The average relative error of simulated values to the values of the real process is less than 4%. The average error for a series of experiments is less than 5%. Thus, this mathematical model can be used as a dynamic part of LDM of sterilization process in an autoclave.

Conclusions. To build a dynamic model of the autoclave is used existing equation for, decomposition of which under sections provides the ability to use them for process modeling of software controlling of the autoclave. Production experiments confirmed the adequacy of the model the real process.

References

[1] V. Tregub, "Pobudova matematychnoyi modeli avtomatyzovanoho aparata periodychnoyi diyi," *Kharchova Promyslovist*, no.3, pp. 165-169, 2004;
[2] S. Ryvkyn and A. Aleksandrov, Termodynamychekye svoystva vodu i vodyanoho para. M.: Enerhoatomyzdat, 1984;
[3] L. Konovalova, Yu. Zahromov, *Teoretycheskye osnovy teplotekhnyky*. *Prymery i zadachy*. Tomsk: TPU, 2001;
[4] Farid Golnaraghi and Bendjamin C. Kuo, *Automatic control systems*. New York: John Wiley&Sons, 2009.

Література

[1] Трегуб В. Побудова математичної моделі автоматизованого апарата періодичної дії / В. Трегуб // Харчова промисловість, 2004. – № 3. – С. 165-169.
[2] Ривкин С. Термодинамические свойства воды и водяного пара / С. Ривкин, А. Александров. – М.: Энергоатомиздат, 1984.
[3] Коновалова Л. Теоретические основы теплотехники. Примеры и задачи / Л. Коновалова, Ю. Захромов // Томск: ТПУ, 2001.
[4] Farid Golnaraghi. Automatic control systems / Golnaraghi Farid, C. Kuo Bendjamin // New York: John Wiley&Sons, 2009.

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THE THERMOELECTRIC VACUUM CROCK-POT AND THE AUTOMATED WORKPLACE FOR ITS RESEARCH AS A CONTROL OBJECT

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Abstract: The technologies of thermal treatment in vacuum are widely used in various fields of production, in particular in the food industry, but their application at farms, hotels or a for domestic purposes is limited because of the big sizes, high cost of processing equipment and complexity of its management at realization of foodstuff processing. Products, made with use of vacuum technologies, keep much more useful substances because they aren't exposed to high-temperature processing and oxidation while preparation. Development and production of the small-sized equipment for realization of heat treatment processes of foodstuff in vacuum would create technical and economic conditions for implementation of temperature processing processes of foodstuff at farms, hotels and even at home that would promote creation of new food, development of new recipes and, in general, development of the new direction in cookery. So the article describes the problem of equipment construction for the process of thermal processing of food in vacuum such as cooking jam, concentration of juices and dairy products, distillation, drying, pickling, and the possibility of building inexpensive compact vacuum unit for the implementation

of these processes (crock-pot) for use at hotels, farms and even for domestic purposes. The analysis of technological schemes for energy efficient evaporation process in vacuum crock-pot is provided. The developed technological scheme of vacuum crock-pot with thermoelectric converters and principle of its operation are considered. Microprocessor block diagram of a multichannel data acquisition system consisting workstation for investigation of thermoelectric vacuum crock-pot as a control object is presented and control algorithms helping to reduce energy consumption and to increase operational reliability in implementing processes and the quality of ready-made products are provided.
Keywords: Thermoelectric vacuum crock-pot, vacuum evaporator, thermoelectric converters.

Introduction: The technologies of thermal treatment in vacuum are widely used in various fields of production, in particular in the food industry, but their application at farms, hotels or a for domestic purposes is limited because of the big sizes, high cost of processing equipment and complexity of its management at realization of foodstuff processing. Products, made with use of vacuum technologies, keep much more useful substances because they aren't exposed to high-temperature processing and oxidation while preparation. Development and production of the small-sized equipment for realization of heat treatment processes of foodstuff in vacuum would create technical and economic conditions for implementation of temperature processing processes of foodstuff at farms, hotels and even at home that would promote creation of new food, development of new recipes and, in general, development of the new direction in cookery.

Therefore the problem of development of the small-sized vacuum crock-pot and the automated workstation for her research as control object is urgent.

Main part

Temperature conditions of foodstuff processing in vacuum at realization of technological processes: jam making, concoction of juice and dairy products, distillation, frying, pickling, drying, etc. can be set in the wide range from -5 ° C to 150 ° C and can change at realization of these processes. All these processes are turning with removal of a part of moisture from a product, thus for their realization it is necessary to use the equipment which represents vacuum evaporator (VE) when processing products with a liquid phase or in hot fan or the condensation dryer when processing products without liquid phase.

For effective realization of processes in VE the following technological schemes are usually used: multicase VE, VE from a mechanical recompression of water vapor, VE with use of vapor-ejector pump and etc. Implementation of the listed technological schemes is associated with use of the expensive dimensional equipment with a big productivity that makes impossible their use when developing compact VE. One of the possible options of creation of the vacuum crock-pot is the technological scheme with use of the heat pump with recovery of heat allocated at vapor condensation.

Generally, at implementation of such scheme one-stage compression thermal pumps which at the same time provide heat supply to the evaporator and cooling of the condenser are used. This allows to lower several times specific power costs of evaporation. But their use in this case is limited to the following factors:

- need of use of the brine scheme with intermediate heat exchangers for reduction of probability of hit in a product of refrigerating agents harmful to organism, used in compression refrigerating devices. It leads to complication of the technological scheme and to increase in dimensions of installation;
- range of energy efficiency of the technological process of evaporation is limited with the maximum temperature of evaporation of 50-60 °C;
- the high cost of the vapor-compression heat pump: 300-1000 euro per kW of thermal power.

One of attractive options of creation of the vacuum crock-pot is use of thermoelectric thermal pumps [1] which in this case have several advantages. It is first of all an opportunity to work in the wide temperature range from - 10 ° C to + 150 ° C. What's more compactness, noiselessness, lack of moving parts and low specific cost. The scheme of one of versions of the small-sized vacuum crock-pot constructed on thermoelectric converters (TEP) is put in fig. 1.

Heat transported from thermoelements to the evaporator (2) and to the condenser (8) and utilization of residual heat are carried out due to application of heat pipes (14, 11). Capacity of the evaporator is closed by a tight cover (1) in which the valve (5) for pressure dumping is built in. In the middle of the evaporator the rotor (3) of a magnetic mixer is located. The (4) mixers stator is placed on an external surface of the evaporator.

Steam from the evaporator by a steam line (6) get in the condenser (8). The supply or removal of heat to the evaporator is carried out by means of the main TEC (7) which on the one hand has thermal contact with a thermal pipe (14) which transports heat to evaporator walls, and from a reverse side thermal contact with the condenser. Thus, the main TEC performs function of the thermal pump of a part of thermal energy emitted in the condenser on higher temperature level in the evaporator which is carries out transfer. For stabilization of temperature condition of the condenser auxiliary TEC (10) which has thermal contact with the lower wall of the condenser is used and carries out withdrawal of excess heat by means of a thermal pipe (11) with the compelled air cooling. Distillate from the condenser goes to the collector (9) placed on tenzo-scales (12). Discharge in system is created by the vacuum pump (13).

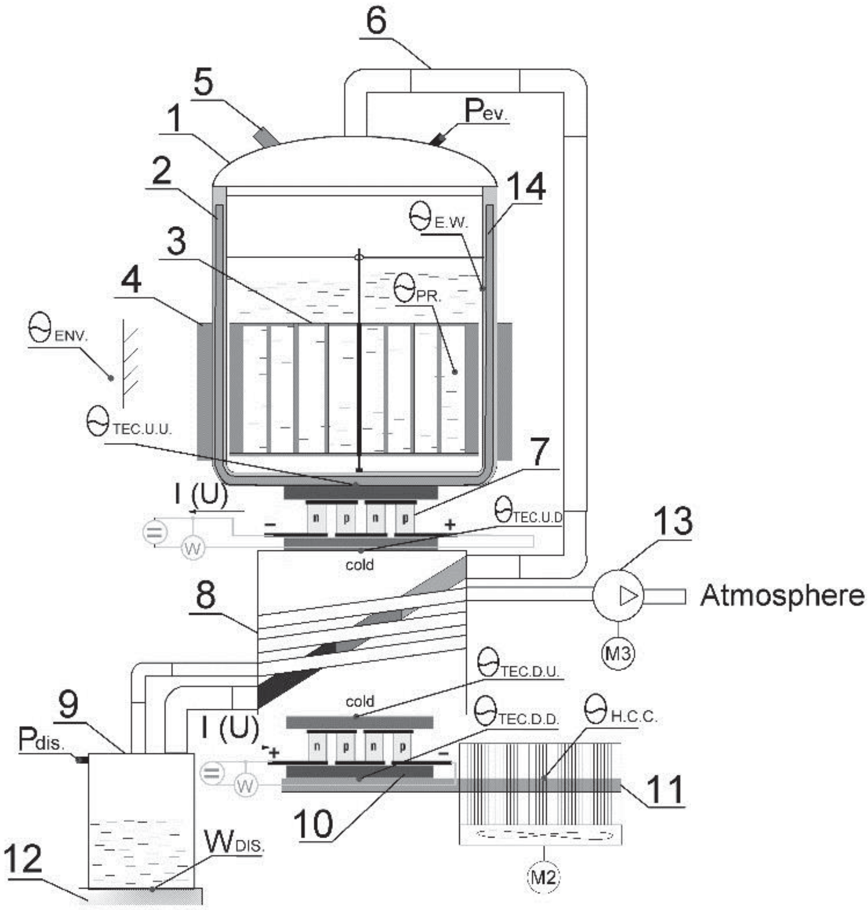
For a possibility of temperature monitoring implementation in control points of the vacuum crock-pot 8 platinum temperature sensors PT1000 (see Fig. 1) which measure temperatures are installed: environment (Θ_{ENV}.), product in the evaporator ($\Theta_{PR.}$.), evaporator walls ($\Theta_{E.W.}$), the heat pipe with the compelled air cooling ($\Theta_{H.C.C}$.), top and lower surface of the main TEP ($\Theta_{TEC.U.D}$., $\Theta_{TEC.D.U}$), top and lower surface of auxiliary TEP ($\Theta_{TEC.U.D}$., $\Theta_{TEC.D.D}$). For control of level of pressure digital sensors of depression are installed in the evaporator (Pev) and the collector of distillate (Pdis) see fig. 1.

Technical realization of the automated workplace of the researcher of processes in the thermoelectric vacuum crock-pot

With a research objective of the vacuum crock-pot as control object (CO), synthesis of structure of automated control system, search of effective algorithms of operation and their approbation the automated workplace of the researcher (AWPR) of the operation modes of nodes of the vacuum crock-pot and technological processes realized in it are developed.

For control of operation modes of nodes of the vacuum crock-pot and monitoring and registration of technological parameters AWPR it is equipped with a built-in multi-channel microprocessor system of data collection and control. The skeleton diagram of this system is provided in fig. 2.

Basic element of built-in system of data collection and control is the ATMega128 (9) microcontroller produced by Atmel. It is the 8-bit RISC microcontroller on AVR kernel checked by time. The microcontroller executes all computing operations, it controls the equipment of installation and provides communication with SCADA system realized on portable PC computer.



1 - evaporator cover; 2 - evaporator; 3 - rotor of a magnetic mixer; 4 - stator of a magnetic mixer; 5 - valve of dumping of pressure; 6 - steam line; 7 - main thermoelectric converter; 8 - condenser; 9 - collection of distillate; 10 - additional thermoelectric converter; 11 – heat pipe with the compelled air cooling compelled with; 12 – tenzo-scales; 13 - vacuum pump; 14 - heat pipe in evaporator walls

Fig. 1 – the technological scheme of the thermoelectric vacuum crock-pot

The main objectives which are solved using the microcontroller:

- information collection from 8 temperature sensors set in different points of installation;
- inquiry of the pressure sensor in vacuum system;
- inquiry of distillate mass measurement system;
- formation of a reference signal of level and the direction of current through thermoelements;
- formation of a reference signal of rotating speed of the vacuum compressor;
- contact with the personal computer
- regulation of temperatures and pressure;
- other computing operations.

The precision temperature information collection system from eight sensors is constructed on the basis of the 24-bit analog-to-digital converter (ADC) ADS1248 (5), produced by Texas Instrument [6]. ADS1248 has built-in programmed current source that allows to take easily measurements of resistance, according to the four-wire connection circuit. The diagram with analog multiplexers (7,8) which switch two of four communication lines going to each of them is applied to implementation inquiry of 8 thermometers of resistance Pt1000. The diagram of multiplexing of measuring signals in case of implementation of the multi-channel measuring instrument of temperature was considered in [3]. The reverse of the direction of current through TEP is carried out by means of switching of contacts (K1, K2, K3, K4) of the relay (P1, P2, P3, P4) which are guided by signals from the discrete outputs of the microcontroller. The data interchange between ADS1248 and the microcontroller is carried out by means of the SPI interface.

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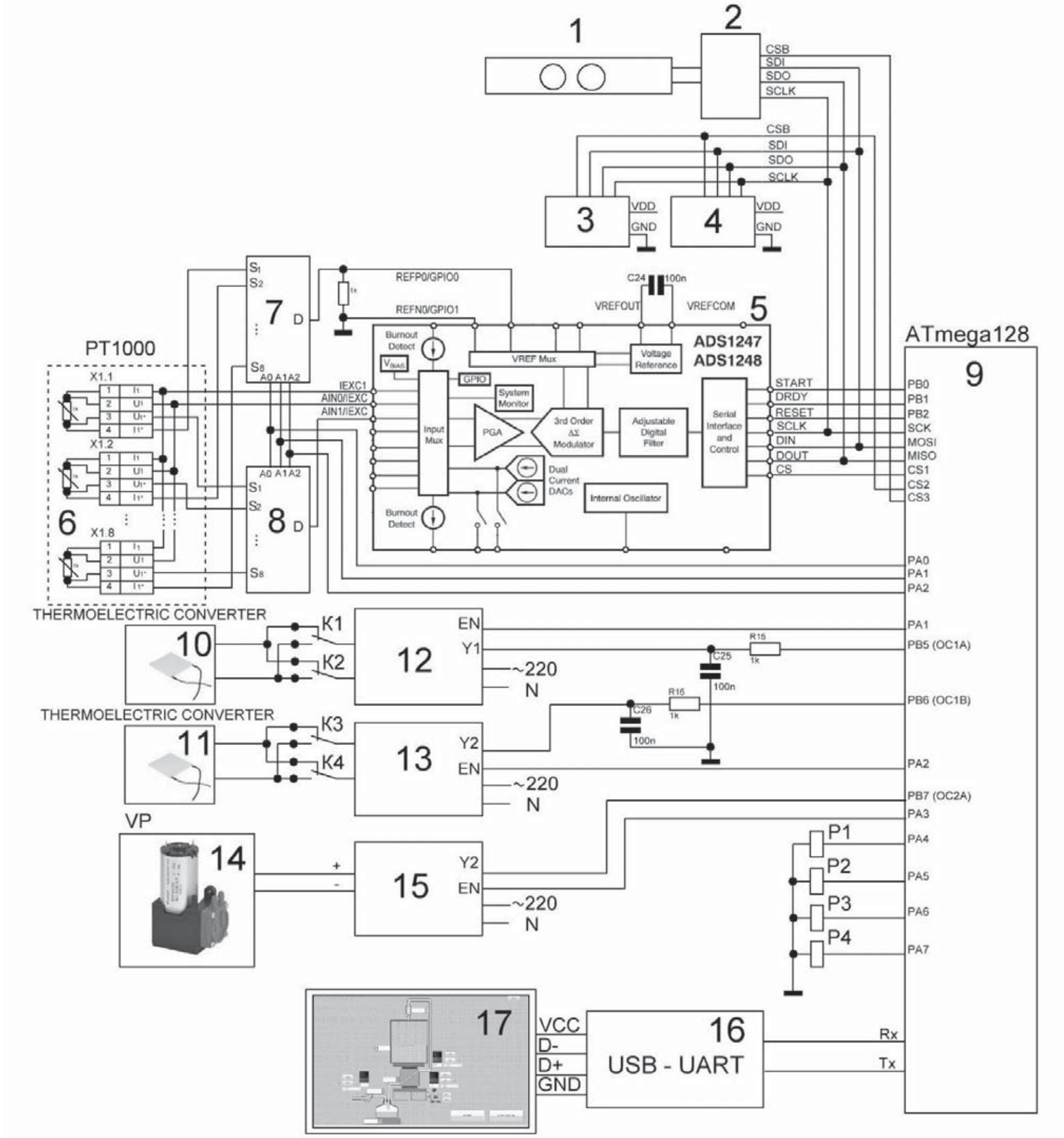

1 - tensometric beam; 2 – tenzo-scales ADC; 3,4 - pressure sensors; 5 - ADC ADS1248 from TI; 6 - resistive sensors of temperature Pt1000; 7,8 - 8th channel multiplexers; 9 - ATmega128 microcontroller; 10,11 - thermoelectric transformers; 12,13,15 - adjustable sources of current; 14 - vacuum pump of a direct current; 16 - transformer of UART-USB interfaces; 17 - the portable computer with SCADA system

Fig. 2 - the skeleton diagram of a multi-channel microprocessor system of data collection and control

Measurement of a pressure level in vacuum system is provided by digital precision sensors [4] with the range of measurement from 10 to 1200 Mbar with permission of 0.012 Mbar. For support of correction of measurements pressure sensors (3,4) are equipped with the built-in sensors of temperature. The data interchange between pressure sensors and the microcontroller is carried out by means of the SPI interface.

A supply of TEC is carried out by means of controlled sources of current (12,13) with power up to 300 W. Change of level of current through TEC in the range from 0 to 15A is carried out by a pulse-width signal from a microcontroller output.

The pressure level in system is supported by change of productivity of the vacuum pump (14) due to change of current of the controlled power supply (15) of the engine of the vacuum pump in the range from 0 to 15A. Level of current of the engine of the vacuum pump is set by a pulse-width signal from a microcontroller output.

For performance measurement of VE the tank for collection of distillate is set on the tensometric beam. Gain, measurements and conversions of signals to a digital code from a tensometric beam (1) is carried out by means of the specialized 24bit ADC (2) [5]. The range of measurement of weight from 0 to 3 kg with permission 0.05 gr.

The microprocessor system of data collection and control by means of the transformer of UART-USB (16) interfaces is connected to the PC (17), on which SCADA is implemented, the system is equipped with the interface of the researcher and performs functions of implementation of programs of automated experiments, data loggings and their archiving.

Conclusion

The created complex of technical means and the developed software allows to make the active experiments for a research of the thermoelectric vacuum crock-pot as control object. It will allow to develop the control algorithms based on the retrieved data providing the energy consumption in case of technological processes implementation and high quality indicators of finished goods. Production of thermoelectric vacuum crock-pots and their use for thermal treatment of foodstuff in at farms, hotels and even at home can promote creation of new food, development of new culinary recipes and generally perhaps development of the new direction in cookery.

References

[1] Chakib Alaoui, “Peltier Thermoelectric Modules Modelingand Evaluation”, International Journal of Engineering, KSA, vol. 5, no. 1, pp. 114-121, Sep 2011.
[2] A. A. D'yakova, A. V. Mazur, D. A. Koval'chuk and A. A. Pushkin, “MNOGOKANAL'NAYA SISTEMA SBORA I OBRABOTKI INFORMATSII NA BAZE KONTROLLERA ADuC7061”, Avtomatizatsíya tekhnologíchnikh í bíznes-protsesív, vol. 17, pp. 17-21, Sep, 2014.
[3] I.G. Nison, Vyparnyye apparaty. Moskva, CA: Bukinisticheskoye izdaniye, 1947.
[4] “MS5611 documentation” [Online]. Available: http://www.daedalus.ei.tum.de/attachments/article/61/ MS5611-01BA01.pdf [Accessed: June. 11, 2017].
[5] “HX711 documentation” [Online]. Available: https://cdn.sparkfun.com/datasheets/Sensors/ForceFlex/ hx711_english.pdf [Accessed: June. 11, 2017].
[6] “ADS1248 documentation” [Online]. Available: http://www.ti.com/lit/ds/symlink/ads1248.pdf [Accessed: June. 11, 2017].

Література

[1] Chakib Alaoui. Peltier Thermoelectric Modules Modelingand Evaluation / Alaoui Chakib // International Journal of Engineering. – KSA, 2011. – Т. 5, № 1. – С. 114–121.
[2] Дьякова А.А. Многоканальная система сбора и обработки информации на базе контроллера ADuC7061 / А.А. Дьякова, А.В. Мазур, Д.А. Ковальчук, А.А. Пушкин // Автоматизация технологических и бизнес-процессов. – 2014. – №17. – С. 17–21.
[3] Нисон И.Г. Выпарные аппараты / И.Г. Нисон. М. : Букинистическое издание, 1947.
[4] “MS5611 documentation” [Electronic resource]. – Access mode: http://www.daedalus.ei.tum.de/attachments/article/61/ MS5611-01BA01.pdf. – Дата звернення: 11.06.2017. – Назва з екрану.
[5] “HX711 documentation” [Electronic resource]. Access mode: https://cdn.sparkfun.com/datasheets/Sensors/ForceFlex/ hx711_english.pdf . – Дата звернення: 11.06.2017. – Назва з екрану.
[6] “ADS1248 documentation” [Electronic resource]. Access mode: http://www.ti.com/lit/ds/symlink/ads1248.pdf. – Дата звернення: 11.06.2017. – Назва з екрану.