

NEW TECHNICAL STANDARDS IMPROVING THE QUALITY IN POSITIONING AND MEASUREMENT

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1. INTRODUCTION

The purpose of this paper is to inform about the latest developments in the field of standards survey instruments and survey methods. They are first of all characterised by introduction of new information technology. These new technologies are represented mainly by GPS, Total Stations, Electronic Levels, RTK, Laser Instruments and other new measuring devices. The new instruments resulted in a revolution in positioning characterised mainly by high accuracy, speed and seemingly simple use. But these “advantages” may hide some dangers and traps which must not be neglected, and which might in the end lead to degradation of surveying profession. Possibility of achieving practically “any degree of accuracy and speed” could result in unnecessary increase of cost of positioning and in saturation of GIS data basis.

A comfortable and easy operation of the electronic “black boxes” could lead to underestimation of operator’s qualification and consequently to blunders resulting in enormous losses with the clients.

One of the ways to escape out of these traps of modern technology is standardisation. Here we want to mention three main areas which in our opinion are most relevant to the tasks of positioning and where the most important changes have been made:

- a) standards for survey equipment
- b) standards for laboratory calibration and testing
- c) standards for positioning within the family of standards for geographic information and geomatics

2. STANDARDS FOR SURVEY EQUIPMENT

The surveying profession has been subject to a rapid technical evolution concerning techniques and equipment. Today Surveyors commonly use digital levels, laser planes, total stations and GPS, however ISO (International Standard Organisation) has not yet succeeded to put on the marked standards for these new instruments. ISO still works hardly with updating and harmonisation of earlier standards for older instruments as example EDM, theodolites and levels.

Inside ISO, several Technical Commissions (TC59/SC4 and TC172/SC6) have produced standards for levelling instruments. Unfortunately these standards made for the same instrument and for the same purpose namely “Field procedures for determining the accuracy of surveying instruments” are often quite different because of different goals of the TC’s. TC59 investigated the standards from the building construction point of view and TC172 from the instrument manufacturer point of view.

Since 1997 a Joint Working-Group for both TC's works on a harmonisation and updating of existing standards. The goal is one standard for one instrument type. One of the projects concerns levels and is chaired by J-M Becker. A reviewed draft proposal has been discussed in Berlin March 1999 and sent to the National Standard Organisations for comments and approval.

The following paper presents firstly general and specific surveyor requests on standards, thereafter the recommended field procedures for the determination of achievable precision with levelling instruments for different applications. A simplified and a full test procedure will be described. But no practical examples are given because a lack of place. For more details we recommend to read ISO standards

2.1 Objectives

The objectives for the standards are to specify field procedures to be followed each time the achievable precision or "accuracy" for a given surveying instrument used together with its ancillary equipment (tripod, staffs, etc) has to be determined. This will allow the surveyor to investigate that the precision in use of the measuring equipment is appropriate to the intended-measuring task.

2.2 Requests on standards

The common requests are as follow: only *one standard for each type of instrument* who can be used *anywhere* and *whiteout* any special equipment by *common field operators* (technicians as well as academics). That is to eliminate confusions, difficulties in application and in interpretation.

Before any fieldwork the surveyor has to answer to the following question:
"*Can I achieve the required accuracy in the project with my equipment, yes or no?*"

The answer depends on *each involved survey team* composition (instruments, ancillary equipment, personal), execution times, project specifications, environmental conditions like meteorology, vegetation, ground surface, etc. The question can also be more general concerning several teams, equipment, projects, time for execution, etc. The Surveyor has to be convinced that if he applies the standards they will help him, otherwise he will not apply them. For these reasons the surveyor asks for *user friendly standards*, low in time consumption (about ½ hour) and with results easy to interpret.

2.3 Field test procedures

The procedures described in this paper are designed for *field* and not for laboratory use. The results are specific for *each* determination and representative only for the *particular* conditions existing at that *time*: weather, environment, ground surface, equipment, staff members, etc. The equipment must always be acclimated to the environmental temperature and adjusted before testing in accordance with the manufacturer handbooks.

2.4 The full field test procedure

This field method is proposed for the determination of the highest achievable precision using one specific type of levelling equipment. Normally it is for the purpose of *precise levelling* where high accuracy is demanded and the set-up observations are made with *equal lengths of backsights and foresights*. The accuracy will be expressed in terms of the *standard deviation for 1km double-run levelling*.

For implementation of this test we have to establish a test line AB of about 60m in a plane area with homogenous ground surface (gravel preferably) free from vegetation or other disturbing factors (water plane, grass). The points A and B have to be stable during the whole operations. The chosen site lengths will be about 30m, which is the recommended distance for precise levelling in most countries.

Note:

- A variation of 10% between the site lengths at each set-up can be accepted. That is a realistic tolerance compatible with normal field applications.
- Also greater site lengths (up to 50 – 60m) can be used for the purpose of testing the equipment's capacity and range of accuracy or according to project specifications.
- All factors specific for each test: equipment, ground surface, vegetation, weather conditions, operators, etc. have to be documented.

The observation procedure:

The measurements are made in two sets with interchanging the positions of the staffs between A and B. Each set consists of *n-pairs of readings* (preferably 20) backwards to staff A - forward to staff B and vice-versa, resulting in n-height differences. Between each pair of readings *a new instrumental set-up* has to be made. All details about how to operate, calculate and evaluate are described in the coming standard with one example in appendix.

Evaluation of the results:

The results analysis is made with statistical tests helping the surveyor to decide whether his equipment allows him to achieve the expected accuracy.

2.5 Simplified field test

This test is based on a limited number of measurements (minimum 10) for checks of levelling equipment used especially at construction *sites where radial measurements* with *unequal sight lengths* at each set-up are of common use. Equal sight lengths are exceptions.

Establishment of a test line:

In a relatively plane area two points A & B have to be monumented at a distance corresponding to the maximum and minimum sight length ranges that will be used inside the specific project. As an example if inside a construction project the needed sight lengths are between 10 and 70m, the distance for AB will be about 80m. The points A and B have to be stable during the test period.

Observation procedure:

The measurements are made in two different steps:

The *first* step with *equal sight length* (40m) is a copy of the accurate test described above limited to 10 set-ups. The goal is to determine a *reference height difference* between A and B, value that is considered as the *true value* of the height difference of the levelled points A and B.

For the *second* step the instrument is placed so that the maximum eccentricity for the set-ups is used: in our example 10m and 70m (Fig.1). Again all observations on both staffs A and B are made for 10 set-ups.

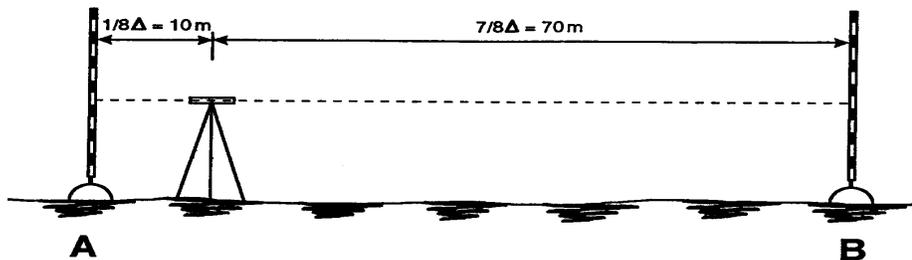


Fig. 1: Second configuration of the test line for the simplified test method

2.6 Conclusion

FIG-C5 is grateful that the ISO Technical Committees TC59 and TC172 have taken in account the requests of the surveying community for the updating and harmonisation of existing standards. We also have noticed that efforts are undertaken to prepare standards for the *new generation* of survey instruments like total stations, laser-planes and perhaps GPS. We hope that these standards will soon be reality.

FIG Commission 5 will contribute with its experts (WG 5,1) to the elaboration of this standards through collaboration with ISO. Furthermore FIG-C5 will help the surveyors to implement these standards in the best way.

3. STANDARDS FOR LABORATORY CALIBRATION AND TESTING

In contrast to the field procedures, discussed in chapter 2, the standards, the strategies and approaches, of laboratory tests and calibrations for modern surveying instruments are very poorly defined or even introduced in practice. Though these metrological procedures become more and more justified also by new aspects of quality management systems as required by standards of ISO 9000 family and also by the complexity of new electronic measurement systems. Documented procedures for a uniform approach are not yet available for the majority of the new instruments.

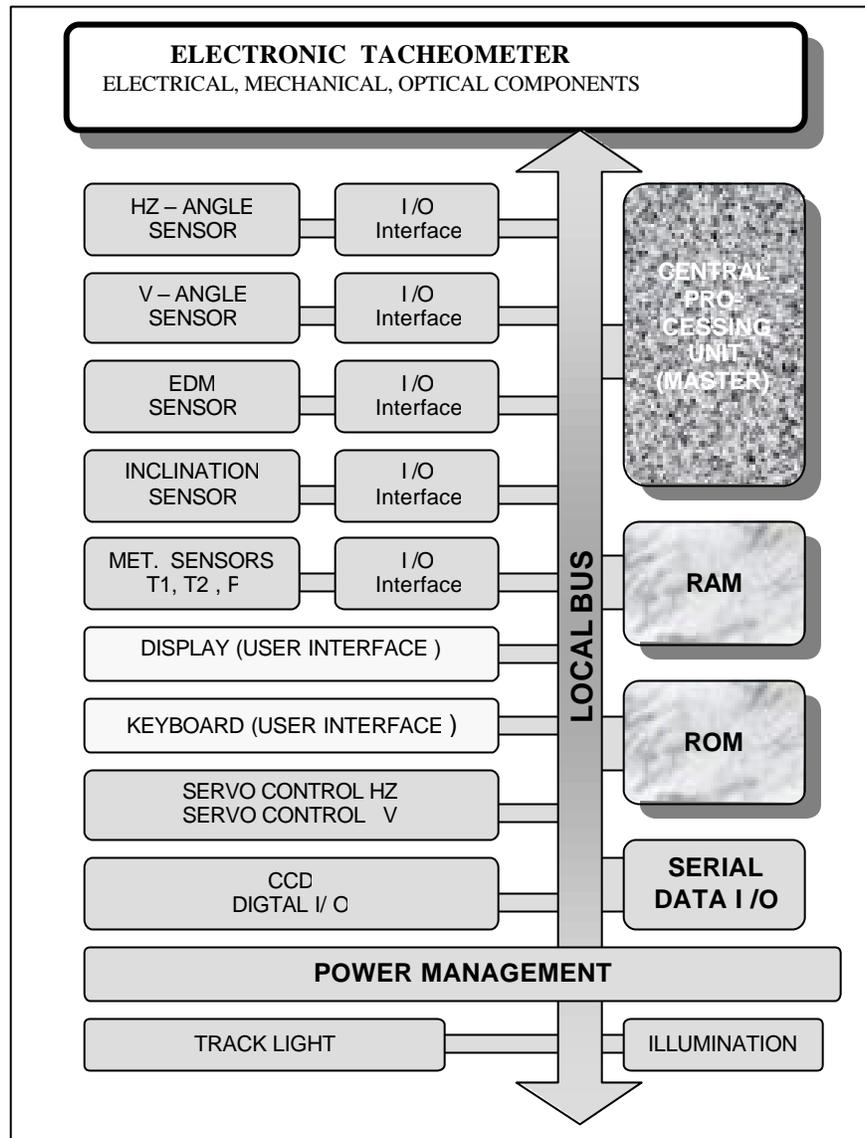


Fig.2: Opto-electronic structure of a modern tacheometer

The old notions concerning the external structure of e.g. a theodolite, from which you could derive well defined procedures for handling, checking, adjusting or calibrating, are partly totally out-dated. Modern surveying instruments are better structured on the base of sensor components or functionality (Fig. 2) This points out much better the opto-electronic concept and clarifies additionally interconnection of sensor units, firmware, application software, data acquisition, data transfer and user interface. Operation of these hybrid systems has become as complex nowadays making it nearly impossible to survey all functions. The first initialising procedure of an electronic tacheometer can require more than 100 (!) operating steps (keystrokes) and settings. Multitude of instructions and data entry not only has the advantage of extended applications but also is implying as well for the manufactures as for the user to produce (instrumental) errors (HENNES, 1998). The complex sequence from original sensor signals to final results often makes it impossible to locate the reason for a wrong measuring result. Furthermore it is impossible to decide if this was a user's wrong operation or a failed measurement. The interaction of configuring an instrument, controlling, correcting and data processing demonstrates Fig. 3. That is why it becomes more and more difficult to design robust checking methods. Particularly it is

advised to check preferable sensor groups or if possible the complete measuring device using a most simple but effective and representative procedure.

In practice this is not so easy, but first rudimental proposals were published (GOTTWALD, 1998, FISCHER 1998). It is a major task for manufacturers, universities or other institutions specialised on this field to prove new test methods with respect to recent developments and short innovation cycles. Moreover it is important that these procedures were economically reasonable and accepted in practice is as much as possible.

GOTTWALD, 1998 and STAIGER, 1998 propose a stepwise proceeding in 4 phases. Phase 1 and 2 consist of routine checks respectively field procedures. They comprise all these actions, which may and have to be realised by the surveyor in the field or short-time before survey. Beside the FIG publication (1994), which relates to EDM, the new drafts of ISO 17123 – 1,2,3, 4 specify investigations to verify appropriate functioning and to determine accuracy in use for levels, theodolites and EDM's. All proposed procedures are field tests without the need of special additional equipment.

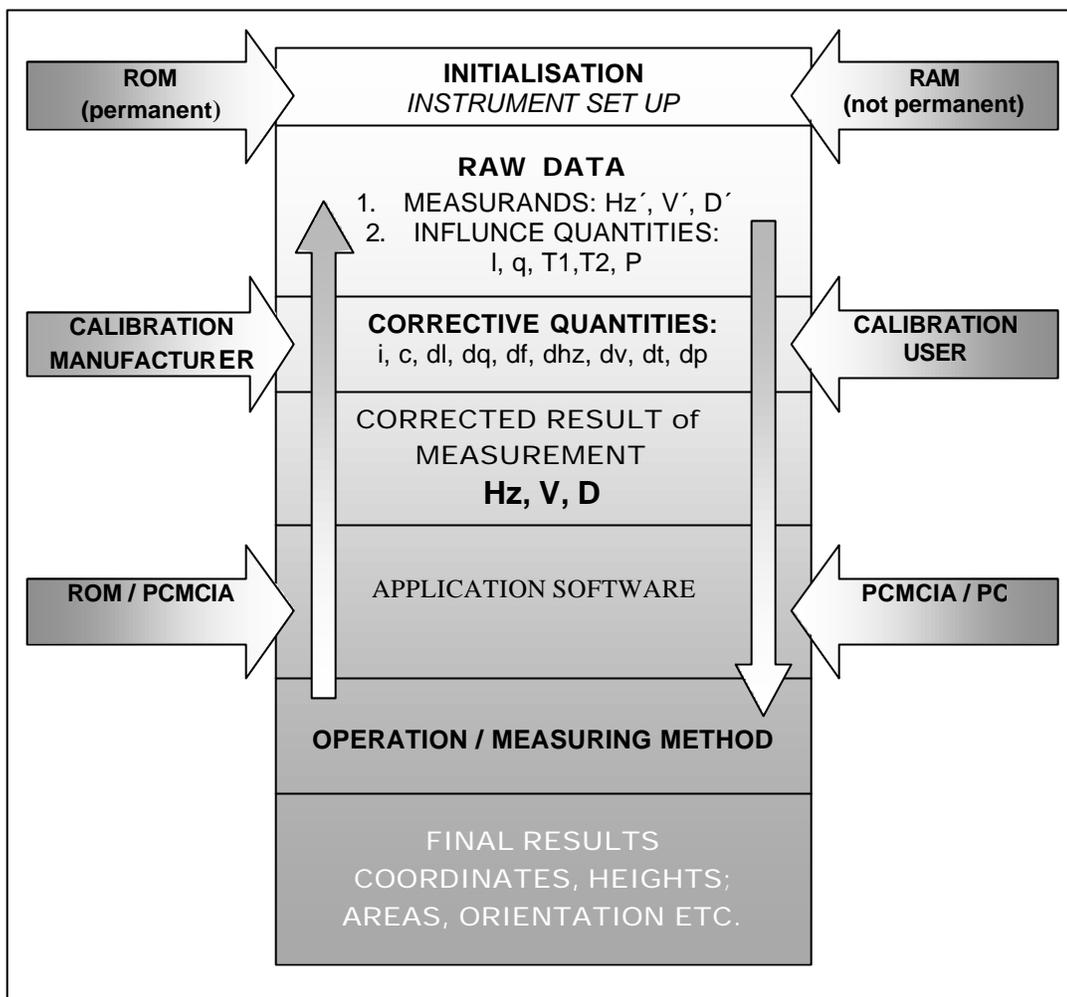


Fig. 3: Measuring process of microprocessor controlled surveying instrument

Phase 3 and 4 encompass calibration and extensive testing for acceptance and performance. They demand for a high grade test equipment and reference conditions, where traceability is guaranteed.

In general preferring of so called *system calibration* or *system checks* can be observed. The objective is to aspire to a global test, which confirms correct functioning of *all relevant sensors, controlling firmware* and the *application software*. Without knowledge of the specific behaviour of a single sensor final results are compared to reference quantities. E.g. FISCHER 1998 describes a proposal and simulation results of investigating a tacheometer.

The practice in calibrating digital levels (phase 3, 4) is similar, but already better proved. Without knowledge of the code, the correlation model and the imaging process *system calibration* yields representative quantities for scale, accuracy, resolution, stability or drift (PIETSCH, 1992, HEISTER, 1994, REITHOFER ET AL, 1996).

The theme quality control and metrological confirmation becomes much more confusing with regard to GPS technology. Though the system is already well established and successfully used in surveying, published methods for checking and calibrating satellite positioning systems are only a few (Bäumker, Fitzen 1996, Ingensand 1997, Landau, 1998, Stewart et.al. 1998) and no common standard.

It is obvious that there are two major reasons for reconsidering new test (calibration) methods, which can only be realised by qualified technical staff:

- (1) New technologies have radically influenced the design of surveying equipment that traditional methods for investigating instruments have become more less obsolete.
- (2) A state of the art quality management system (QMS) demands for a metrological confirmation system, which should include documented procedures for field and lab checks. The old instructions do not cover all the requirements of the QMS. For the time being there are no standards (ISO, EN etc.) closing the gap properly.

In order to attain new concepts for economical acceptable test (calibration) method it is necessary that

- ◆ the chain from the uncorrected measurands to final results is documented by manufacturers in all details (reference manual),
- ◆ the instrument can be reset any time in a controlled basic configuration with clearly documented defaults,
- ◆ user friendly operation with a minimum of misoperations is provided,
- ◆ simple but effective testing methods (4 phases model) are proposed by manufacturers, universities or other qualified institutions,
- ◆ independent accredited calibration laboratories are to constitute, guaranteeing traceability and which are specialised on investigating geodetic equipment. These institutions should be able issuing calibration certificates in accordance with the WECC or any other international organisations.

These remarks may stimulate the discussion about instrument testing between practitioners and experts with the objectives to establish new guidelines for calibration or performance tests, procedures for effective checking the functional units of the “black-boxes”. But new guidelines have as well to be set up data processing procedures, to guarantee reliable results and best accuracy.

4. STANDARDS FOR POSITIONING GEOGRAPHIC INFORMATION

Activities on Standards related to positioning of Geographic Information are being treated mainly by ISO/TC 211 and by CEN/TC 287. Most of the pre-standards are now completed or short before completion. If we consider that according to GIS specialist over 80 % of all activities on global, national and regional level have spatial or geographic aspect it, is no surprise that the initiative for standardisation in this field came from the GIS experts and not from surveyors. The most important documents in this field are *ISO/WD 15045-11.8 Geographic Information/Geomatics – Part 11: Spatial Referencing by Coordinates and pre-standard ENV 12762:1998: Geographic Information – Referencing – Direct Position*. Continuously increasing adoption of modern surveying instruments and namely GPS for positioning and navigation makes it necessary for surveying profession to ensure national and international standards for geo-referencing and spatial co-ordinate positioning. Control Networks, Grid Transformation and Geoid Models should guarantee these standards. Due to a continuously increasing global aspects of geographic information positioning by GPS methods will gain on importance in the long run.

Geographic Information can be defined as any information that can be referenced to a location on the Earth. Importance of Geographic Information is increasing as it is used more and more commonly for decision making by governments, enterprises and private citizens. Spatially positioned data exerts in the modern “*information society*” a great influence over our daily lives both now and in the future. If we define surveying as an “*art of positioning*” the application of geographic information in the Information Society represents a great challenge for our profession.

Only well positioned information (in space as well as in time) can provide a reliable platform for information services based on data derived from both terrestrial and airborne resources. The fact that geographic information is more and more important in growing number of applications such as transport, telecommunications, environment, agriculture, marketing, medicine, geology, etc, stresses the importance of common standards including for positioning. This concerns all levels of positioning local, national, continental and global. These standards should ensure full seamless interoperability of all spatial information. Any negligence in unique standard definition of the reference systems or lack of accuracy in positioning can lead to great losses in time and money if not to a complete inoperability of information systems based spatially located data.

A vision of so called “*Digital Earth*” was presented at the IST 99 Conference in Helsinki as “an integrated, distributed and easily accessible rich source of geo-referenced information and tools”. This vision can be achieved only if we manage to develop tools, data sets and methods to integrate geographic information into the Information Society. To develop these tools means not only to provide appropriate platforms and multimedia instruments but first of all **to base the information on reliably spatially and temporally referenced data.**

5. CONCLUSION

Since 1995 FIG WW in Berlin FIG has established liaison with ISO/TC 211 Geographic Information/Geomatics. In 1998 FIG Task Force for Standards was created and FIG Commission 5 “Positioning and Measurement” included in its working plan

activities dealing with Standards, Quality Assurance and Calibration. The mission of the FIG in this field is to adapt the new standards to modern surveying technologies and technical developments and to assist individual surveyors to select optimum procedure for given tasks. Surveying profession must also be able to provide and maintain reference frames, which would enable integration of geographic information (based on spatial and temporal positioned data) into the Information Society. This is one of the most important tasks of surveying profession at present.

LITERATURE

- BECKER, J.-M.: The new updated ISO Standards for Survey equipment. in: Geodesy Surveying in Future, Gävle, Sweden, 1999.
- BECKER, J.-M.: History and evolution of height determination techniques especially in Sweden. Surveying in Future, Gävle, Sweden, 1999.
- BÄUMKER, M., FITZEN, H.-P. (1996): Permanente Überwachungsmessungen mit GPS. In: Brandstätter/Brunner/Schelling(Hrsg.): Ingenieurvermessung 96, Ferd. Dümmler's Verlag, Bonn, p. B7/1 – B7/12
- FISCHER, E.-N.(1998): Prüfung elektronischer Sensorsysteme bei elektronischen Tachymetern. Allgemeine Vermessungs-Nachrichten (AVN), p. 374 – 378.
- GOTTWALD, R. (1998): Prüfung und Kalibrierung von Vermessungsinstrumenten. Vermessung, Photogrammetrie, Kulturtechnik, p. 409 – 413.
- HEISTER, H.(1987): Zur automatischen Kalibrierung geodätischer Längenmeßinstrumente. Schriftenreihe des Studiengangs Vermessungswesen der Universität der Bundeswehr München, Heft 27.
- HEISTER, H.(1994): Zur Überprüfung von Präzisions-Nivellierlatten mit digitalem Code. In: Schriftenreihe des Studiengangs Vermessungswesen der Universität der Bundeswehr München, Heft 46, p. 95 – 101.
- HEISTER, H. (1996): Qualitätssicherung und Kalibrierung geodätischer Meßmittel. In: Brandstätter/Brunner/Schelling(Hrsg.): Ingenieurvermessung 96, Ferd. Dümmler's Verlag, Bonn, p. C2/1 – C2/9
- HENNENES, M (1998): Tachymeter – Technologien, Instrumentenfehler, Kalibrierung. Paper presented at DVW- AK 5 Workshop, Febr. 16./17., Darmstadt.
- INGENSAND, H.(1997):Neue Verfahren zur Zertifizierung geodätischer Messinstrumente. In: IX. Internationale Geodätische Woche Obergurgl, Institutsmitteilungen der Universität Innsbruck – Geodätisches Institut, Heft Nr. 17, p. 93 - 107
- LANDAU, H. (1998): Zur Qualitätssicherung und Vernetzung von GPS-Referenzstationen. Vermessungswesen und Raumordnung (VR), Vol. 60/8, p. 438 – 445.
- PIETSCH, U. (1992): Untersuchungen zur Systemgenauigkeit der automatisierten digitalen Nivelliere NA2000/NA3000. Diplomarbeit, Institut für Geodäsie (unveröffentlicht).
- REITHOFER, A., HOCHHAUSER, B., BRUNNER, F.K. (1996): Calibration of Digital Levelling Systems. Österreichische Zeitschrift für Vermessung und Geoinformation (VGI), Vol.84, p. 284 - 289
- STAIGER, R. (1998): Zur Überprüfung moderner Vermessungsgeräte. Allgemeine Vermessungs-Nachrichten (AVN), p. 365 – 372.
- STEWART, M., TSAKIRI, M., MARTIN, D., FORWARD, T.(1998): Traceability and Calibration of Satellite Positioning Systems. Survey Review, Vol. 34, 269, p 437 – 446.
- SLABOCH, V.: ISO and the Surveyor. FIG Congress, Brighton Commission5, Proceedings, 1998.

SLABOCH, V.: Present State of Standardisation in Surveying Profession. Proceedings from the Conference Surveying in Future, Gävle, Sweden, 1999.

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