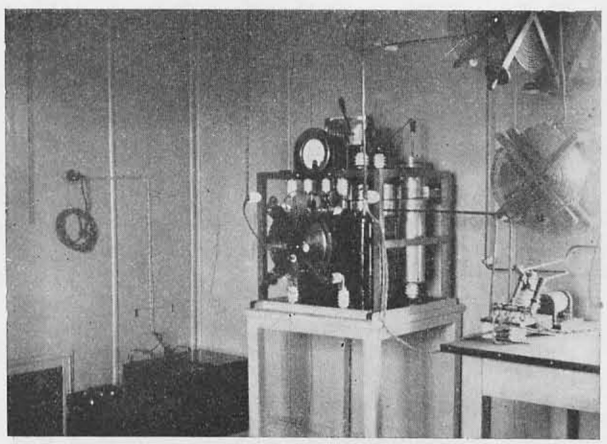


Fig. 14. Transmitter.

The distribution of the 110 volt current is controlled from a panel in the engine room; connections can be made to the transmitter, to the electric lighting of the station-house and the pendulum cellar, and to the charging of 6 and 60 volt accumulators.

The Recording Room.

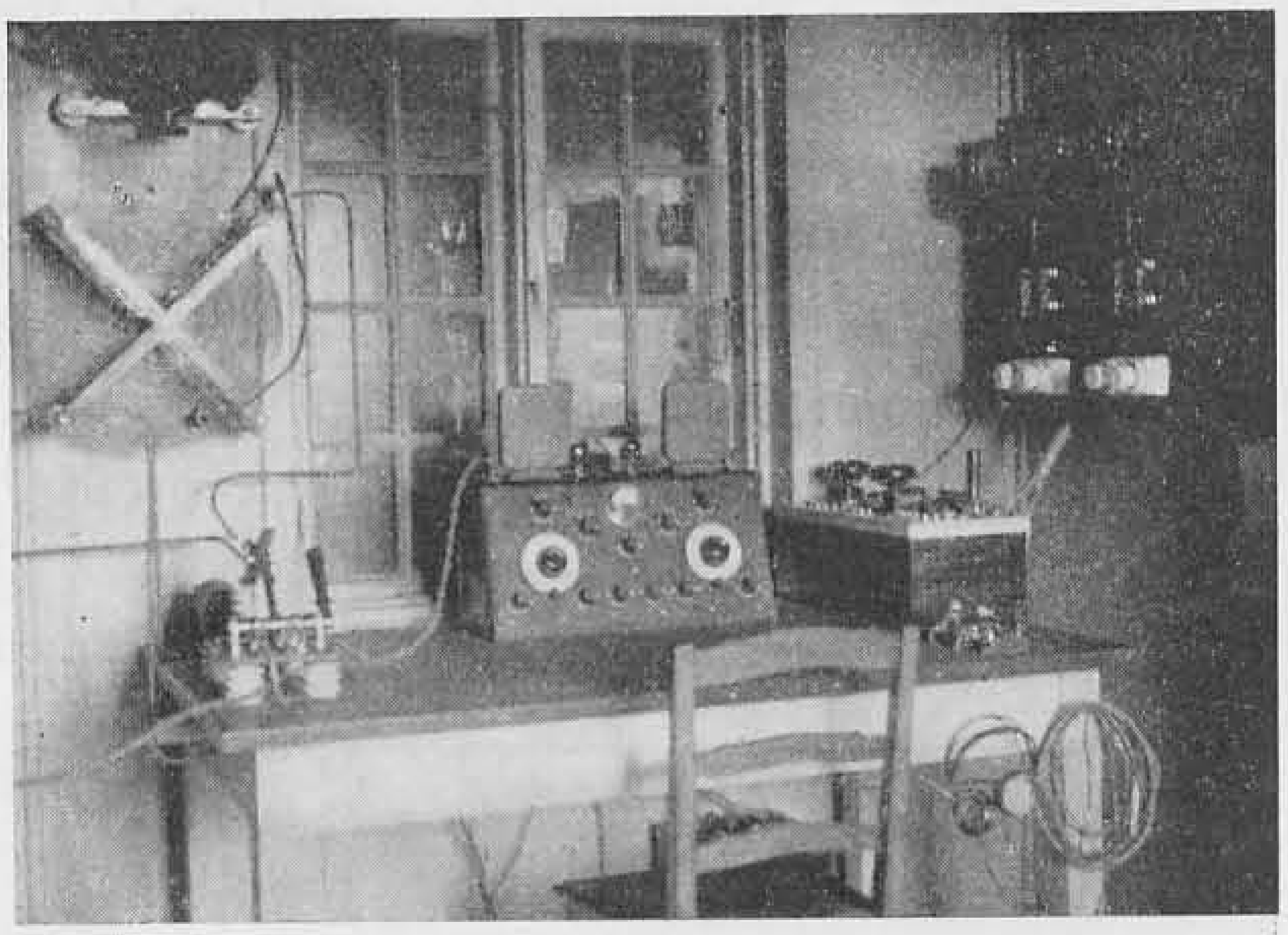


Fig. 15. Receiver.

The area of the room is 4× 6.5 m. It is heated through holes in the wall by the iron stove in the adjoining transmitter room. The stove burns continually, but nevertheless the variations of temperature are considerable, the temperature varying from about 0 to 16° C.

The room has no windows. It has two 110 volt white lamps in the ceiling and two plug-connectors for 110 volt amber hand-lamps. These lamps can only be used when the motor is running, and therefore 6 volt lighting has been installed in this room as well as in the pendulum cellar; there are three amber lamps in the ceiling. The current for the 6 volt lighting comes from a 6 volt accumulator in the transmitter room.

There is another 6 volt accumulator furnishing the current for the recording lamps.

Plate VIII shows a plan of the recording room and the position of the recording apparatus, the lamps and the galvanometers.

The piers are 50 cm. high and are cast in concrete directly on the rock; the concrete floor is cast round the piers.

A base 9 cm. high is cast on each pier for the galvanometers.

There are 3 pieces of recording apparatus, one for each component. They are of the same construction as those used in the station København and they also are supplied by Masing.

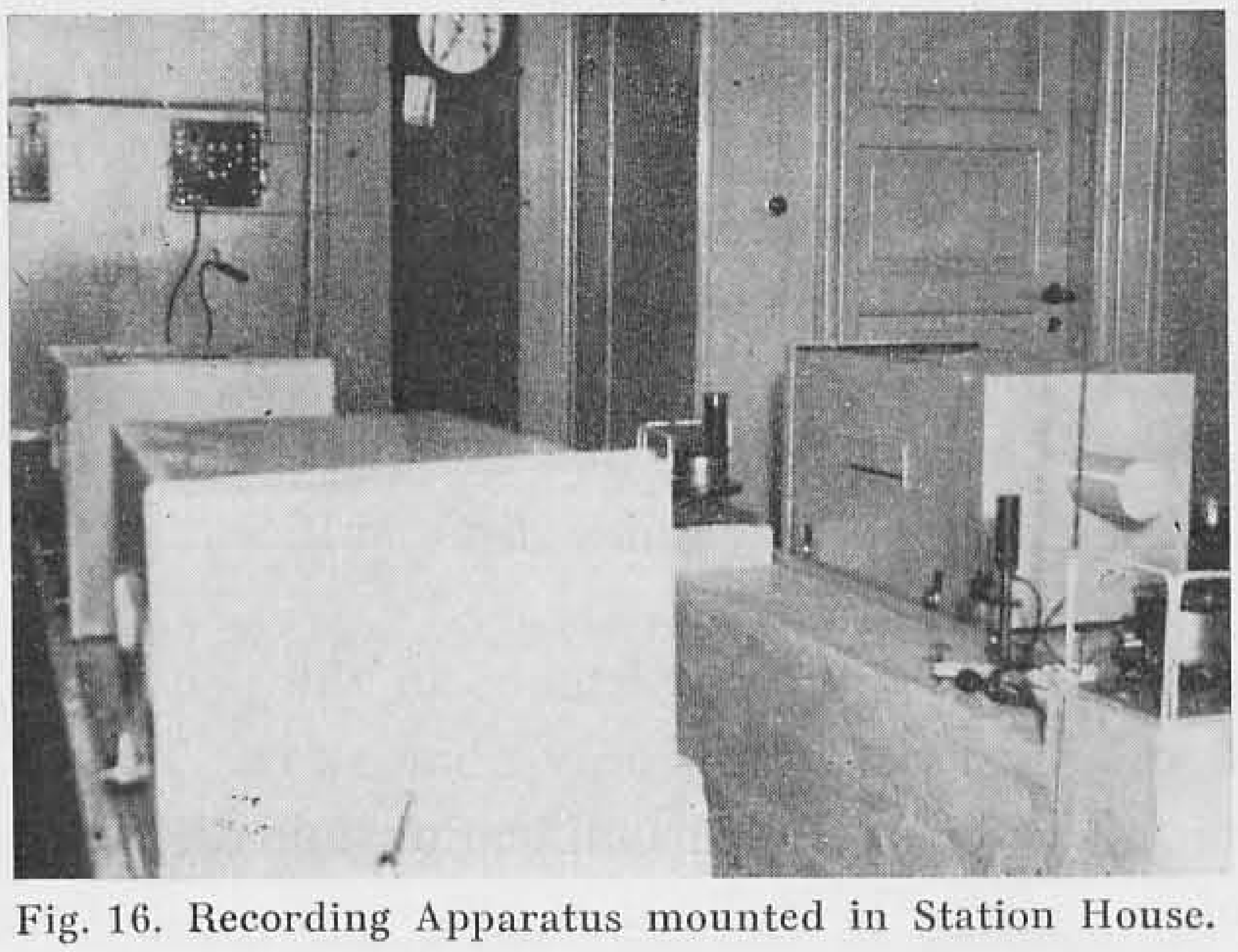


Fig. 16. Recording Apparatus mounted in Station House.

The placing of the recording apparatus as shown in the plan has been chosen principally in order to facilitate the disposition of the instruments for the determination of the constants of the seismographs, and at the same time to ensure a safe position of the galvanometers and the recording lamps by placing them inmost on the piers.

In the station København the galvanometers and lamps are rather exposed, as it is necessary to pass close to them, and the determination of the constants of the seismographs is rendered difficult by the closeness of the instruments.

This inconvenience had to be avoided here, and the surface of the piers and the size of the recording lamps were proportioned so that the telescope used for the determination of the constants could be placed on the piers; to sight the mirrors of the galvanometers the recording drums must be removed, but lamps and galvanometers can be left untouched in their proper places. The base of the telescope is constructed specially for this purpose.

The main clock of the station has been hung in the recording room. It is provided with a minute-contact as described on page 14—15 and controls the time-marking on the seismograms. A spare clock also provided with minute-contact is placed in the transmitter room.

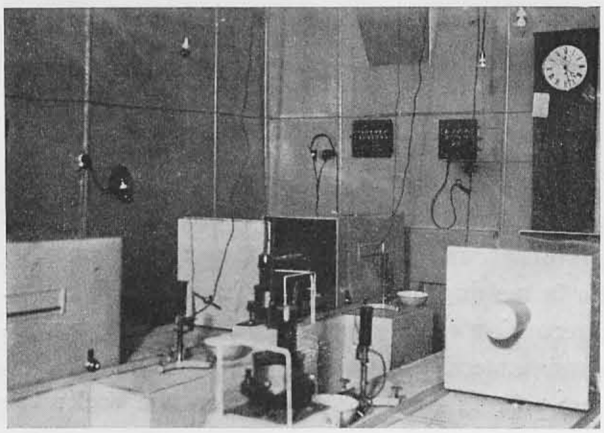


Fig. 17. Recording Apparatus mounted in Station House.

The Mounting of the Pendulums.

In January the three pendulums were mounted.

The pendulums are all supplied by Masing in Dorpat and, as mentioned on page 11, the two horizontal pendulums had previously been mounted in the station København, where they had worked satisfactorily and where the leader of the expedition had had the opportunity of working with the pendulums and of learning to adjust and to attend to them. The vertical component is of the same construction as the one mounted in København.

Plate IX shows the placing of the three pendulums. The vertical component is so placed behind the others that its mirror can be sighted between them. Each pendulum is mounted on three bolts cast into the piers.

The placing is such as to give the distance necessary for the determination of the constants in the smallest possible space, and at the same time sufficient room round and between the instruments for working on them.

The length of the room is only 3.55 m., and the distance to the pendulum mirrors from the telescope mounted on a special base, only about 2 m. This is hardly sufficient for an accurate determination of the magnification and therefore double reflection is used; the pendulum mirror is inclined a little to the sighting line of the telescope and another mirror has been fixed to the frame in such a position that a ray in the direction of the telescope axis which meets the movable mirror when in its zero position is reflected so as to meet the fixed mirror perpendicularly, and thus returns by the same route. Therefore when the pendulum mirror swings, the deflection of the ray is doubled; the scale can be read with greater accuracy, which compensates for the short distance.

The telescope is in a fixed position. It sights the mirror of the vertical component pendulum directly, but the mirrors of the horizontal components are sighted by means of totally reflecting prisms. The mirror of one of the horizontal components is on one side of the axis.

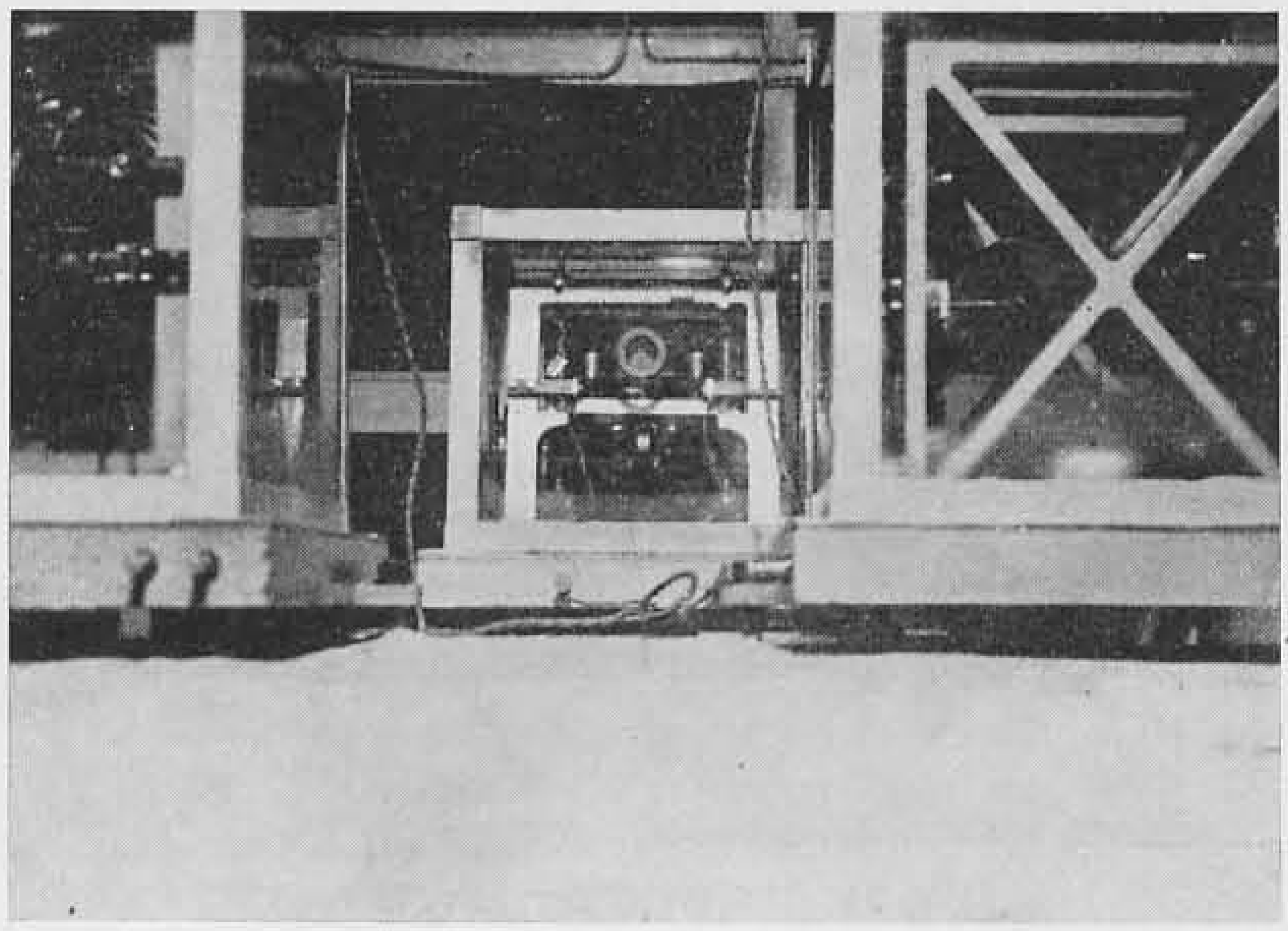


Fig. 18. Galitzin Pendulums mounted in Cellar.

The scales of the telescopes are worked on ground glass and are very clearly lighted by means of rows of small 6 volt lamps.

Great stress has been laid on rendering the disposition of the instruments for the determination of the constants as practical as possible, in the cellar as well as in the recording room; but some difficulty is encountered because the two rooms are separated. During the determination of the constants a telephone connection is established by means of a hand cable.

The pendulum and the galvanometers are connected by a 6-cored armoured signal cable for low voltage; the single leads are 6 mm^2 copper wires; the variation of resistance with temperature is insignificant.

After the erection of the pendulums the constants were determined about once a month. The period of oscillation of the horizontal component pendulums is about 12 sec., that of the vertical component about 10 sec. The transmission factor is not much more than 40, and it has been kept so low because the microseismic movement is very strong.

On January 12th 1928 the seismological station was opened and the two horizontal seismographs set working; except for two days when work had to be done in the cellar, they have been working uninterruptedly from that time. The mounting and adjusting of the vertical seismograph was finished at the end of February, but it only recorded now and then as the use of the kerosene stove for the drying of the cellar made the variation of temperature too great. From the middle of July, when the heating of the cellar was discontinued, the vertical seismograph worked well. About 400 seismographic records were brought back to the Geodetic Institute in September 1928.

It had originally been planned to prepare the films after their exposure so that they need not be developed until they had been sent to Copenhagen. It was not possible, at least not in the winter, to use running water for their rinsing. Advice was, however, given of the following procedure, which was carried out with good result.

When the records have been developed and fixed they are one by one stretched between two pieces of thick, loosely wooven material and hung so that the upper short side dips into a basin filled with water. The water is sucked up and drifts down along the records which by this means are rinsed sufficiently.

Fig. 19. Masts under Erection.

Time Service.

When the pendulums had been set working, the time service had to begin.

The clock of the station is, as previously mentioned, provided with a minute-contact, connected to the time-marking electromagnets; it has also a lever second-contact as described on page 17.

The error of the clock is determined daily by means of Nauen scientific time-signals. A telephone, mounted in the recording room, is used, and the second-beats of the clock are made audible by means of an inductance coil on the receiver as described on page 17.

For a control the ONOGO signals are also taken. By means of a switch the time signals are marked on the seismographic records, where their distance from the minute-marks of the clock can be read.

The time service is completed by the comparison of the minute-contact and the second-contact of the clock. The second-contact can be switched on to the circuit of the time-marking electromagnets, so that the seconds are marked on the seismographic records. When the second-contact and the minute-contact are switched on alternately, their mutual position can be read from the marks on the records.

In this way the seismographic records are used for the time-determinations which in the station København are made on the chronograph.

The Completion of the Establishment.

In the middle of May 1928 all the indoor fitting was finished and the outdoor work could be continued.

Since the wireless connection had been established in October, a double wired 30 m. long antenna hung from two provisionary masts, only 9 m. high, had been used; on the rock underneath was a 700 m. long old and otherwise useless copper-wire serving as counterpoise.

The work yet to be done was the blasting for the foundations of 11 poles for the counterpoise and of 2 masts, and boring for the casting of the bolts for the stays. Then the poles for the counterpoise were to be set up and their foundations cast, and the two 25 m. high masts erected.

Fig. 20. Station House and Masts.

In the last days of June the main masts were erected, and the 6 wired counterpoise, insulated by means of porcelain eggs, was in place; consequently the reach of the transmitter was considerably extended.

In the middle of July the entire establishment was completed; a month later the expedition left Scoresby-Sund and the control of the combined station was taken over by a physicist sent out from the Geodetic Institute.

The coordinates of the seismological station are $\varphi = 70°29'$ N., $\lambda = 21°57'$ W., $h = 69$ m. They were measured from an astronomical point near by, which was determined by the astronomer Aage Nielsen who wintered in Scoresby-Sund in 1925 as a member of the expedition which prepared the colonisation of the place.

In September 1929 the second year's records were received in Copenhagen together with the year's report. The station has worked well and no unforeseen difficulties have arisen.

The humidity has caused no trouble. In the pendulum cellar no daily variation of temperature has been perceptible except for a sudden rise and fall when the station has been entered. Fig. 21 shows the temperature curve of the year as recorded by the thermograph.

Summary of Meteorological Observations during the Year 1927—28.

Year	Month	Mean Temp.	Min. Temp.	Max. Temp.	Rainy Days	Snowy Days	Northern Lights	Remarks
		Degrees C.	Degrees C.	Degrees C.				
1927	August	+ 4.6	— 3.5	+ 18.6	4	2	1	
	September	— 0.2	— 5.5	+ 8.1	0	6	15	
	October	— 7.1	— 20.1	+ 3.0	0	4	21	
	November	— 9.9	— 21.6	+ 10.1	0	12	11	Max. Temp. + 10.1 one evening when a strong föhn-wind was blowing.
	December	— 14.4	— 33.5	+ 0.2	0	10	18	
1928	January	— 14.4	— 25.9	— 2.6	0	8	20	
	February	— 12.7	— 31.2	+ 2.0	0	12	11	On the 28th and 29th it rained for an hour in the evening.
	March	— 14.0	— 26.5	+ 4.1	0	5	17	Only little snow.
	April	— 7.5	— 19.6	+ 1.6	0	10	5	Northern lights not observed after April 16th when the light nights began.
	May	— 1.0	— 9.4	+ 5.9	0	8¹)	—	¹) 5 of these days had only little snow.
	June	+ 1.2	— 5.1	+ 8.6	2	3	—	
	July	+ 4.6	— 2.5	+ 17.2	3	—	—	
	Total...	— 5.9	...	...	9	80	119	

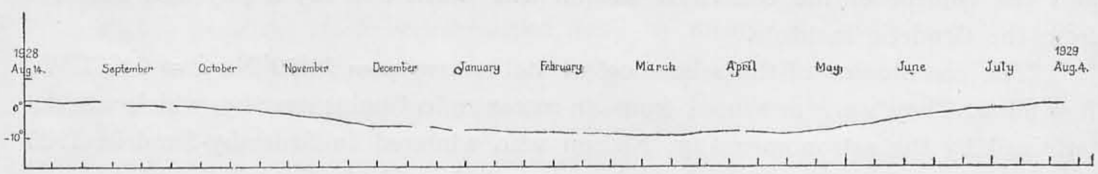
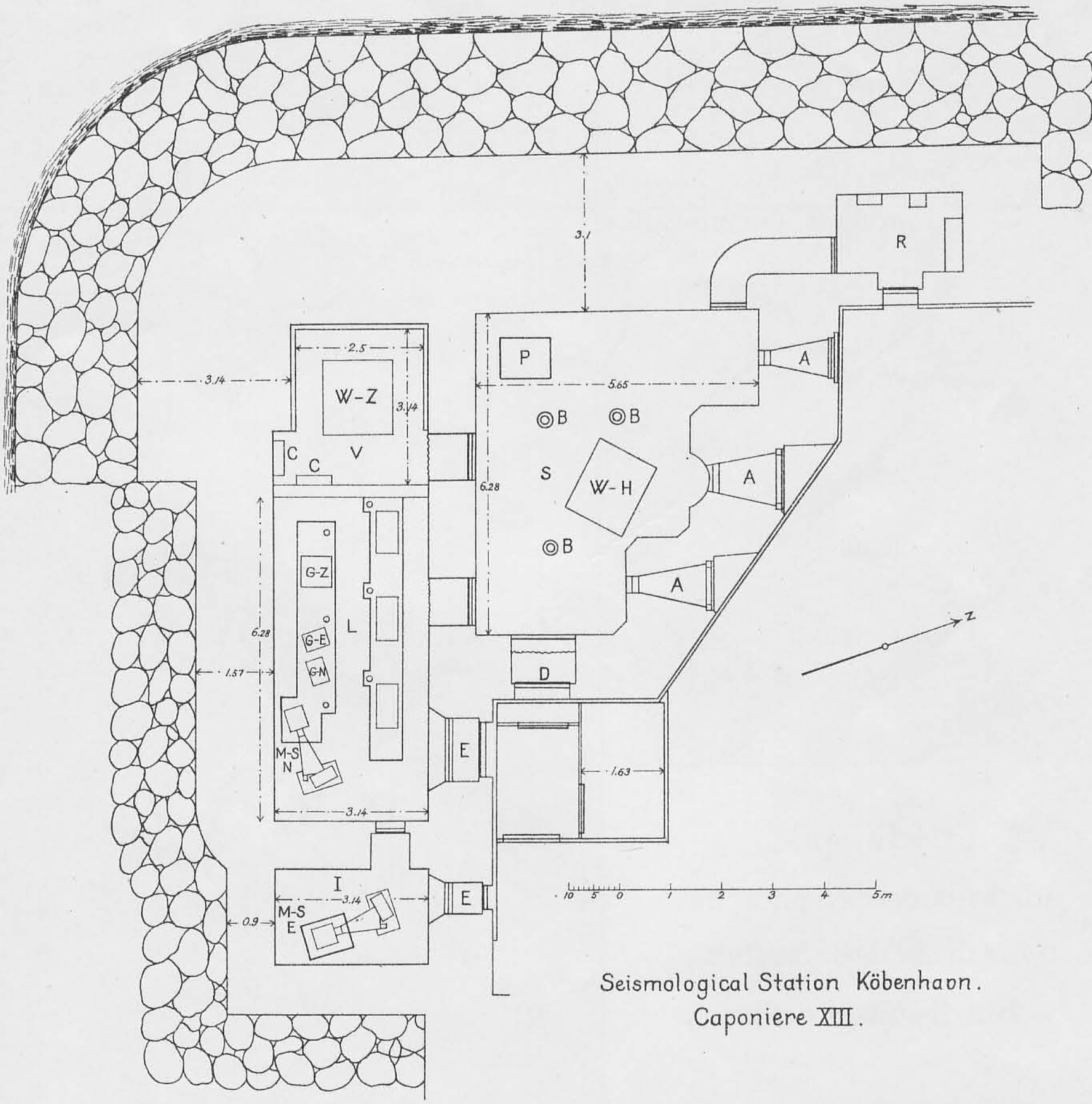


Fig. 21. Temperature Curve. Aug. 14th 1928—Aug. 4th 1929. Pendulum Cellar.

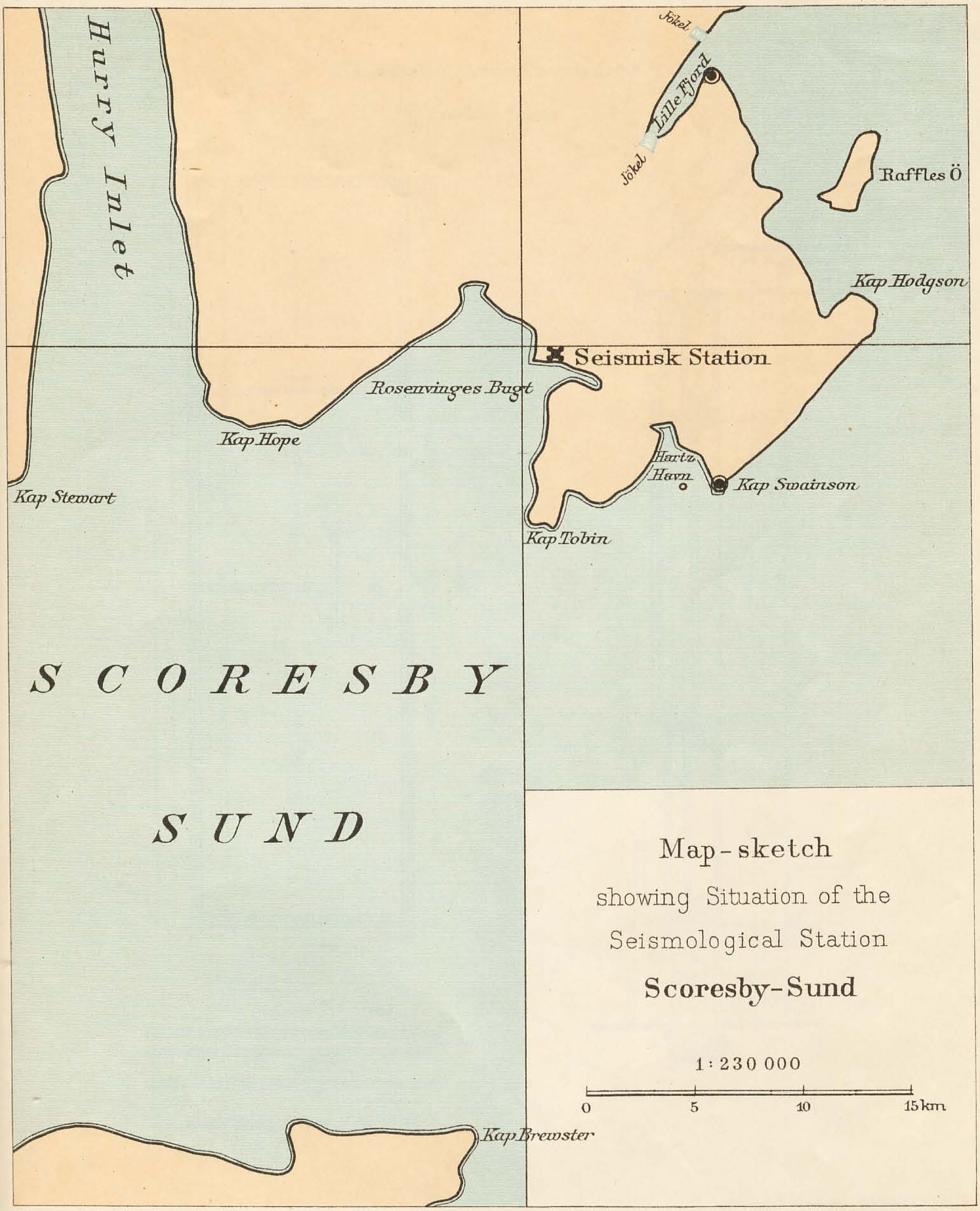
In the year which has passed the station has stood its proof and we feel justified in hoping that seismological work is ensured in these Arctic regions for coming years.

Geodætisk Institut. København 1930



Seismological Station Köbenhavn.
Caponiere XIII.

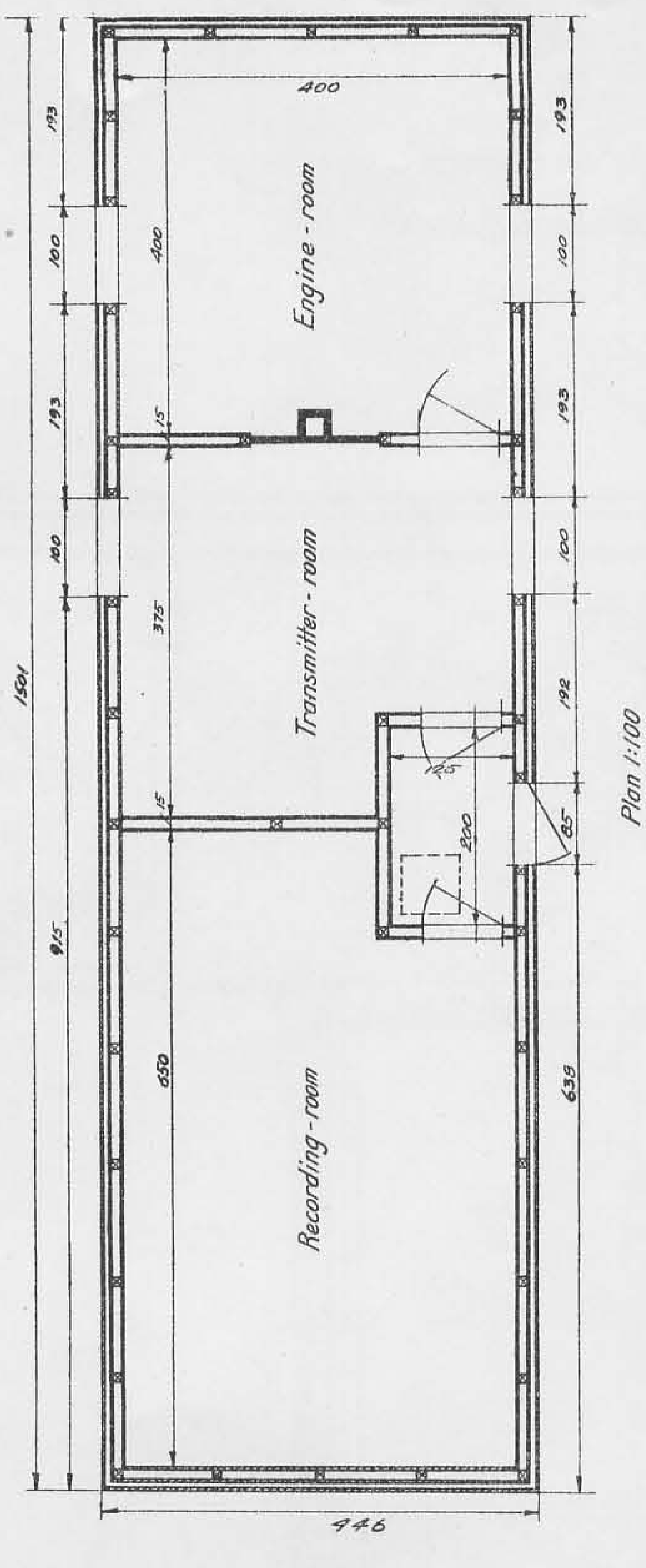
Geodætisk Institut. Köbenhavn 1930



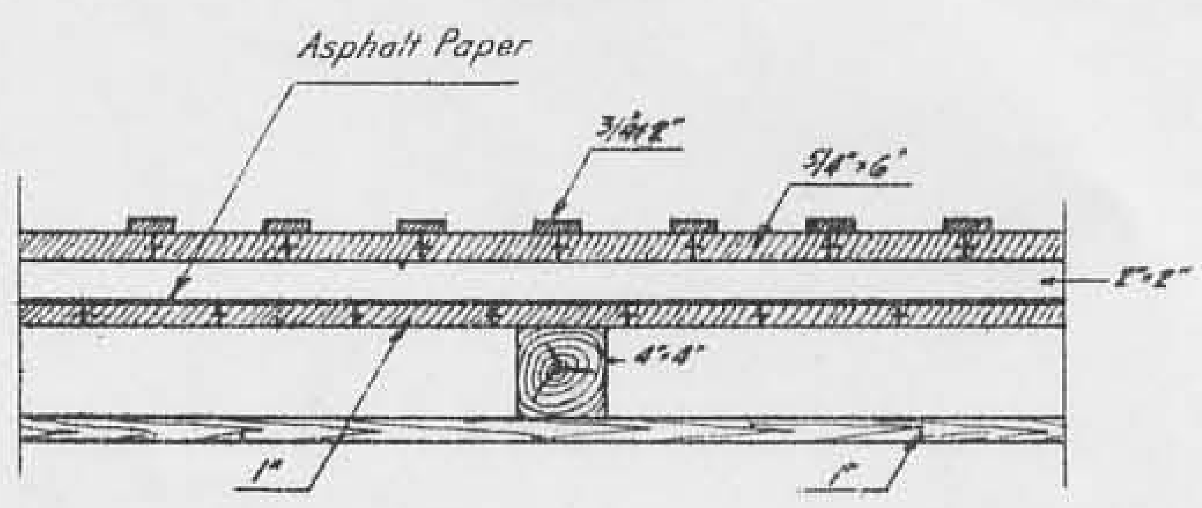
Geodætisk Institut. Köbenhavn 1930

Seismological Station Scoresby-Sund

Station-House

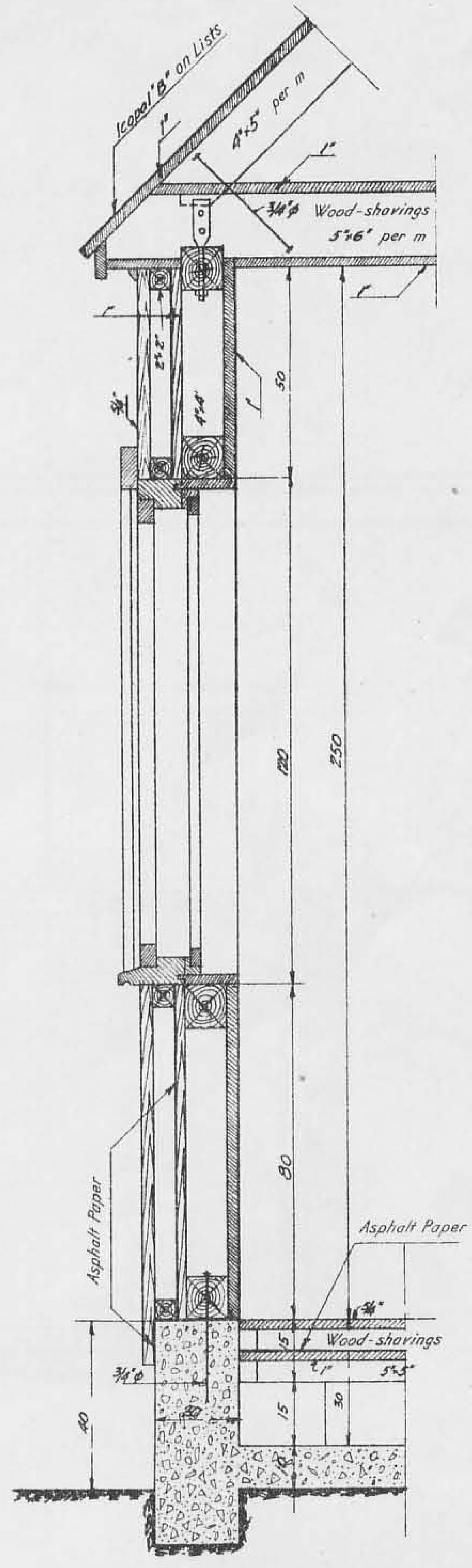


Plan 1:100



Horizontal Cross-section of Outer Wall

1:20

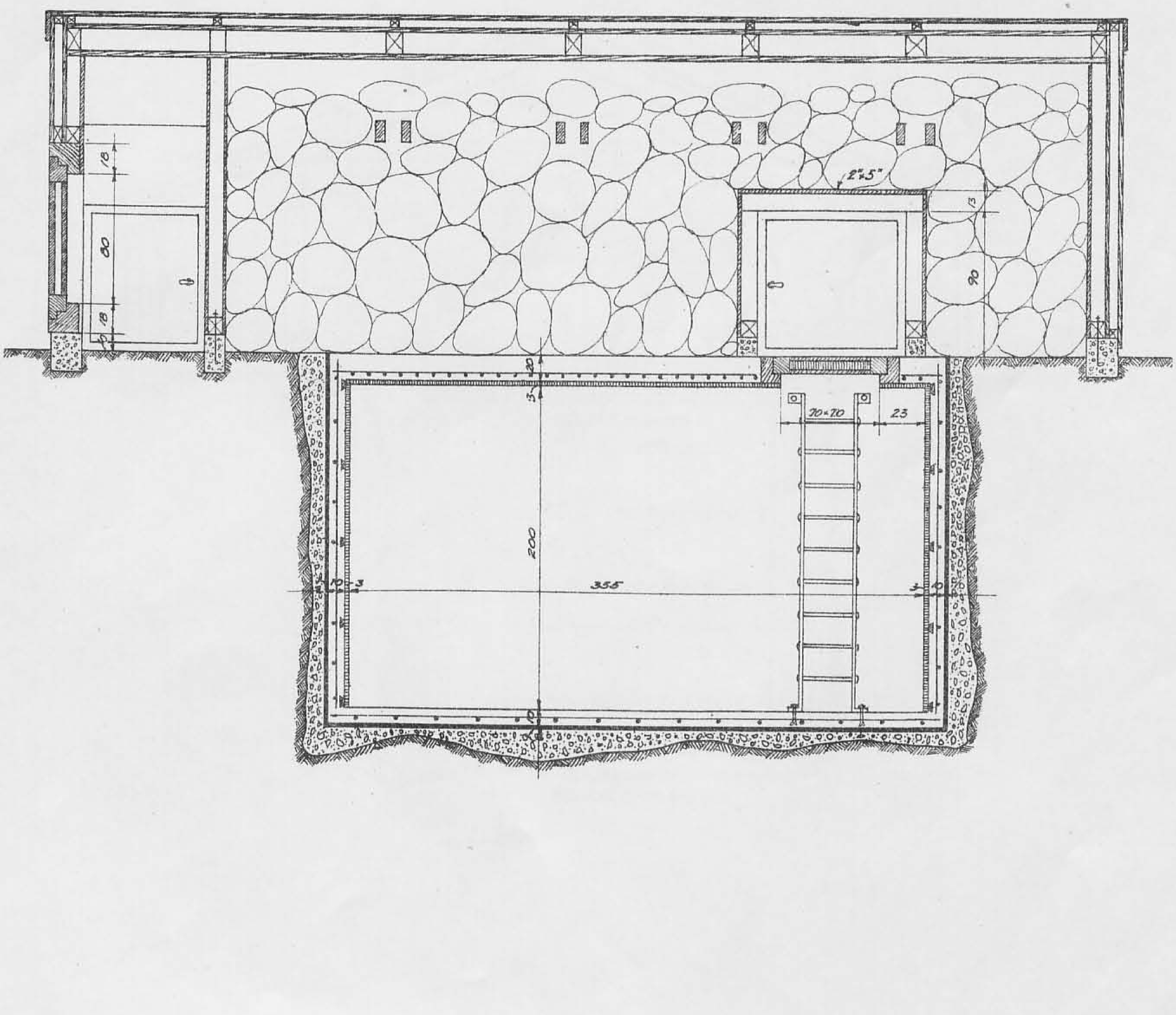


Cross-section of Outer Wall

1:20

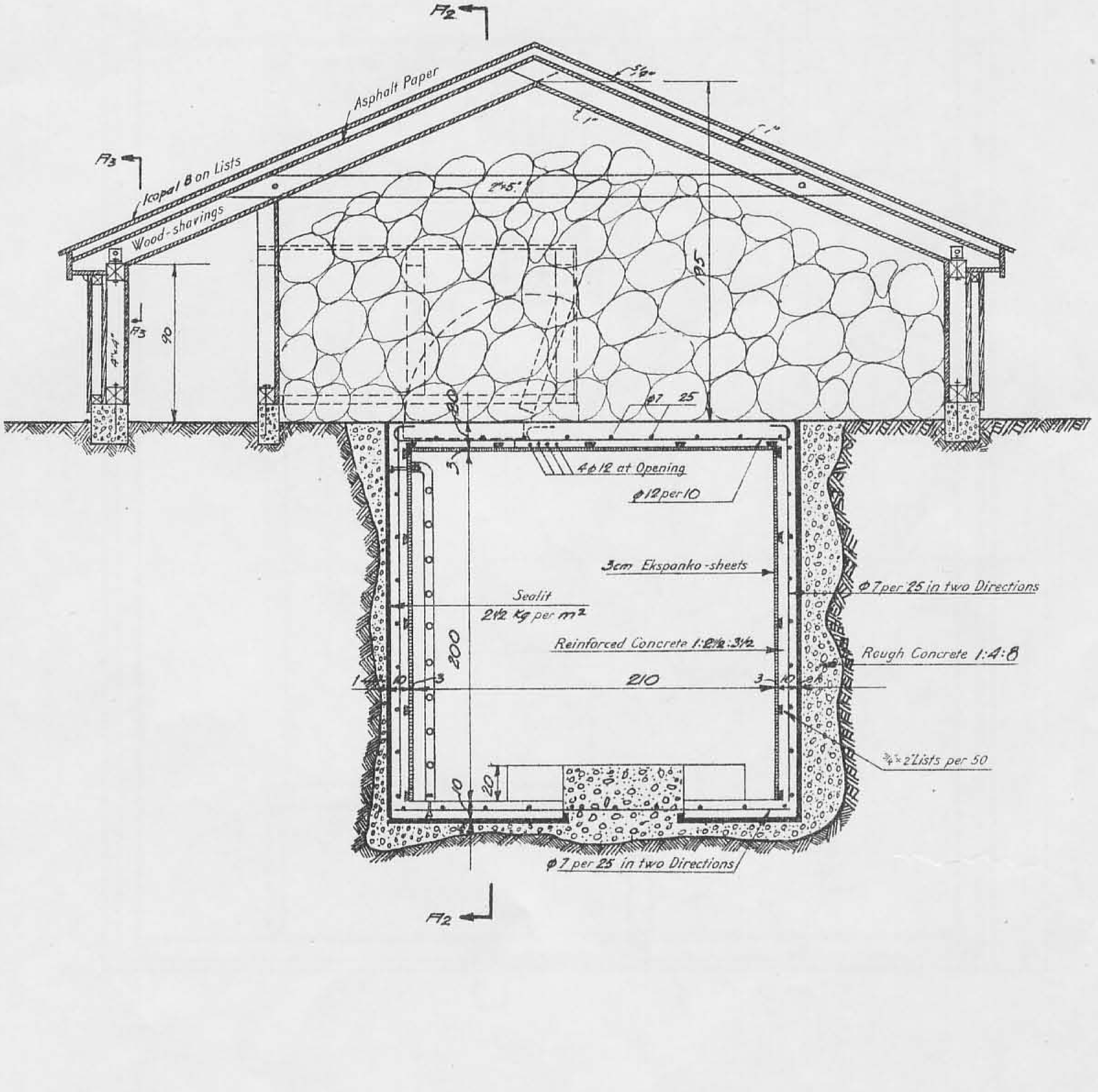
Geodætisk Institut. København 1930

Seismological Station Scoresby-Sund
Pendulum Cellar with Building over
Section A_2-A_2 (see Plate VII)
Scale 1:40



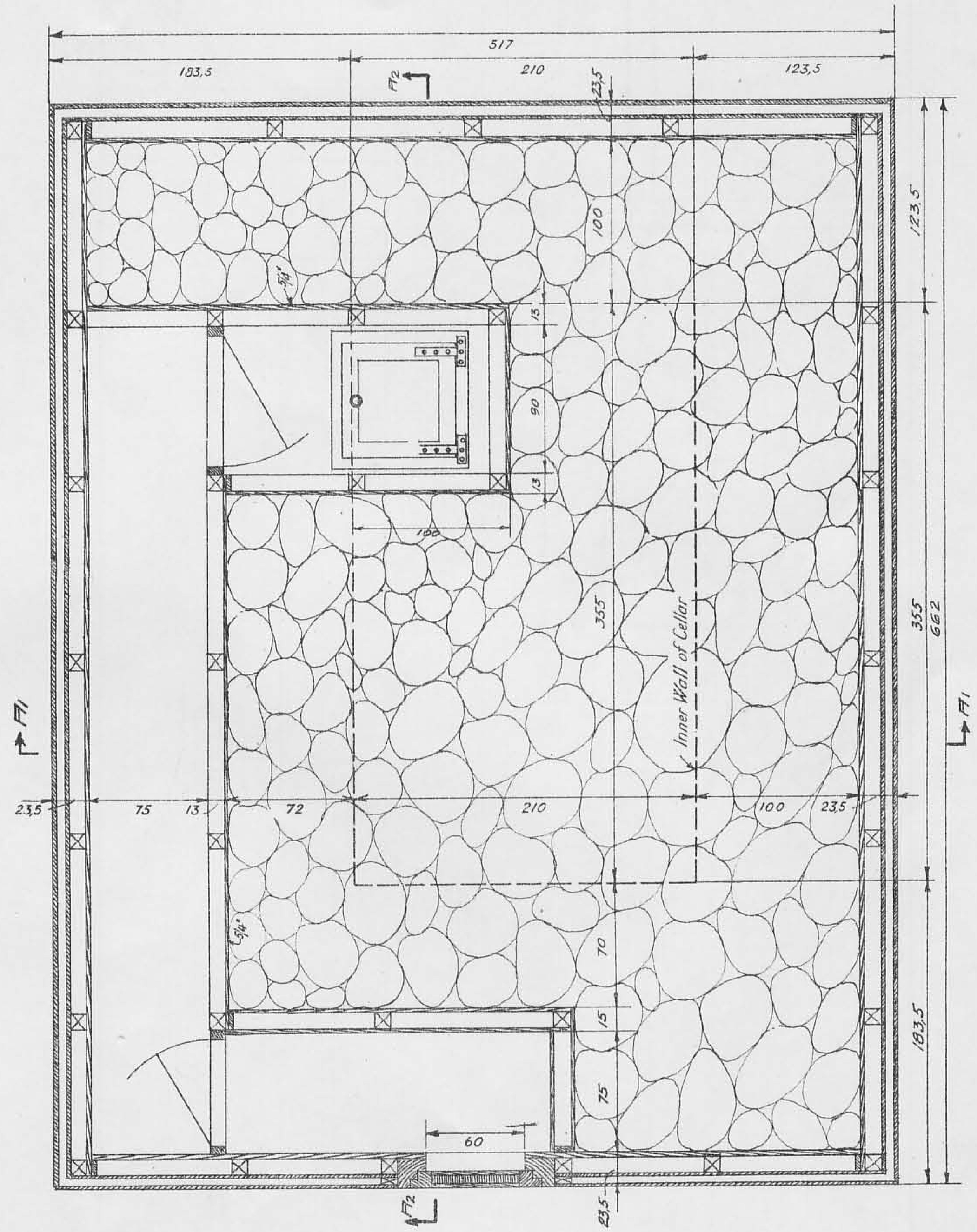
Geodætisk Institut. København 1930

Seismological Station Scoresby-Sund
Pendulum Cellar with Building over
Section A_1-A_1 (see Plate VII)
Scale 1:40



Geodætisk Institut. København 1930

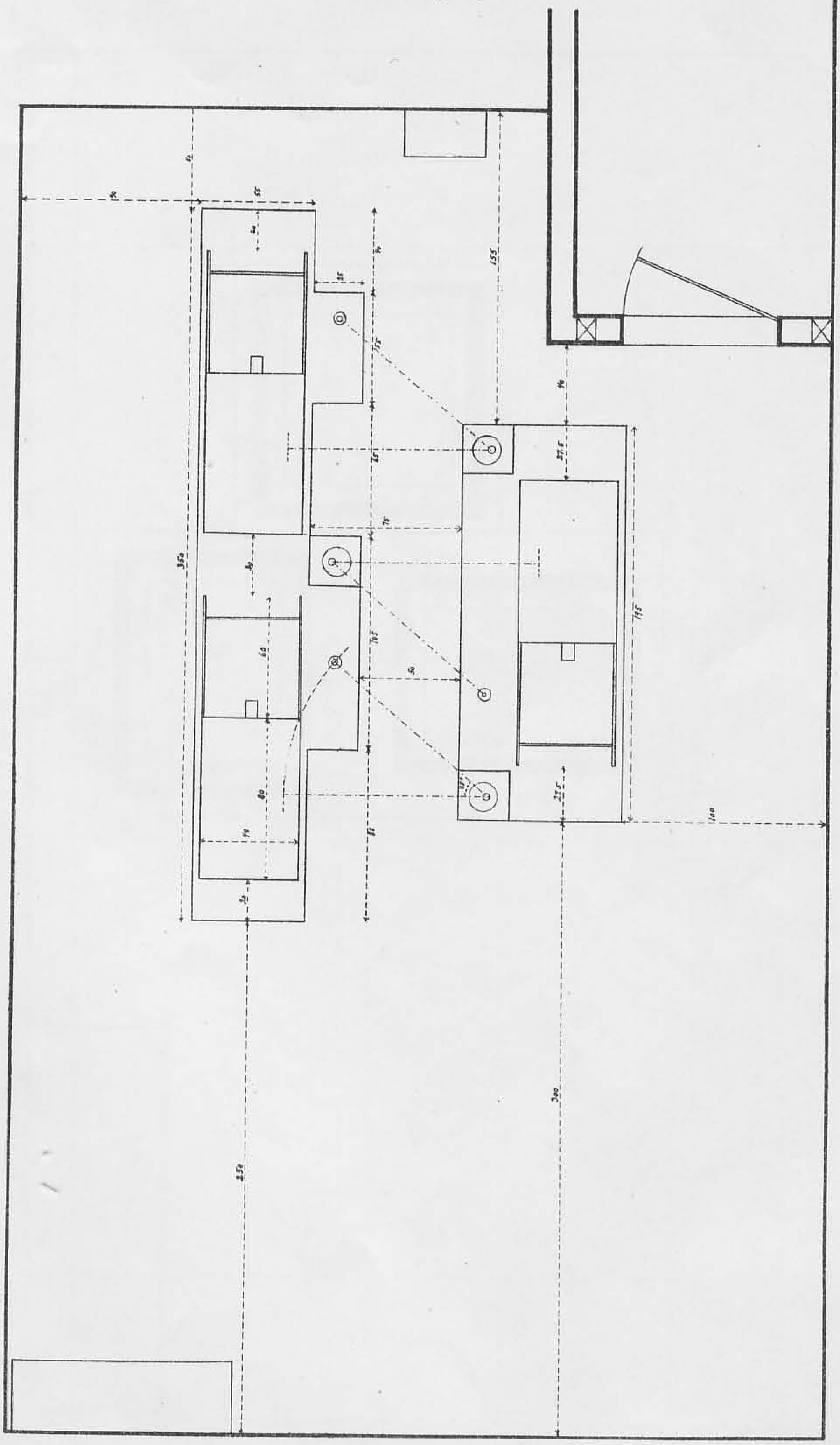
Seismological Station Scoresby-Sund
Building over Pendulum Cellar
Scale 1:40



Geodætisk Institut. København 1930

Plate VIII

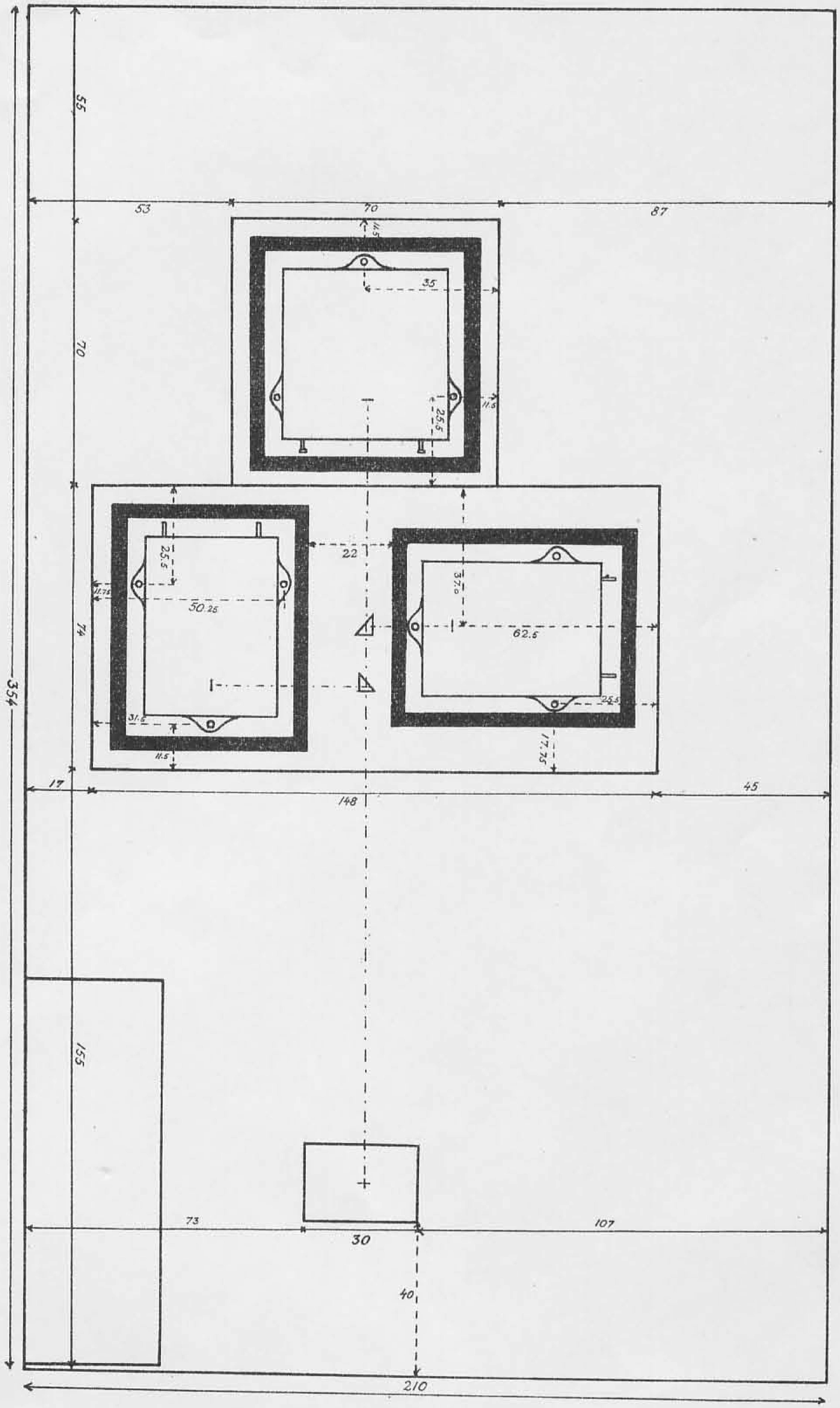
Seismological Station Scoresby-Sund
Plan of mounted Recording Apparatus
Scale 1:33



Geodætisk Institut. København 1930

Plate IX

Seismological Station Scoresby-Sund
Plan of mounted Pendulums
Scale 1:17,5



Geodætisk Institut. København 1930