# AN AUXILIARY FOR EXTREMELY ACCURATE MEASUREMENT OF ANGLES

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## *DESCRIPTION.*

The device under consideration, manufactured by the firm of Otto FENNEL Sons, Cassel, is designed to measure small angles, or any small variations of angles, with an accuracy greatly exceeding the ordinary.

For this purpose, an achromatic glass prism, adaptable to the object lens of the telescope and covering about half of this lens, is made to rotate on its axis through an angle which may reach 30°, perpendicular to the principal section of the instrument, thus changing the angle of deviation up to about 30 % of its value.

The advantages of this method of measurement are: (1) that the two points whose difference in direction it is desired to measure, may be simultaneously sighted and brought into coincidence — a matter of prime importance where the marks sighted are movable or uncertain, and at an observation spot which is not perfectly motionless; (2) a considerable increase in accuracy due to the fact that, for the measurement of an angle the instrument provides a rotation value one hundred or one thousand times greater than the angle to be measured.

The rotation of the prism is produced by a 10-step micrometer screw of 0.4 mm. pitch of thread, which acts on the polished projecting arm of the prism, and is held permanently in contact with the point of the screw by the pressure of a spring.

Of particular importance in the present case is the safeguarding of the axis of the prism against lateral displacements. This is assured by means of the conical bearing of the axis and is, besides, by no means a difficult problem in precision mechanics.

As it is necessary that the angle may be measured in any plane passing through the observation point, the mounting of the prism must be arranged so that it may turn freely about the axis of the telescope.

Suppose that two points are to be brought into coincidence; after correct setting of the axis of rotation and the "swing-back" (oblique) axis of the theodolite, the prism is made to turn about the axis of the telescope until the plane of its principal section contains the points; the prism is then made to rotate about its axis by means of the micrometer screw and finally the rotation is read off on the screw. The head of the screw is divided into 100 parts of 1 mm. each; the mounting is graduated in 360°, least reading 1/10th degree.

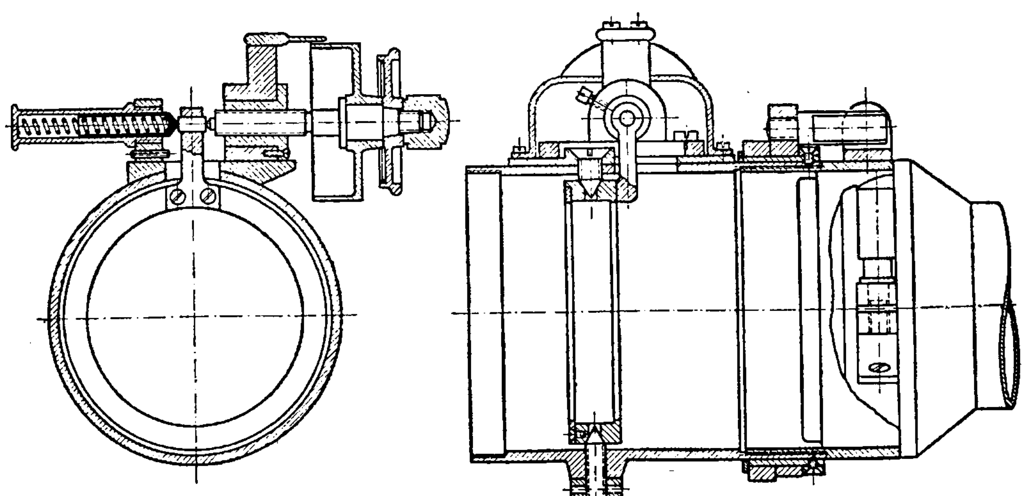

FIG. 1
*Sections through the prism micrometer*

In order to sight on any points which may be desired, an arrangement has been provided by which a suitable deviation prism may be fitted in front of the object lens.

In the model constructed up to the present, the prism angle, for geodetic reasons, measured $1^{o}08'.7$, the deviation angle, in the zero position, consequently half. It is probable also that appreciably greater prism angles can be employed. With the prism under consideration, even for a rotation of $30^{o}$, the images were scarcely less luminous while remaining distinct and without troublesome chromatic aberration. (Fig. 1).

*Procedure in taking observations :*

For calibration, and to give an idea as to the possible accuracy which might be attained, an ordinary tachometer theodolite from Otto Fennel Sons workshops was used, magnification 26, and a corresponding levelling stave with vernier on which the division in centimetres was traced in white on a black ground. (Fig. 2).

As the magnification of the telescope and the capacities of the measuring device under test were not yet in proper relationship, it was impossible to attain the maximum accuracy.

By means of the measuring prism the division lines were successively brought into coincidence with those of the vernier and thus, as is well-known, it was possible to obtain a very exact adjustment.

The perpendicular from the observation point to the levelling stave with vernier situated at the same height at a distance of 65.740 m. from the initial summit of the angle, intersected the latter at point 0.4250 m.

Thus, for example, if the coincidence setting were obtained at point 0.6580, the corresponding angle was given by the two right-angled triangles with short sides

$$0.8100 - 0.4250 = 0.3850 \quad \text{and}$$
$$0.2250 + (19/20)\,.0.2087 - (19/20)\,.16 = 0.2713.$$

The principal division of the stave commences at 0.2000 and the zero of the vernier is displaced towards the right to 20.87 vernier divisions = 19.83 cm.; 20 vernier divisions = 19 cm.

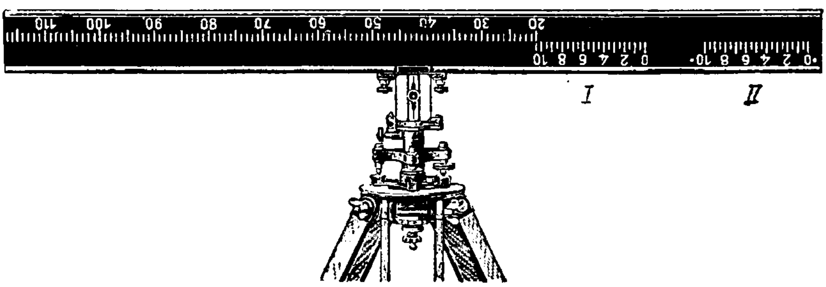


Abb. 5 Nonienlatte.

Fig. 2
*Levelling stave with vernier*

It is particularly important, in these cases, to bear in mind the fact that the coincidence setting must always be effected at one and the same place in the field of vision with relation to the cross wires.

*Repetitions of sights on geodetic levelling staves : mean errors :*

In order to check the reliability of the settings, the various levelling-stave coincidences were each repeated 10 times. As the readings were afterwards taken on the screw, all personal errors in the results were eliminated.

In consequence of rather unfavourable atmospheric conditions, the images were not absolutely motionless, but somewhat agitated.

Results showed, in spite of this, that the mean error of a single coincidence setting was equal to ± 0.40", while the mean error for an average of 10 coincidences was ± 0.12".

However, for the lesser part these mean errors are due to the micrometer, and for the greater part to the observer and the optical medium (air).

*Practical Application :*

It would seem that the instrument may be used for accurate physical, geodetic and astronomical measurements of every kind. Its range of usefulness becomes particularly evident with the larger magnifications of the telescope. With well-defined marks within the limits of measurement, appreciably smaller mean errors are obtained than with the most accurately graduated circles. In particular, the instrument might possibly be advantageously used for scientific research work (for instance, measurement of the parallax, position of the stars, temperature coefficients), in common with the purely practical measurements.

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## GOTHIC BUBBLE SEXTANT WITH DETACHABLE ARTIFICIAL HORIZON AND ELECTRIC LIGHTING.

constructed by the firm of HENRY HUGHES & SON, Ltd., 59, Fenchurch Street, London, E.C.3.

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This sextant has been specially designed for use as an ordinary sextant for observations of altitude above the visible horizon, or by merely attaching the bubble gear, which, in effect, is an artificial horizon, to enable observations to be made when the natural horizon is not visible.

The principle of this apparatus has been described in *Hydrographic Review,* Vol. VI, N° 2, November 1929, page 140. More detailed information on the same instrument will be found in *Hydrographic Review,* Vol. XII, N° 1, May 1935, page 155. These two numbers of the *Review* describe the apparatus in the compact form provided for air navigation (Booth R.A.F. Sextant Mark VIII).

In its composite type, the Gothic sextant has a limb specially designed to be light and extremely rigid so that it is not affected in any way when the Bubble Horizon is secured in place.

The telescopes are of the very latest type with large fields of view and maximum light transmission. A high-power Prismatic Telescope with large field of view and an erect image is supplied for use with the Artificial Horizon. The mirrors are of ample size to match the telescopes.

The angles are read by means of a micrometer head instead of a vernier and magnifier so that an angle can be read in a few moments to the nearest ten seconds of arc by the naked eye.

The mounting on the index arm usually used for the magnifier is utilised to carry a small flash lamp bulb which is fed from a dry battery placed inside the handle and controlled by a switch on the handle, which is pushed in when the light is required at night to read the altitude observed.

The Bubble Attachment consists of the bubble system, two mirrors and a collimating lens, the optical parts being so arranged that the rays from the bubble always emerge horizontally from the lens whether the sextant be tipped up or down from its true position of pointing at the horizon. Thus, the instrument gives as much freedom in handling when used with the artificial horizon as when used with the natural horizon, and it is not necessary to bring the bubble to a fixed mark before making coincidence with the object observed.

The actual bubble system consists of three chambers, the pump chamber with flexible diaphragm operated by the control screw; the actual bubble chamber, which is connected to the pump chamber; and the third chamber, connected to the bubble chamber by a very small aperture. The pump and bubble chambers should be full of liquid, but the third chamber should only contain a little fluid, the remainder of the chamber being occupied by air.

Thus, the air space in the third chamber permits of thermal expansion of the liquid without rapid immediate effects on the bubble.

Owing to the three chamber system, a suitable bubble will maintain its size for quite a long time.

The bubble is sensitive to about one minute of arc.

The bubble should always be returned to the third chamber after use, and the attachment removed from the sextant and again secured in its place in the sextant case.