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САРГАЗАКОВА Ш.С., КУДАБАЕВ М.Д., САРГАЗАКОВ А.А.,ИСКЕНДЕР КЫЗЫ Ч.
[1]КГУСТА им. Н. Исанова, Бишкек, Кыргызская Республика

SARGAZAKOVA SH.S., KUDABAYEV M.D., SARGAZAKOV A.A., ISKENDER KYZY CH.
KSUCTA n.a. N.Isanov, Bishkek, Kyrgyz Republic
akylbek.chymyrov@aca-giscience.org

APPLICATION OF ELECTRONIC LEVELS AND IMPACT OF THEIR ACCURACY ON CONSTRUCTION MEASUREMENTS

ПРИМЕНЕНИЕ ЭЛЕКТРОННЫХ УРОВНЕЙ И ВЛИЯНИЕ ИХ ТОЧНОСТИ НА СТРОИТЕЛЬНЫЕ ИЗМЕРЕНИЯ

Азыркы учурда Кыргызстанда турак-жай имараттарын жана курулмаларын куруунун темпи жана масштабы кескин өсүп жатат. Бул макала отуз жыл аралыгында чыгарылган WILD NA2000, Sokkia SDL50 жана Leica LS15 сыяктуу санариптик нивелирлерди салыштырмалуу талдоого арналган. Жүргүзүлгөн изилдөөнүн негизинде авторлор тарабынан өнүгүүнүн жүрүшү жана заманбап технологиялардын электрондук геодезиялык аспаптар менен тыгыз байланышы көрсөтүлүүдө. Бул берененин темасы өтө актуалдуу болуп саналат, анткени биздин Бишкек шаарыбызда, курулуш иштери жогорку денгээлде жүрүүдө демек, мындай инструментке болгон муктаждык абдан жогору.

Өзөк сөздөр: *санариптик нивелир; кодтуу инвардык рейка; алмашуу интерфейси; RAB-коду; автоматтык фокусировкасы; автоматташтыруу; пайдалануу-порту.*

В настоящее время в Кыргызстане увеличиваются темпы и масштабы строительства жилых зданий и сооружений, а такой геодезический прибор как электронный нивелир, очень ценен и необходим в данной отрасли. Данная статья посвящена сравнительному анализу цифровых нивелиров, выпущенных на протяжении порядка тридцати лет, таких как, WILD NA2000, Sokkia SDL50 и Leica LS15. Особое внимание уделяется техническим характеристикам, изучение и анализирование которых, несут за собой выводы и итоги. На основе проведенного исследования, авторами наглядно показывается ход развития и тесная связь современных технологий с электронными геодезическими приборами – нивелирами. Тема данной статьи является актуальной, так как на примере нашего города Бишкек, мы можем видеть высокую степень застраиваемости, и следовательно, потребность в таком приборе весьма высока.

Ключевые слова: *цифровой нивелир; кодовая инварная рейка; интерфейс обмена; RAB-код; автоматическая фокусировка; автоматизация; пользовательский порт.*

Currently, in Kyrgyzstan, the pace and scale of construction of residential buildings are increasing, and such a geodetic device as an electronic level is in high demand in the industry. This article provides comparative analysis of digital levels released in last thirty years, such as WILD NA2000, Sokkia SDL50 and Leica LS15. Particular attention is paid to the technical

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characteristics, the study and analysis of which are the conclusions and results. Based on the study, the authors clearly show the development and close connection of modern technologies with electronic surveying instruments – levels. The topic of this article is relevant as we can observe high rate of urban development in case of Bishkek, therefore, the demand for such a device is considered to be high.

Key words: *digital level; level error, invar code rake; exchange interface; RAB-code; auto focus; automation; user RS-232 port.*

Leveling (from fr. Niveler - "to level", "to put at the level"), the principle of operation, from the moment of its invention and to this day, remains unchanged - geodetic device for leveling, i.e. determination of the difference between the height and several points of the earth's surface.
The main task of the level is to build a stable horizontal, with which any deviations become noticeable.

The history of the existence of this device is more than a thousand years old. The first model of the modern level appeared in ancient Egypt. For the construction of complex structures they needed appropriate auxiliary equipment. The exposition of the first simple level, arranged in the form of communicating vessels filled with liquid, is given in the works of G. Alexandrian in the II century BC. e. In the simplest form, the level existed until the seventeenth century with real world applications. In 1609 Galileo supplemented it with a measuring tube. Through some period of time Johann Kepler in 1611 improved the device, adding to it a net thread. In 1674, Montenarius replaced ordinary threads with long-range ones. Optical levels appeared only in the middle of the XIX century after 1857. In Amsler Laffon's workshop was built a shifting level. The measuring device in its common form known to us was built only at the end of the XIX century, when scientist D. D. Gedeonov invented a optical level in 1890, it became the ancestor of modern devices. The tool soon found practical applications. Levels began to be used in construction, engineering research and topographic and geodetic works. Swiss researcher G. Wilde offered internal focusing on the sight tube, contact level, optical micrometer and invariant rails. German developers of the Opton company in 1950 created levels with a self-established line of sighting. Thanks to the scholars G. Yu. Stodolkevich and N. A. Gusev upgraded the level by adding automatic compensators [1].

On terminology: electronic and digital levels are same devices as different manufacturers use the symbol "Digital Level" [2].

Researched digital levels

The digital level is based on the principle of the digital method of the phase range finder i.e. measurements are automated up to display of the result on an electronic screen and to an external data storage device. The phase method itself for measuring distances is the most common method of geodetic ranging and is used to measure distances from tens of meters to tens of kilometers [3].

The first almost fully automated digital level in the world - Wild NA2000 was launched in the early 90s [4], and based on this quote, this device will be considered the first digital level in our article.

The measurement results are given in digital form and can be simultaneously recorded on the REC - GRM10 module (designed for simple control and notification operations), a GRE data terminal (Generic Routing Encapsulation) or a computer. For the WILD NA2000 level, a special leveling rod has been designed, consisting of three segments. On face side of the device is a binary code with alternating stripes for electronic reading. On the reverse side, the usual checker divisions are applied, which makes it possible to use it for ordinary optical levels [5].

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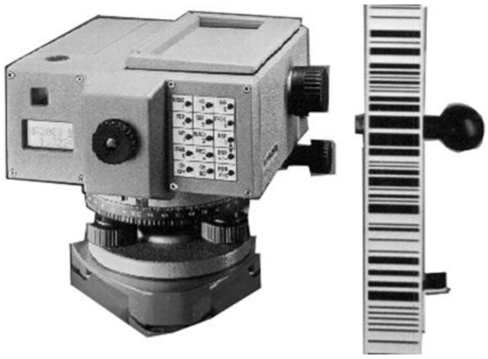

Figure: 1. First digital level Wild NA2000 and barcode rail

By automatically taking samples, the productivity and accuracy of geometric leveling is significantly increased. Observer errors are excluded from the observation process. When aiming at the object and setting the focus, the set number of readings is taken with their subsequent averaging [6].

The investigated digital level Sokkia SDL50 was released in 2005. Sokkia was one of the first to launch a digital level. Especially for the first released electronic level SDL30, the company has created a fiberglass leveling rod, operating based on reading information from a bar code printed on it. This technology was named "RAB-code" (RAndom Bi-directional) [7]. It provides accurate results under various conditions and improves the accuracy of distance measurements.

Figure: 2. Digital level SDL50 and fiberglass staff with RAB-code

Finally, the third digital level under study is the Leica LS15. Many operations are automated, which greatly facilitates the difficult work of surveyors performing high-precision measurements. Automatic focusing and working with a digital camera through a simple and intuitive interface of Leica LS digital levels make leveling comfortable and fast, and the data obtained is reliable. Data import and export is carried out using USB sticks or Bluetooth, which makes data exchange even more convenient. By pressing one button of the device after sighting at the target, the digital level will automatically perform all the operations necessary for accurate and reliable recording of the report [8].

Figure: 4. Leica LS15 digital level and Leica GPCL3 invar staff.

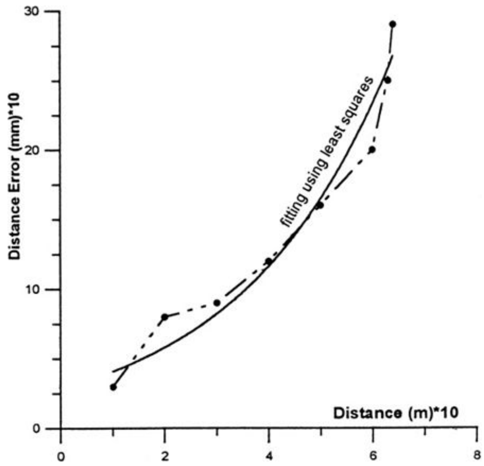

Figure: 5. Accuracy of horizontal distance

The technical characteristics of the investigated electronic levels are listed in Table 1.

Table 1

Name		**Wild NA2000**	**Sokkia SDL50**	**Leica LS15**
Year of release		early 90s	2005	2016
Mean square error of excess measurement for 1 km double stroke, mm	code invar rail	1.5	0.8	0.2
	standard rail	2.0	1.5	1.0
	visual measurements	2.0	2.0	2.0
Measurement time, sec		4	3	2.5
Distance measurement accuracy		3-5 mm at 10 m	10 mm at 10 m	15 mm at 30 m
Measurement range	electronic	from 0.8 to 100m	from 1.6 to 100m	from 1.8 to 110 m
	visual	от 0.6 м	от 0.6 м	от 0.6 м
Compensator operating range		±12′	±15′	±10′
Accuracy of the compensator		0.8″	inf. absent.	0.3″
Visual tube (zoom)		24x	28x	32x
Round level division		8′/2 mm	10′/2 mm	8′/2 mm
Horizontal circle with divisions, °		from 0 to 360	from 0 to 360	from 0 to 360
Objective diameter, mm		36	36	36
Optical sight		yes	no	no
Autofocus		no	no	4 sec.
Operating temperature range, ° C		-20°…+50°	-20°…+50°	-20°…+50°
Memory (number of measurements)		2 000 (64 KB)	2 000 (64 KB)	30 000 (1 GB) USB memory stick

Exchange interface	RS-232C On-line mode	RS-232C CSV/SDR33	RS232/USB Bluetooth Mini USB
Battery type	GEB79	Lithium-Ion BDC46	Lithium-Ion GEB331 (GEB 371)
Keyboard	15 keys	8 keys	28 keys backlit
Weight, kg	2.5	2.4	3.9
Dust and moisture protection	inf. absent.	IPX4	IP55

The data in the table were taken from the official websites and dealers of the companies, as well as technical documentation of the investigated devices [9], [10], [11].

The result of this comparative study is:

- reduction of the RMS of the elevation measurement by 1 km of double stroke;
- reducing the time of measurements with a barcode rail;
- increasing the accuracy of distance measurement;
- increasing the measurement range;
- increasing the frequency of the telescope;
- increase in the internal memory of the device;
- increase in the exchange interface;
- the emergence of autofocus and electronic level;
- improvement of the complex protection of the device.

Conclusion

Development is part of processes around us, without which it becomes impossible to improve the quality of construction work. This article deals with innovations related to geodetic instruments that allow bringing the process and economics of construction to a higher level, i.e. are the engine of the industry development. Innovative technologies have evolved, are developing and will continue to develop, even though our construction market is full of various devices and ideas. Electronic level is a precision tool used for accurate leveling. This paper examines the use of electronic levels and the effect of their accuracy on construction measurements.

In conclusion, the objective of the tools is to assist, or even free a person from doing work. We, as authors, are confident that this article has demonstrated a close connection between innovative technologies and the construction industry, showing a significant simplification, acceleration, and reduction in the cost of construction and construction methods.

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