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SOME REMARKS TO THE CALIBRATION AND USE OF PRECISE LEVELS

The plumb line (Vertical) is a general datum for geodetical and astrometrical measurements. For its detection pendulous compensators, liquid surfaces, –prisms or –lenses built in the optical system of the instruments and levels on the instruments are used. It is an inherent feature of levels that the damping of the bubble movement causes smoothing effect concerning the vibrations of the instruments. Thus it seems to be useful to discuss some problems of the levels.

Referring to a letter of the French scientist Thévenot (see [1]), bubble levels have been known since 1661. An uptodate and detailed description, however, of the physical principles ruling their function is first given in [2]. Unfortunately these are not generally familiar even today. Therefore it can have interest to repeat summarizing that the equilibrium of the bubble is determined by the hydrostatic buoyancy, by the surface tension and by the distribution of pressure in the filling liquid (see also [3]). Only the first one is generally considered as directive force, although the neglection of both other factors leads to significant errors.

From this point of view a statement of Zagrebin [4] seems for us of interest that the Coriolis force can influence the equilibrium of the bubble. Zagrebin explains this statement by a Coriolis force appearing in the suspension level when rotating the passage instrument around its vertical axle. In consequence of this force a deviation of the bubble position is generated by the liquid streaming in the level vial. Zagrebin interprets by this effect the inclination differences between the arrays of EW and WE measurements on passage instruments. This would mean that so–called early level readings were made in course of these measurements, i.e. the bubble was slowly moving yet when read. As early readings are cautiously avoided at measurements with levels and the movement of the bubble stops after one or two minutes even in case of levels with a scale value of **1"/2 mm**, it is more likely that the inclination differences discussed by Zagrebin and previously investigated by other authors (see e.g. Brkic [5] and Krüger [6]) are related to other sources of errors. The most significant effects have among these manufacturing failures of levels ; accordingly the careful examination of levels represents an important problem of astrogeodetical measurements (e.g. Sárdy [7] and Teleki [8]).

The so–called geometric failures of levels were examined in details by Barnes and Mueller [9]. These investigations deserve special attention if compared with the instruction of the US Army Map Service "Calibration of Level Vials" [10]. The authors have not considered, however, some earlier European publications dealing with this topic and thus they re–discovered so certain phenomena, and others were omitted. Namely the dependence of the level constant (mean sensitivity) on the position and length of the bubble have been examined by Wanach already [11]. Further from the conclusions of the investigations by Wyss [12] only the first item should be quoted here : "Der Parswert ist eine Funktion der Blasenlänge und des Blasenortes". (The scale value of the level is a function of position and length of the bubble), which proves the fact of the re–discovery. Disregarding further remarks on parallelisms and priority, only problems shall be treated here that are not generally known in this field as it comes evident e.g. at A.R. Robbins [13].

As a general rule in measurements with precise levels the so–called mean sensitivity or level constant is still used. So e.g. Harin [14] and Dulian [15] give methods to determine the level constant neglecting the curvature failures of levels. The method of Harin is suitable also for the determination of the so–called periodic failures of the micrometer screw of the level trier. The failures of the micrometer screw of modern level triers are, however, much smaller than the curvature failures of the levels to be examined and the method proposed gives thus – in spite of its mathematical interest – not much new for the practice in comparison to the most simple method known. Very similar situation arises for the method of Dulian, where the level constant is determined with the help of star observations. In this connection it should be mentioned that for this purpose theoretically all astrogeodetical methods can be used which are based on the observation of stars and simultaneously the level is used for the measurement of angles. B. Dulian described in [15] a method for the determination of the constant of the suspension level by measurements with a passage instrument suitable for the photoelectric detection of star transits. The examination of the curvature failures of the levels has been neglected, too, and instead here the failures of the level trier, the manufacturing failures of the slot system on the reticule of the passage instrument, those of the refraction, of the star position and of timing appear.

The computations with individual division values of levels are even in case of diagrams proposed in [9] (or according correction tables) not free from certain neglections. Moreover, this computation method is less comfortable than the use of the angular values computed for the graduations as proposed earlier by Wyss [12] and by Tárczy–Hornoch [16]. These latter methods use namely the integral curves ("summenlinie") of the correction diagrams or tables proposed in [9], thus simplifying the computation of the angular value of bubble displacements to one substraction. In addition Wyss enables by an approximative solution, Tárczy–Hornoch by the method of the least squares the computation of the angular value of bubble displacements between bubble positions with different bubble lengths. Thus the consideration of the variation of the bubble lengths is during the measurement rendered possible, too.

Besides geometric failures, the most important error sources of levels are their so–called temperature errors. These arise from dilatational movements of the metallic casing, further the effects of small temperature gradients in the liquid of the level. In this connection it is to mention that a dilatation difference of 1 micron on the edges of the casing produces an angular desadjustment of 1" by usual form and size of precise levels (see [3]). Further, in consequence of a small temperature gradient in the liquid of the level the equilibrium of the surface tension forces on the perimeter of the bubble are disturbed. Thus the final equilibrium of the bubble is determined by that of the buoyancy and result of surface tension forces. Such errors arise from inhomogeneous illumination, from the breathe of the observer and from unequal cooling of levels due to wind effects. These latter errors are of varying magnitude which depend on the circumstances during the measurement, but their value is commensurable with the geometric failures. It must be, however, considered that geometric failures influence primarly the effect of temperature errors, too. The correction of temperature errors can be carried out only in the knowledge of the geometric failures (see [3]). The different sources of temperature errors, as well as their connection with the geometric failures renders rather problematical the correction of temperature errors by a single so–called temperature constant. In our opinion the most powerful defence against temperature errors is better temperature insulation and better arrangement of the measurement environments (illumination, bubble observation).

As a conclusion it can be stated that in connection with the calibration and use of precise levels investigations are carried out in different places without adequate coordination. It would be adviseable to compare the results of all these investigations in the framework of an international working group to promote the efforts for the unification of astrogeodetical measurements.

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