

Investigation of Heat Meters Data Processing Software

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Abstract - Investigation procedures of heat meters data processing software are described. Software verification methods used in this analysis are proposed and discussed as well.

Key-words – measurement devices, software verification, measurement instruments directive.

1 Preface

Nowadays, measurement device parameters and characteristics basically depend on microprocessors and their software. Hence, verification of measurement device software (MDS) is very important. After adoption of the Measurement Instruments Directive (MID), verification of MDS will be necessary [1]. The MID started in the early nineties, was approved in spring of 2004, and after transition period it will become fully functional in autumn of 2006. The MID introduces a “new approach” to the measurement device software and its verification. Due to MID birth, in 1997 WELMEC (Western European Legal Metrology Cooperation) formed the work group WELMEC-SOFTWARE. The main object of this group was extended formulation of essential MDS requirements. Some time later, PTB (Physikalisch-Technische Bundesanstalt) formed another work group MID-SOFTWARE, which elaborated and concretized WELMEC requirements. On the basis of MID and documents published by these groups, three stages of MDS verification were proposed in [2]. The heat meters data processing software investigation procedure is part of software functionality investigation stage and will be analyzed in this paper.

2 Mathematical Model of Heat Meters Calculator and Procedure of Calculators Data Processing Software Investigation

In order to illustrate the need of this investigation we will give an example. On the ground of the OIML (International Organization of Legal Metrology) recommendations [3] and

Lithuanian Common Verification Procedure for heat meters [4], the heat meters software verification basically is restricted to estimation of data processing errors. However this gives no answer to the question how measurement algorithm and software will work in the case of false signals [5-6], which can be generated by meter sensors. The problem can be solved by implementing the following investigations[7]:

- Fault detection investigation;
- Investigation of stability of measurement data processing algorithms.

For this the method of simulation of signals of heat meters external sensors is proposed. The simulation of temperature sensors could be performed using resistor bridge load. The load limits of standard heat meter are $500 \div 800 \Omega$. Flow sensors could be simulated by external pulse generators. Pulse parameters of standard heat meter are: pulse repetition frequency within the range $0 \div 1000 \text{ Hz}$, pulse amplitude $-3 \pm 0.3 \text{ V}$ and pulse duty cycle - $20 \div 80 \%$. Pressure sensors could be simulated by means of standard current source with the limits $4 \div 20 \text{ mA}$.

A block scheme of the used verification equipment is presented in Fig. 1. Resistor bridges R1, R2 simulate temperature sensors. Functional generators G1 and G2 simulate flows of the flow and return liquids. Software, written in the C language and implemented using LabWindows/CVI, controls all devices.

Investigation is performed in the following order. Control software starts generators and universal counter which begins calculation of the pulses fed to the heat meter calculator. Pulse generators have to be stopped after not less than 1000 pulses were counted up. Then control software reads the data from all devices via a communication interface, i.e. temperatures of a flow and return

liquids, volumes of the passed liquids, quantity of the heat given up calculated by heat meters calculator and number of pulses counted by universal counter.

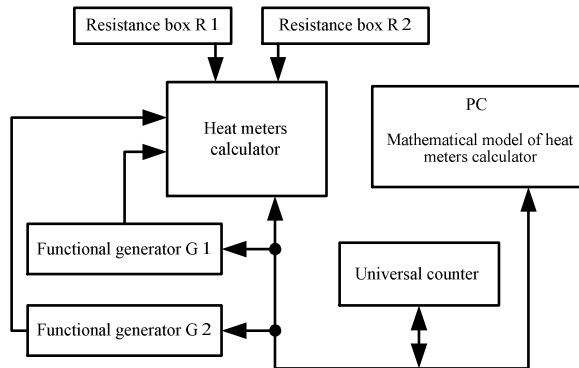


Fig.1 Verification equipment

Then the reference volume of the passed liquid is calculated according to the formula:

$$V = N k . \quad (1)$$

Here, N – number counted pulses, k – value of one pulse, i.e. pulse/m³. The reference quantity of the heat given up can be calculated using expressions presented in the OIML recommendations [3], i.e.:

$$Q_{ref} = k \Delta \Theta V . \quad (2)$$

Here, Q_{ref} - reference quantity of the heat given up, $\Delta \Theta = \Theta_{flow} - \Theta_{ref}$ temperature difference between the flow and return of the heat exchange circuit. V - volume of the passed liquid calculated using expression (1), k - heat coefficient calculated using expression

$$k(p, \Theta_{flow}, \Theta_{return}) = \frac{1}{v} \frac{\Delta h}{\Delta \Theta} . \quad (3)$$

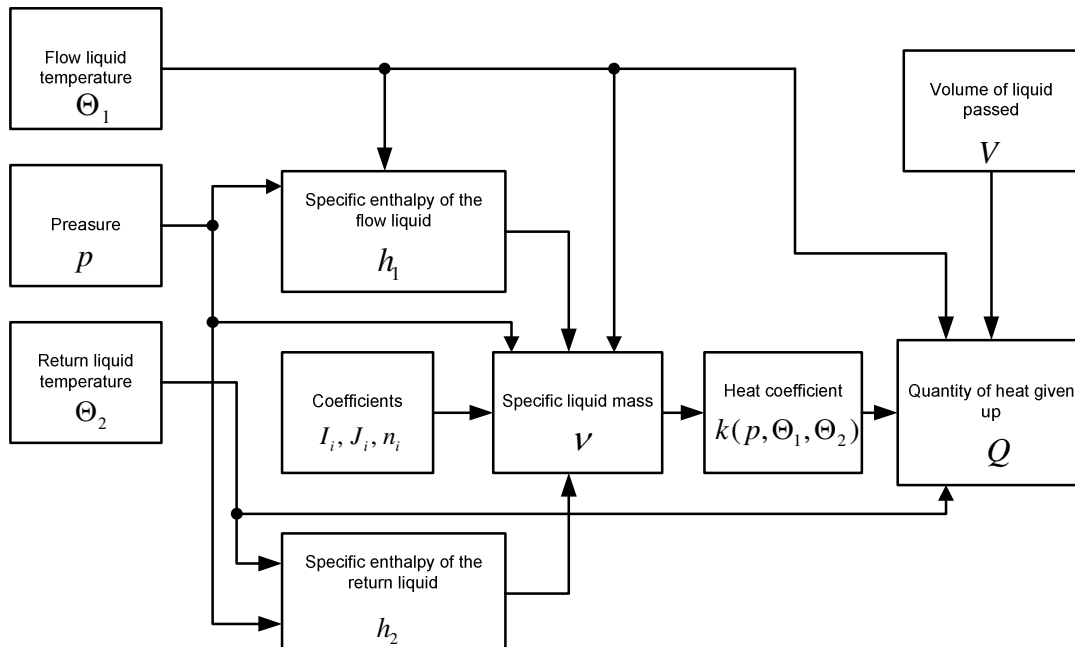


Fig. 2 Mathematical model of heat meters calculator

Here $\Delta h = h_{flow} - h_{ref}$ - specific enthalpy difference between the flow and return enthalpies, v - specific liquid mass, p – pressure of the liquid. The formulas for calculating of specific liquid mass and enthalpies could be found in [4].

The mathematical model of heat meters calculator is depicted in Fig 2. After calculations of reference quantity of heat given up the relative error of heat meter measurement results is estimated according expression

$$E = \frac{Q_{ref} - Q_m}{Q_{ref}} . \quad (4)$$

The maximum permissible error of the heat meter calculator is

$$E_c = \pm(0.5 + \Delta \Theta_{min} / \Delta \Theta) . \quad (5)$$

Here, $\Delta \Theta_{min}$ - minimum temperature difference – parameter of the specific heat meter.

3 Results of Heat Meters Data Processing Software Investigation

The standard verification procedure of heat meters covers the estimation of the maximum permissible errors of calculators. In consequence it is not possible to answer the following questions: how a heat meter calculator will response to faulty signals received from sensors and how these faults influence measurement results?

In order to answer these questions, the experiment of investigation of heat meters data processing software using the type approved heat meter was carried out.

Primarily, the ramp and random flows were simulated. Parameters of corresponding pulse sequences were:

- Increasing pulse repetition frequency within the range 0 ÷ 1000 Hz ,
- Randomly changing pulse repetition frequency within the range 0 ÷ 1000 Hz .

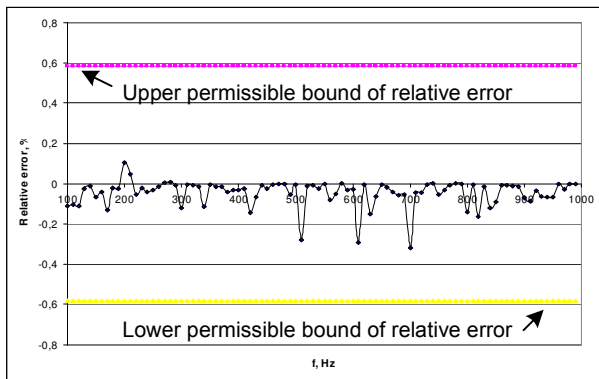


Fig. 3 Relative error of heat meter calculator with ramp flow

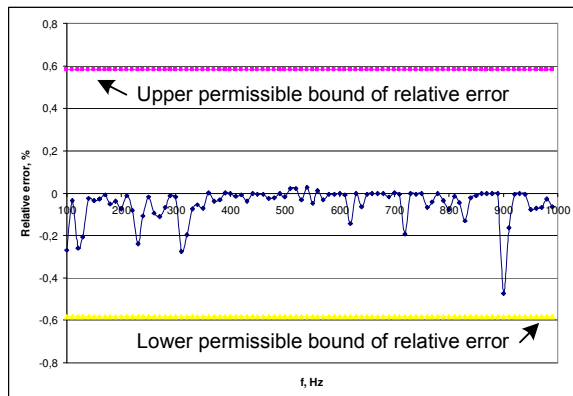


Fig. 4 Relative error of heat meter calculator with random flow

Results presented in Fig. 3 and 4` results demonstrate that flow type (ramp or random) have no influence on relative error of a heat meter calculator in a sense that it remains within the maximum permissible error range.

The next experiment included investigation of a heat meter calculator response to the “faulty” signals received from simulated sensors. The following signals were used:

- Amplitude of the pulses was changed randomly within the range 3 ± 0.3 V ,
- Pulse duty cycle was changed randomly within the range 20 ÷ 80 % .

In both cases the randomly changing pulse repetition frequency was used. Results are presented in Fig. 5 and 6. It is obvious that a heat meters calculator operates within the maximum permissible error range till pulse repetition frequency reaches 500 Hz. At higher pulse repetition frequencies the maximum permissible error range is exceeded 2 times in the case of randomly changing pulse amplitude. In the case of randomly changing pulse duty cycle the maximum permissible error is exceeded 20 times.

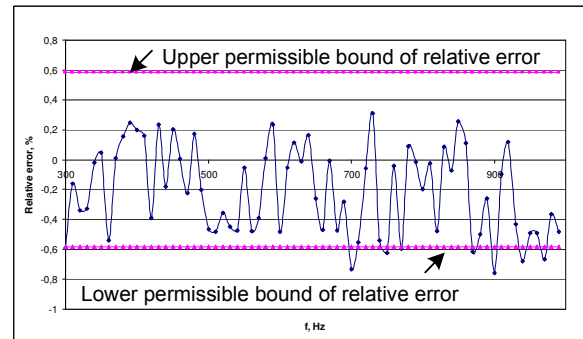


Fig. 5 Relative error of heat meters calculator with random pulse amplitude

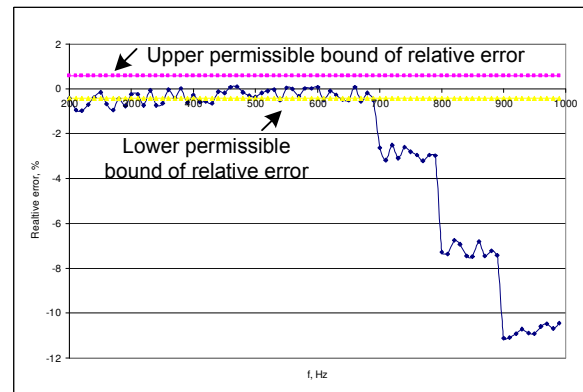


Fig. 6 Relative error of heat meter calculator with random pulse duty cycle

Consequently our experiments with the type approved heat meter pointed out that in some cases, especially when parameters of signals (pulse amplitude and duty cycle) received from sensors reach marginal but still permissible values, heat meter calculator wrongly calculates the value of heat given up. To get such as results by standard heat meters verification procedure would be difficult or even impossible. From this is clear that after adoption of the Measuring Instruments Directive and starting investigation of data processing software of heat meters some of them fail to pass the type approval stage.

4 Conclusions

1. The proposed verification equipment and investigation method of the heat meter data calculator processing software enable to determine the compliance of heat meter calculator with the requirements of the Measuring Instruments Directive (MID).
2. Experiments with the type approved heat meter demonstrated that in some cases, especially when parameters of signals (pulse amplitude and duty cycle) received from sensors reach marginal but still permissible values, heat meter calculator wrongly calculates the value of heat given up.

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