vibrating ground. The accuracy and speed in such territory are not appreciably diminished.

(*e*) In many cases more reliable altitude-values of bench marks (near the coast, mines, in tectonic territories, railways, canals) are obtained when after a certain time interval the same levelling is repeated with Ni 2. This second levelling including the first will not require more time than one with a high-precision instrument of the ordinary type. The results of repeated levelling disclose changes in altitudes caused by alterations of ground (sinking and rising) and these can be eliminated to a certain extent; the same also applies to refractional influences.

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THE FILOTECNICA SALMOIRAGHI SYSTEM OF PRECISION AUTOMATIC LEVEL

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Automatic Levels can be obtained by the aid of various optical and mechanical means. Among these, Filotecnica Salmoiraghi has selected one with the object of attaining the following ends:

(1) To reach, and eventually surpass, the maximum precision required for the most rigorous exigencies.

(2) To attain a strong and simple constructive scheme.

(3) To permit the operator to have continuous control of the operation of the instrument.

(4) To incorporate in the instrument the micrometer for reading the stadia fractions of interval.

The features of the Automatic Precision Level Mod. 5190 are as follows:

Weight, without tripod	11 kg
Overall dimensions of case	230 × 480 mm
Aperture	45 mm
Magnification	30 ×
Resolving power	$<0''\cdot6$
Shortest focusing distance	3 m
Automatic pendular levelling device with completely aperiodic damped pendulum	
Practical period of return in position of rest about	$0^s\cdot25$

A general aspect of the instrument is shown in *Fig. 1.*

The method adopted is that shown in *Fig. 2.* In this scheme the organ sensitive to the direction of earth gravity is a pendulum in which the pin friction is practically cancelled by a long elastic hinge made of very low elastic hysteresis material.

In *Fig. 2* the reticle R_1 is visibly suspended as a pendulum connected to two thin bars l_1 and l_2, which are rigidly fixed at the top and bottom.

In order to obtain automatic levelling it is necessary that, by varying the inclination of the body of the instrument, the image of outer objects should appear fixed in respect of the reticle and that, therefore, the respective movements should be equal. To obtain this, it is necessary that the equivalent length of the pendular suspension should be equal to the focal length of the main lens O_1 of the automatic level.

The theory of elasticity supplies the means for calculating the effective equivalent pendulum length allowing for the effect of the elastic rigidity of the small bars. The result is that these bars fixed rigidly at the two ends must be longer than the focal length of the lens O_1 and of a constant quantity even if the inclination angle of the fixing is variable; this constancy is important because it shows that this elastic pendular suspension entirely, with all the precision required, solves the automatic levelling problem.

The reticle R_1 has stroke-ends within limits imposed by the requirements of the optical scheme, only because it is necessary to avoid collimation occurring in a too extra-axial direction of the optical scheme.

Inasmuch as the relation between length and section of the suspension bars is very strong, the equivalent friction of the suspension is very low and the reticle R_1 can follow the variation in the direction of the axis of the pendulum in respect of the variation in the direction of the gravity field, with such slight errors that they are not noticeable even when observing the position with the most powerful optical means.

Easy experimental determinations have shown that this pendular system is capable of assuring the indication of direction of the gravity field with a precision which is better than that afforded by the best air-bubble level.

The pendular system is used in the scheme shown in *Fig. 2* as follows: the

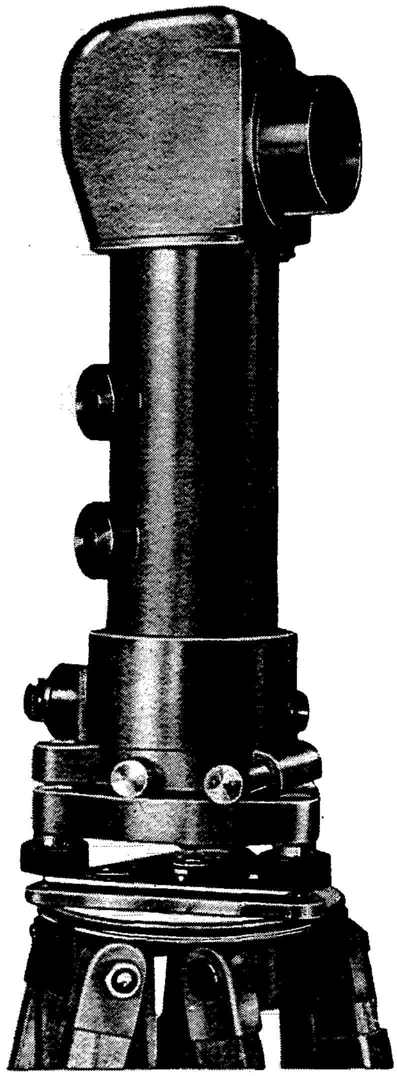

Figure 1

lens O_1 with its optical centre and the reticle R_1 individuate a vertical or almost vertical axis having a constant direction in respect of the vertical itself.

The couple of mirrors S_1 and S_2 renders the axis horizontal, or almost horizontal, which forms the sight axis of the level. (There are two mirrors, because two reflections are necessary in order to attain equality not only as to size but also as a sign between the pendular movement of the reticle R_1 and the movement of outer objects when the mechanical axis of the whole instrument is changed).

The optical system comprising the two lenses O_2, the prism P, the reticle R_2, and the eyepiece O_3, may be considered as an observation microscope which, with the enlargements and the necessary power, examines the position of the reticle R_1 in respect of outer objects and therefore allows sighting in the same way as the terrestrial eyepiece of an ordinary telescope. The prism P is a pentagonal prism only in order that the final image may be upright.

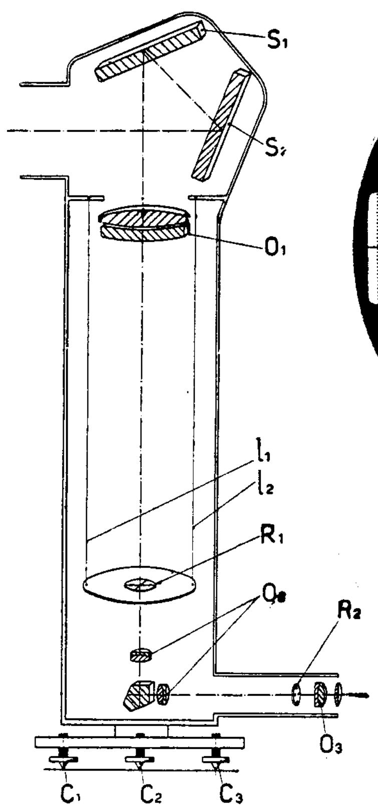

Figure 2

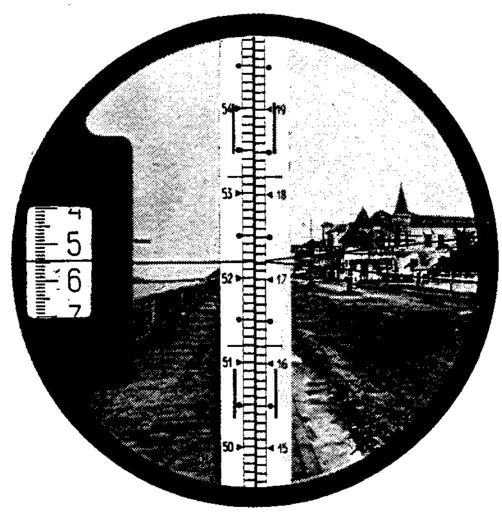

Figure 3

The reticle R_2 allows the checking of the position of the reticle R_1 in the operation field of the instrument and also that the reticle R_1 is within the automatic levelling field and does not stick at one of the stroke-ends. For this reason the reticle R_2 has engraved lines at distances from one another which individuate the free field allowed to the reticle R_1. *Fig. 3* shows the definite aspect of the observation field. The operational regularity of the instrument may be checked by observing whether the image of the panorama does not move in respect of the reticle R_1 during the manœuvring of the foot screws C_1, C_2 or C_3 and whether this stability is maintained in the whole of the field individuated by reticle R_2.

It can definitely be asserted that with the scheme in *Fig. 2* the problem of the construction of maximum precision levels wished for is technically solved inasmuch as the pendular system adopted sets practically no limits to the precision, which is limited only by the power of sighting of the optical parts; consequently the problem is reduced to one of correct optical operation of a telescope which is easily solved by modern technique even concerning sighting powers which are superior to those required for the highest exigencies of precision levelling.

It should be noted that this problem is not so easily solved in air-bubble levels in which the lack of self-action would make it difficult to utilize the higher sighting power.

The optical scheme shown in *Fig. 2* is suitable for the incorporation of the micrometer for reading the stadia fractions. As a matter of fact, it is sufficient to move the optical unit composed of the two mirrors S_1 and S_2 vertically in a direction parallel to itself in order to obtain the required movement of the collimation axis.

The double reflection of the optical unit completely cancels the effect of the slight mechanical oscillations which may accompany the movement, and in this way the precision of collimation is maintained.

This system of moving the collimation axis is free of the introduction of any aberration even in the smallest collimation distances, a fact which does not occur—as is known—in the classical parallel plate micrometer (optical micrometer).

The reading of the movements of the collimation axis is given immediately by reading the movements of the optical axis; *Fig. 3* shows how the graduated scale rigidly connected to this movement is visible in the level eyepiece.

Note: More detailed information concerning automatic levels can be found in the notes of the *Atti della Fondazione Ronchi*, Anno. 9 No. 4 (1954).

Summary of

HYDROSTATIC LEVELLING ACROSS THE WESTERSCHELDE

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(1) In 1951 an underwater main for transport of gas was constructed from De Griete to Baarland in the Westerschelde, which is about 4·2 km large in this area.

This offered an opportunity to carry out a hydrostatic levelling before the mains were used for their proper purpose.

The hydrostatic levelling took place in December 1952 after a long period of preparation, during which some difficulties with a great air bubble (1175 l) in the main were eliminated by the aid of additional taps.

It appeared that one of the mains was damaged, probably by a ship's anchor, so that only one main could be used for the hydrostatic levelling.

(2) The observations were carried out from December 16–24, 1952.

As only a few observers were available, two recording tide-gauges were used to measure the water level in the main's ends. These gauges recorded the water level on scale 1:1, the time on the scale: 1 hour = 3 mm.