ON AN APPARATUS FOR DETERMINING THE INCLINATION AND
DIRECTION OF BORE HOLES AND THE DIP AND DIRECTION
OF THE DIP OF STRATA PASSED THROUGH BY BORE HOLES.

BY JOHN GOODMAN, PROFESSOR OF ENGINEERING
IN THE UNIVERSITY OF LEEDS.

(*Read 4th March, 1909. Manuscript received 30th December, 1909.*)

The apparatus is for the purpose of determining the inclination and the direction of the inclination of bore holes, which when carried to a great depth are liable to run away from the vertical direction. It furnishes also means whereby the dip or inclination of the strata passed through by the bore holes and the direction of the same can be ascertained.

The apparatus consists of a hollow pendulum, in the form of a hollow cone of any light and suitable material, preferably non-magnetic. Aluminium is well suited for the purpose. The full angle of the pendulum cone is about 100 degrees.

A pivot pin secured to a circular base plate supports the pendulum from the apex end of the hollow of the pendulum in such manner that the base plate and pivot pin can be tilted at a considerable angle and still allow the pendulum to hang truly vertical. An agate bearing is inserted in the apex of the hollow of the pendulum or cone. A magnet is secured to the upper end or apex of the pendulum by a screw projecting from the apex of the same and passing through a hole in the centre of the magnet, and a nut or cap screwing on to the same. The nut is formed with a hemispherical cap, the centre of which, when the nut is screwed down on to the magnet, coincides with the point of support for the cone, that is the point of the pivot.

The above-mentioned base plate is connected by two or more pillars to a second circular base plate—the clockwork base plate.

A spindle is provided passing through a central hole in the clockwork base plate in the same vertical line as the pivot, and carries a plunger or enlargement at its lower end, the underside of which is hollow, so that when pressed against the upper side

of the hemispherical cap, it bears with its circular rim against the same ; the contact of the rim and hemispherical cap taking place at the same instant all round the rim of the plunger, and not at one part before the other.

A helical or other spring surrounding the spindle bears with its lower end against the upper side of the presser or enlarged head of the plunger, and with its upper end against the under-side of the clockwork base plate.

The end of the plunger projecting above the clockwork base plate is connected with a trigger or other release device, operated by clockwork mounted on the clockwork base plate. When the plunger is raised by pulling up the presser spindle and compressing the spring, the cone is released so as to swing freely on its pivot support, and the spindle is held raised by a catch device or a wound-up cord or chain. The clockwork is set for a given time of release and set going, so that when the time elapses the catch is released, allowing the plunger to be pushed down by the spring. In the case of a wire wound on a barrel, the clockwork device may be arranged to allow the plunger to move slowly downwards as the wire gradually unwinds from the barrel, coming in contact with the hemispherical cap after the lapse of a given time interval.

The apparatus is fitted and carried in a hermetically closed tube, attached to a rope or rods for being lowered into the bore hole.

The apparatus is lowered into the bore hole with the pendulum swinging freely on its support, and the magnet free to swing into the magnetic meridian, turning the pendulum with it, and with the clockwork release apparatus set to allow ample time for the apparatus to be lowered, and for the pendulum and magnet to come to rest. It will be evident that under these conditions the angle of inclination to the vertical of the bore hole will be the same as the angle between the plane of the base of the cone pendulum and the base plate below it ; whilst the angle between the direction or line of greatest inclination of the base of the cone pendulum to the base plate, and the direction of the magnet will give the horizontal direction of the deviation of the bore hole from the vertical.

The release device of the clockwork fixes the magnet and cone in these positions with respect to the apparatus and to each other.

To facilitate reading the last-mentioned angle, the rim of the cone close to the base is marked with degrees all round.

The angle of inclination of the cone is most conveniently obtained by measuring off by means of a gauge or cathetometer the highest and lowest points of the base rim of the cone from the base plate.

In order to apply the apparatus for the purpose of ascertaining the dip and direction of the dip of the strata, the tube enclosing the apparatus is prolonged downwards and provided on the inside with one or more cutting or scratching teeth. When the lower end of the tube is dropped down over and raised again from the unbroken end of the core in the bottom of the bore hole, a scratch or scratches are left on the outside of this core, so that when the latter is afterwards broken off and raised, its position with respect to the apparatus and consequently to the readings obtained from the apparatus as previously described can be determined, and hence the dip and direction of the dip of the strata as shown by the core.

A modification of the method of using the apparatus for this latter purpose is to bore a hole into the core to receive the apparatus, and fix it in the core by dropping cement into the hole above the apparatus. After the cement has set, the core is broken off and raised to the surface with the apparatus inside.

In order that the apparatus may be more readily and clearly understood, a drawing is annexed (Fig. 1), which is a section of the inclined part of a bore hole containing the apparatus, the latter being shown partly in section :—*a* indicates the sides of the bore hole, and *b* the hollow cylinder enclosing the apparatus ; *c* is the hollow pendulum cone supported by the pivot pin *d*, carried by the base plate *e* ; *i* is an agate inserted in the apex of the hollow of the cone, to reduce liability to derangement from wear between the point of the pivot pin and the part of the cone resting immediately on the point. The upper end of the cone terminates in a short screwed stem *g*, and a magnet *h* rests on the shoulder at the bottom of the stem ; *k* is a cap

nut, which is screwed down on to the stem g and secures the needle h to the top of the cone c . The cap portion of the nut k is formed on the outside as a hemisphere, having the point of the pivot pin d as its centre.

The base plate e rests on a ledge or flange formed on the inside of the enclosing cylinder b ; l is the so-called clockwork base plate, which is carried from the base plate e by two more pillars m .

Immediately above the cap nut k and in the central or axial line of the apparatus is provided a spindle or plunger n , which passes through and is guided by a hole in the boss on the underside of the clockwork base plate. The lower end n^1 of the spindle or plunger is enlarged and made hollow, so that when pressed against the hemispherical cap, it bears only with its circular rim against the cap; o is a helical spring surrounding the spindle or plunger n , resting with its lower end on the enlargement n^1 and bearing with its upper end against the underside of the clockwork base plate l . The upper part of the plunger or spindle n passes through a hole in the lever p , the latter being hinged at q . A cross pin r is fitted in the spindle immediately above the lever p , so that when the latter is raised the plunger n is lifted out of contact with the cap nut k , allowing the pendulum cone c to swing free with its base truly horizontal. When the lever p is released, the helical spring o pushes the plunger down on to the nut cap, fixing the cone and needle in the position which they have at the time with respect to the apparatus; s , as shown, is a case containing an ordinary alarum clock, which is carried on the clockwork base plate. The free end of the lever p is connected to the lower end of a flexible wire or cord t , the upper end of which is secured to the projecting end u of the alarum spindle, so as to be wrapped round the same when the alarum is wound up, thus raising the lever p , lifting the plunger n and allowing the cone and magnet to hang free. The alarum release is then set to go off after a certain time interval, and in this state the apparatus is lowered into the bore hole. On the lapse of said interval, the alarum release goes off and the spindle u runs down, unwinding the cord t and freeing the spring o to push down the plunger n , which latter fixes the cone and the magnet in the position in which they have come to rest.

Fig. 1.

The upper end of the hollow cylinder *b* is hermetically closed by the cover or cap piece *w*.

The means above set forth for freeing the magnet and cone and for securing them in any position in which they may have come to rest are not limited, as other means both mechanical and electrical suitable for effecting this purpose are well known or will readily suggest themselves.

The rim *c*¹ of the cone is graduated all round in degrees as shown on the righthand side of the cone, the magnet being secured so that its centre line lies in the central plane of the cone passing through the zero and 180° mark. The angle of inclination of the cone is most readily ascertained by finding by means of a gauge or cathetometer the highest and lowest points respectively of the base rim of the cone from the base plate *e*. The difference between these heights divided by the diameter of the base of the cone will give the sine of the angle of deviation of the bore hole from the vertical. 4 are scratchers or scrapers of steel, diamonds, or the like, secured on the inner side of the tube *b* close to the lower end of the same, so that by raising and lowering the bottom of the tube in the annular space surrounding the core, scratches or marks can be made on the sides of the cone, so that when this portion of the core is afterwards broken off and brought to the surface, if the lines of bedding can be traced, the dip and direction of the dip of the strata, as shown by the core, can be deduced. To facilitate the marking of the core, the scratchers may be formed on or attached to a flat spring or springs 5, secured to the lower end of the tube.