Terrestrial Magnetism *and* *Atmospheric Electricity*

VOLUME V

JUNE, 1900

NUMBER 2

THE MAGNETIC OBSERVATORY AT DE BILT, NEAR UTRECHT.

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At the time of the removal of the Central Observatory of the Royal Meteorological Institute of the Netherlands from Utrecht to a place which would better answer the purposes of such a building, there arose the question as to the best way of erecting an observatory for terrestrial magnetism. The mode of answering this question depends wholly on the purpose aimed at in building the observatory. It is my intention to indicate, in a few words, my opinion on the subject, and the way in which it has been realized at de Bilt, near Utrecht.

During the past ten years the science of terrestrial magnetism has received a great impetus. Everywhere magnetic surveys have been instituted and finished, or are still in progress. The theoretical requirements are getting more and more exacting, and are demanding, in consequence, greater refinement in the instruments employed and in the methods of observation.

In such a period, the establishment of a new magnetic observatory is not an easy task. A great many factors must be duly taken into account and the possibility of future disturbing influences, such as electric tramways, must be fully considered.

Under such circumstances it will be but proper to set some limits, and to settle clearly what is to be considered as necessary.

[PLATE III.]

Dr. William Gilbert.

In the first place, magnetic surveys should have some base station where there is a magnetic observatory, whence the observers may start upon their work, and to which they may return as often as the exigencies demand. The observations made at the various points can thus be properly reduced and corrected with the aid of the continuous observations at the base station.

Secondly, it is desirable that at a number of points, distributed as regularly as possible over the surface of the globe, the numerous variations and fluctuations of the Earth's magnetism be simultaneously and continuously recorded, so as to furnish, ultimately, a basis upon which an accurate theory can be constructed.

Finally, there ought to exist certain institutions, suitably situated, for investigating and testing different qualities of magnets, as, for example, conducting researches concerning the instrumental constants, inductive capacity of iron, steel, etc.

These desiderata can best be fulfilled by a magnetic observatory consisting of two buildings. In one of these the variations of the three magnetic elements can be continuously registered and permanently fixed, and in the other the elements can be determined in absolute measure as often as seems necessary. In the second building, moreover, all other magnetic investigations could be instituted which require a space sufficient to allow different observers (three, for example) to work simultaneously; *e. g.*, in comparing instruments, without running the risk of mutual interference from each other's magnets.

The above stated ideas have been the principles on which the magnetic observatory at de Bilt has been constructed. Thus this observatory consists of two buildings, the one containing the variation-instruments for eye-reading and for continuous registration by photographic means, and the other adapted to making the absolute observations and for conducting special investigations. This arrangement of having two separate buildings instead of one, as is the custom at some places, appears, on the whole, more advantageous.

As, consequently, the purposes of the two buildings differ very widely, it necessarily results that they must also be very unlike, in their structure as well as in the materials used. At the same time there also exist certain properties which they must have in common.

As a first condition it may be stated that the material of which both observatories are built should show no magnetic properties. It is easily understood that every nail or hinge made of steel, iron,

or even any other less magnetic material, will deflect a magnetic needle accidentally in its neighborhood, and so disturb the observations. If such a magnetic mass were irregularly distributed through the building, it would be altogether impossible to make any reliable observations.

There is still another way in which the material of the building may interfere with the correctness of the observations. Suppose the observing room to be constructed of a substance more or less capable of being magnetically induced. It will then act somewhat like a protecting ring of a galvanometer. In other words, the Earth's magnetic field will be feebler inside than outside the observing room.

In the same way a change in one of the elements of terrestrial magnetism in the neighborhood of the observatory may cause a change of less intensity in the corresponding element within it. The instruments placed in the room in order to determine these changes will, therefore, be influenced in a slighter degree than they would be if placed outside. Moreover, this defect will not be wholly eliminated by the manner of determining the "coefficients" of sensitiveness of the instruments.

In order to avoid these imperfections all the materials used in the construction of the Magnetic Observatory of de Bilt were subjected to a most rigorous examination concerning their magnetic properties. From all the materials, the metallic as well as the different kinds of stone and their respective mortars, many samples were taken in order to discover whether they caused any appreciable deviation when placed near a freely suspended magnetic needle.

It was adopted, as a rule, that if the substance, reduced in size to a cubic centimeter, produced a deviation of one-tenth of a minute on a needle twelve centimeters long, at a distance of five millimeters from one of the poles, it would be rejected. In this manner we experimented on nails, screws, hinges, locks, keys, bolts, clamps, and other pieces made out of copper and brass, also on bricks, many kinds of sandstone, square stone, an artificial tuff or pumice-stone, lime, sand and Portland cement, and various other kinds of cement. Materials were rejected and replaced by other specimens, which were perhaps again rejected, until at last we were convinced that the architect had made no use of materials showing any appreciable magnetic properties. The different kinds of stone produced especially great difficulties. It is a known fact that brick can not be used at all, and as there was at first a proposition to

erect the building on an argillaceous ground southward of Utrecht, I feared that also the clay of which bricks are baked showed the same feared properties. It was also possible that clay is not magnetic in itself, but becomes so when converted into brick. To investigate this question, I took bricks in their different phases of development; viz., from dried clay, half-baked brick, etc., to the thoroughly baked and finished brick. The result was, that clay showed no magnetism at all, and that the growing brick got more and more magnetic as it approached its final condition. The explanation is not very difficult: by heating the clay, the iron which it contains in oxydized state is gradually reduced to a lower degree of oxydation in which it is magnetic.

Different kinds of sand and square stone also showed the capacity of being magnetically induced, principally when red veins were to be seen, probably due to the presence of iron. All samples showing such qualities were rejected, and, consequently, whole loads of stone were refused. Even the artificial tuff stone above mentioned showed a minute action on the magnetic needle; but considering that the deflection was almost inappreciable, I found no objection in adopting it for the outer walls of the observatory for variation-instruments. In the building for absolute observations a kind of sandstone was used, which showed no magnetic properties at all.

In concluding what I proposed to tell about testing materials with reference to their magnetic properties, I must add that, of course, the square stone for the pillars on which the instruments were to be placed, was also submitted to a minute examination.

In the beginning of our investigations concerning the magnetic properties of materials, I was of the opinion that a kind of multiplication-method could be applied here as in some galvanometric observations. In order to do so, I approached the needle, for example, with a copper bolt; the needle showed a little deflection. I withdrew the bolt, and the needle ran back; as it returned I approached with the copper bolt again, and obtained a greater deflection, which could be multiplied to a very considerable extent by approaching and withdrawing the bolt rhythmically at the proper moment. My first conclusion was that the copper bolt was very appreciably magnetic, but I soon learned that by applying this method, all metal objects seemed to be more or less magnetic. I, therefore, ordered a bar of the purest electrolytic copper, but found it also to be magnetic in no little degree. In short, the method proved to be quite

FIG. 1. THE MAGNETIC OBSERVATORY FOR ABSOLUTE OBSRRVATIONS.

FIG. 2. THE MAGNETIC OBSERVATORY FOR VARIATION OBSERVATIONS.

false; for the oscillations of the needle were undoubtedly due to electric currents induced by the needle itself in the moving samples of metal being examined. Afterwards I made my tests, as said before, simply by placing the object as quietly as possible in the immediate proximity of the needle.

A second condition for obtaining valuable results is, that the observatory be beyond the sphere of influence from artificial causes, *e. g.*, such as would arise from the proximity of factories, railways, roadways, etc. In this respect the de Bilt Observatory is very happily situated, the only road of any significance being the highway between Utrecht and Arnhem, traversed by carriages, tram-cars, and wagons. The distance of the magnetic observatories from this road is almost two hundred and fifty meters. No appreciable pernicious influence from the above-named causes have, as yet, made themselves felt. In the titles to property immediately surrounding that of the Observatory, there is a restricting clause that no such annoyances may be constructed at any time. The only fear at present is, that the new nightmare, bothering magneticians so sorely at the present time—namely, the electric tramway—may also attack us. Still, doubtless, this can be avoided by some protecting interference on the part of the Government, should the danger seriously threaten.

Finally, the effect of temperature, and principally its oscillations, must be provided for in planning the observatory. In this respect the limits for the temperature changes to be tolerated are much more restricted for the variation observatory than that for the absolute measurements. In the former, an almost constant temperature throughout the year must be striven after, whilst in the latter case, temperature needs to be fairly constant only during the interval for making the observations. Accordingly the observatory for variations is wholly shut off from its surroundings by double walls, having an intervening space of 1.60 of a meter thickness, filled up with loose turf ground.

After these preliminary notes on the general requirements which were fulfilled in the magnetic observatory buildings, a brief description regarding their construction will readily be understood.

The observatory for *absolute measurements* (Figs. 1, 3, and 4) is erected on firm foundation walls which extend almost one meter above the surface of the ground, and on which the floor of the

observation room rests. The building contains two rooms: one having an inside space of $7 \times 5\frac{1}{2}$ meters, the second, adjacent to the former, and separated from it by two doors with an interspace of 0.60 of a meter, has a floor-surface of $3 \times 2\frac{1}{2}$ meters.

Access from outside is had to the larger room by a small portal containing a staircase of five steps, and three doors through which one must pass before entering.

The walls consist, for a substructure, of square stones and for the superstructure of a series of five sections, the outer one being of sandstone, followed by an air space, then by plaster-board,¹ sawdust, and again plaster-board, the whole being supported by a wooden framework. The different sections are respectively 0.12, 0.06, 0.40, and 0.06 of a meter thick. The floor is also double with an interspace filled up with sawdust.

The principal room has no windows, sufficient light coming from openings in the ceiling below the sky-lights; all light can be excluded by drawshutters.

Six pillars of square stone built in the beton floor of the cellar, project through openings in the floor of the large room, and are arranged in such a manner that five of them stand precisely under the sky-lights referred to above. Instruments placed on these pillars are illuminated accordingly in a most satisfactory manner, the light being distributed equally on all sides. In one of the walls there are several holes through which two fixed marks, whose azimuths have been determined, can be sighted on with the instruments standing on the three most distant pillars designed to give opportunity for comparing the instruments of three observers at the same time.

The second room is intended particularly for astronomical observations required for determining the azimuth of the above-mentioned marks. For that purpose in three of the walls there are large windows, which can be drawn wholly down, so as to leave the horizon unobstructed. The northern window enables one to observe Polaris, whilst sun azimuths and stellar transits can be taken from this and the other windows. In the middle of this room there are two nearly juxtaposed piers, one for the universal instrument (alt-azimuth circle), the other for an induction coil used for determining the magnetic dip according to Schering's method; the position of the axis of the inductor can be determined with the universal instrument. The ballistic galvanometer, used in this method, rests on the central pillar in the adjacent room.

¹ Boards made of reeds and gypsum.

Fig. 3. Vertical Section Through A B.

Fig. 4. Horizontal Section.

THE OBSERVATORY FOR ABSOLUTE OBSERVATIONS.

Fig. 5. Vertical Section Through A B.

Fig. 6. Horizontal Section.

THE OBSERVATORY FOR VARIATION OBSERVATIONS.

The outer walls of the building for observing and recording *magnetic variations* (Figs. 2, 5, and 6), are constructed in very much the same way as for the first building except that, for the external section, an artificial tuffstone is employed. The interspace between the plaster-board has a thickness of 1.60 of a meter, and is filled up with loose turf ground, as already stated.

These walls include a space of an area 13×8 meters, which is occupied by two quite separate small buildings, each having a floor surface of $4 \times 5\frac{1}{2}$ meters, and a height of $3\frac{3}{4}$ meters. Around these inner buildings, and between them, are corridors, and moreover above them a free air space, the whole being so arranged as to procure an equable distribution of temperature. The walls of these compartments are constructed out of two plaster-board partitions, with an interspace of 0.1 of a meter.

In each compartment is a set of four symmetrically arranged pillars for supporting, the one a set of eye observation instruments for the three magnetic elements, and the other the various parts of a photographically recording magnetograph, with its cylinders and clock-work.

Both compartments have doors leading to the corridor between them, access to the corridor from outside being had by means of the portal (see Figs. 5 and 6), which is similar to that of the absolute observatory. From the portal, moreover, access is given by means of a staircase to the cellar containing the boiler of the heating system, the tubes of which run along in the corridor surrounding the two observation rooms. In this corridor are to be found also the orifices of eight ventilating tubes in the exterior walls. By regulating the hot water circulation and opening or shutting the ventilation tubes, the temperature of the air in the corridors ordinarily oscillates between the extremes of 18.2 and 17.8 degrees Centigrade. In that case no fluctuation of temperature at all is observed in the observation rooms. Only in summer there is some difficulty in lowering the temperature sufficiently; however, a special system of cooling the air by ice will overcome this difficulty.

The plans of the buildings and the superintendence of the construction were intrusted to the government architect, Mr. D. E. C. Knüttel. He not only executed the work very satisfactorily, but also responded most readily to all of my, at times, very extravagant wishes.