Automation of processes of temperature modes control in security system based on HACCP principles

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Abstract. According to the requirements of the Technical Regulations of the Customs Union, (TRCU) 021/2011 “On safety of food products” the enterprises manufacturing food products, including public catering enterprises, have to incorporate and maintain the system of safety based on the principles of the Hazard Analysis and Critical Control Points (HACCP). One of the HACCP principles states that the monitoring of checkpoints and critical checkpoints shall be provided at the enterprise. The monitoring and control of temperature modes of premises, refrigerating and freezing installations is mandatory according to HACCP requirements. The questionnaire survey carried out by the authors has shown that the temperature mode is under control at 9 of 10 catering establishments. In case of such process organization the checkpoints or critical checkpoints can be traced not in time, which brings about not only the degradation of produce quality, but the indicators of its microbiological safety too. In order to eliminate this peril, it is recommended to organize not a periodic but a permanent control over these checkpoints. It is attained due to incorporation and development of an automated system of control of temperature modes of premises, refrigerating and freezing installations. The article presents technical support and software of the automated system of process control developed by the authors, which has been approved officially at A la fourchette LLC (Moscow). The incorporation of this automated system implements a permanent guaranteed monitoring and control of microbiological risk, increases labor productivity; enhances accuracy and stability of fulfilled operations, etc. A bilateral link between education and business has been implemented in this study.

1. Introduction
The tremendous qualitative and quantitative changes in the sphere of public catering have taken place in the Russian Federation within the recent 25 years. A transition from the state property to private property has radically changed the attitude to labor, quality of cooking, responsibility for the rendered services [1]. They have begun to pay more attention to safety of cooking [2, 3], which, certainly, is related, first of all, to implementation of the requirements of the Technical Regulations of the Customs Union (hereinafter referred to as the “TRCU”) 021/2011 “On safety of food products” [4]. The Technical Regulations are mandatory for enterprises and organizations of all forms of property manufacturing food products. According to TRCU 021/2011 it is necessary to incorporate and
maintain functioning of the security system based on the principles of the Hazard Analysis and Critical Control Points (HACCP). Despite the fact that this requirement has been fulfilled over the years in many foreign countries, it became mandatory only since 2015 in the RF in due legal form. The HACCP principles have been presented for the first time in Codex Alimentarius standard that saw the light in 1969 [5]. The implementation of these requirements in the RF proceeds with great difficulties, since it is involved with a wide spectrum of risks and problems, however, this aspect is of great importance for providing food supply security of our country [6].

One of the problems of maintaining requirements of food products safety is low level of processes of automation at public catering facilities. The productivity of personnel labor increases, operational costs get reduced, the period of operation of refrigerating compressors increases, protection of refrigerating installations from accidents is provided due to automation of refrigerating and freezing installations [11]. The automation guarantees a permanent control of quality of manufactured products, its freshness and safety, particularly, microbiological safety [12, 13] according to the requirements of Codex Alimentarius Commission [19, 20].

The maintenance of the required indicators regarding microclimate of the production premises reduces the personnel disease incidence, contributes to increasing labor productivity and produce quality, and is the factor determining the comfort of labor conditions [9, 10].

2. Methods and subjects of research

Such general scientific and special methods of investigation have been used in the research as observation, analysis, enquiry, simulation, development of software. The purpose of research is the development of automated system of control and monitoring of checkpoints of temperature modes of premises and refrigerating installations (refrigerating and freezing chambers) of catering establishments. The subject of research is the public catering enterprise A la fourchette LLC, Moscow.

3. Research results

It is necessary to incorporate and maintain monitoring checkpoints and critical checkpoints in the system of safety based on HACCP principles [7]. The authors have carried out observation of the processes of registering temperature parameters in the food units of the state publicly-funded pre-school educational institution No. 23 of Vyborgsky district of Saint-Petersburg, he state publicly-funded pre-school educational institution No. 27 of Vasyleostrovsky district of Saint-Petersburg, state budget educational institution of secondary school No. 10 of Vasyleostrovsky district of Saint-Petersburg and inquiry of the number of CEOs of catering establishments of Saint-Petersburg (table 1).

Table 1. List of CEOs and specialists of catering establishments that have taken part in the inquiry.

| Full name           | Position, place of employment                                      |
|---------------------|---------------------------------------------------------------|
| E.P.Chernysheva     | Director General, FLORIDAN COMPANY JSC, Saint-Petersburg       |
| O.M.Gaponova        | Director General, Saint-Petersburg State Unitary Enterprise Social Food Production Facility YUNOST, Saint-Petersburg |
| E.E.Kushleikene     | Director for Production and Culinary Shops, TD Intertorg LLC, Saint-Petersburg |
| M.D.Gushchina       | Chief Process Engineer, facilities administration of Gazprom PJSC, Saint-Petersburg |
| O.A.Krasnozhen      | Production Director, hypermarket “Lenta”, Saint-Petersburg     |
| M.Yu.Vlasova        | Production Director, Astoria CJSC, Saint-Petersburg            |
| R.D. Deniskin       | Executive Chef of fresh markets “Gastroman”, Chief Cook of gastro-bar Spirit, Saint-Petersburg |
| I.I. Kiselev        | Chief Cook of Multipurpose Center “Gorny”                      |
| Yu.A.Shargalin      | Chief Cook of “Kulinarnaya Artel No.1”, Saint-Petersburg       |
The information analysis has shown that the process of monitoring and control of temperature modes of premises, refrigerating and freezing installations is implemented at these of catering establishments manually with several-fold frequency. It is quite probable with such process organization that a deviation from checkpoint will not be traced in time. It can bring about material and moral losses. The organization of monitoring of checkpoints with the use of automated system in a permanent mode makes it possible to effect process control due to installation of sensors of registration of temperature modes and use of software making it possible to trace the real-time indicators thereof. Therefore, the authors have developed a system of monitoring checkpoints in accordance with the principles of building automated systems [8, 14, 15].

The requirements and principles of incorporating a system of food products safety based on HACCP principles [16, 17]; current state, capabilities and prospects of using automated processes at the catering establishments have been studied; an automated system of monitoring, in particular, temperature in the premises of public catering facilities, refrigerating and freezing chambers has been developed in the course of conducting research.

Sequence of work fulfillment:
- selection of technical equipment (controller, temperature sensor);
- development of diagram and program of thermometer operation based on Arduino Mega board;
- development of software.

3.1. Selection of technical equipment

The authors have carried out analysis of the following types of controllers: Siemens Simatic S7- 200, OVEN PLC 150, Velocio Ace 3090v5, Arduino Mega 2560 [18]. Arduino Mega 2560 controller is the most suitable for project purposes, since it features a necessary quantity of ports and is affordable.

The authors have carried out monitoring of sensors available in the sales networks when selecting a temperature sensor, viz: LM35, TMP35, TMP36, TMP37. These are the most widespread; the devices are sufficiently precise and not expensive. The main parameters of temperature sensors are shown in Table 2.

| Sensor type | Temperature measurement range, °C | Output voltage offset, mV | Scaling factor, mV/°C | Output voltage at +25°C, mV |
|-------------|----------------------------------|---------------------------|-----------------------|----------------------------|
| LM35, LM35A| 0 … + 150                        | 0                         | 10                    | 250                        |
| LM35C, LM35CA| 0 … + 110                       | 0                         | 10                    | 250                        |
| LM35D       | 0 … + 100                        | 0                         | 10                    | 250                        |
| TMP35       | + 10 … + 125                     | 0                         | 10                    | 250                        |
| TMP36       | - 40 … + 125                     | 500                       | 10                    | 750                        |
| TMP37       | + 5 … + 100                      | 0                         | 20                    | 500                        |

The temperature measurement range of the considered temperature sensors is within the limits of 0°C and higher. The temperature sensor TMP36 makes it possible to measure negative temperature, therefore the authors have chosen this model.

3.2. Development of diagram and program of thermometer operation based on Arduino Mega board

The power supply of Arduino Mega can be provided both through USB connection and directly from an external power supply. The AC/DC voltage converter, storage battery can be used as the external power supply. The connection is provided through connector of 2.1 mm located on the board, or
through Vin and Gnd leads connected to plus and minus of power supply, accordingly (Figure 1). The platform is programmed by means of Arduino IDE software. Figure shows a diagram of the thermometer based on Arduino Mega board.

3.3. Development of software
There are 3 variants of implementing this task:
1. Development of module software in C++ language with the use of SDK libraries of Espressif System and libraries of external development agencies.
2. Development of software in scripting language Lua with the use of ready operating system NodeMSU, which features its filing system SPIFSS, built-in interpreter and is able to execute Lua scripts from the device memory.
3. Development of module software in C++ language with the use of multitasking real-time operating system FreeRTOS written in C language with an open initial code. This solution helps create several processes fulfilling tasks thereof.

The authors have selected a variant with the use of operating system NodeMsu and programming language Lua, which is the fastest and simple in terms of implementing an assigned task. At that, it is not suitable for implementation of projects, where it is necessary to provide the multitask character of this module due to memory shortage.

The authors have developed the software of a controller supporting protocol MQTT [18]. The device initialization takes place upon switching on power supply. At this stage module connection to the existing WiFi network is provided, mqtt – client is launched, which provides for server ping, sending pin status with time intervals of 2 s, and bugging port 1884 for receiving messages from the server. The time interval of 2 s is shown as a test one, it can be changed later depending on the task to be solved.

Upon emergence of a command from the broker, its fulfillment takes place and the device returns to the command awaiting mode. If a command fails to arrive, the device continues to be in the standby mode.

After module energizing the initialization file init.lua, where the basic procedures are described, begins to get fulfilled. This script implements a scenario of starting remote files. Further, setup.lua scis fulfilled, where an initial configuration of controller GPIO outputs is described, after that a module of
connection to WiFi network gets started. A connection to the existing WiFi network is provided in accordance with parameters preset in configuration file.

The configuration file specifies parameters of access point, to which a module is connected (ssid and password) as well as settings for connection to a broker (its IP-address, port and lines, through which it will send and receive messages from the user).

Later a web-server and application, accomplishing the main logic of program and MQTT of application.lua protocol, will start in parallel. At that, MQTT – client gets started, two lines for data receiving and transmitting are set up, the module begins to ping MQTT – broker to IP address specified in configuration file and send its identification number ID, information on the state of outputs and information received from DHT sensor in json format to it. The second line changes over to the mode of port 1884 bugging for receiving messages from the server. The work through Web-server is also envisaged.

4. Conclusions

The selection of technical equipment (controller Arduino Mega 2560, temperature sensor TMI136) has been effected; the diagram and program of thermometer operation on the basis of Arduino Mega board and software of the process of monitoring and control of temperature modes of premises and refrigerating and freezing installations of catering establishments have been developed in the performed research. The developed software has been tested at A la fourchette LLC (Moscow) according to the requirements of ISO 10012-2003 in the volume required to maintain stability of measurement results. The incorporation of automated system of this process control helped provide stability of control of temperature modes of premises, refrigerating and freezing chambers of catering establishment; permanent guaranteed monitoring and control of microbiological risk according to the requirements of Codex Alimentarius Commission; improving accuracy and stability of performed operations. The developed software does not require any extensive knowledge from a user; the interface is intuitive and user-friendly.

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