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UNCERTAINTY OF THE MEASUREMENT OF LEVEL AND FLOW USING EHP-TEKNIIKKA MEASUREMENT SYSTEM

This paper describes an uncertainty evaluation for the measurement of water level and flow at small rivers, channels, ditches and wells all-year-round in field conditions using EHP-TEKNIKKA Measurement Systems. The EHP-TEKNIKKA Measurement Systems can be used in the different areas such as mining, water supply and water discharge, energy sector, forestry, pulp and paper, fishery and agriculture. The uncertainty of measurements must be quantified and considered in order to prove conformance with specifications and make other meaningful comparisons based on measurements. Type A uncertainties were obtained from repeatability study of the calibration process, a repeatability study of the real-time monitoring process and a system stability test. Type B uncertainties were obtained from calibration certificates and estimates.

Keywords: *uncertainty of measurement, measurement of water level and flow, calibration dependence.*

Introduction

The measurement of water level and flow are important for real-time monitoring system and are increasing interests for the optimization of water consumption. For example when measurement result used such branches of business, where it is necessary to measure the amount and quality of water in the field conditions as well as in changeable conditions.

The result of measurement is always an estimate of true value with some degree of uncertainty. A number of standards are references within this work; The Guide to the Expression of Uncertainty in Measurement (GUM) [1] defines uncertainty evaluation within the metrology community; ISO 5725 [2] defines accuracy (trueness and precision) and etc.

Components of uncertainty for different factors are classified as Type A obtained by statistical analysis of a series of observations or Type B obtained by other means. Regardless of classification all components are modeled by probability distributions quantified by their variance and combined to give a total uncertainty. The total uncertainty is multiplied by a coverage factor to give bounds to the possible range of values within which the true value may lie, at a given confidence level. This is known as the expanded uncertainty [3].

This paper describes an uncertainty evaluation for the measurement of water level and flow at small rivers, channels, ditches and wells all-year-round in field conditions using EHP-TEKNIKKA Measurement Systems.

Previous works considering such an approach has been focused on the estimation of the measurements' uncertainty of technological process and productions or investigate research laboratory while this paper presents the results of practical using this methods.

1. Monitoring water flow in small rivers

1.1. Measurement Method

EHP-Tekniikka Ltd. has developed technical solution, which offer possibility for automatic wireless online monitoring of water flow at small rivers, channels, ditches and wells all-year-round in field conditions. The solution is based on the monitoring of water level by water level sensor and field measurements of the dimensions of river bed and velocity of water.

The solution has been specially developed for field conditions in the following areas: mining, water supply and water discharge, energy sector, forestry, pulp and paper, fishery and agriculture [4].

The water flow is calculated automatically according to the data collected by the water level sensor and previously recorded measurements of river, channel, ditch or basin bed and velocity of water. By installing the system to any open water source it's possible to monitor the water quality on-line, continuously and in real time, whereas the data is transferred to single pc, automated system or Internet. System provides the possibility to send water flow alarms via sms-messages to a designated telephone number.

1.2. Measurement of water level

During the time of preparation for level measurement consist on calibration of the pressure transducer relative indications tape measure.

The zero level is assumed to be closest to the bottom of a small river, channel, deep ditches or the top of the protective well of the sensor of the pressure transmitter. The liquid level is measured first, then a tape measure pressure transducer.

A picture of the installation of the pressure transmitter can be seen on fig. 1.

The reading of the transmitter is calibrated in accordance with the values of the tape measure in the reading of the transmitter is corrected H_2, then H_2 can be estimated using equation (1).

$$H_2 = H_0 - H_1. \quad (1)$$

The level measurements are made to determine water-surface area of the section F_B and f_s its compartments and the disposition can be seen on fig. 2, section 2-2.

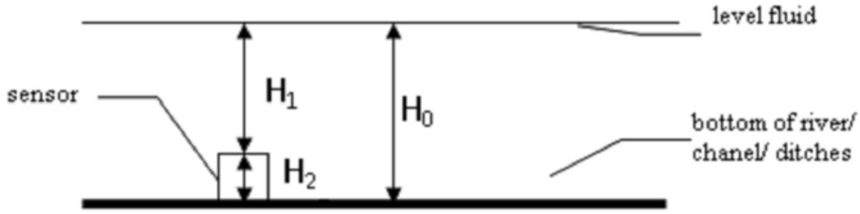
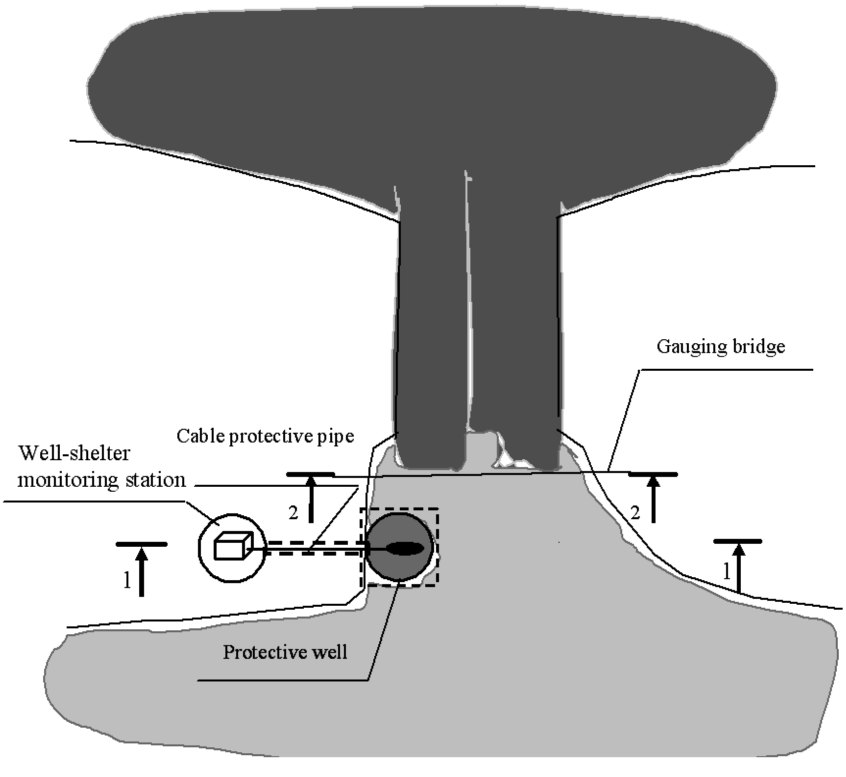


Fig. 1. The scheme of installation of the pressure transmitter relative to the bottom of a river, channel or deep ditches (H_0 – the height of the liquid level measured by tape measure; H_1 – the height of the liquid level measured by the pressure transducer; H_2 – is the height of pressure transducer above the bottom of the protective well)



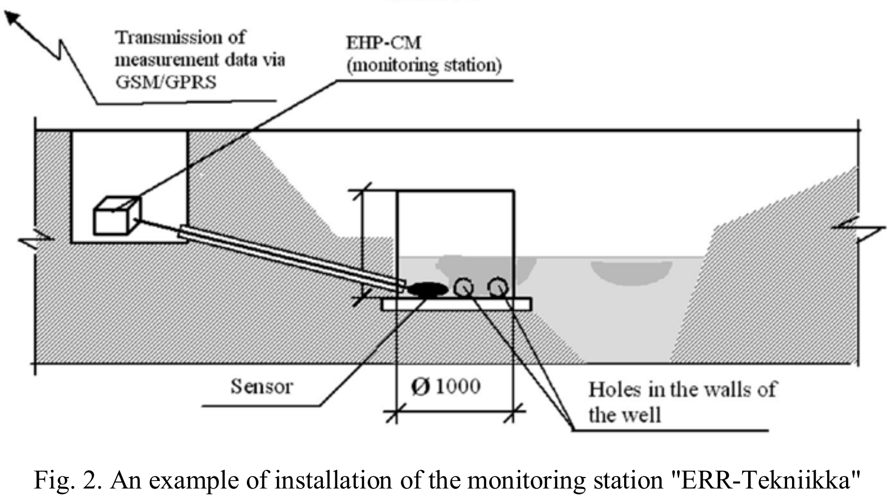


Fig. 2. An example of installation of the monitoring station "ERR-Tekniikka" in the river, channel or deep ditches (begin)

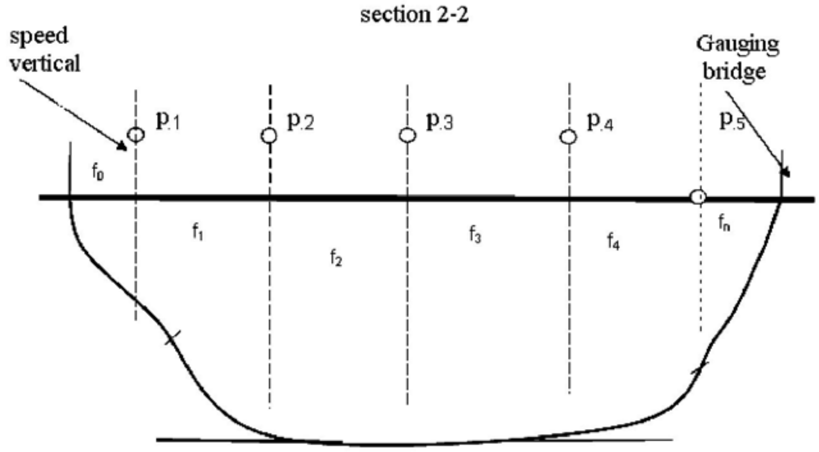


Fig. 2. An example of installation of the monitoring station "ERR-Tekniikka" in the river, channel or deep ditches (end)

The area of the water flow is determined by the equation (2), and section water flow f_s using (3).

$$F_B = \sum_{s=1}^{N} f_s \,, \tag{2}$$

$$f_s = 0,5 \cdot (h_i + h_{i+1}) \cdot b_{i,i+1} \,. \tag{3}$$

In each speed vertical should be measured the flow velocity of water at different depths: first – the bottom; 80 %; 60 %; 20 % of the total water level and the water surface (see fig. 2, section 1-1). Each length measurements of flow velocity should be carry out at a point not less than 100 seconds.

The calculation of average vertical speed of the flow is carried out according to spot measurements of speed based on the different equations depends on the number of measurement results.

The measured water flow rate and the liquid level is made in the system software, build the curve of dependence of consumption from water level, derive the equation of this dependence (fig. 3).

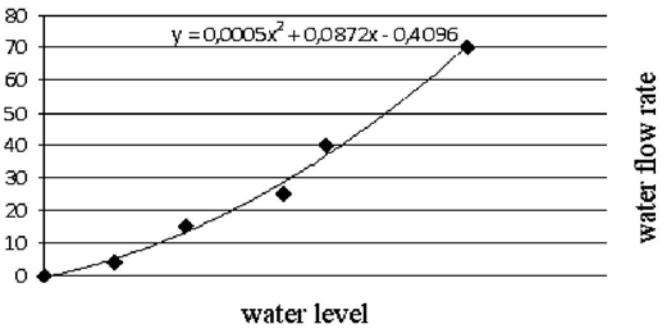


Fig. 3. The calibration dependence of water flow rate from water level

The processing of the measurement results is carried out automatically with a predetermined frequency (e.g. 1; 5; 10; 15; 30 and 60 min and up to 14 days). The measurement results are presented in the form of charts or tables, the summary result of measurement can be represented at standard form (4):

$$(X \pm \Delta), \quad P = 0,95. \tag{4}$$

The accuracy control of measurement results carried out periodic calibration of the EHP-Tekniikka Measuring System, and the primary measuring transducer (sensor hydraulic pressure STS ATM/PTM).

2. Uncertainty Evaluation

In the GUM accuracy is replaced by the term Uncertainty of measurement which includes all sources of uncertainty. When quantifying the uncertainty of a measurement the aim is to establish a range of values within which we have confidence that the true value lies. Therefore all the factors affecting the measurement result must be considered and their effect on the measurement result quantified. Typical factors affecting measurements include:

– uncertainty of the reference used to calibrate the instrument,
– random variation in use (repeatability),
– differences in results from different operators and conditions (reproducibility),
– environmental uncertainty (uncertainty in temperature used for compensation),
– uncertainties in alignments and setup parameters,
– rounding errors [3].

As described in a large number of publications, the uncertainty quantification is based on identification and estimation of the effects of all sources of uncertainty. A well accepted approach is the V&V [5] method that defines Verification as the activity to evaluate the number error, and Validation as the activity to evaluate physical uncertainties [6]. We used method consists of the identification and characterization of each source of uncertainty. Identification step provides a list of uncertainty sources:

– physical model;
– time and space discretization;
– input data;
– iterative convergence;
– round-off;
– computer programming.

The uncertainty evaluation procedure used enables the effects of all of the above sources of uncertainty to be quantified.

After all steps of estimate we can see results are given in tabl. 1.

Table 1

The indicator values of accuracy of measurement technique

Readout	**Range measurements**	**Measurement accuracy** (P = 0,95), ±δ, %
Level, m	0,02 …. 20	1,2
Flow, m^3/s	0,167 … 30	6

Conclusions

Following the uncertainty evaluation procedure set out in this paper an evaluation of the measurement of water level and flow at small rivers, channels, ditches and wells all-year-round in field conditions using EHP-TEKNIKKA Measurement Systems was carried out. Type A uncertainties were obtained from repeatability study of the calibration process, a repeatability study of the real-time monitoring process and a system stability test. Type B uncertainties were obtained from calibration certificates and estimates.

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The research described herein has been carried out as part of the measurement of water level and flow at small rivers, channels, ditches and wells all-year-round in field conditions using EHP-TEKNIKKA Measurement Systems Project at the Ecological problem of North Institute of Archangelsk. Thanks is given to the support and technical expertise Aleksey Koptelov, Nikolay Larionov and Risto Markky Tapio Hilyanen.

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НЕВИЗНАЧЕНІСТЬ ВИМІРЮВАННЯ РІВНЯ І ВИТРАТИ ЗА ДОПОМОГОЮ ВИМІРЮВАЛЬНОЇ СИСТЕМИ EHP-TEKNIIKKA

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У статті представлена оцінка невизначеності результатів постійного вимірювання рівня води і витрати в малих річках, каналах і інших невеликих водоймищах в польових умовах за допомогою вимірювальної системи EHP-TEKNIKKA, Фінляндія. Ці вимірювальні системи можуть застосовуватися в різних сферах економіки і бізнесу, володіють низкою технічних і економічних переваг. При оцінці невизначеності отриманих результатів встановлено, що невизначеність типу А може бути оцінена шляхом постійного контролю за процесом калібрування, вимірювань, а також в ході оцінки стабільності вимірювальної системи, а оцінка невизначеності типу В може бути знайдена в результаті розрахунку за стандартними залежностями.

Ключові слова: *невизначеність вимірювання, вимірювання рівня і витрати води, градуювальна залежність.*

НЕОПРЕДЕЛЕННОСТЬ ИЗМЕРЕНИЯ УРОВНЯ И РАСХОДА С ПОМОЩЬЮ ИЗМЕРИТЕЛЬНОЙ СИСТЕМЫ EHP-TEKNIIKKA

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В статье представлена оценка неопределенности результатов постоянного измерения уровня воды и расхода в малых реках, каналах, и других небольших водоемах в полевых условиях с помощью измерительной системы EHP-TEKNIKKA, Финляндия. Эти измерительные системы могут применяться в различных сферах экономики и бизнеса, обладают рядом технических и экономических преимуществ. При оценке неопределенности полученных результатов установлено, что неопределенность типа А может быть оценена путем постоянного контроля за процессом калибровки, измерений, а также в ходе оценки стабильности измерительной системы, а оценка неопределенности типа В может быть найдена в результате расчета по стандартным зависимостям.

Ключевые слова: *неопределенность измерения, измерение уровня и расхода воды, градуировочная зависимость.*