Data Acquisition Implementation in a Heat Transfer Laboratory

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Abstract *– Conduction heat transfer is an important concept in the introductory-level thermal sciences course in the Mechanical Engineering Technology program at Purdue University. The supporting conduction heat transfer laboratory experiment demonstrates basic transient and steady-state heat transfer concepts through a comparison of three different metals. The existing procedure requires temperature measurements taken manually from fifteen individual thermocouples at intervals throughout approximately a 90-minute time period. Students spend most of their in-laboratory time switching to each channel of the multi-channel data monitor and writing down temperature values, and have little time to comprehend the underlying heat transfer principles observed. This paper describes an investigation of the capabilities of data acquisition (DAQ) hardware and software in conjunction with the upgrade of the conduction heat transfer laboratory experiment. The upgrades include the integration of DAQ equipment and code into the laboratory procedure and the refurbishment of the existing conduction apparatus. This paper summarizes the existing heat transfer experiment and the work completed thus far on upgrades, and presents some of the difficulties encountered in implementing DAQ on an experiment of this type.*

INTRODUCTION

All Mechanical Engineering Technology Students at Purdue University are required to complete the course Heat/Power for both their Associate and Bachelor of Science degrees. This is a one semester, three credit hour introductory course in thermodynamics and heat transfer, consisting of three one hour lectures and one two hour lab per week. The pre-requisites for this class include one semester of physics, calculus, and the introductory Mechanical Engineering Technology course, Computations and Analysis in MET.

This paper describes efforts to investigate the capabilities of data acquisition (DAQ) hardware and software in conjunction with the upgrade of laboratory procedures. The laboratory procedure selected for upgrade and investigation is entitled *Conduction Heat Transfer.* The upgrades included the addition of data acquisition equipment and software to eliminate the manually read multi-channel data monitor for recording temperatures over a certain amount of time and the refurbishment of existing conduction fixtures.

The Data Acquisition hardware and software used to upgrade the above mentioned laboratory procedures were National Instruments'™ SCB-68 DAQ Board and LabVIEW™ 6.1 software with MS Excel™ as a data analysis tool. LabVIEW™ (**Lab**oratory **V**irtual **I**nstrument **E**ngineering **W**orkbench) is software that uses a graphical programming language, known as G programming language, to create programs relying on graphic symbols to describe programming actions [1]. The graphical interface used for controlling data acquisition, developed in LabVIEW™, was designed as an introduction for students with no prior data acquisition knowledge.

CONDUCTION HEAT TRANSFER THEORY

In the conduction heat transfer experiment [2], three insulated cylindrical specimens connect a high temperature heat source (hot plate) and a low temperature heat sink (ambient air). The lab apparatus contains three specimens: brass, aluminum, and steel. Type T thermocouples are equally spaced along the length of each bar to monitor temperature, as shown on the following page in Figure 1. Upon application of the heat source, the temperatures at each station will begin to rise. This is called transient heat transfer because the amount of energy flowing through the bar changes with respect to time.

Eventually the temperatures reach a point where they remain relatively constant. Under such steady state conditions, heat flow is constant. The heat flowing in equals the heat flowing out. The theoretical steady state temperature distribution along each specimen's length should vary linearly with distance, in accord with Fourier's conduction equation (1) shown below.

$$\dot{Q} = -kA\frac{\Delta T}{\Delta x} \tag{1}$$

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FIGURE 1
INSTRUMENTED METAL BARS WITH INSULATION

Steady state heat flow is generally related to a specimen's geometry, thermal conductivity, and temperature gradient. The temperature gradient is the temperature change with respect to distance from the heat source.

The time for each specimen to achieve steady state is called response time. In other words, response time is equal to the duration of transient heat transfer. The faster a given material heats or cools, the shorter its response time. For a fixed set of test conditions, response time is largely determined by a material's thermal conductivity.

The temperatures from the type T thermocouples were originally recorded using a multi-channel data monitor, shown below in Figure 2.

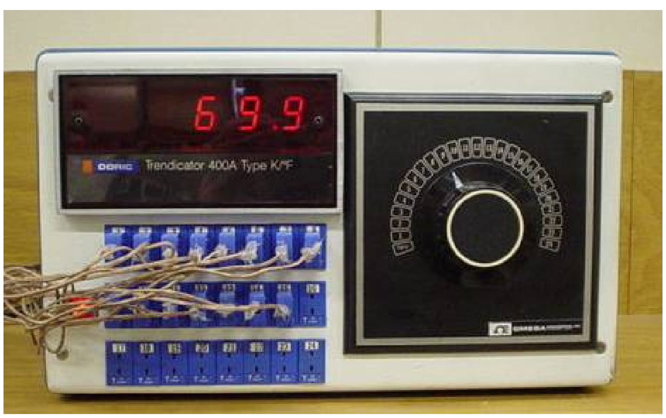

FIGURE 2
MULTI-CHANNEL DATA MONITOR

The multi-channel data monitor only displayed one channel at a time which resulted in students turning a dial to select one of the fifteen channels and recording each temperature individually each minute for the first ten minutes, every two minutes for the next ten minutes, and every five minutes there after. The data collection process took place for 90 – 120 minutes, resulting in approximately 30 data points for each thermocouple or 450 data points overall.

LABORATORY UPGRADE

The current upgrade includes replacement of the existing type T thermocouples with new, well-insulated type T thermocouples at the same equally spaced positions located along the length of the bars. The well-insulated type T thermocouple wire was used in order to minimize the risk of thermocouples shorting out and giving inaccurate data. The old thermocouple wire provided minimal protection after stripping the wire as shown below in Figure 3. The new high temperature wire provided each conductor with a rubber coating inside of the high temperature wrap, as shown below in Figure 4.

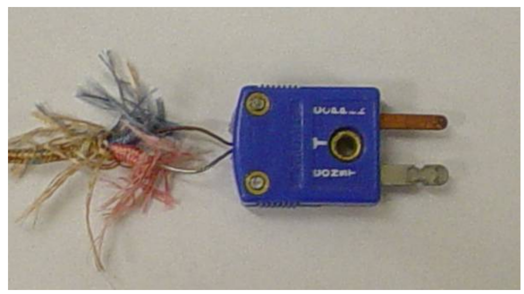

FIGURE 3
EXPOSED WIRES

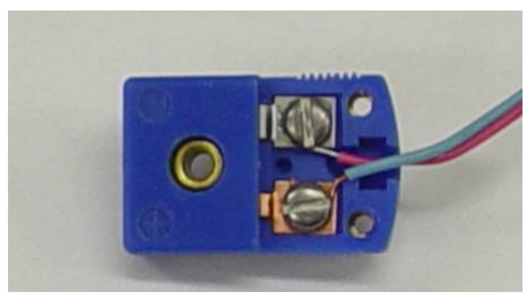

FIGURE 4
WELL-INSULATED WIRES

Other upgrades include the replacement of the multi-channel data monitor with National Instrument™'s SCB-68 DAQ Board and LabVIEW™ software. The LabVIEW™ user interface is shown on the following page in Figure 5.

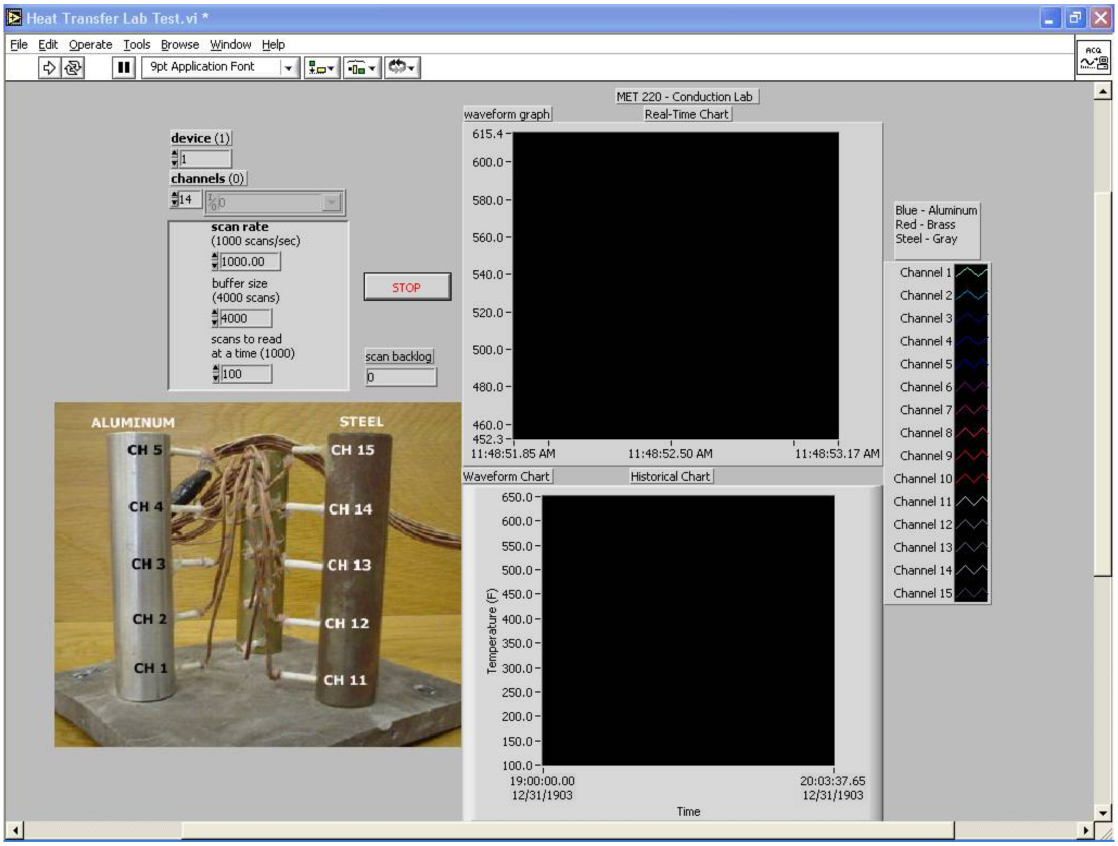

FIGURE 5
LABVIEW™ USER INTERFACE

The above-mentioned upgrades allow students to collect approximately 80 times the previous amount of data points with the click of a few buttons. The equipment upgrades also allow students to learn more in depth information about what is occurring due to the additional free time. The additional free time created from the automation allows the students to return to their desks for discussion related to the heat transfer theory and expected outcomes. In addition to the advantages listed above, students are also now able to see real-time and historical feedback from charts plotting temperature versus time. Before the upgrades, students were required to hand type all of the data recorded in their lab manuals into a spreadsheet after the laboratory procedures were completed.

EQUIPMENT LIMITATIONS

Although the upgrades allowed for approximately 80 times the previous amount of data points to be collected with less effort, there are several limitations to the amount of data that can be collected. Due to hardware limitations the buffer size and scan rate had to remain variable in order to compensate for the lack of capabilities of the computer used to collect the data. All of the data being stored is written to a temporary file, or buffer, until the mean can be taken of the previous 100 data points collected. The mean is taken of 100 data points per channel and stored. The mean was taken as part of a larger effort to filter electronic noise out of the data.

One should use caution when altering the scan rate to ensure that a wide range of temperatures is not averaged. When utilizing all fifteen channels of the SCB-68 DAQ unit, the LabVIEW™ software is not capable using differential measurements, which would in theory reduce the amount of electronic noise recorded.

LabVIEW™ was unable to use fifteen differential channels to record data because the reference channel's .dll was called 15 times per scan. LabVIEW™ is only capable of assigning one .dll per scan for a specific request, hence an error message was received and the program shut down. In order to utilize fifteen single-referenced channels of the SCB-68 DAQ unit simultaneously, a sequence structure containing an Analog Input Configuration virtual instrument was utilized, as seen on the following page in Figure 6.

The LabVIEW™ program collected more data at a higher quality with fifteen single-referenced channels when using a more powerful computer with 512 MB RAM, and an Intel® Pentium® IV processor, as compared with an older computer possessing 128 MB RAM and an Intel® Pentium® III processor.

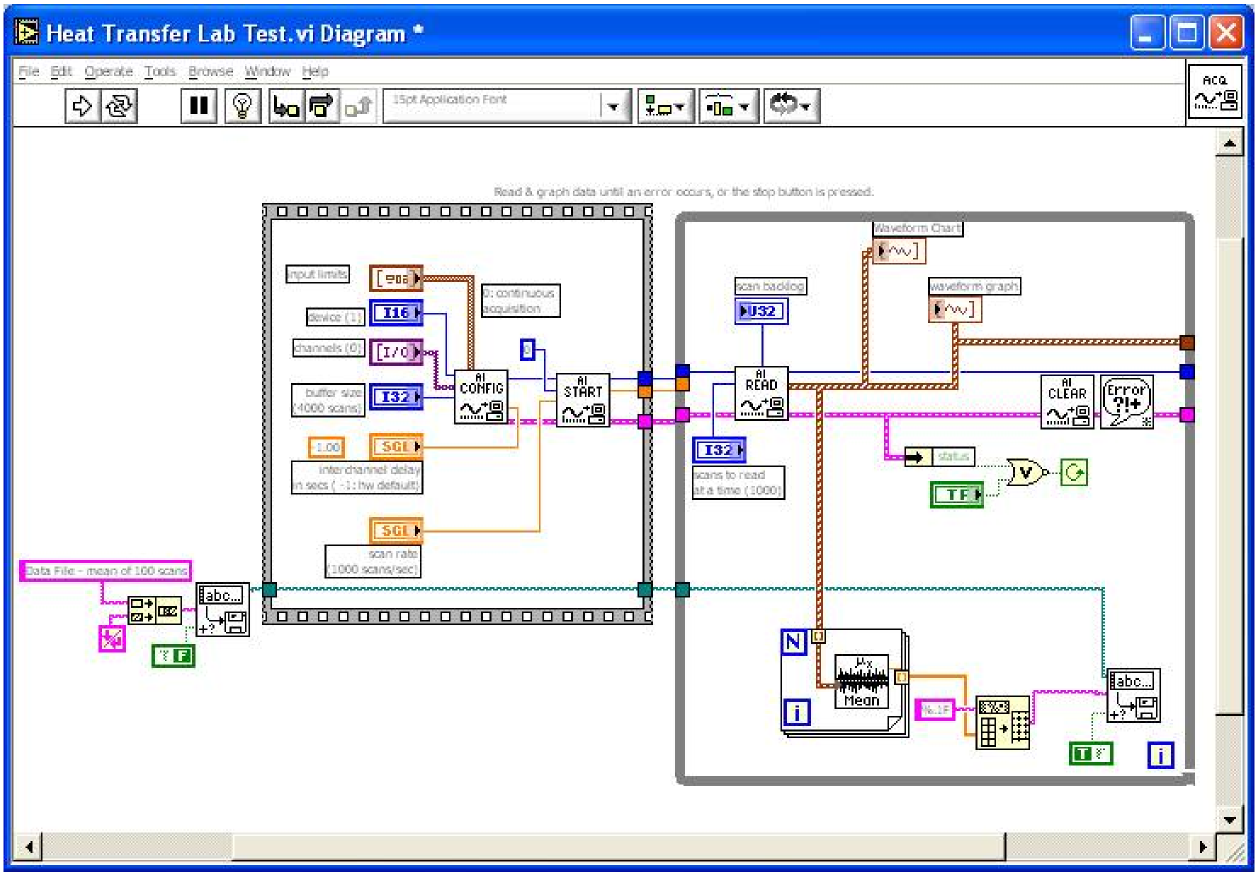

FIGURE 6
FINAL CONDUCTION LABVIEW™ DIAGRAM

SUMMARY

The total equipment upgrade cost for the Conduction Heat Transfer lab (10 stations) was approximately $245. This included high temperature thermocouple wire, new type T thermocouples and other miscellaneous requirements. The LabVIEW™ software and DAQ boards were installed prior to this laboratory upgrade.

The new LabVIEW™ user interface provides the students with more time to examine the experiment fundamentals, rather than focusing on the timeliness and accuracy of manual data collection. Students can view the real time data on both the temperature graph and historical plot, which provide several avenues for discussion while the experiment is conducted.

This laboratory procedure now helps to introduce data acquisition to the students pursuing an Associate of Science Degree. Those who continue for a Bachelor of Science Degree should find this a nice predecessor to a later Instrumentation and Controls course that also utilizes data acquisition.

REFERENCES

(1) Bishop, Robert H. (2001). Learning with LabVIEW 6i. Upper Saddle River, NJ: Prentice Hall.

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