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EFFECT OF AMBIENT TEMPERATURE ON THERMODYNAMIC TEMPERATURE MEASUREMENTS

Abstract. The development of science and technology is closely related to the use of measuring instruments. Measurements are one of the ways to know nature as a process and help to make scientific discoveries and apply these discoveries in production and technology. Measurements are also of great importance as the only means of monitoring technological processes in various fields of industry and production processes. Properly organized measurements ensure the reliability, economy and convenience of conducting production processes, as well as provide opportunities for their extensive automation. In addition, it is not possible to provide safe and trouble-free maintenance of production processes and facilities without using measurement tools. Today, the national economy of the country is provided with a large arsenal of measuring instruments of both domestic and foreign production, from the simplest primary converters and measuring devices to complex automatic tools and systems that allow controlling technological devices and complex production using information and computers. A wide variety of measuring tools requires the right choice for specific purposes. In this regard, one of the important issues is the question of their metrological assurance. Accurate and correct measurements performed during technological processes lead to an increase in product quality, a reduction in waste products, as well as a minimization of time and material losses. For this reason, ensuring the accuracy of temperature measurements performed in technological processes is one of the most urgent issues today. The research work has shown that the most important part of the error of the temperature measurements is the influence of the environment on the measurement process. For this reason, the amount of this effect was determined and analyzed during the research work.

Keywords: technological processes; environmental effects; measurements; thermodynamics; metrology; accuracy.

Introduction

As we mentioned, the set of technical tools that serve to perform measurements, the methods and rules of performing measurements, as well as the interpretation of their results are considered as the concept of measurement technique. The place of measuring technique in our modern world can be characterized by the following information. Currently, the costs of measuring equipment during production processes in industrial enterprises make up approximately 10-15 % of all material consumption. In some areas of the economy, such as oil refining, petrochemistry, chemistry, radio electronics, micro-processor technology, etc., these costs are even 25%.

The section of measuring technique, which includes measuring methods and measuring devices used in technological processes, was considered as a part of technological measurements. The set of measured parameters included in technological measurements are quite different for different industries, mainly depending on the specifics of technological processes. Depending on the nature of the technological process, it is possible to classify all production in different industries mainly into two groups. These are continuous and discrete (numerical) manufacturing technological processes. The first group, i.e. technological processes of a continuous production nature, includes oil refining, drilling, petrochemical, chemical, metallurgical, thermal energy, hydropower, etc. The second group, i.e. discrete (numerical) manufacturing technological processes, includes machine building, device making, radio electronics, food, etc. production areas. Measurement of temperature, pressure, consumption, level and amount of substance in continuous technological processes makes up more than 86 % of the total amount of all measurements. The remaining 14 % measurements are the measurement of the substance's composition and physical-chemical properties, as well as electrical quantities.

As we mentioned, temperature is the critical factor and the most important parameter used during technological measurements, as well as determining the efficiency of the process and the quality of the product. As we know, there are several ways to measure the temperature of technological processes, and each of them has its own disadvantages. In the course of our research work, the effects of environmental temperature, which have a significant impact on the standardization of metrological assurance of thermodynamic temperature measurements, were investigated. The research work provided the basis for designing a new innovative model. By means of this innovative and modern method, a comparison of temperature measurement tools, especially thermocouples, with traditional process temperature measurement methods was made and it was determined by which methods and tools the accuracy can be increased.

Measuring temperature through traditional measuring methods prevented some of the thermowell problems by eliminating the need to intervene in the technological process. Unfortunately, this method also had its challenges, as the internal temperature of the process could not be accurately or within a reproducible interval due to the environmental temperature effect factor that could affect the measurement.

It is for this reason that during the research, the characteristics of the ambient temperature, which affect the thermodynamic temperature measurements, were studied and analyzed.

Method and materials

During the research work, the effect of ambient temperature on thermodynamic temperature

measurements in technological processes was investigated and this effect was analyzed through comparative tests. These tests were performed under both artificial and natural environmental conditions and the results were compared.

The following materials were used during the research work.

1) technological pipe with a diameter equal to 20 cm;
2) oil solution;
3) K type thermocouple;
4) artificial wind generator;
5) simulator.

In order to carry out this research, an experimental experiment was conducted to determine the temperature of the oil solution when it flows through the pipe. During the experiment, oil began to flow from inside the pipe with a diameter of 20 cm. At this time, in order to determine the temperature of the pipe surface, a surface sensor and a transmission head are connected to the pipe surface. An experiment was then carried out on how the temperature from the pipe to the transmitter head can be distributed in the surface sensor assembly (Fig. 1).

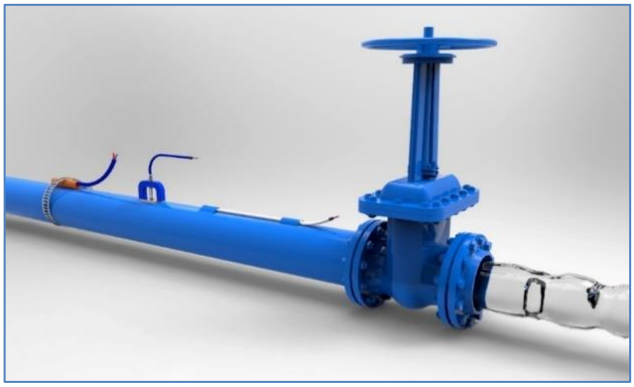

Fig. 1. Measuring the temperature of the liquid flowing through the pipe

During the conducted experiments, the importance of the surface temperature affecting the temperature of the oil solution passing through the pipe and the ambient temperature affecting that pipe was determined.

Analysis of the effect of ambient temperature on the thermocouple

In the tests carried out during the research work, it was determined that there is a non-linear relationship between the temperature of the liquid flowing through the pipe and the thermal effect of the ambient temperature on the pipe. To correct and linearize this nonlinear relationship, it is relatively difficult to model it. The use of insulation for the temperature measurement assembly can reduce much of the non-linear heat transfer and also help create a one-dimensional heat transfer profile for the temperature assembly and transfer head. Such linearization of heat transfer does not eliminate all inaccuracies in the measurement of tube surface temperature, but it reasonably allows finding a solution to correct for changing and constant environmental and process conditions.

During the research work, free convection of the thermocouple attached to the pipe was initially performed. During free convection, the thermodynamic temperature of the oil liquid passing through the pipe was determined under normal ambient conditions. Free convection simulation was analyzed during the experiment.

Then, a forced convection environment was created for the thermocouple placed on the technological pipe through which the oil solution passes. At this time, a wind with a speed of 2 m/s was created by means of an artificial wind generator, and its effect on the thermocouple was studied. During the conducted tests, it was determined that the ambient temperature affects the temperature of the material passing through the pipe in the range of 10-18%, both through free and forced convection. Fig. 2 and Fig. 3 show the heat loss profiles from the surface temperature unit to the ambient for both free and forced convection.

During the conducted research, the ambient temperature and wind speed were measured at different time intervals in the simulation of free convection. At that time, the temperature coefficient was in the range of 1,195e+001 and 9,002e+001, and the wind speed was in the range of 3,245e+001 and 4,975e+001.

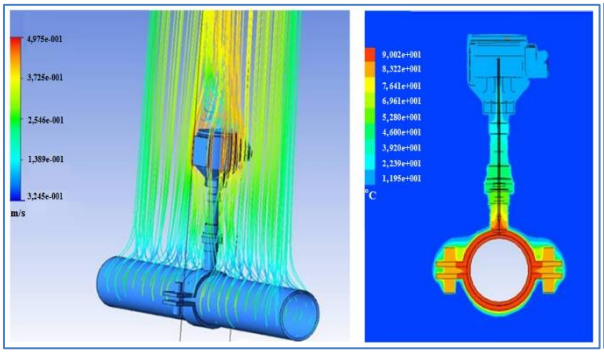

Fig. 2. Simulation of free convection

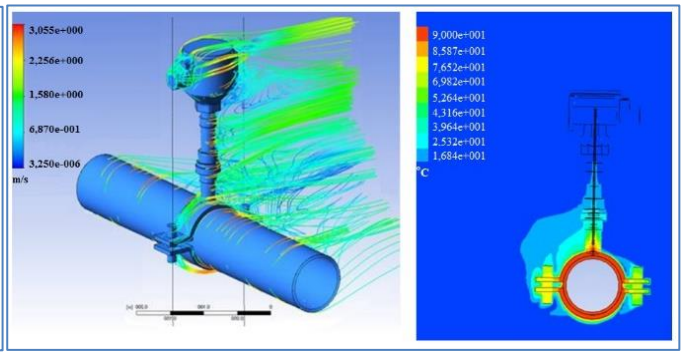

Fig. 3. Simulation of forced convection (wind speed increased by 2 m/s)

During the conducted research, the ambient temperature and wind speed were repeatedly measured at different time intervals in the simulation of forced convection. At this time, the existing wind speed (between 3,245e+001 and 4,975e+001) was increased by 2 m/s.

As a result of this increase, the temperature coefficient changed between 1.684e+001 and 9.00e+001.

Later, during the performed research, tests were conducted to measure the thermodynamic temperature of the fluid in the pipeline using an immersion resistance thermocouple.

The figure below shows the measurement of the temperature of the liquid in the pipeline using an immersion resistance thermocouple and the comparison of the temperature of the thermally insulated surface of the pipe (Fig. 4).

During the test performed, the ambient temperature varies between 24 °C and 31 °C, while the process thermodynamic temperature remains stable at 30 °C.

As the difference between the thermodynamic temperature of the process and the temperature of the environment affecting the process increases, the difference between the thermodynamic temperature of the process and the temperature of the surface changes up to 2 °C.

Also, the same behavior can be seen with a similar change in ambient temperature as shown in Fig. 5.

Under the same test conditions, the ambient temperature drops from 30 °C to -5 °C. As the difference between the thermodynamic temperature of the process and the ambient temperature increases, the difference between the thermodynamic temperature of the process and the temperature of the surface changes to almost 15 °C

In the graph shown in Figure 6, the difference between the technological process temperature and the surface temperature during the test performed under changing environmental conditions is considered as a variable.

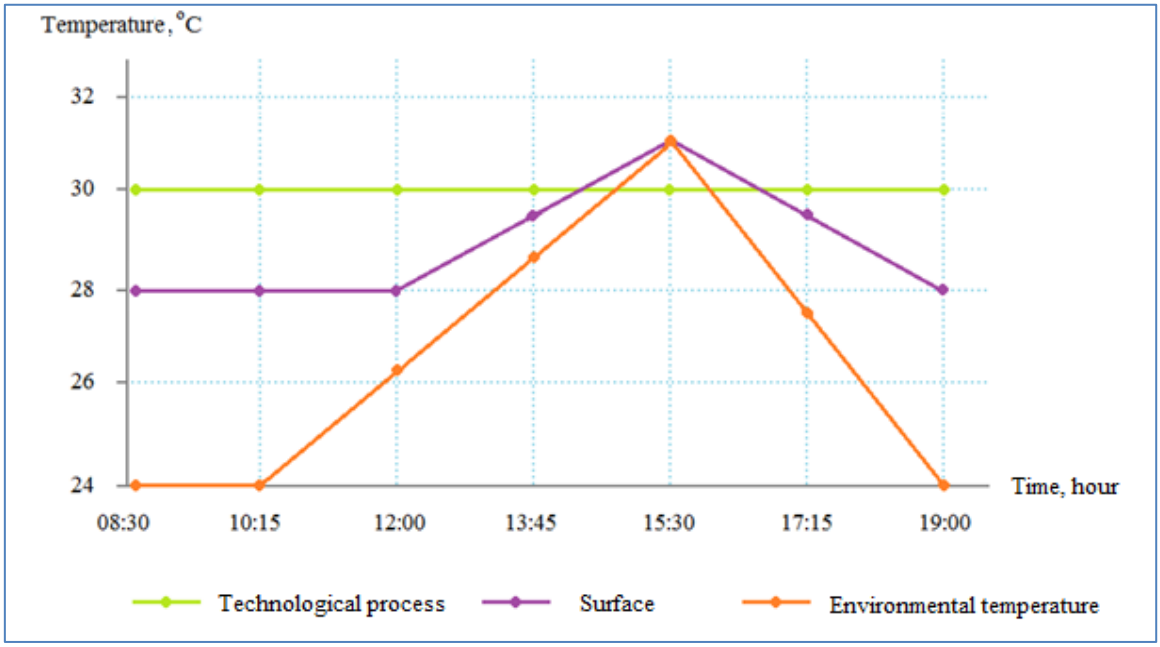

Fig. 4. Comparison of surface sensor and thermocouple detector at constant process temperature

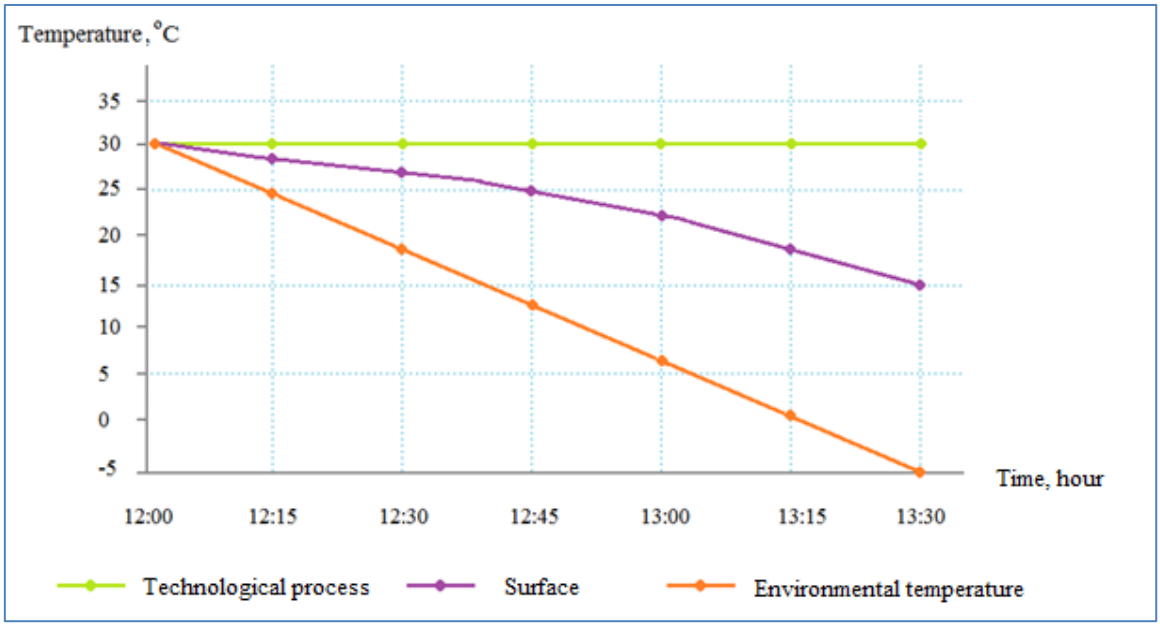

Fig. 5. Comparison of insulated surface sensor and thermocouple detector during ambient temperature changes

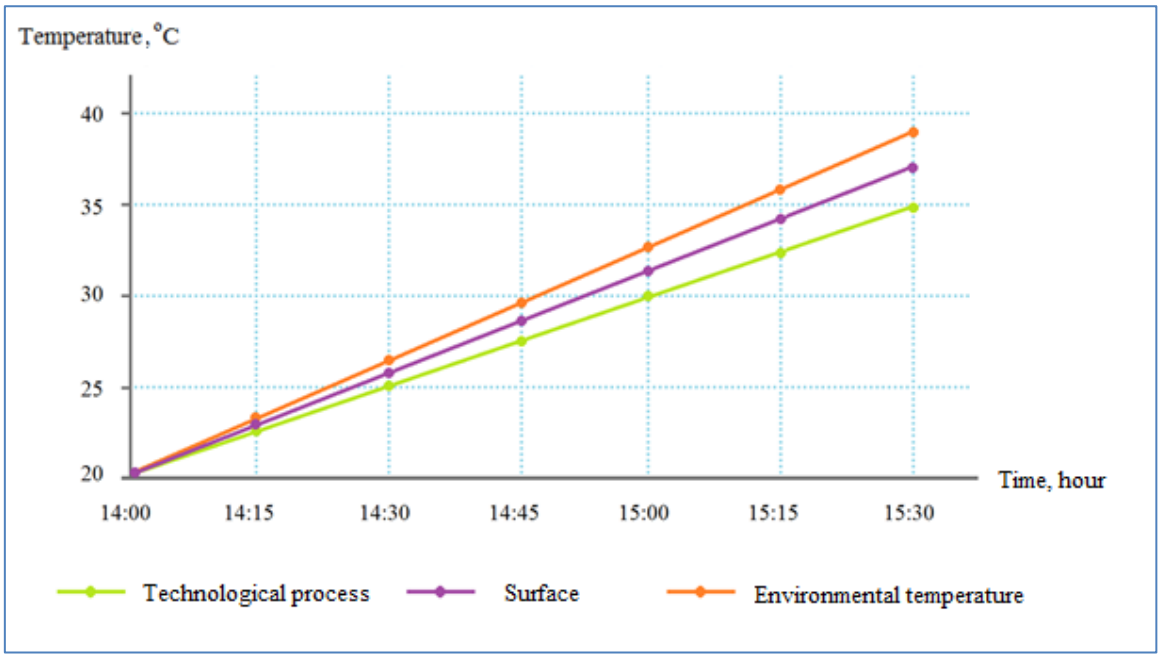

Fig. 6. Graph of dependence of surface temperature with technological process

As the process temperature rises, the error or difference between the process temperature and the surface temperature increases.

This relationship makes it difficult to compare the two values because it depends on the process temperature, the ambient temperature, and the thermal conductivity of the measuring device.

The above-mentioned graphs suggest that one of the most important methods of increasing the accuracy of temperature measurements performed during technological processes is the minimization of the environmental temperature affecting these measurements.

During the performed test work, it was determined that the temperature of the liquid flowing through the pipeline can vary depending on the ambient temperature and the surface temperature of the pipe. However, this variation is not taken into account during thermodynamic temperature measurements.

Conclusions

During the conducted research, the environmental conditions affecting the change of this temperature during the thermodynamic temperature measurement at all stages of the technological process were analyzed. Analyzes performed during the experiment were compared using free and forced convections.

During the performed test work, it was determined that the temperature of the liquid flowing through the pipeline can vary depending on the ambient temperature and the surface temperature of the pipe. However, this variation is not taken into account during thermodynamic temperature measurements.

This significantly affects the accuracy of temperature measurements performed in industrial enterprises and production processes.

Conflict of interest

The authors state that there is no conflict of interest regarding the publication of this article.

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Вплив температури навколишнього середовища на термодинамічні вимірювання температури

Н. Іскандаров

Анотація. Розвиток науки і техніки тісно пов'язаний із застосуванням вимірювальних приладів. Вимірювання є одним із способів пізнати природу як процес і допомагають робити наукові відкриття та застосовувати ці відкриття у виробництві та техніці. Вимірювання мають велике значення також як єдиний засіб контролю технологічних процесів у різних галузях промисловості та виробничих процесів. Правильно організовані вимірювання забезпечують надійність, економічність і зручність ведення виробничих процесів, а також надають можливості для їх широкої автоматизації. Крім того, без використання вимірювальних засобів неможливо забезпечити безпечне та безаварійне обслуговування виробничих процесів і обладнання. Сьогодні народне господарство країни забезпечене великим арсеналом засобів вимірювальної техніки як вітчизняного, так і зарубіжного виробництва, від найпростіших первинних перетворювачів і вимірювальних пристроїв до складних автоматичних засобів і систем, що дозволяють керувати технологічними пристроями і складним виробництвом за допомогою інформації та ЕОМ. . Велика різноманітність вимірювальних інструментів вимагає правильного вибору для конкретних цілей. У зв'язку з цим одним із важливих питань є питання їх метрологічного забезпечення. Точні і правильні вимірювання, що проводяться в технологічних процесах, призводять до підвищення якості продукції, зменшення відходів, а також мінімізації часових і матеріальних втрат. Тому забезпечення точності вимірювань температури в технологічних процесах є однією з актуальних проблем сьогодення. Дослідження показали, що найважливішою частиною похибки вимірювань температури є вплив навколишнього середовища на процес вимірювання. З цієї причини кількість цього ефекту була визначена та проаналізована під час дослідницької роботи.

Ключові слова: технологічні процеси; вплив на навколишнє середовище; вимірювання; термодинаміка; метрологія; точність.