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MOBILE AND MULTIPOINT TEMPERATURE MEASUREMENT SYSTEMS BASED ON Pt100 SENSORS FOR FUTURE STUDY OF ENERGY EMITTED FROM THE URANIUM EXPERIMENTAL ASSEMBLY

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Белевич М. и др. E13-2018-39
Мобильные и многоточечные системы измерения температуры
на основе датчиков Pt100 для будущего исследования энергии,
выделяемой экспериментальной урановой сборкой

Целью нашего проекта было создание простых и дешевых устройств, которые могут одновременно измерять температуру во многих точках. Система сможет работать на экспериментальной урановой сборке в условиях высокой радиации, такой как сборка Quinta коллаборации Energy + Transmutation RAW. Quinta имитирует системы, управляемые ускорителем (ADS). Знания о производстве энергии внутри установки, подобной этой, очень важны для будущего проекта ядерных реакторов четвертого поколения. Сконструированная система измерения температуры (TMS) дает возможность получения этой энергии с использованием измерений температуры. Система была построена на основе готовых компонентов. Мы работали над связью этих приборов с программой управления LabView и развитием надежной системы калибровки. В данной работе представлены варианты создания установки, процедура калибровки и первый результат измерения.

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Препринт Объединенного института ядерных исследований. Дубна, 2018

Bielewicz M. et al. E13-2018-39
Mobile and Multipoint Temperature Measurement Systems Based
on Pt100 Sensors for Future Study of Energy Emitted from the Uranium
Experimental Assembly

The goal of our project was to construct simple and cheap devices which can simultaneously measure temperature in many points. The system will be able to work on uranium experimental assembly in high radiation environment like Quinta assembly of Energy + Transmutation RAW collaboration. The Quinta assembly simulates Accelerator Driven Systems (ADS). Knowledge about energy production inside installation like this is very important for the future project of the IV-generation nuclear reactors. Designed Temperature Measurement System (TMS) gives possibility to obtain this energy by using temperature changing measurement. The system was built by ready-to-use components. We focused on communicating these devices with LabView self-prepared control program and developing a reliable calibration system. This paper presents construction way, calibration procedure, and the first result of measuring.

The investigation has been performed at the Veksler and Baldin Laboratory of High Energy Physics, JINR.

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CONSTRUCTION OF TEMPERATURE MEASUREMENT SYSTEM — DEVICES

The main goal of the project was to create multipoint system for precision temperature measurement (TMS) with some specific features. The TMS should be mobile, not heavy, simple to prepare, with good resolution, stable work in a long period of time (hours–days), relatively cheap, with easy method of increasing the number of measurement points. TMS should also be fully automatic and after each break should automatically return to normal work — without any extra effort. Finally, we must remember that sensors will be located in high radiation environment and should be very small (potentially located at very small air gap). The TMS is used for temperature measuring in Quinta experimental assembly (Energy + Transmutation RAW Collaboration [1]), and can be used at the Slow Control Systems (SCS) [2–4] to control the temperature inside the rack with electronic equipment for MPD–NICA collider [5]. This work was a part of the Summer Student Practice in Dubna of July 2017.

TMS was built with ready-to-use components and equipment of the Polish company LUMEL [6]. System contains SM61 — data logger with www server [7], SM1 — 2-channel module of analog inputs [8], P19 — temperature and humidity sensor [9], power supply and platinum thermistors (Pt100 sensors). SM61 allows to record up to 1 GB of data. This data logger read out up to 2500 values from slave devices (up to 100 devices, each 25 registers). It is easy to connect with it, for example, via FTP and web servers. SM1 is a module destined to convert standard signals, resistance or temperature signals into numerical data accessible through the RS-485 or RS-232 port by means of the MODBUS protocol.

The system was tested on two SM1 devices that can measure temperature in four different points. The temperature is measured by P19 sensor at the same time for control purposes. The device is easy to extend by adding another SM1 module (or SM2 — 4 channels) with additional Pt100 sensors. Each SM1 module can work with two standard Pt100 sensors. The system uses RS-485 connection protocol to communicate between different parts of the device. To download the results from SM61 recorder, both www server with FTP protocol and our

LabView program [10] can be used. Both of them use connection by Ethernet (standard LAN cables). A Pt100 sensor is a precisely manufactured thermistor. Its resistance at 0°C is 100 Ohm and it rises with increasing of temperature. The resistance is changing almost linearly with temperature changing. There are many types of Pt100 sensors. They can have from two to four wires and also different resolution or level of errors. More wires can give correction on changes of cables resistance. Please note that in the future our system should use the most precise Pt100 with the smallest heat capacity. Current Pt100 sensors are covered by cuprum cube $5 \times 5 \times 5$ mm. SM1 measures temperature by Pt100 and converts data to digital signal which is sent to data logger by RS-485 protocol. SM1 AC/DC converter can work in three different modes: 0–10 V, 0–20 mA and mode used by us 4–20 mA, which gives possibility to detect a failure of the system. P19 module is a temperature and humidity sensor. Unlike Pt100 it does not require any calibration, so it can be used as a point of reference for Pt100 calibration. It measures temperature based on a dew point. SM61 sends data requests to SM1 and logs the received data. It can be configured to collect data with different frequency and using more SM1. To download data or configure the devices, SM61 is temporarily connected to PC by Ethernet cable.

To wrap up, the TMS system is designed as follows: data logger SM61 is connected in parallel through the RS-485 bus with two SM1 AC/DC converters. There are two Pt100 sensors connected to each converter. Electronic devices should be placed away from the temperature sensors, which will be located in a highly irradiated place. For this purpose the connection between them is extended with a LAN cable (twisted pair). In addition, temperature and humidity sensor P19 is connected in parallel, also via bus 485. P19 sensor is powered by an

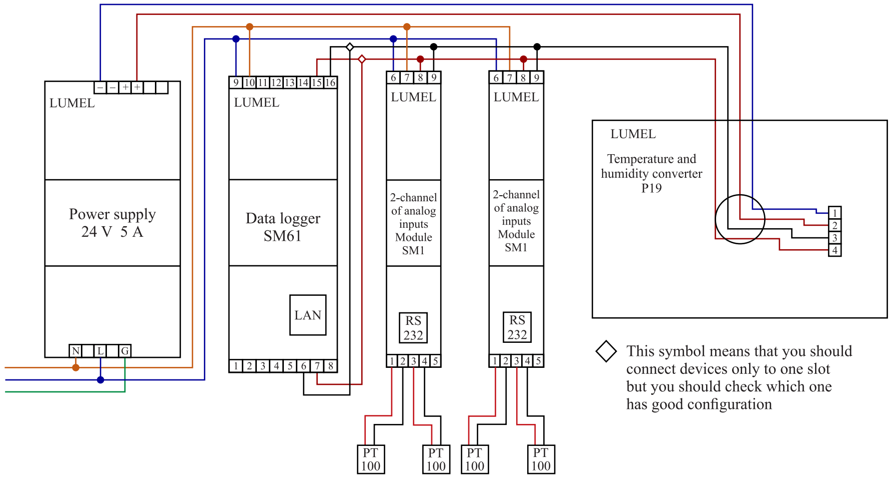

Fig. 1. Schematic diagram of temperature measurement system (TMS)

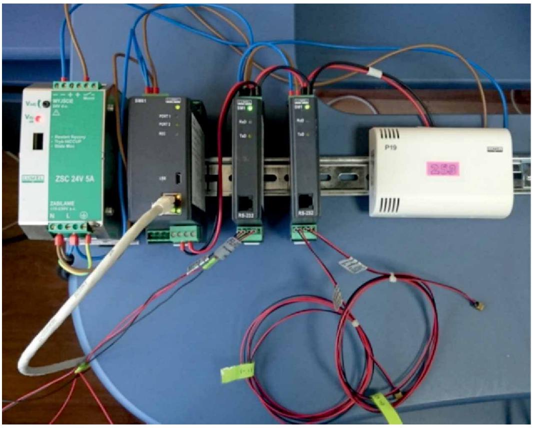

Fig. 2. TMS assembled installation

additional 24 V power supply. All system components require an external 230 V power supply. We use a power strip with noise filtering and a surge protector. All elements are mounted on a metal rail in rack for its stability. A scheme of the TMS is shown in Fig. 1, the real picture of the TMS is in Fig. 2.

CALIBRATION AND MEASUREMENT

SM61 was set up by using web interface which is a built-in device provided by LUMEL. The system can be controled also by program written in LabView [10]. Our LabView program allows an easy calibration using linear approximation (see Fig. 3). It requires only 2 points. In our case we used boiling and freezing point of water (i.e., 100 and 0°C). A dedicated panel for calibration was prepared in TMS LabView program where it can be performed easily. Each thermistor can be calibrated separately and there is no way to get calibration measurements for more than one thermistor at once. This procedure needs two reference points at which linear approximation is performed. User must choose calibration points before the procedure starts. The measurement itself is not a single measurement, but the temperature is measured at some time interval. Length of this interval is up to the user. Measurement stops only after user tells the program to stop it. Then measurements from this period are re-calculated and used as a measured value in this point of reference. Calibration value from TMS LabView program does not alter the way the data are saved on the SM61 recorder. Data are adjusted only when it is shown in TMS LabView program. Without calibration data are presented as they are on the SM61.

To achieve measurement at freezing point, a mixture of water and ice was prepared. Then we closed it in vacuum flask to keep the temperature stable and

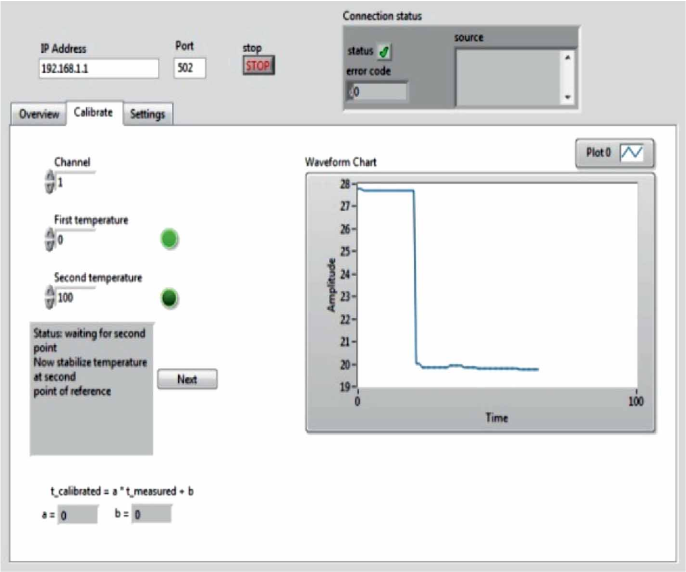

Fig. 3. TMS LabView program — calibration panel

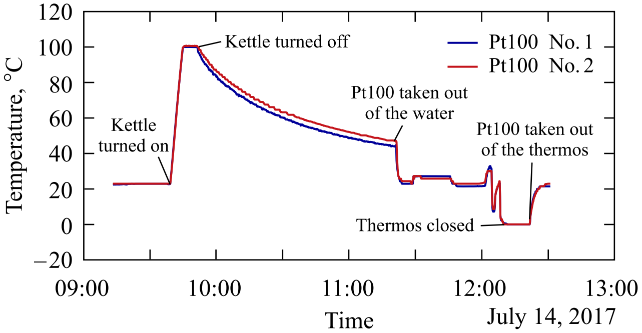

Fig. 4. Periodic scheme of the whole calibration process

dipped two thermistors in it trying to keep them in the middle of this system and separate them from each other (Figs. 4 and 5). To measure the boiling point we turned on an electric kettle and hung Pt100 thermistors with their cables, which we tried to keep in the middle of the water level, separated from each other. We have made sure that the kettle will not turn off when water gets to the boiling temperature to get measurement in a longer period of time (Figs. 4 and 6).

As we can see at the freezing point calibration gives us good results but at boiling point there are many fluctuations. The reason for this is probably the

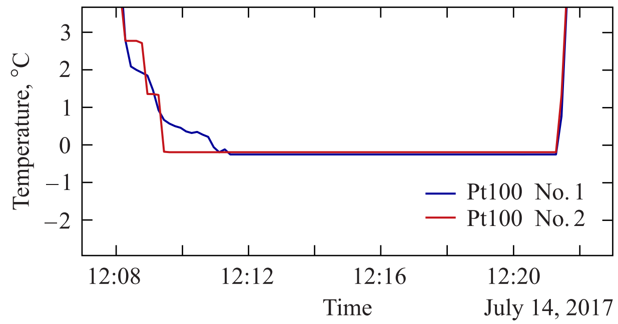

Fig. 5. Calibration at freezing point

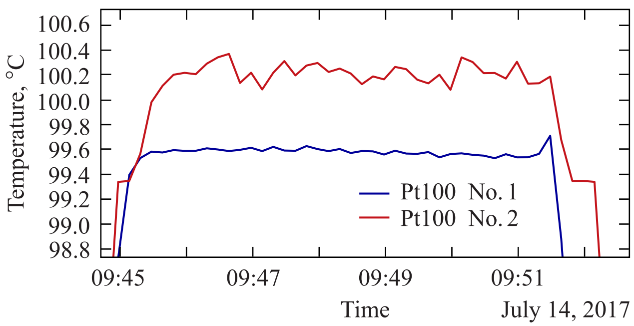

Fig. 6. Calibration at boiling point

fact that our setup was not stable enough for as dynamic environment as boiling water. To perform calibration correctly this measurement must be prepared better. One way is to fix thermistors properly to make their movement within the system impossible. Another solution is to change the point of measurement to a more stable one. For the best result of calibration we suggest using a melting metal alloy, for example, Wood's alloy, which should give us the best result in the second point of calibration at temperature about 70°C. For higher temperature we should find alloys with melting point around the expected temperature range.

Finally, the TMS system was ready to work. We have carried out many test measurements on our system. Some of them in natural environment (inside and outside the room) and some during experiment (radiation environment). TMS worked properly in all cases: long period of time, temperature below and above zero Celsius, big and small changes, bad weather and strong radiation.

In Fig. 7 we can see an example of long-period measurement. Two-day measurement inside and outside the room at the same time. It was winter time and temperature outside was strongly changing during the night. Probe No. 4 was outside and touched the window (influence from building temperature). Probe

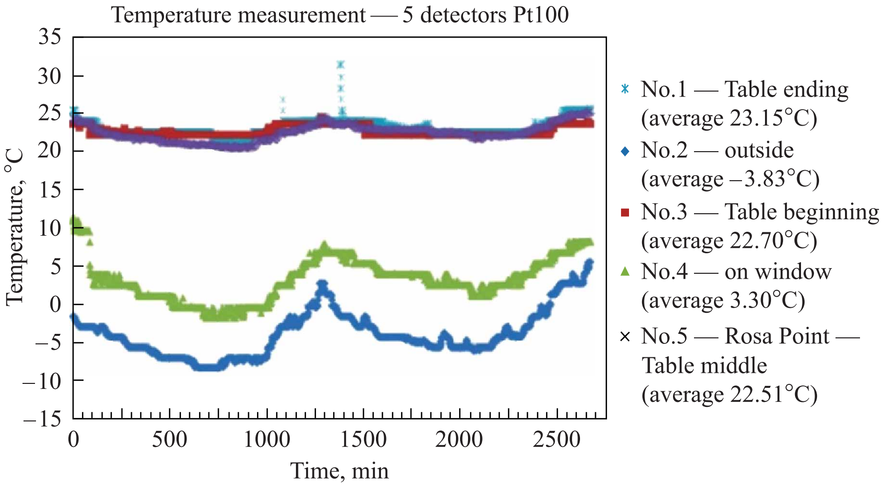

Fig. 7. TMS two-day measurement at 5 points simultaneously. Probes No. 1, 3 and 5 were inside the room, probes No. 2 and 4 — outside the room. Measurement "0" min start point 15.02.2017 15:00

No. 2 was about 30 cm from the building wall. Probes inside the room were located at different lengths from the window (window is colder than room). On the plot we can see the two thin vertical blue peaks (probe No. 1) — the probe was held by hand for a moment. We see that the system was sensitive to any kind of changes in the temperature.

CONCLUSIONS

Many hours of test measurements were carried out. Obtained results are satisfactory. The designed system has proven itself in practical operation in both hardware and software parts. It is durable, simple, cheap and easy to use.

Taking everything into consideration, the designed system has a number of advantages, but it is not without flaws, either. Primarily, the calibration is not too precise (but still precise enough for experiments performed so far). Low calibration accuracy is due to the fact that the two thermistors were not stably fixed in the middle of the vacuum flask, which is the main reason of many fluctuations at boiling point. This problem can be solved by building a stable thermistor stand with calorimeter.

The TMS project is used for temperature measuring in the Quinta experimental assembly (Energy + Transmutation RAW Collaboration), but it can also be used in SCS (Slow Control Systems) to control temperature inside the rack from MPD–NICA collider. The biggest advantage of this device is that it can be used in almost every situation in which we need multiple temperature measurement. The LabView app gives us even more options, for example, to connect it with air circulation system in rack to control the temperature inside it. In the future, we hope to develop and improve the TMS system.

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