# RT-Lab - the Equipment for Measuring Thermophysical Properties by Transient Methods

**V. Štofanik[1], M. Markovič[1], V. Boháč[1], P. Dieška[2] and Ľ. Kubičár[1]**

[1] Institute of Physics SAS, Dúbravska cesta 9, 845 11 Bratislava, Slovakia
[2]Department of Physics, STU, Ilkovičova 3, 812 19 Bratislava, Slovakia
Email: *vladimir.stofanik@savba.sk*

***Abstract.*** *The paper introduces novel equipment RT-Lab for measuring thermophysical properties of various materials by means of the transient methods we have developed in our laboratories. The entire measuring process can be realized by the RT-Lab. The equipment can operate in several measuring regimes and different transient methods. Functionality of the RT-Lab was verified by measurement of the thermophysical properties of the standard material BK7 using pulse transient method. The RT-Lab replaced the electronic unit RT 1.02 that for its operation required two additional expensive equipments, the programmable power source (KEPCO ABC 15-7 DM) and the precise multimeter (KEITHLEY-2010).*

*Keywords: Transient methods, Thermophysical properties*

## 1. Introduction

Recently a new class of dynamic methods for measuring thermophysical properties - the transient methods - started to be spread in research laboratories as well as in technology [1, 2]. The measuring process, generally, is based on the generation of a heat disturbance and the recording a temperature response. Thermophysical parameters are then usually evaluated by fitting of the temperature function over the recorded temperature response. The temperature function that represents a model of the used method is a solution of the partial differential equation considering appropriate boundary and initial conditions. The conditions have to follow the experimental set-up otherwise a data shift might be found [3]. A broad range of experimental set-ups with one or two probes arrangements, considering heat source in a various forms: point, line, plane, disc, strip, etc. and considering a pulse regime or step-wise regime has been published [4]. Several types of instruments based on transient methods started to be involved onto market [4, 5, 6]. The first generation of those instruments utilizes commercial programmable current or voltage sources to provide the energy for the heat disturbance and precise voltmeters or multimeters to record the temperature responses. Further development of measurement methodologies and construction of new thermophysical sensors simplified the measuring process. New types of instruments composed of the recent electronic elements started to be constructed [7, 8]. This paper introduces the RT-Lab equipment we have developed and constructed and it also illustrates the measurement of basic thermophysical parameters of the standard material BK7 using the pulse transient method.

## 2. Theory of the pulse transient method

The specimen in a form of cylinder (Fig. 1) of the non-limited length and of the radius $R$ is made of material that is characterized by the thermal conductivity $\lambda$, thermal diffusivity $k$, specific heat $c_p$ and density $\rho$. The heat loss from the specimen surface is considered by heat transfer coefficient α. The heat source of the radius and the thermophysical parameters similar to the specimen has a perfect thermal contact with the specimen and the negligible heat capacity.

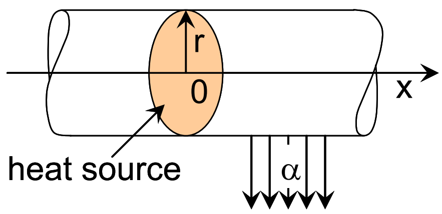


Fig. 1. Model of the transient method working with cylindrical form of the specimen

The temperature function of the heat equation according to [9] has a form

$$T(t,x,r)=\beta\frac{q}{\lambda}R\sum_{i=1}^{\infty}\frac{J_0\left(\xi_i\frac{r}{R}\right)}{\xi_i(\xi_i^2+\beta^2)J_0(\xi_i)}\left[e^{-\xi_i\frac{x}{R}}\Phi^*\left(\frac{x}{2\sqrt{kt}}-\xi_i\frac{\sqrt{kt}}{R}\right)-e^{\xi_i\frac{x}{R}}\Phi^*\left(\frac{x}{2\sqrt{kt}}+\xi_i\frac{\sqrt{kt}}{R}\right)\right] \quad (1)$$

where $\beta=\frac{\alpha R}{\lambda}$; $\{\xi_i\}$ are the roots of the equation $\beta J_o(\xi)-\xi J_1(\xi)=0$; $q$ is the heat output power of the heat source in a form of the step-wise and $\Phi(x)=\frac{2}{\sqrt{\pi}}\int_0^x e^{-t^2}dt$, $\Phi^*(x)=1-\Phi(x)$.

The relation (1) characterizes the step-wise measuring regime. When the $t_0$ is the duration of the heat pulse, the temperature for the times $t>t_0$ is expressed by the relation

$$T^*(t,x,r)=T(t,x,r)-T(t-t_0,x,r) \quad (2)$$

where $T(t,x,r)$ and $T(t-t_0,x,r)$ are given by the relation (1).The relation (2) characterizes the pulse transient regime.

## 3. Experimental set-up

The experimental set-up is shown in Fig. 2. A chamber of the instrument RT 1.02 (developed at Institute of Physics SAS) has been used for temperature control. A new electronic unit RT-Lab has been used for generation of the heat pulse as well as for scanning the temperature response. The specimen BK7 with density 2510 kg m$^{-3}$ consists of three parts of square dimensions having cross-section 30×30 mm and thicknesses 15, 10 and 15 mm. The heat pulse energy $Q$ = 55772 Jm$^{-2}$ and the heat pulse width $t_0$ = 7 s were used.

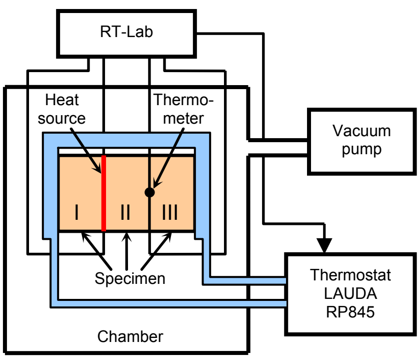


Fig. 2. An experimental set-up

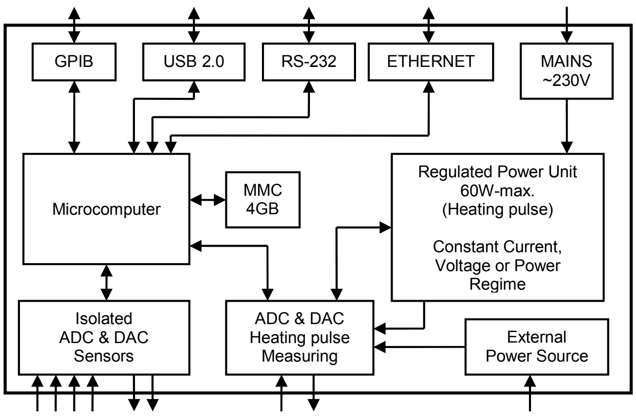


Fig. 3. Block diagram of the RT-Lab

Block diagram of the RT-Lab is shown in Fig. 3. The internal programmable power unit can operate in constant current, constant voltage or constant power regime. Two ADCs are dedicated primarily to measure voltage on and current through the heater. Four-channel isolated ADC is dedicated for sensing the temperature response and signals of some additional sensors. Two independent programmable constant current sources are incorporated to support passive sensing devices (e.g. thermistors or RTDs). The measured data are stored in standard Multimedia Card (MMC) with a capacity up to 4GB. The RT-Lab, operating in standard mode, performs the measuring and the acquisition of all signals itself. Alternatively some signals can be measured with assistance of external commercial instruments and transmitted via the standard GPIB (IEEE-488.2) interface to the RT-Lab for acquisition. Two local interfaces; the USB 2.0 and RS-232 provide connection with PC. The RS-232 interface is intended also to control a programmable thermostat (e.g. LAUDA RP845). The Ethernet interface allows remote control of and data transfer from the RT-Lab to a long distance.

## 4. Results

Parallel measurements were realized, i.e. the original electronic unit of the RT 1.02 and the new RT-Lab were used alternatively. Typical temperature responses measured by the RT 1.02 together with KEITHLEY-2010 multimeter and by the RT-Lab are compared in Fig. 4. Main difference between the way of measurement of the thermoelectric voltage values was in the sampling (scanning) rate and thus in the conversion time. In the case of KEITHLEY-2010 multimeter the conversion time was approximately 0.7 s, while in the case of the RT-Lab the conversion time was only 0.1 s. Nevertheless, Fig. 4 illustrates that the temperature responses measured by the both systems are in a perfect match. Thermophysical parameters of the BK7 specimen calculated from the measured temperature responses and using relation (2) are the followings: thermal diffusivity $k$ = 0.581 $m^2s^{-1}$, specific heat $c_p$ = 784.75 $JKg^{-1}K^{-1}$, thermal conductivity $\lambda$ = 1.145 $Wm^{-1}K^{-1}$ and the heat loss coefficient $\alpha$ = 23 $Wm^{-2}$.

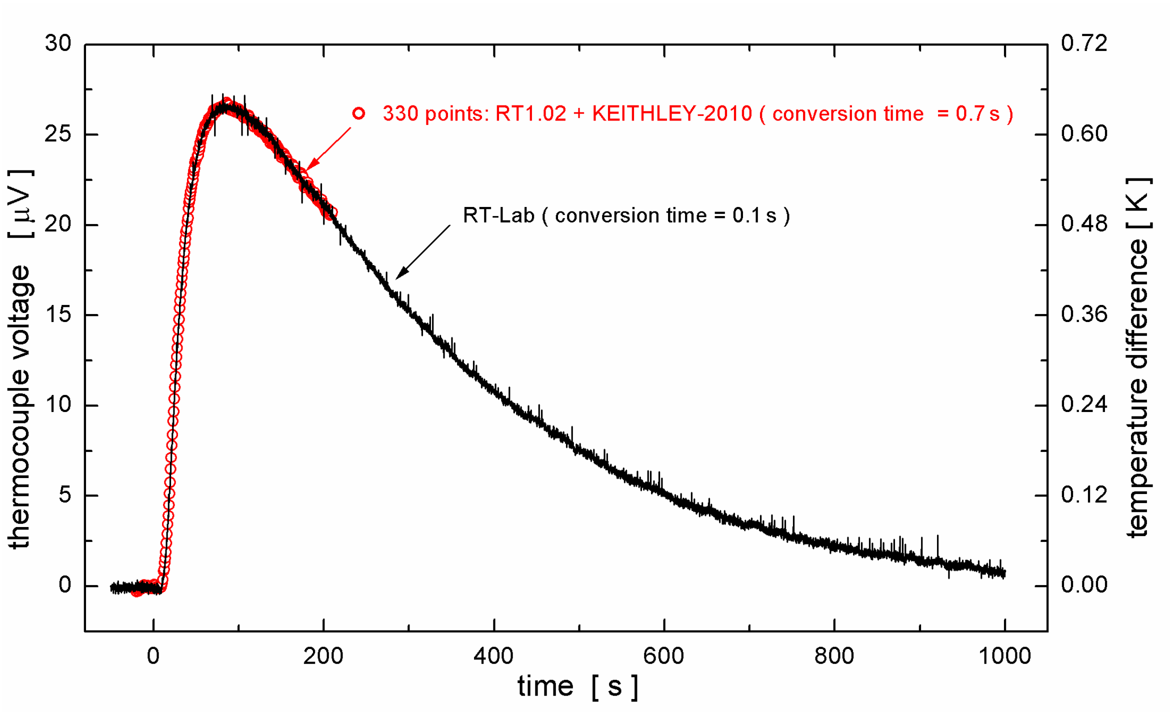


Fig. 4. Typical responses measured by differential K-type thermocouple with assistance of the KEITHLEY-2010 multimeter and with the RT-Lab

## 5. Conclusions

New electronic equipment for measurement of thermophysical properties by transient methods, the RT-Lab, has been developed and constructed and its operation was verified. The equipment can be used for measurement by pulse transient method, by step-wise transient method and by several other methods using two probes system. In the RT-Lab standard measuring mode, the entire measuring process is controlled by the unit itself. However the RT-Lab can still communicate via interfaces with external instruments. Even though the RT-Lab has been primarily intended to measure thermophysical properties, one may also consider many different measuring or test applications where the equipment can be utilized.

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