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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A 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 at Energy+Transmutation RAW Collaboration. The Quinta assembly simulates an Accelerator Driven Systems (ADS). Knowledge about energy production inside installation like this is very important for the future project of 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 the construction way, calibration procedure and the first result of measuring.

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1. Construction of Temperature Measurement Systems — 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 an easy method of increasing number of measurement points. TMS should also be

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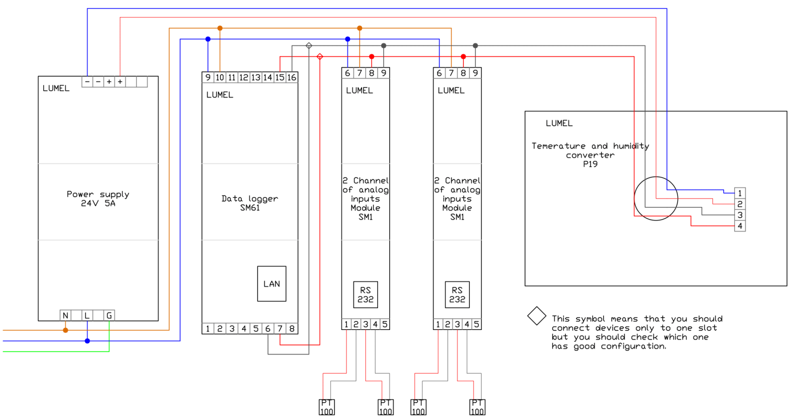
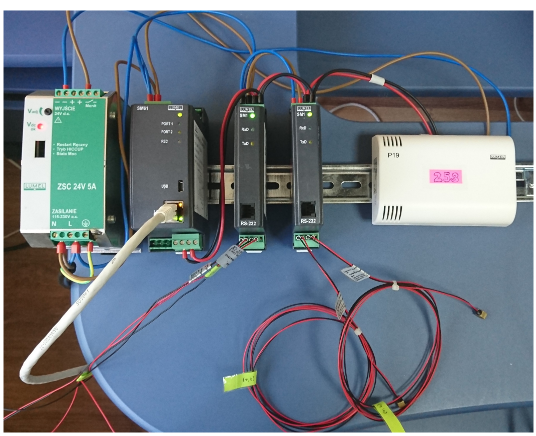
fully automatic and after each break should automatically return to normal work — without any extra effort. Finally, we must remember that sensors will be located in high radiation environment and should be very small (potentially located at very small air gap). The TMS is used for temperature measuring 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 Summer Student Practice in Dubna in July 2017. TMS was built with ready-to-use components and equipment of the Polish company LUMEL [6]. System contains SM61 [7] — data logger with WWW server, SM1 [8] — 2-channel module of analog inputs, P19 [9] — temperature and humidity sensor, power supply and platinum thermistors (Pt100 sensors). SM61 allows to record up to 1GB of data. This data logger readout 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 the 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. A 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 RS485 connection protocol to communicate between different parts of the device. To download 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 in 0°C is 100 Ohm and it increases with increasing of temperature. The resistance is changing almost linearly with temperature changing. There are many types of Pt100 sensors. They can have 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 the $5 \times 5 \times 5$ mm^3 cuprum cube. SM1 measure temperature by Pt100 and convert data to digital signal which is sent to data logger by RS485 protocol. SM1AC/DC converter can work in 3 different modes: 0–10 V, 0–20 mA and the mode used by us of 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 log the receive data. It can be configured to collect data with different frequency and using more SM1. To download data or configure the devices, SM61 is temporary connected to PC by Ethernet cable. To wrap up, the TMS system is built as follows: data logger SM61 is connected in parallel through the RS485 bus with two AC/DC converters SM1. 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 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 (a), the real picture of the TMS is in Fig. 1 (b).



(a) Schematic Diagram of temperature measurement systems (TMS).



(b) The picture of the TMS assembled installation.

Fig. 1. Assembled system.

2. Calibration and measurement

SM61 was set up by using web interface which is built-in device provided by LUMEL. The system can also be controlled by a program written in LabVIEW [10]. Our LabVIEW program allows an easy calibration using linear approximation (Fig. 2). It requires only 2 points. For our purpose, we used boiling and freezing point of water (*i.e.* 100°C and 0°C). A dedicated panel for calibration was prepared in the 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. A calibration value from TMS LabVIEW program does not alter the way the data are saved on the SM61 recorder. Data are adjusted only when they are shown in the TMS LabVIEW program. Without calibration, data are presented as they are on the SM61.

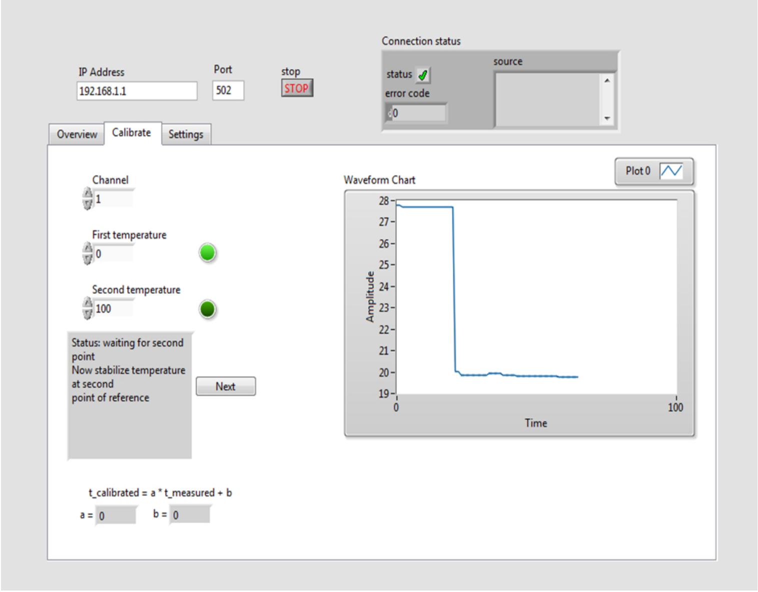
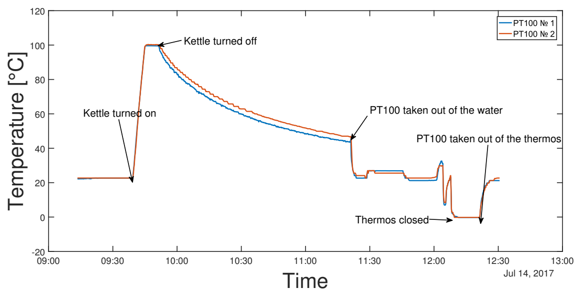
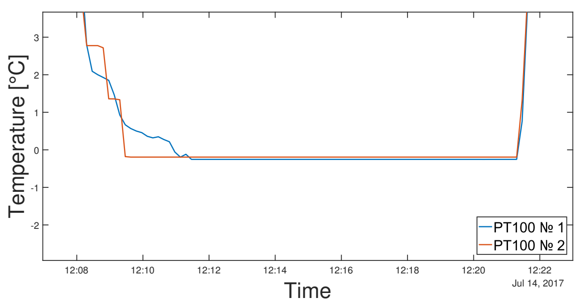


Fig. 2. TMS LabVIEW program — calibration panel.

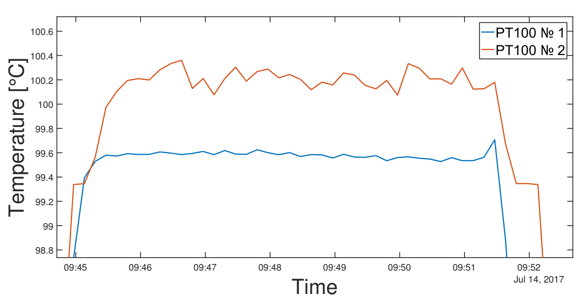
To achieve measurement in freezing point, a mixture of water and ice was prepared. Then we closed it in a vacuum flask to keep the temperature stable and dipped two thermistors in it trying to keep them in the middle of this system and separate them from each other (Fig. 3 (a) and (b)). To measure the 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 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 (Fig. 3 (a) and (b)).



(a) Periodic scheme of the whole calibration process.



(b) Calibration at freezing point.



(c) Calibration at boiling point.

Fig. 3. System calibration charts.

As we can see, at the freezing point, calibration gives us good results but at the boiling point there are many fluctuations. The reason for this is probably the fact that our setup was not stable enough for such a 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 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 in temperature about 70°C. For higher temperature we should find alloys with melting point around the expected temperature range.

After all 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 of the room), and some during the experiment (radiation environment). TMS worked properly in all cases: long period of time, temperature under and above zero Celsius, big and small changes, bad weather and strong radiation.

In Fig. 4, 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 night. Probe No. 4 was outside and touched the window (influence from building temperature). Probe No. 2 was about 30 cm from the building wall. Probes inside the room were located at different distances from the window (window

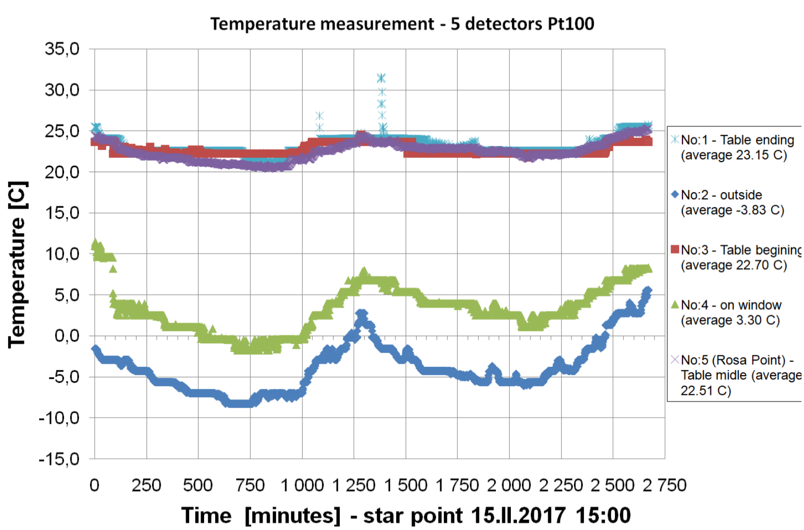


Fig. 4. (Colour on-line) TMS two-day measurement in 5 points simultaneously. Probe Nos. 1, 3 and 5 were inside the room. Probe Nos. 2 and 4 outside the room.

is colder than the room). On the plot, we can see the two thin vertical peak (probe No. 1) – the probe was held by hend for a moment. We can see that the system was sensitive for any kind of changes in the temperature.

3. Conclusion

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

Taking everything into consideration, the built 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 a 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 expgraperimental 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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