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AUTOMATION OF LASER-FLASH THERMAL DIFFUSIVITY MEASUREMENTS

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ABSTRACT

An automated experimental set-up which provides thermal diffusivity values of materials by the laser-flash method is described. This system features measurements in a real time environment with complete automation of the entire experiment using a desk-top calculator.

INTRODUCTION

Dynamic methods of measuring thermal conductivity and thermal diffusivity offer the advantage over static techniques of not requiring measurements of the power input or absolute temperatures. Further, the short measurement times result in heat loss effects having a smaller influence on the measurement than in steady-state methods. These advantages, coupled with the shorter overall time required for measurements, has led to the development of a large number of dynamic techniques in recent years [1,2]. Of these methods, the flash method, and particularly the laser-flash technique [3], perhaps offers the greatest simplicity and versatility in measuring the thermal diffusivity of materials. Since the development of this technique progress has been made in reducing measurement errors and data acquisition time. An algorithm developed by Powell [4] has helped in the analysis of experimental data by using a technique which minimizes the sum of the squares of nonlinear functions without the necessity of calculating derivatives. Larson and Koyama [5] have developed an analysis method using an analytical solution which computes the thermal diffusivity with the aid of a digital computer. An automated technique developed by Taylor [6] records the transient temperature response on an oscilloscope and employs a complex digital data acquisition system to reduce and calculate the thermal diffusivity values automatically. An improvement to this system has been made by Perovic and Maglic [7] by using an analog-to-digital converter

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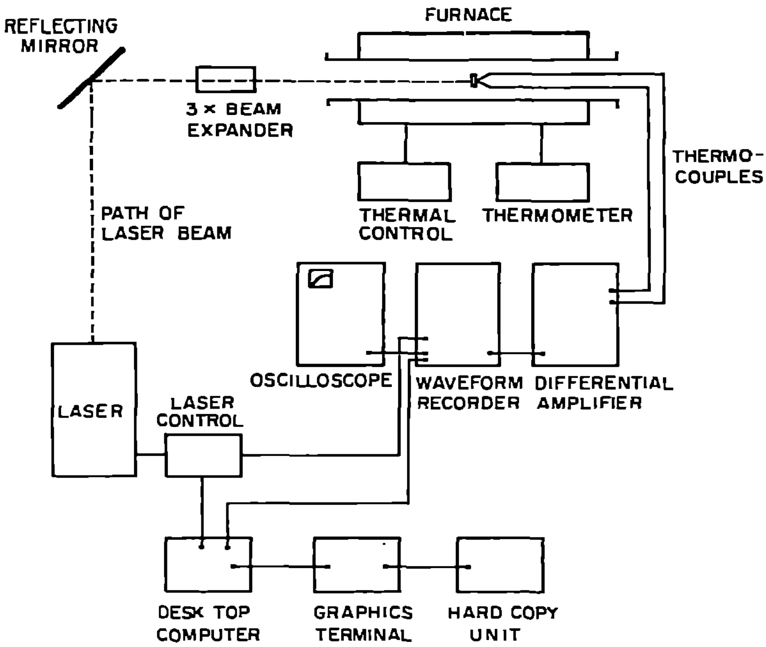

Fig. 1. Block diagram of the experimental set-up for the flash-diffusivity measurement.

coupled to a multichannel magnetic tape recorder which transfers the information to a CDC 3600 computer.

In this paper, we wish to communicate our results on the development of a system which will not only provide thermal diffusivity values in a real time environment, but one which will additionally provide complete automatic control of the entire experiment using a desk-top calculator.

EXPERIMENTAL

A complete block diagram of the system is shown in Fig. 1 [8]. The heart of the system is a Hewlett Packard 9825 desk-top calculator * which is used to control a Coherent Radiation Model 41 CO_2 laser. Data is recorded with the aid of a Biomation 805 transient digitizer which samples and stores the transient response into 2048 time intervals. Data is initially displayed on an oscilloscope to insure that the experiment is working properly. The data stored in the digitizer are then read by the calculator and are stored on the calculator's internal cartridge unit. The data are then analyzed and the results can be printed out or plotted on a graphics terminal.

Data from the digitizer are transferred to the calculator via a 16-bit digital interface. The laser control unit is modified by connecting relay contacts

* Reference to a trade name or product does not imply endorsement by the authors or by the Department of Energy.

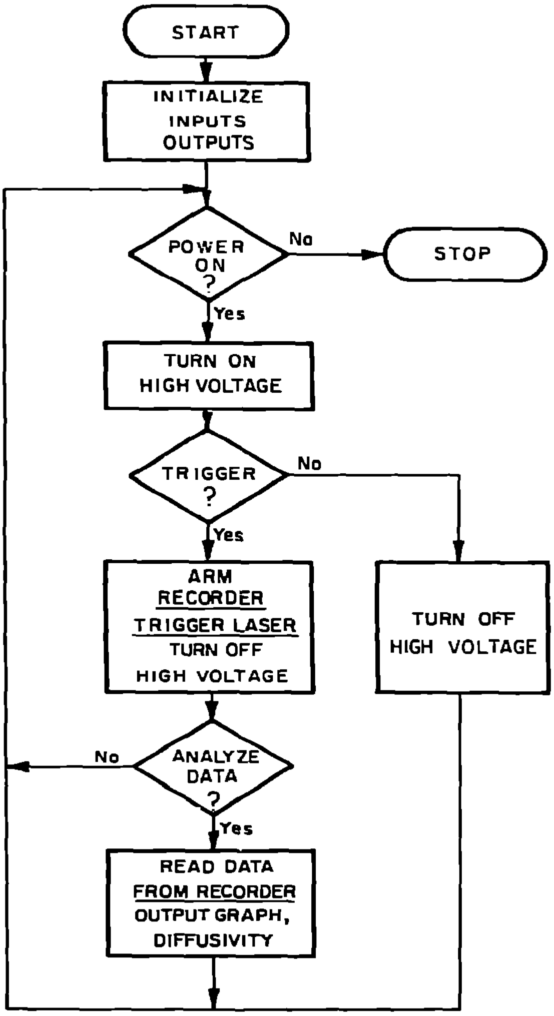

Fig. 2. Flow chart of the computer program for automated data acquisition and control.

across the control switches. The relays are operated by three output lines from the same 16-bit interface used by the digitizer.

The flowchart of the program used is shown in Fig. 2. When the program starts, it sets the digitizer and laser to an initial state. The calculator then asks the operator if the laser is to be turned on. A "no" reply will stop the program, whereas a "yes" will turn on the laser's high voltage circuits. The system is now ready for an experiment. The operator can now choose to stop the experiment, turning off the laser and returning the program to its initial state, or to proceed, causing the digitizer to be armed and the laser to be pulsed, and subsequently turned off. Finally, if the data appearing on the oscilloscope appear valid, the operator can choose to have the data read by the calculator and analyzed.

A typical hard copy from the experiment is shown in Fig. 3; also shown are the thickness of the sample (L), and T_{max} which is the maximum tem-

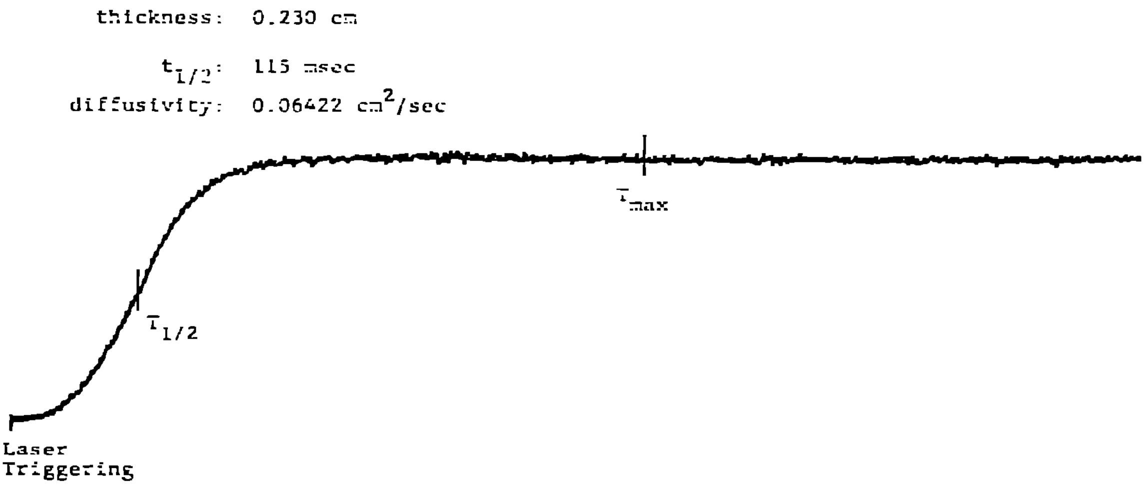

Fig. 3. A typical data output from the automated experiment.

perature reached by the back surface of the sample. $T_{1/2}$ is one-half T_{max} and $t_{1/2}$ is the time from laser triggering to the temperature $T_{1/2}$. The thermal diffusivity, α, is calculated from the equation given by Parker et al. [3]

$$\alpha = 0.139L^2/t_{1/2}$$

The only errors introduced by this technique are caused by the digitization error of the digitizer which results in an error of 0.1% or less in finding $t_{1/2}$.

In our applications of the automated laser-flash technique to naturally-occurring shales and rocks, especially at low temperatures, no corrections for radiative heat losses are necessary. But these can be incorporated easily enough in our computer analysis program for measurements on materials at elevated temperatures.

ACKNOWLEDGEMENTS

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