Computer-Aided Design of Gas Flow Temperature Measurement Errors

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Abstract – The system for computer-aided calculation of additional systematic errors of natural gas temperature measurement is developed. Calculation is made for the data on real working conditions of the gas metering unit. The following errors are calculated by the system: error caused by heat exchange between the thermometer case and the pipe wall, error caused by heat exchange between the pipe wall and the ambient air, error caused by temperature decrease as the gas is throttled through the pressure differential device.

Keywords – gas, errors, computer-aided design, measurement of gas temperature, temperature transducers.

Introduction

Economical consumption of natural gas is possible only in the condition of its metering. This requires accurate metering of natural gas at all stages of its transportation and delivery to consumers. The accuracy of such a metering is defined by technical base, normative and metrological base [1, 2].

A negative factor affecting the accuracy of measuring the flow and volume of natural gas is the presence of heat exchange processes in the metering system, which may lead to the occurrence of additional systematic errors in measuring the gas temperature and, accordingly, the errors in measuring the flow and volume of gas [3].

Errors of flow temperature measurement

Error of flow temperature measurement consists of the following components:

- the error caused by heat exchange between the thermometer case and the pipe wall (ΔT_T);
- the error caused by heat exchange between the pipe wall and the ambient air (ΔT_x);
- the error caused by temperature decrease as the gas is throttled through the pressure differential device (ΔT_{thr});
- the error caused by temperature decrease as the gas pressure is reduced at the gas pressure regulator (ΔT_{red});
- the error caused by temperature signal lag at cyclic variations of the flow temperature (ΔT_{lag}).

The combined additional error of flow temperature measurement can be calculated as:

$$\Delta T = \Delta T_T + \Delta T_x + \Delta T_{thr} + \Delta T_{red} + \Delta T_{lag}. \qquad (1)$$

Calculation of these errors is a complicated process since there is a need to accomplish computation of the gas properties (density, viscosity, isentropic exponent etc.) as well as the heat exchange processes in the pipe. In order to calculate the gas flow temperature measurement errors, various methods can be used: calculation by means of a calculator (simple but time consuming and not efficient), application of MS Excel (more efficient than the calculator but there is no possibility to accomplish a cycle computation with the exit by a condition "while"), Matlab (efficient but requires special skills from the user). To simplify the process of calculating the errors a special CAD system was developed.

The developed CAD system provides calculation of ΔT_T, ΔT_x, ΔT_{thr} errors.

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The system is built using the following technologies:

- HTML (HyperText Markup Language). This is the standard markup language for creating web pages and web applications;
- CSS (Cascading Style Sheets). This is a style sheet language used for describing the presentation of a document written in a markup language like HTML;
- JS (JavaScript). This is a language which is also characterized as dynamic, weakly typed, prototype-based and multi-paradigm;
- PHP (Hypertext Preprocessor). This is a server-side scripting language designed for Web development.

To perform the calculation of errors, the following data should be entered by the user:

- General data of the metering system;
- Properties of gas;
- Parameters and characteristics of the gas flow;
- Parameters and characteristics of the pipeline;
- Parameters and characteristics of the temperature measuring transducer;
- Parameters and characteristics of the ambient air;
- Parameters and characteristics of the thermal isolation of the pipeline.

The navigation menu of the CAD software consists of the following items (see Fig.1):

File (Файл) - allows the user to create a new calculation, open or save a file with input data that has been entered by the user;

Edit (Правка) - allows to return from the calculation results page to the data input page;

Calculation (Розрахунок) - performs the calculation and displays a table with a short list of the calculation results;

Fig.1. Navigation menu.

Protocol (Протокол) - on the basis of calculation results, creates a protocol and displays it to the user in PDF format;

Help (Допомога) - allows the user to view information about the program and about the errors of gas flow temperature measurement.

After entering all the input data the *Calculation* button should be pressed. The system will execute the calculations and return a short list of the calculation results together with the curves of the flow temperature measurement error versus the distance from the primary device (see Fig.2).
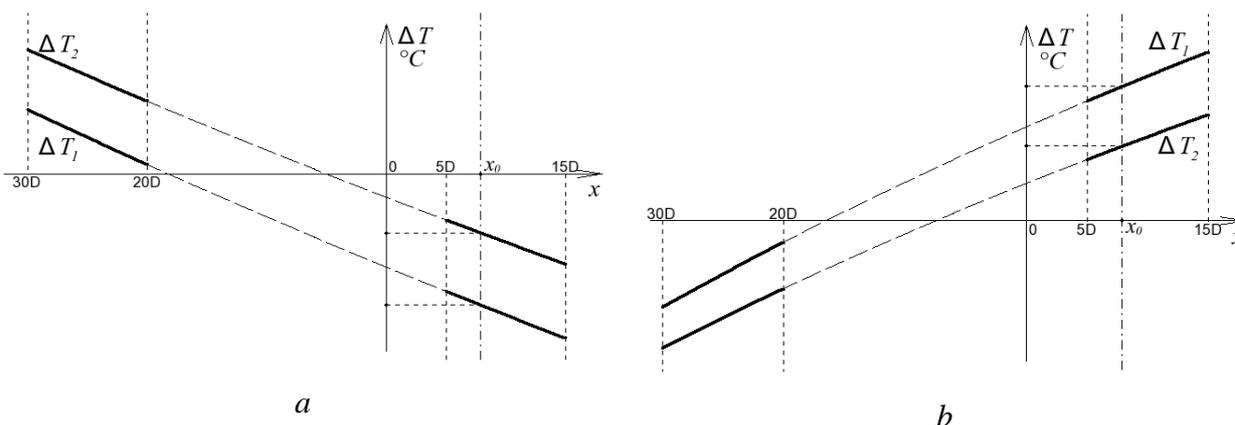
Fig.2. Curves of flow temperature measurement error $(\Delta T_T + \Delta T_x)$ versus the distance from the primary device (*a* – winter conditions; *b* – summer conditions).

The short list of the calculation results includes the velocity of the gas flow, the heat flux from the gas to the ambient air, the temperature of the pipe internal surface, the temperature of the pipe external surface and other. The CAD system returns the recommendation on whether there is a need to install the heat insulation for the flow meter or not.

Conclusion

The article presents the system of computer-aided calculation of additional systematic errors of natural gas flow temperature measurement on the basis of initial data on the real operating conditions of the gas metering unit. The system interface is currently developed in Ukrainian, and its translation into English is planned for the future.

References

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