Check of Digital Levels

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ABSTRACT

The usage of digital levels has been up to now an area between field-check and lab-calibration procedures of components. The field checks can be categorized as line-of-sight check and adjustment. Investigation of temperature behaviour of the instrument's compensator and the evaluation of geometric specifications of the levelling staff are the domains of lab calibrations. In this paper - together with special recommendations for digital levelling - an overview of all checks and calibration procedures will be presented.

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1. INTRODUCTION

This papers bases partly on a discussion paper presented by Prof. B. Witte, Bonn, Prof. W. Schwarz, Weimar, and the author on the occasion of a "Runder Tisch"-meeting1) which has taken place at the TU Graz, in September 2001. The main goal of this discussion was the categorization of checking, testing, and calibration of digital levels including all components of a levelling system. These procedures will be presented at the end of this paper in a figure. This paper gives additional recommendations for the application of digital levels in regular and special environment with artificial illumination.

2. REMARKS AND RECOMMENDATIONS IN THE APPLICATION OF DIGITAL LEVELS

2.1 Additional Recommendations for the Levelling Procedure

In addition to the general rules in the usage of optical and digital levels the following remarks should be mentioned: As the behaviour and the performance of digital levels are a function of the implemented software, the software version has to be part of the protocol to enable later investigations. According to optical levelling procedures it is recommended to make multiple readings to check the variation of the readings and the time-dependent behaviour of the instrument's occasional drifts. In precision levelling the staff-end readings should be avoided to reduce systematic errors which occur with certain digital levels. The distances to the staff should exceed 35 m to reduce the influence of asymmetric refraction. The symmetric distance set-up configuration should be balanced - $\Sigma D_b = \Sigma D_f$ - at the end of a levelling line. Optimal focusing is necessary to get reliable readings. The code of the rod should be clear of obstacles, shadows or additional patterns generated by branches, gates, fences or other optical effects. The minimum code area has to be ensured according to the recommendations of the factory's manual.

Temperature gradients have to be avoided with respect to the change of the line-of-sight stability as a function of temperature [Meier-Hirmer, 1997; Ingensand, Meissl,1995] .

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1) The "Runder Tisch" is an alliance of university calibration labs in Germany, Austria and Switzerland. The main goal of this group is an information exchange with the topic of calibrating geodetic instruments. A first step has been a comparison of length calibration by an interchanging procedure with a set of invar staffs calibrated at all labs. This group is conducted chaired by Prof. Heister, UNIBW, Munich since 1996.

The levelling staffs have to be handled carefully as they represent the metric reference system in the order of microns. Vertical shocks, bending or contamination with dust and mud has to be avoided to guarantee the proper function of an invar staff. The clearance of the invar band in the aluminium corpus should be checked. Experiences have proved to use two bubble levels to check the proper vertical set-up of the staffs. The use of centring rings is necessary to avoid the influence of the eccentric invar band position in the staff's corpus.

2.2 Digital Levelling under Artificial Illumination Conditions

Especially in tunnels under artificial illumination the recommendations of the manufacturers have to be strictly followed. The users have to regard that Leica levels require an infrared share of the light spectrum, while the Trimble/Zeiss DiNi asks for a regular spectrum of light. The intensity profile of the illumination has to be homogeneous as some digital levelling procedures require symmetric code exposure and illumination.

2.3 The Influence of the Earth's Magnetic Field

As the compensators in actual instruments up to now show reaction to the magnetic field of the earth it is recommended to inform the users about the anomalies by magnetic inclination maps of the region. Additionally the user should ask the manufacturers with respect to changes in the production of compensators and the magnetic shielding, respectively.

3. USER CHECKS AND ADJUSTMENTS OF THE INSTRUMENT AND COMPONENTS

3.1 The Digital Level Instrument

The adjustment of the line of sight has to be carried out according to the procedure described in the of the manual or the respective adjustment application software to guarantee the proper correction of the electronic line of sight. Simple methods have to be rejected because of the instrumental errors as the line of sight-focus function.

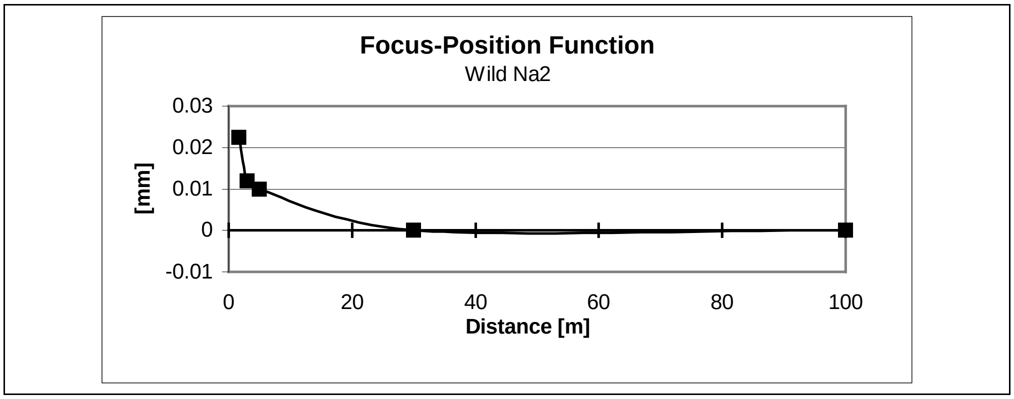


Fig. 1: Line of sight-focus function

While the constant line of sight inclination is corrected by symmetric or distance-balanced set-up positions, the focus functional deviation of the line of sight is a non-linear hyperbola function and has to be taken into account in precise levelling with varying lengths of sight. In addition most digital level procedures have a change of a near- and a far-field code in the distance range between 5 m and 15 m and thus additional systematic effects may be expected in a extreme variation of the distances to the staff.

3.2 Compensator Check and Specialities during the Levelling Procedure

As a simple method a light knock with the knuckle permits to check the clearance of the compensator. There is one speciality with respect to the compensator function: as all compensators are of the pendulum type, the compensator is systematically deviated by the centrifugal force during the change from the back-sight to the fore-sight direction.

3.3 Tripod Check ad Adjustment

Tripods have to be checked with respect to their stability and damping behaviour. Especially the wood-metal joints should be checked and if necessary fastened on a regular cycle according to the advices (instructions) of the manual. A simple test to check the damping of the leg joint is: One positions the tripod upside down and watches the slow-down movement of the legs.

3.4 Tribrach

Especially the Tribrach screws have to be free of play which can be checked by twisting the lower part against the upper part.

4. FIELD TESTS

4.1 Test Lines and Test Fields

The German Standard DIN 18732-2 proposes different test field configurations. The conclusion of Huep [2001] is that this procedure requires a great deal of work and the influence of line of sight deviations is neglected. Another simplified approach is the recommendation of ISO 17123-2 which is a simulation of a levelling line using fixed rods with variations of the level set-ups. These tests can be carried out either in a field- or a lab-environment. Experiments at the IGP/ETHZ have shown that this test procedure is capable to find systematic instrumental errors and give an impression of the accuracy achieved with this levelling configuration. This test can be regarded as a quality assurance procedure. More significant tests should be carried out during field tests regarding the geodetic rules of precise geometric levelling and including the recommendations of the manufacturers.

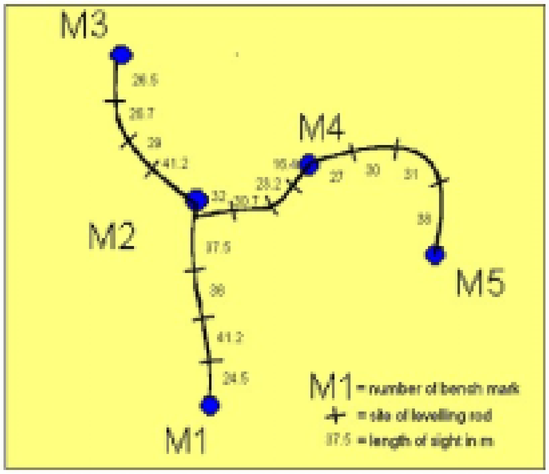


Fig. 2: The Metsähovi test field for precise levelling instruments [Takalo, 2001]

Several test lines were installed worldwide at several places for example the well-known "Koblenz-test-loop" and the Metsähovi test field (see Fig 2)

5. LAB TEST AND CALIBRATION PROCEDURES

Similar to the afore-mentioned field test and check procedures the scientific lab tests can be categorized in component-tests and calibrations, and system calibration. A common test procedure is the calibration of invar staffs.

5.1 Interferometric Calibration of Levelling Staffs

The goal of calibrating levelling staff is the determination of the scale and the zero point correction. All invar staff comparators base on the same principle of interferometer-controlled horizontal or vertical shift of the staff and an opto-electronic device (Schlemmer microscope, CCD and semiconductive position sensors) to determine the position of the flanges or the centre of the code-bars, respectively. The achieved accuracy of the production line at NEDO, Dornstetten, is in the order of a few microns standard deviation for the position of a single code bar. An interchanging test between TU München, UNIBW, München, TU Graz has demonstrated great coincidence of the results in the order of a few microns. The expansion coefficient of invar bands is in the order of 0.6 up to 1.2 ppm.

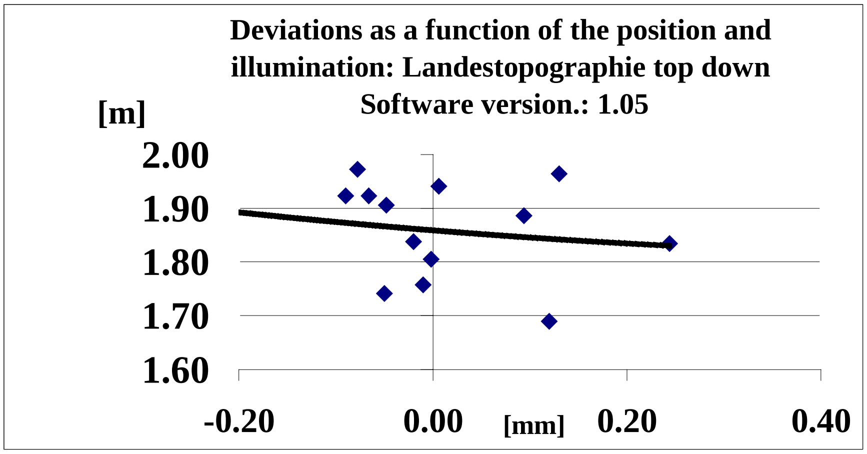
5.2 System Checks and Calibration Procedures

During the last two years a system calibration discussion came up to use the afore-mentioned interferometric calibration devices - especially the calibration devices with a vertical shift of the staff. First experiments have shown the necessity of such procedures [Brunner et al., 2001; Takalo, 2001] as tests have indicated cyclic and other systematic errors. The actual problem of system calibration procedures is the influence of refraction caused by the air conditioning in the labs; but this will be solved in the near future.

5.3 ETH Lab Tests of the Levelling Staff-End Problem in Connection with Artificial Illumination

During the last two years - under contract of AlpTransit - investigations were focussed on the illumination problem with digital levels, especially with the Zeiss DiNi digital level type.

Investigations of the staff-end problem have shown results, which have not been published up to now. The test procedure is simple as a comparison between a 3 m invar staff with full image exposure and a 2 m invar staff was made. The instrument was set up on an industrial tripod with a vertically shiftable column. The instrument has been shifted vertically in 5 cm steps in the range of 1.8 m up to 2 m and 2.8 m to 3 m, respectively. The difference between the 3 m staff and the 2 m staff-end readings has been calculated. These tests have shown that any disturbance or reduction of the minimum code information of 30 cm may cause systematic errors. In addition tests were carried out under the condition of artificial illumination with spotlights. The detrimental influences of inhomogeneous illumination to the Zeiss digital level evaluation procedure was also a result of these tests.



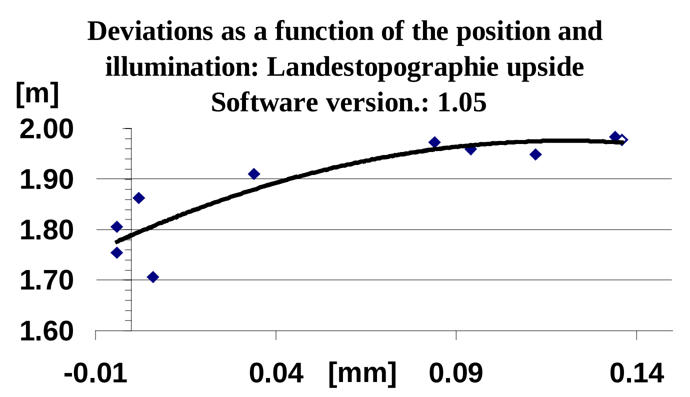


Fig. 3: Illumination effects

6. TESTS, CHECKS AND ADJUSTMENTS AT THE FABRICATION PLANTS

During the manufacturing process a lot of individual tests are carried out. Especially components as compensators, CCD sensors, and optics are checked separately before the assemblage. These tests can be regarded as incoming inspection. After the assemblage the whole system undergoes several functional tests and calibration procedures. At first, line of sight adjustment - the visual and the electronic line of sight - is made by using a special collimator with a recticle carrying the individual code in the focal plane. Additional checks with a certain number of instruments of a series confirm the environmental specifications stated by the manufacturers, e.g. the behaviour against dust, moisture, and shock. These tests encompass Electro Magnetic Compatibility EMC. For the higher accuracy class of instruments the temperature behaviour of the line of sight is monitored in a climate chamber. In instruments with higher accuracy the results are implemented in a correction function (polynomials, etc.) and will be calculated in the electronic height reading.

7. OVERVIEW OF THE CHECKING, ADJUSTMENT, AND CALIBRATION PROCEDURES

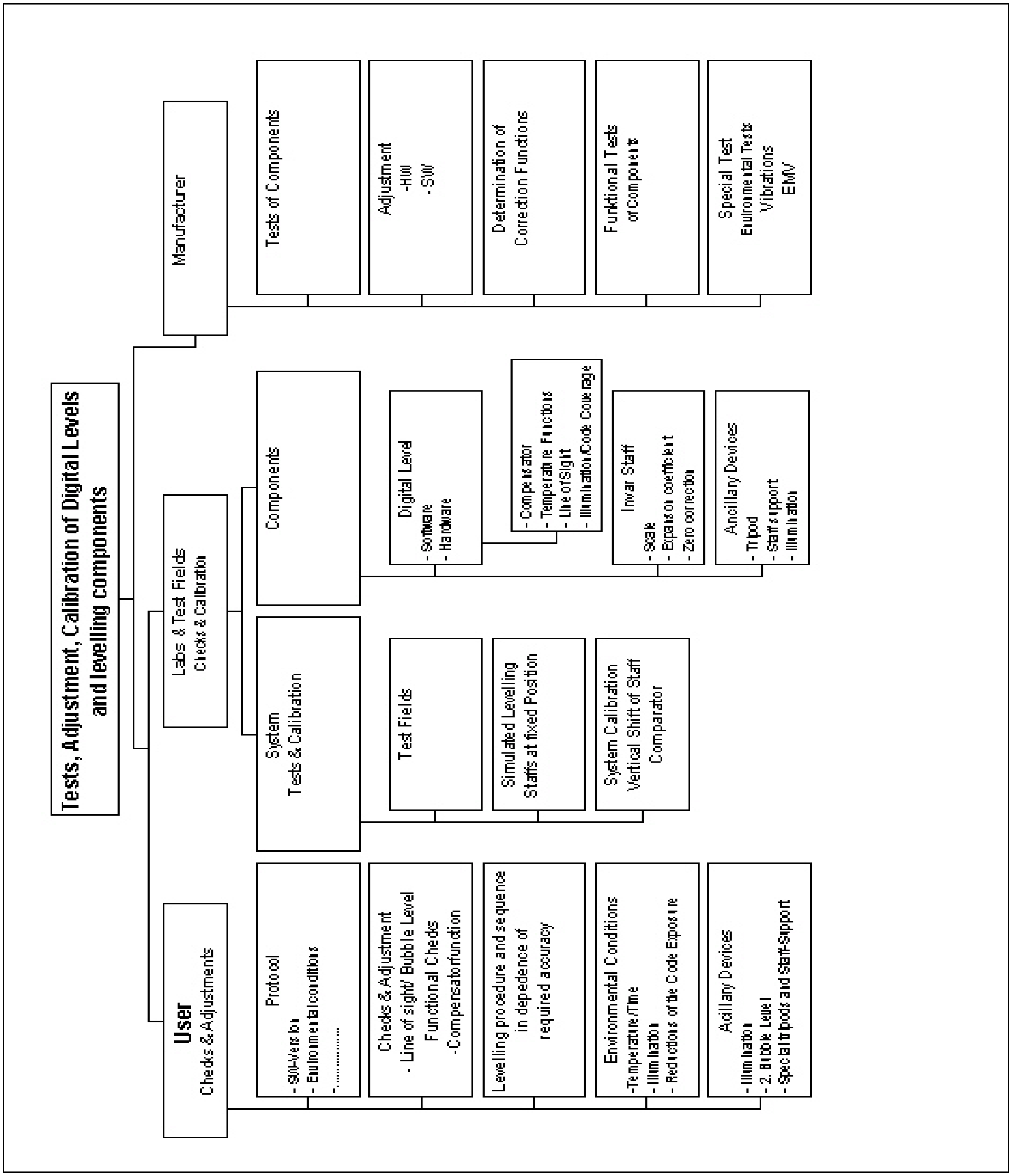


Fig. 4: Overview of the check, adjustment and calibration procedures

8. CONCLUSIONS

After about ten years of experiences with digital levels there is still a permanent request of testing and checking this type of instruments and the levelling procedure. While the characteristics of components as levelling staffs are well known up to now by a lot of calibrations on interferometric staff calibration devices, system calibrations in the sense of black box tests is at the beginning of its operability as refraction influences of the lab-atmosphere superimposes the calibration procedures up to now. First results have left a lot of questions in the digital levelling procedure.

The ten-year experience has also shown that the well known rules of classical optical levelling have to be strictly regarded to prevent systematic accumulating errors in digital levelling. A contradiction to the euphoric statements of the manufacturers' brochures a substantial education, knowledge and training in precise levelling is an absolute prerequisite for reliable results.

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BIOGRAPHICAL NOTES

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- Studies of geodesy at the University of Bonn, in 1984 received a Ph.D. for his thesis on "Development of Electronic Inclinometers" at the Institute of Geodesy, Bonn.
- Several years as a development engineer at Leica AG, Switzerland, and then head of the "Basic Research and Applications" group in 1989.
- Memberships: Swiss Geodetic Commission (SGK); Swiss Society of Photogrammetry; Swiss Commission for Geodesy; International Federation of Surveyors, Commission 5; International Standardization Organization TC 172 SC6; International Association of Geodesy (IAG); German Geodetic Commission (DGK); Swiss Society for Surveying and Rural Engineering.