CS486C – Senior Capstone Design in Computer Science

HeetShield 2025 Project Description

Project Title: Measurement System Automation	
Sponsor Information:	Steve Miller/Manager Miller Scientific Inc. 1802 W. Kaibab Lane, #120 Flagstaff AZ 86001

Project Overview:

We develop and produce thermal insulations for the aerospace community and for fire fighters. To check the performance of those materials, we measure the thermal diffusivity of the materials (how heat spreads through our insulations) and use that value to calculate thermal conductivity (how much heat makes it through). After 3 years of work, we recently completed development of our own in-house thermal diffusivity apparatus.

Thermal diffusivity is measured by sending a pulse of heat through a sample and determining how long it takes for that pulse to get through the sample. We make measurements from atmospheric pressure down to 0.1 Torr or lower, and between room temperature and 750C. These measurements allow us to predict how our materials will perform when used on a re-entry vehicle at the edge of space or a hypersonic aircraft.

To be accurate, the tests must be conducted when the temperature and pressure are very stable. If the temperature and pressure change even slightly during the test, we don't know if the change was due to the sample performance or the stability of the temperature and pressure in the chamber.

Once the temperature and pressure are stable, data collection takes about 5 minutes. Our workflow for our apparatus looks like this:

1. We collect 30 seconds of data to record how stable it is.
2. We then turn on a lamp for a few seconds (generate a heat pulse) that heats up a metal plate adjacent to our test sample.
3. We collect the data that shows the heat pulse moving through the sample over time.
4. We analyze the data and calculate thermal diffusivity.

Finally, thermal conductivity is calculated by multiplying thermal diffusivity by density and heat capacitance.

While the above description makes this sound easy and straightforward, it actually takes many hours to achieve the level of stability required for good results.

- Temperature. For example, off-the-shelf thermostat and temperature controllers introduce pulses into the voltage that make the temperature fluctuate. We need the temperature to be constant within 0.01C to get reliable data. We now achieve this by using a regulated DC power supply and manually adjusting the voltage output until the temperature is on target and constant with 0.01C. It can take hours to do this, and often we accept a slightly off target temperature if it's steady. A temperature control system that was more automatic and accurate would save hours of effort and frustration.
- Pressure. Achieving the target pressure is similar. We have a vacuum pump that removes the air from the test chamber. We control the pressure by opening and closing the valve. The internal pressure changes as gasses are released from the sample at various pressures. We conduct our tests in a nitrogen atmosphere so we have to backfill with nitrogen once we get close to our target pressure. Adding and removing gasses shifts the temperature so constant pressure adjustments are required. A pressure control system that monitored and maintained pressure at a set value would make this system much easier to use.
- Lamp. Turning the lamp on and off is also manual in the present configuration. Ideally the lamp could be set for specific amount of "ON" time, like 7.3 seconds, and controlled with a relay.
- Output. It also would be better to calculate thermal diffusivity instantaneously. We collect data at a rate of 8Hz. It should be possible to display the calculated thermal diffusivity values for each line of data, as well as a running average, then store that data in a file for use in calculating thermal conductivity.
- Safety. The ideal system would also include safety and maintenance. For example, lamp hours should be tracked, pump oil needs to be changed, and parts can fail. The system should monitor and report any unsafe conditions or items needing maintenance.
- Software. As you can see all of the shortcomings identified above revolve around make the system easier, faster and more reliable. Thought should be given to the ideal user interface, and the expected inputs and outputs. We currently use LabView and we are open to keeping the same package or upgrading to something else if it's within our budget.

For this project, we would like a system with the following minimum features:

- The system allows the test operator to set the test conditions and walk away.
- The operator should then be notified when the conditions are stable and a test can be run.
- The operator should be able to set the lamp time and start the test sequence.
- The control panel should display data and thermal diffusivity.
- The operator will then decide if the test needs to be repeated with a shorter or longer lamp time, or we are ready to move on to different test conditions.
- The system should achieve and maintain the specified test conditions until the operator changes them.
- The output should be a data file with a table indicating test temperatures and pressures, as well as the corresponding diffusivity values.

- The system should include an error report process that lists any anomalies during the test, and if possible, indicates the standard deviation of the predicted vs the measured results.

The goal of this effort is to make the test system as safe and reliable and accurate as possible.

The person who developed the test method, the late Dr. Jozef Gembarovic, could reliably gather data at six or seven pressures in a single day. We can only collect 1 or 2 at most. We don't know what kind of control or analysis system he had but we know its possible, and it would be greatly appreciated if our system could be automated.

Knowledge, skills, and expertise required for this project:

- Ability to learn about and work safely around industrial equipment
- Coding ability in LabView, Python or whatever language is chosen
- Familiarity with electromechanical systems, like actuating valves and relays

Equipment Requirements:

You will need to recommend the automation equipment we need and allow time for procurement.

Software and other Deliverables:

- A strong as-built report detailing the design and implementation of the product in a complete, clear and professional manner. This document should provide a strong basis for future development of the product.

- Complete professionally documented codebase, delivered both as a repository in GitHub, BitBucket, or some other version control repository; and as a physical archive on a USB drive.