Calibration of Electromagnetic Flowmeters Krohne DN 25

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***Abstract* - Metrology is an experimental science with the ultimate goal - to define more precisely the physical magnitudes such as length, weight, voltage and others. Assessment of physical magnitudes often leads to an analysis of the results of measurements made. In this paper is a calibration of the two electromagnetic flow meters, brand KROHNE IFM 5080K with 25 DN (nominal diameter of the tube which measured the flow of water, which is expressed in mm 27.5 mm). Reference standard (etalon) was PISTON PROVER OT 1500, owned by the Bureau of Metrology of the Republic of Macedonia. The aim is to show the process of calibration, metrological to compare two devices for measuring the flow of fluids from the same manufacturer in terms of the reference standard and to provide analysis of the results obtained. In the end the results of measurements which can be seen in the behavior of electromagnetic flow meters, minimum and maximum values of flow, the average relative error of ten measurements for five different values of flow and uncertainty of these measurements. Constant of the reference standard is confirmed by its internal calibration. Treceability be provided through a set of weights, thermometer and a device for monitoring the ambient conditions that have calibration certificates.**

***Keywords* - calibration, etalon, uncertainty, standards, measurement points.**

I. INTRODUCTION

Calibration is a set of procedures which, under certain conditions, establishing relationship between the values of the size measure indicates that the measuring system or values that represent materialized extent or reference material, with appropriate values achieved benchmark-etalons. The result of calibration allows or assignment values of measuring size or determining what adjustments should be applied to indicating. Calibration can also determine other metrological properties such as the impact of influential sizes. The result of calibrations may be registered in a document sometimes called a calibration certificate or calibration report. In this calibration will compare the results, ie behavior of two el.-mag. flow meters from the same manufacturer Krohne.

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1.1. Benchmark and calibration equipment

In performance of calibration using two electromagnetic flow meters, reference standard - calibrator PISTON PROVER OT 1500, pulse counter, instrument for measuring temperature, humidity and pressure of the environment - TESTO, thermometer for measuring water temperature. Metrological characteristics of these devices are given in the tables that follow.

1.1.1 Electromagnetic flow meters KROHNE IFM 5080K

Tab.1 Metrological characteristics of electromagnetic flow meters KROHNE

Serial no.	xx857	xx858
Pulse output	active (amplitude 15 V)	active (amplitude 15 V)
Output pulse rate	1 kHz for 10 m^3/h	1 kHz for 10 m^3/h
Time constant	ONLY I	ONLY I
Cut - off	OFF	OFF
GK	3.742	3.819
Power supply	(200-260) V AC/50 Hz	(200-260) V AC/50 Hz

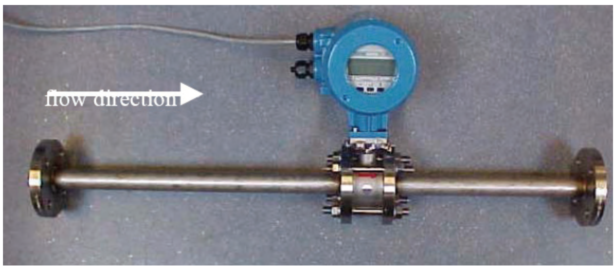

Fig.1 - KROHNE electromagnetic flow meters

1.1.2. Reference standard PISTON PROVER OT 1500

Reference etalon which is used belongs to the BOM with serial number 050418 produced by Trigas FI GmbH. Treceability is to PTB through Trigas FI GmbH. Calibration certificate is WD 5000-L-I17.

Tab.2 Technical Specification OT1500

Flow range	1.5 to 1500 l / min
Temperature range	0-38 oC
Operating pressure	5-12 bar
Linear encoder (length)	100 cm
Input frequency range	0-10 KHz
Analog Input (12 bit resolution)	voltage 0-5 V, current 4-20 mA
Repeatability	+ / -0.03%
Certificate of Calibration	DKD Germany

Fig.2 - PISTON PROVER OT 1500

1.1.2 Counter of electromagnetic pulse (pulses)

Counter who used belongs to the BOM produced by Electronic Control. Treceability is the UME by BOM Laboratory for time and frequency.

Double Chronometry is a technique used in positive displacement calibrators. Reduces uncertainty by ensuring that during the execution of the data targets (complete) pulses are counted and time for both, flow meter which are tested and the linear encoder is used in Calibrators. This technique eliminates the possibility of the involvement of unknown fractions of pulses in calibration interval therefore avoid the uncertainty that is potentially very large, particularly at low flows where pulses are small for both flow meter and linear encoder.

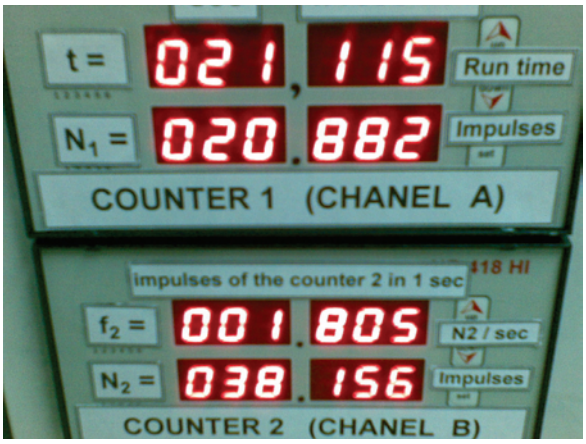

Fig.3 - Counter of electromagnetic impulses

1.1.3 Instruments to measure ambient conditions and watertemperature

Ambient conditions are recorded and recorded continuously with TESTO instrument for measuring temperature, humidity and pressure situated in the same laboratories as well as piston prover. Water temperature is measured with a mercury thermometer.

Tab.3 Technical Specification for thermometer with mercury

Measuring range	**-10...+50 °C**
Resolution	**0,1 °C**
Calibration Certificate	DKD-K-06701 Germany

Tab.4 Technical Specification TESTO
(digital instrument p, h and t)

Type	650
Calibration certificate	UME G3NM-0100 Turkey

II. AMBIENT CONDITIONS

The range of variation of ambient conditions are recorded and corrections are applied to the measurements.

Reference conditions

- Medium for calibration is water with conductivity ≥ 200 mS / cm
- water temperature (20 ± 5 °C close to 20 °C possibly)
- water pressure downstream of flow meter (2 ± 1) bar
- Ambient temperature range: from 15 °C to 25 °C
- Ambient relative humidity range: from 45% to 75%
- Ambient range of atmospheric pressure: from 86 kPa to 106 kPa (0.86 bar to the 1.06 bar)

III. MEASUREMENT PROCEDURE

The flow is calculated by the following relation

$$Q = \frac{Vc}{t} = \frac{Vuut}{t} \qquad (1)$$

$$Vc = \frac{Nc}{Kc} \qquad (2)$$

In this relations, Q is the current flow which passes through flow meter (KROHNE), Nc is the number of pulses from the encoder, Kc is a constant of the Calibrator and Vc is the volume of water that passes through the reference standard OT 1500. Volume of water that passes through the Krohne-flow meter can be calculated according

$$Vuut = \frac{Nuut}{Kuut} \qquad (3)$$

For the electromagnetic flow meter with pulse output, Kuut is their output const, Nuut is a number of pulses from Krohne-flow meter.

Constant of calibrator Kc is performed under actual conditions of waterdraw (internal calibration OT1500). This constant must be reduced in normal (standard) conditions of 20 ^oC and 1 bar by applying appropriate corrections. The system of relations that define the constant Calibrator under normal conditions can be represented as follows

$$Kc = \left(\frac{N_E}{V_W} \right) * \left(\frac{C_T}{C_E} * C_P \right) \quad (4)$$

Where
C_E = [1 + (TE-20) * CEE] Correction for thermal expansion of the linear encoder

C_T = [1 - (Tt-20) CEt] Correction for thermal expansion of the cylinder Calibrators

Cp = [1 - (ΔP) * CEp] Correction for expansion of the pressure in the cylinder Calibrators

T_E temperature linear encoder at each water draw

Tt water temperature in the cylinder during each water draw

ΔP differential pressure (pressure in the cylinder - Ambient Pressure)

CE_E temperature coefficient of expansion of the linear encoder (published by the manufacturer, 1.1 * 10-5 1/0C for Mitutoyo AT11N)

CEt coefficient of thermal expansion of surface cylinder (3.46 * 10-5 1/0C on 316 steel)

CEp coefficient of surface expansion of the cylinder due to internal pressure. For 1500 this is OT 5.3 * 10-9 1/mbar

Kuut for the electromagnetic flow meter Krone is 360 pul/lit under Technical protocol

1KHz Puls exit 10 m^3/h flow.

Measurements were performed after a period of stabilization of 30min. According to the technical protocol measurements are performed in the following points:
1 m^3/h; 2.5 m^3/h; 5 m^3/h; 7.5 m^3/h; 10 m^3/h;

After collection of values for 10 measurements and that for all measurement points above the reference standard (etalon-calibrator) piston prover and electromagnetic flow meter (UUT) Krone, the volume of water that passed through both devices is calculated according to relations (2) and (3) and relative error as

$$E\% = \frac{\overline{Vuut} - \overline{Vc}}{\overline{Vc}} * 100 \quad (5)$$

Q_E value of flow is calculated with relation (1).

Average, the experimental standard deviation of a value and experimental standard deviation of the mean can be determined from the measurements are performed n = 10 times.

The mean value obtained from

$$\overline{V} = \frac{1}{n} \sum_{i=1}^{n} V_i \quad (6)$$

experimental standard deviation of a value

$$s(V_i) = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (V_i - \overline{V})^2} \quad (7)$$

experimental standard deviation of the mean is

$$s(\overline{V}) = \frac{s(Vi)}{\sqrt{n}} \quad (8)$$

Uncertainty is calculated by the following relations

$$u_A^2 = \frac{1}{N(N-1)} \sum_{\alpha=1}^{N} (E_\alpha - E)^2 \quad (9)$$

$$U_A = 2u_A \quad (10)$$

$$U^2 = U_A^2 + U_B^2 \quad (11)$$

Where:
N e number of repetitions (measurements)

E [%] is the average relative error of flow meter (REF. standard), ie Wed Mount. α given in relation (5), αby E N . . . , 1 =

UA [%] e type A is the uncertainty of the confidence level of 95% (k = 2)

UB [%] is the type B relative uncertainty of etalon value of the flow of level of confidence 95%

U is the uncertainty of the combined level of confidence 95%

Results of calibration of electromagnetic flow meters Krohne nr.xx857 and nr.xx858

Electromagnetic
flow meter br.xx857

Q[m3/h]	Q_E[L/h]	Q_{Emin}[L/h]	Q_{Emax}[L/h]	E[%]	N	V_E[m3]	T[^{o}C]	p[bar]	U_A[%]	U_B[%]	U[%]
1	998.84	995.71	1001.48	-0.167	10	22.5240	24.5	2.5	0.014	0.049	0.051
2.5	2504.13	2495.73	2518.48	-0.163	10	25.5308	24.5	2.5	0.006	0.049	0.049
5	5003.53	4984.38	5016.96	-0.066	10	33.5786	24.5	2.5	0.014	0.049	0.051
7.5	7492.56	7472.94	7503.15	-0.068	10	23.2683	24.5	2.5	0.012	0.051	0.052
10	10048.66	10008.66	10086.53	0.083	10	20.0625	24.5	2.5	0.023	0.052	0.057

Electromagnetic
flow meter nr.xx858

Q[m3/h]	Q_E[L/h]	Q_{Emin}[L/h]	Q_{Emax}[L/h]	E[%]	N	V_E[m3]	T[^{o}C]	p[bar]	U_A[%]	U_B[%]	U[%]
1	999.38	993.46	1007.62	-0.075	10	10.1975	24.5	2.5	0.018	0.049	0.052
2.5	2504.72	2496.70	2514.28	-0.097	10	22.8105	24.5	2.5	0.016	0.049	0.052
5	5016.48	5006.56	5050.32	-0.045	10	26.9630	24.5	2.5	0.012	0.049	0.050
7.5	7520.26	7482.02	7562.69	-0.064	10	21.3640	24.5	2.5	0.016	0.051	0.053
10	10009.41	9935.28	10046.08	-0.103	10	24.9470	24.5	2.5	0.017	0.052	0.055

Where:
Q_E is the average flow through the etalon, ie average value of Q_E
Q_{Emin} a minimal amount of flow through the benchmark, ie minimum $Q_{E\alpha}$
Q_{Emax} a maximum value of the flow through the benchmark, ie αmaximum of $Q_{E\alpha}$
Average relative error [%] of flow meter ie average value of Eα is given as

$$E_\alpha = \frac{V_{T\alpha} - V_{E\alpha}}{V_{E\alpha}}.100$$

where:
$V_{T\alpha}$ is the volume of water indicated by flow meter (Krohne)
$V_{E\alpha}$ is the volume of water indicated by the reference standard (OT1500)
N e number of repetitions (measurements)
V_E medium volume is indicated by the reference standard, ie average value from $V_{E\alpha}$
T [^{o}C] average temperature of the water used in calibration.

U_A [%] e type A is the uncertainty of the confidence level of 95% (k = 2)
U_B [%] is the type B relative uncertainty of etalon value of the flow of level of confidence 95%
U is the uncertainty of the combined level of confidence 95%.

IV. Thanks

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V. Literature

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