AC 2009-2123: UNDERGRADUATE VALIDATION OF CUTTING-EDGE CALORIMETRY OF AN INDUSTRIAL AFFILIATE'S NOVEL ENERGY SOURCE

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Undergraduate Validation of Calorimetry of an Industrial Affiliate's Novel Energy Source

Abstract

A major component of the Rowan University (RU) engineering program is the clinic course, which gives students the opportunity to work with industrial partners on real projects, while still maintaining a classroom environment. The Blacklight Power (BLP) project consists of the validation of calorimetry results of a novel heat source of an industrial affiliate. Analyzing the results of the calorimetry experiments they performed, following protocols they developed themselves, students demonstrated that their data consistently had less than 1% error. The work involved setting up rigorous protocols, MATLAB programming, Labview data collection and analysis, as well as summarizing the experimental results. These students have experienced, first hand, what is required to bring a potential novel energy source forward. This paper describes how these students were involved as part of their junior and senior clinic course work to be the first group to replicate these results in a third party location outside of the industrial affiliate's own labs. An important part of the engineering pedagogy at Rowan University is to ensure that students have the benefit of using their engineering skills in an applied manner – to real world challenges. This paper starts with a short background on the clinic program, which provides the skeletal system for this and many other projects. It will then go into a project overview that includes the objective, test setup and procedure which entail how the students used different skills from their engineering background to troubleshoot problems within the project. The next section provides the current results of the students' work followed by a conclusion and discussion of results.

Background

The Engineering clinic program at RU provides unique projects and learning environment for its undergraduate students. Traditional lecture courses generally do not provide much practical experience and while they may effectively relate the concepts they teach, they do not provide the experience of applying these concepts the way an open ended problem might. The alternative is providing students with internships, which do take place in a professional environment and work may be tangible to the employer, but generally do not provide for a favorable learning environment.

The RU clinic program combines the relative merits of both the classroom environment with the more professional goals of an internship into one course. The students are assigned to a project, generally with an industrial partner or another university, and the students use whatever skills at their disposal towards the goal of that particular project. A wide variety of projects allows students to request projects in areas that are of interest to themselves, rather than generic problems and projects that are focused on demonstrating a particular concept. This program does have real projects where results are expected, but are conducted in more of a classroom environment, with access to engineering faculty members who can provide advice where needed.

This program is a significant part of the curriculum and is taken every semester for the four year program. The freshman clinic is a more introductory course, in a classroom environment where the focus is on the introduction of laboratory procedure and different disciplines of engineering. The sophomore clinic program is also based on a classroom setting, but students are given an open ended project for each semester, generally related to their particular discipline.

The junior and senior clinic programs make strong use of previous coursework, all the while forcing them to engage new problems. Students from both junior and senior classes are combined and assigned to a variety of projects that are often sponsored by industrial partners of the university. They are then given real world problems by people relying on the results, and must provide a solution or service of good quality in order to earn good marks. These projects can employ a wide range of skills, but are never merely transparent problems without actual use. Just as in a professional setting, the skills used and needed vary based on the needs of a project and may change throughout the semester. The clinic bridges the gap of the engineering coursework and theory while giving actual application of those techniques in a professional setting.

This paper and the work discussed in it come as a direct result of one of these clinics. While writing journal articles isn't necessarily unusual for undergraduates, doing so in a lecture course is. Additionally, this particular paper has a slightly different focus than most other engineering papers, in that it is more on the side of research than engineering.

Project Overview

Objective

The purpose of the BLP project was to validate the affiliate's claims of remarkably high heat gains supposedly due to the chemical reaction of a proprietary catalyst and hydrogen. The clinic team at Rowan University acted as a third party in verifying the results that BLP's internal tests achieved. In order to accomplish this, three different types of tests were required.

The first is a simple calibration of the equipment set-up used in BLP's own testing. This is done to ensure that the amount of energy that is placed into the cell is equal to the amount of energy coming out of the cell. Any significant gain or loss of energy that was unaccounted for would make any claims using the test set-up difficult to justify. Additionally, verifying the actual heat run tests using BLP's catalyst was also an important aspect of this project. These are the tests of interest, for which third party verification was essential. Having an outside group run these tests away from the proprietor's own labs would serve to show the results are externally replicable. Finally, to give even stronger support that the calorimeter is in fact accurate, and the equipment does not tamper with results, known chemical reactions are completed and measured in the same setup. By using commonly known reactions where the heat generation can be verified theoretically via conventional methods, it is possible to validate the accuracy of the equipment when heat is being generated chemically. One such reaction being the thermal decomposition of ammonium nitrate and magnesium reacting with iron oxide.

Test setup

The test system consists of a few basic components. The data acquisition system consists of a desktop computer utilizing LabView, which is connected to all of the experiment sensors through a scb-100 connector block. A power supply is used as a reference voltage for any thermocouples in the system. A programmable power supply is used in conjunction with the resistive heaters to heat the cell with a known quantity of energy. The amount of heat that is dissipated from the cell during the process is measured using a basic calorimeter which consists of a vacuum chamber holding the cell and heating elements. A vacuum pump is used to bring pressure inside the chamber to a minimum in order to create a thermally insulating environment around the cell. Wrapped around this chamber is a coil of copper tubing, through which a supply of chilled water flows. A water reservoir and chiller are used to keep supply water at 20°C, and a small pump keeps water flowing at a constant rate. The water temperature is measured at both ends of this coil, the difference of which provides the change in temperature. Using this temperature difference along with the flow rate of the water, it is possible to calculate the total amount of energy being radiated in the form of heat. Chamber pressure is measured through the use of two baratron capacitive manometers, one measuring on a scale of approximately 1 to 1000 Torr and one from .001mTorr to approximately 1Torr. Finally, after the completion of the heating cycle helium is pumped into the chamber in order to maximize heat transfer while leaving the system in a controlled environment. Figure 1, located below, gives an overview of the system and its components.

Figure 1: System Overview

Obstacles and Procedure

Prior to each run, the students running the experiment verify the equipment is functioning properly within the expected parameters of the experiment. This includes checking to ensure the water flow rate is correct, the programmable power supply is properly connected to the cell, and the vacuum pump is functioning properly for each run. Following stringent procedures prior to running the experiments aids students in building the proper attention to detail required in a more professional laboratory environment. The experience of seeing a piece of equipment fail and learning to diagnose the situation is a valuable lesson, yet it is one rarely encountered in more traditional coursework. A faulty piece of equipment would usually have been replaced or repaired before a student actually went to use it in most laboratory courses. Since results rely heavily on relatively small measurements, proper equipment usage and maintenance is crucial. The procedure is designed to eliminate discrepancy occurrences, but as in any empirical experiment this is not always the case. Frequent dis- and re-assembly of equipment allows for the intrusion of errors, which may sometimes appear to have no curable cause. This project reinforces just how vital proper equipment procedure is, as results are based solely on the correct obtainment of data. For example, after moving to a smaller cell and lower water flow rate results were off by an order of magnitude. Faulty thermocouples were blamed as the culprit for quite some time until the realization came to light that the manufacturer's claim of range for the flow-meter was off. Seemingly a simple mistake, the amount of time needed to test the equipment correctly made this a weeklong affair.

After ensuring the equipment is in proper order the calorimeter is vacated of air, ensuring that a pressure of less than 10mTorr is left in the chamber. As mentioned before this serves as an insulation barrier to ensure all energy used to heat the coils around the cell is actually being absorbed by it, instead of the surrounding atmosphere. Of course this is somewhat redundant since temperature changes are constantly recorded, it makes for a clearer picture and more accurate results. Once the heating cycle is complete, which consists of a set time and energy input for a calibration – and a temperature limit for heat runs, helium is introduced into the calorimeter to increase heat transfer between the cell and the coil of water around it. The system is left to cool down for several hours, after which the cell may be replaced with a new one and the recorded data is analyzed. Most of the analysis is done via a small Matlab program, which takes care of producing the various graphs, and calculating efficiencies etc.

Results

Calibrations

Rowan University has a commitment to BLP to continue heat runs and calibration tests during the spring semester of 2009. Over the course of the semester, from January 30, 2009 to May 19, 2009, the team would have conducted and completed approximately six calibration runs per week in preparation for later heat runs. More runs would have been possible early in the spring semester if malfunctions did not occur with the vacuum pump. The team has run exhaustive calibration tests on the calorimeter for a range of heat input similar to the levels that might be expected with varying quantities of chemicals. The goal of these calibrations being the verification of the equipment, and establishing a good backing for the accuracy of the

calorimeter. In a successful calibration run, the percent difference should be within or near one percent. Figure 2 gives an example of a successful calibration run completed by the fall semester team. Table 1 below provide a complete list of the successful calibration runs completed on the large scale reactor during the Autumn 2008 semester (very few calibrations have been completed for this spring team at the time of this writing). Figure 3 is a compilation of these results, ranging from 900-2700kJ input.

Figure 2: Input and Output Energy of a Calibration Run in Relation to Time

Table 1: Calibration Test Results

Run	Date	Input (kJ)	Output (kJ)	Δ kJ	% Difference	Coupling
1	9/9/2008	1441.0299	1421.5444	-19.4856	1.3614	0.986478
2	9/10/2008	1445.731	1421.351	-24.3806	1.7007	0.983137
3	9/11/2008	2735.1967	2714.983	-20.2136	0.74176	0.99261
4	9/18/2008	1801.7422	1787.4226	-13.5779	0.75645	0.992052
5	9/19/2008	2334.545	2321.7293	-12.816	0.55048	0.99451
6	9/21/2008	1168.7181	1146.1633	-22.5548	1.9487	0.980701
7	9/23/2008	909.4645	899.2298	-10.4598	1.1475	0.988746
8	10/8/2008	3071.7207	3023.4735	-48.2551	1.5834	0.984293
9	10/9/2008	1448.1185	1431.23	-16.8885	1.1731	0.988338
10	10/10/2008	2334.401	2336.9973	2.5926	0.111	1.001112
11	10/11/2008	2723.6541	2705.6178	-18.0363	0.66441	0.993378
12	10/15/2008	1443.899	1421.882	-22.0277	1.5366	0.984752
13	10/16/2008	1803.9952	1778.895	-25.0999	1.4011	0.986086

14	10/17/2008	2341.057	2319.699	-21.3583	0.91652	0.990877
15	10/25/2008	1175.55	1168.967	-6.5911	0.56226	0.9944
16	10/28/2008	2708.22	2658.65	-49.5699	1.8473	0.981696
17	10/31/2008	1794	1778.87	-15.1332	0.84706	0.991566
18	11/3/2008	1437.69	1428.75	-8.9425	0.62394	0.993782
19	11/6/2008	910.3444	904.2311	-6.1132	0.67379	0.993285
20	11/11/2008	2353.31	2318.443	-34.8315	1.4904	0.985184
21	11/20/2008	2694	2690.886	-3.2079	0.11914	0.998844
22	11/21/2008	1798.765	1811.7036	12.9385	0.71672	1.007193
23	11/24/2008	1505.5091	1488.3226	-17.1864	1.1481	0.988584
24	12/4/2008	1003.3923	991.877	-11.5146	1.1542	0.988524
25	12/5/2008	1439.626	1425.747	-13.8795	0.9687	0.990359
26	12/11/2008	2013.8056	1979.9226	-33.8829	1.6968	0.983175
27	12/12/2008	1104.6064	1102.0479	-2.5586	0.2319	0.997684
28	12/15/2008	2595.1798	2582.9229	-12.2569	0.47341	0.995277

Figure 3: Coupling vs. Energy Input Overall

Heat Runs

As mentioned before, a total of 2 heat runs were performed during the last quarter of 2008 and more heat runs will be completed after proper calibration in the spring semester. Both were completed at the SJTP which will also be the location for all of the spring semester runs. Table 3 summarizes these heat runs. Figures 4 and 5 show the input and output energy of the first heat run, and the recorded cell temperature respectively. Figures 6 and 7 display the same for the second heat run. The results show that we were able to obtain about 700-750 kJ of exothermic reaction from both heat runs. Although the second heat run produced more energy it is assumed that both cells contained approximately the same amount of chemicals.

Table 2: Experimental Runs

Run	Date	Input	Output (kJ)	ΔkJ	% Difference	Coupling
1	11/14/2008	1268.3255	1982.2574	713.9319	43.9264	1.562893279
2	12/19/2008	1329.161	2074.4576	745.2966	43.7944	1.560727105

Figure 4: Input and output energy of heat run performed on 11/14/2008

Figure 5: Cell temperature of heat run performed on 11/14/2008

Figure 6: Input and output energy of heat run performed on 12/19/2008

Figure 7: Cell temperature of heat run performed on 12/19/2008

Conclusion

The results of the verification in terms of the calorimeter accuracy are very promising. Calibrations were almost always found to have couplings above 99%, which means we can assume that the calorimeter is very accurate. This accuracy undoubtedly holds true for heat runs as well, which means that the proprietary catalyst can be said to be generating 700-750kJ of excess heat for these tests. Verifying BLP's calorimetry setup in the Engineering clinic has given a handful of students the chance to work on real world problems more akin to the work many can expect to be given after graduation. By working with industrial affiliates, Rowan is able to present problems that are beyond the scope of what could be expected in a lecture course. This course serves to produce a meaningful service to its partners while creating a strong learning environment for the students. This particular project served to validate a company's test set-up and that the results of their tests with a proprietary catalyst can be replicated by third party teams. The clinic program serves to provide professional experience to undergraduate students in an environment outside of an internship setting.