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The Automation of Two Dual Push-Rod Dilatometers[1]

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The method used to automate two dual push-rod dilatometers is presented. The two dilatometers are operated simultaneously under computer control and the data are collected concurrently. The computer system, a PDP 11, is part of a laboratory network where any one of four systems can control the dilatometers. The thermal expansion results are calculated and displayed in real time.

KEY WORDS: automation; computer control; dilatometer; thermal expansion.

1. INTRODUCTION

In the measurement laboratory environment, the need to computerize instruments that have lengthy data collection times becomes critical. The computerization of these types of instruments yields several benefits. It frees the staff from monitoring the experiment for special events, such as temperature turnarounds and isothermal soaks. Computerization also allows long tests to proceed without interruption, such as an overnight test. It reduces errors introduced by handling the data manually. It also allows the results of the test to be displayed in real time while the test is in process. This last feature is very useful because a test that has failed can be aborted before allowing the test to come to completion. In general, more sophisticated controls can be applied to the test by automation than can be done manually.

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2. DILATOMETERS

Two dual push-rod dilatometers, Dilatronics II, are being used for thermal expansion measurements. Both units are manufactured by Theta Industries and can measure expansion from liquid nitrogen temperature, 77 K, to 1900 K. The low-temperature testing, below 1100 K, is done using a quartz assembly. A ceramic assembly is used for the high-temperature tests, above 1100 K. A low-temperature control system was built at the Thermophysical Properties Research Laboratory (TPRL) to regulate the cooling and heating rates for tests using liquid nitrogen to cool the sample. Figure 1 is a logic diagram of the temperature control system. The control system was designed and built to be an integral part of the existing dilatometer temperature controller. The system offsets the thermocouple signal to extend the temperature range downward to 77 K so that it was not necessary to modify the temperature controller. The controlling logic drives both the power to the furnace and a selenoid which lets liquid nitrogen flow into the sample assembly. The heating from the furnace and the cooling from the liquid nitrogen in tandem provide the means of controlling the temperature to within a degree or two. The control system allows a sample to start at room temperature, cool to 77 K, heat back up to a maximum of 900 K, and cool back to room temperature either manually or under computer control. A temperature-controlled antifreeze bath is used to hold the transducer head and vacuum cover at a constant temperature. Antifreeze was chosen over water to eliminate evaporation of the coolant. Vacuum-tight covers were installed to allow testing under vacuum and in inert gases.

3. CONTROLS

The computer controls the furnace power, the temperature direction (heating or cooling), and the temperature turnaround points. This is accomplished through an interface between one of a maximum of five computers and the two dilatometers. The logic diagram of the interface is

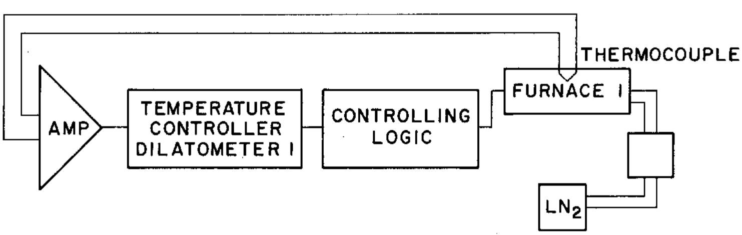

Fig. 1. Temperature controller system.

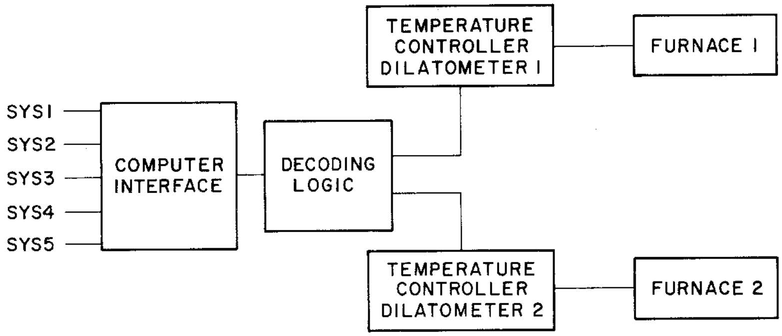

Fig. 2. Interface to dilatometers–computer.

shown in Fig. 2. The temperature controller and furnace make up the temperature controlling system described in Fig. 1. The decodin logic decodes the four input signals from the computer into the signals for the temperature controllers: controller 1 or 2 selection, furnace on/off, and heating/cooling.

4. INTERFACING

The interfacing is accomplished by using serial lines for the digital voltmeter (DVM) control and reading and a parallel interface for furnace control. The DVM was selected instead of an analog-to-digital converter (ADC) to obtain the best accuracy for reading the thermocouple voltage since speed is not critical and thermocouple voltages are in the microvolt range. Two types of DVMs are used, a Fluke and two Vidar IDVMs. Each unit has a 100-channel scanner and the scanners are wired in parallel to all of the equipment in the laboratory. The output port of the parallel interface is wired to transistor drivers which are connected to an interface on the back of the dilatometer. The dilatometer interface has an input port designed so that five computer systems can be connected to it in parallel. Each system uses four lines to select the proper furnace settings. Each line is opto-isolated to allow the five systems to be used together. With this configuration one system can use the dilatometer at a time without the need to switch lines when another system is to be used. This design requires that the dilatometers be operated simultaneously. This approach was used to minimize the use of parallel interface lines because the computers control several other devices as well as the dilatometers. Figure 3 is a diagram of the system wiring.

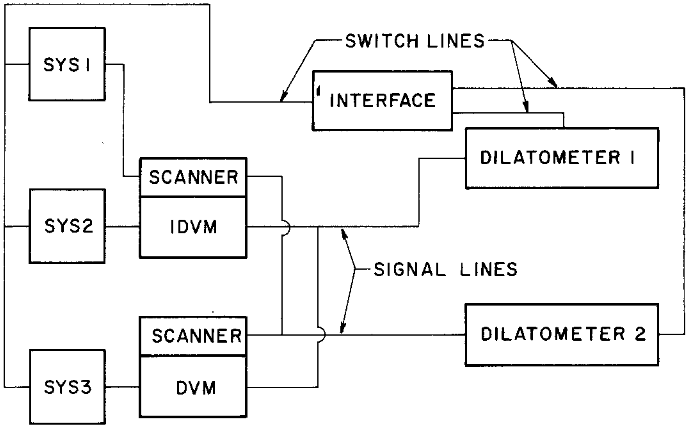

Fig. 3. Computer system interface.

5. DATA COLLECTION

The data from the dilatometers are collected by reading the thermocouple and the transducer output from each unit with a digital voltmeter/scanner pair. The program alternately scans the two dilatometers by taking a reading of the thermocouple and the transducer together, calculating the temperature from either type K or type S thermocouple data and checking it against the desired value, then switching to the other unit and repeating the operation. The data pair is collected within 0.5 s and a time delay between the data collection for the two dilatometers is typically 1.0 s. This rate of data collection ensures accuracy even at high heating rates, 10°C/min.

6. SYSTEM DESCRIPTION

The computers used are two PDP 11/34As and a PDP 11/73. The PDP 11/73 is normally used as a laboratory management system but can be used for experimental work when needed. Each system is equipped with at least one RL02 disk drive, 128K bytes of memory, an LA180 or P300 printer, several graphics terminals, 16 programmable switches, access to a digital voltmeter and scanner combination, and a digital plotter. The systems are running RSX11M, a multiuser time-shared operating system. Each system is capable of running at least two experiments with the DVMs simultaneously plus supporting a couple of other users. The decision to have multiple computer systems was made to allow continued operation in

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Answer the following questions for Dilatometer 1

Enter the thermocouple material...1.   CHROMEL/ALUMEL
                                  2.   PLATINUM/PLATINUM-RHODIUM

                                  Enter option (1) : <CR>


Standard list:
       1......FUSED SILICA
       2......BOROSILICATE
       3......TUNGSTEN
       4......SAPPHIRE
       5......COPPER
What is the standard sample? (1,2,3,4 or 5): <1>
What is the test sample? : <GLASS>
What is the length of the STANDARD ? (Inches) : <2.001>
What is the length of the SAMPLE? (Inches): <2.002>
Enter the water bath reference temperature (K): <295.>
What is the STARTING temperature? (K): <300.>
What is the FINAL temperature? (K): <1000.>
Enter any turn around temperatures (K)
(Maximum of TWO, separate with a comma) : <CR>
Enter number of degrees per point (10.0) :<CR>


Answer the following questions for Dilatometer 2

Enter the thermocouple material...1.   CHROMEL/ALUMEL
                                  2.   PLATINUM/PLATINUM-RHODIUM

                                  Enter option (1) : <CR>


Standard list:
       1......FUSED SILICA
       2......BOROSILICATE
       3......TUNGSTEN
       4......SAPPHIRE
       5......COPPER
What is the standard sample? (1,2,3,4 or 5): <3>
What is the test sample? : <GLASS>
What is the length of the STANDARD ? (Inches) : <2.>
What is the length of the SAMPLE? (Inches): <2.>
What is the STARTING temperature? (K): <300.>
What is the FINAL temperature? (K): <500.>
Enter any turn around temperatures (K)
(Maximum of TWO, separate with a comma) : <1000.>
How long to HOLD at turnaround (0 min): <CR>
Enter number of degrees per point (10.0) :<CR>

CALIBRATION COEFFICIENTS.. 0.00000E+00
                           0.10000E-01

Do you want to change the calibration COEFFICIENTS (N) : <CR>

** SET UP THE DILATOMETERS AND PRESS RETURN **
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Fig. 4. DILTWO interactive input.

the event that one of the systems went down. Each system is as redundant as feasible. The program that runs the dilatometers is the same on all of the systems.

7. PROGRAMMING

The program that runs the expansion experiment is written in FORTRAN IV and PDP 11 assembly language. The program, DILTWO, first collects the input data from the operator interactively. The operator enters the starting, ending, and any turnaround temperature points for each dilatometer. He also enters the bath reference temperature, the sample description and standard type (copper, tungsten, sapphire, borosilicate glass, or fused silica), the length of both, and the type of thermocouple used for temperature measurement. Figure 4 is a copy of the interactive portion of DILTWO. The operator's responses are enclosed in angle brackets. The room temperature is determined for each dilatometer by taking 10 readings and averaging them. The program plots both values on a graphics terminal using an autoscaling plotting routine. DILTWO next turns the furnace on and sets the temperature direction (heating or cooling). This starts the experiment. DILTWO then continuously reads the temperatures of the samples and compares them to decide whether or not to save the value. If the temperature is within 0.2°C of the next selected temperature, DILTWO calculates the thermal expansion from the transducer voltage using the method described in ASTM E228-71 and plots the

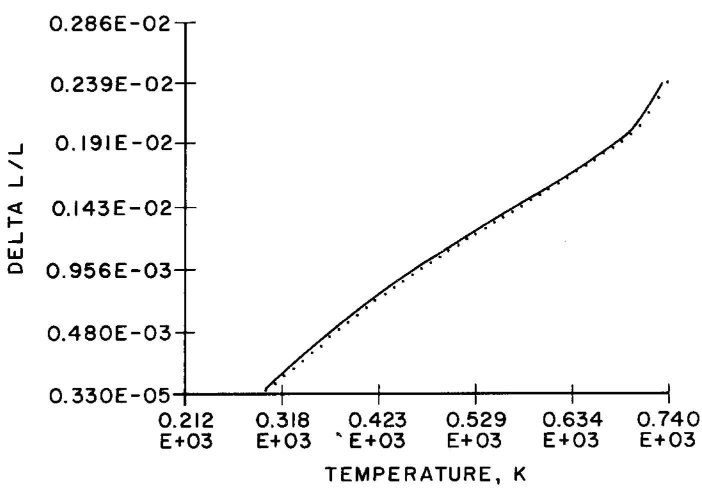

Fig. 5. DILTWO plotting output.

results on the terminal. The thermal expansion for the NBS standard at the ambient temperature is computed, if the ambient temperature is different from the reference temperature for the standard. If so the experimental data are corrected by this difference. The plot shows the expansions from both dilatometers simultaneously (Fig. 5). When a turnaround point is reached, the program will reset the furnace direction for that dilatometer without disturbing the other dilatometer. The program will keep a running file of data on the computer in case of a power failure so that the data up to that point will be saved. A second program, DILAT, is used to reanalyze data that has been collected previously. DILAT can also be used to run a single dilatometer in the calibration mode. In this mode two NBS standard materials are run against each other and a polynomial equation is generated to correct the expansion.

8. RESULTS

A thermal expansion run can be made on either one or both dilatometers from any one of three computer systems. The sample can be programmed to start at room temperature and heat or cool to a turnaround temperature, hold for a predetermined time, cool or heat back to room temperature, and stop or continue to another turnaround temperature, all without operator intervention. As a result sample thermal hysteresis and thermal curing can be easily studied.