Technology-Hospital Collaboration in Thermodynamics: Experience with Actual Student Projects

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Abstract

A previous work[1] by the authors outlined a partnership between their institutions that focused on providing mechanical engineering technology students some practical experience with the thermodynamic systems of a hospital. Several potential projects were summarized in the paper and benefits to both students and to the hospital employees were identified.

Although a previous junior-level Applied Thermodynamics class only toured the hospital facilities, current students in the same class are required to investigate steam generation and use at the hospital. Research, testing and analysis of the boiler systems are required as is a written report and final oral presentation. The final written reports are also to be provided to the hospital for the education of the staff.

Columbus Regional Hospital has three boilers for creating steam. Two of the boilers are *fire-tube* boilers, while the third is a *water-tube* boiler. Generally, only the fire-tube boilers are operating as the water-tube boiler functions as a back-up system. Two groups of three students each are asked to analyze the boiler to determine its efficiency. One group is asked to study alternative fuels to compare with natural gas and while the other group determines the effect of utilizing an economizer to pre-heat the water.

These projects address several program outcomes including teamwork, written and oral communications and ethics as well as the thermodynamic technical content.

Introduction

Thermodynamics is admittedly a challenging science for both students and teachers. Concepts including entropy, enthalpy and internal energy are difficult to learn. Real world applications are valuable in assisting students in identifying thermodynamics at work in their world. For this reason, the authors, in a partnership described in more detail in a previous work [1], continue to work together to provide students in a junior-level thermodynamics class a real world experience by studying and reporting on thermodynamic systems at Columbus Regional Hospital (CRH) in Columbus, Indiana.

For the class in the fall semester of 2004, the students studied the boiler systems used by the hospital to supply steam used for sterilizing instruments and for heating air in the air-handling system by passing the steam through a counter-flow heat exchanger (a process for a future project). The class had 2 groups of 3 students and each group was assigned to study the boiler system as well as a unique aspect of the system.

One group was to investigate alternative fuels for creating the heat that produces the steam. Currently, the hospital burns natural gas to supply the heat but the group explored a switch to a different fuel and considered both the engineering and economic consequences of such a switch. They discovered that coal would be significantly cheaper to burn but is not practical due to issues related to transportation, storage and air cleanliness as well as the overall perception of a hospital burning coal. While burning coal may no longer be the dirty operation as in the past, its image still suffers, especially relating to a hospital.

The second group was assigned to study the operation and potential economic benefits of using an economizer. The economizer, which the hospital has but is not currently using, routes some of the hot natural gas exhaust through a heat exchanger to pre-heat the water flowing into the boiler. In theory, this should reduce the amount of heat required to boil the water and, therefore, decrease the natural gas purchased from the local gas company. This group analyzed the technical aspects of the economizer as well as the potential economic benefits to determine its feasibility. One possible oversight was to determine the investment required to install the economizer with its associated piping and heat exchanger, although for CRH, this was a non-factor considering it's already in place.

Finally, in order to address several learning outcomes of the institution and therefore accreditation agencies (ABET)[2], the groups were required to submit a written report, to make an oral presentation and to rate themselves as members of a team performing a specific task. Assessment rubrics were developed to evaluate the reports, oral presentations, including both the individual presentations and the overall team presentation, and teamwork. For the presentations, several faculty from other disciplines within the Purdue College of Technology at Columbus/SE Indiana attended and scored the individual and team presentations. These results are discussed later. Ideally, members of the hospital staff would also have been present for the presentations but that wasn't convenient for this semester. In future work, the presentations would ideally take place at the hospital. The reports have been distributed to the hospital.

Background Information

Steam is produced at the hospital for use in sterilizing medical instruments and for heating air used in climate control. Three boilers are available for providing the heat to generate the steam. Two of the boilers are fire-tube boilers, shown in Figure 1[3], and the third is a water-tube boiler, shown in Figure 2[3]. The water from the local municipality is treated by a water softener and de-aerator before it enters the boilers. This treatment removes any un-dissolved gases and heavy metals from the water in order to avoid corrosion.

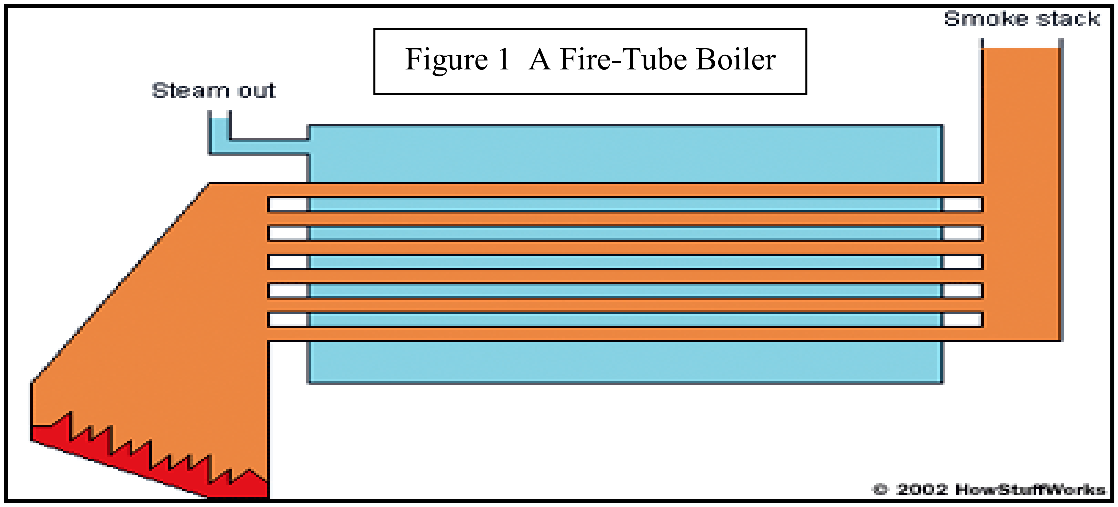

Figure 1 A Fire-Tube Boiler

For the fire-tube boilers, the natural gas is burned within the tubes as water is circulated around them. Water enters the boiler tank from the bottom using a feed-water pump. The steam, then, quite naturally floats to the top of the tank and is directed out of the

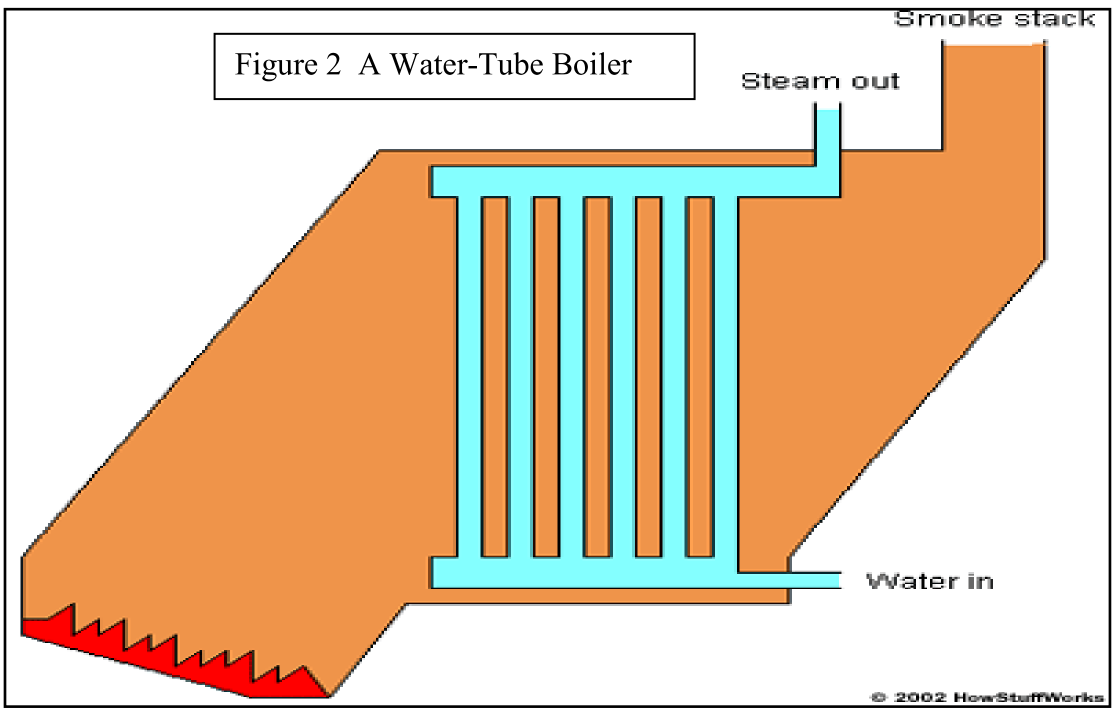

Figure 2 A Water-Tube Boiler

tank using a piping system. In the water-tube boilers, water circulates through the tubes as the natural gas is burned in the tank surrounding the tubes. Typically, only one of the fire-tube boilers is operating. During peak times, mainly in winter when the demand for heated air is greater, the second fire-tube boiler may be used or the water-tube boiler may be activated since it has a higher steam-generating capacity. Table 1 below lists the inlet and outlet conditions for each of the two types of boilers.

Table 1. Specific Properties of Boiler Water/Steam

	Inlet Water Temperature (°F)	Inlet Water Pressure (psig)	Exit Steam Quality	Exit Steam Pressure (psig)
Fire-Tube Boiler	210	125	Saturated Vapor (1.0)	100
Water-Tube Boiler	210	125	Saturated Vapor (1.0)	110

After being generated by the boilers, the steam is used either to sterilize instruments by directing it through a regulator and piping it around the hospital or to heat air for use in the climate control system of the hospital using a 2-step process. The steam is used in a heat exchanger to heat glycol which is then used in another heat exchanger to heat the air. This process reduces corrosion by not allowing the steam to condense and oxidize the pipes.

As mentioned previously, the two groups of students studied the use of alternative fuels and the use of an economizer to pre-heat the incoming water temperature.

Project Results

Alternative Fuels

This group first used the information in the Table 2 below to determine how much heat was being provided by combusting the natural gas and then used that value as the standard heat required of all other possible fuels.

Table 2. Characteristics and Properties of Incoming Natural Gas Flow				
Composition	Pressure	Specific Weight	High Heating Value	Cost
90% Methane 5% Ethane 5% Nitrogen	3.5 psig	0.077 lb/ft^3	1129 BTU/ft^3	\$0.00906/ft^3

Students were required to use available resources, primarily the internet, to research natural gas and the other possible fuels to determine the heating value as well as the cost. Also, the project required the students to work with the English unit system, a not altogether pleasant experience.

The cost estimates made by the students of the various fuels are summarized in the Table 3 below.

Table 3. Annual Cost Estimates for Various Alternative Fuels	
Natural Gas	$59,122
Diesel	$99,205
Gasoline	$103,914
Kerosene	$109,987
Propane	$78,815
Coal	$12,478

In their conclusions, the group stated that in comparing the fuels "several factors need to be looked at. These included, the cost and availability of the fuel, the type of boilers used, the cost to purchase and install new equipment if needed, the system's efficiency, and the environmental impacts associated with the heating fuel. If coal were chosen, CRH would need to build or buy some type of storage facility to contain 300 tons of coal. If it were not stored on site then it would need to be trucked in on a regular basis. Coal is also a very dirty fuel. There would need to be a filtration system installed for the exhaust gases. To provide all the things mentioned could cost more money than the coal would save."

One of the goals of the research project was to get the students to think beyond the purely technical aspects of a project. Classroom work and assignments focus typically on only thermodynamics while ignoring the effects on the real world. These projects invite the students to consider all constituencies involved and to experience that nearly all such projects regardless of discipline involve much compromise. The conclusions of the first group above indicate that the group successfully thought beyond the thermodynamics and considered related factors.

Potential Benefits of Economizer

The second group also analyzed the boilers but focused on the use of the economizer to pre-heat the incoming water to the boilers by using the wasted exhaust gases. This required the students to make several assumptions. Most student work in the thermodynamics class requires no real assumptions – problem solutions are fairly straightforward or, at most, may require manipulations of properties and/or equations to complete the solution. For this particular project, with the sort of minimal direction that typically accompanies real world problems, students assumed that 100% of the heat obtained from the combustion of the fuel is transferred to the working fluid; any potential or kinetic energies in the incoming fuel are neglected; and the boiler is in steady operation all year. Clearly, not all of the heat generated by the combusting fuel is transferred to the working fluid but the group realized that it didn't really matter when evaluating the utility of the economizer. Consistency was all that was needed.

In their efforts, the group computed the reduction of heat required of the boiler by increasing the temperature of the incoming water from 1 to 10 degrees. Note that at 125 psig, water boils at approximately 352.9 °F and that the maximum increase of 10 °F only increases the water to roughly 220°F. This group performed no analysis of the heat exchanger required between the exhaust gases and the incoming water. Table 4 below lists the heat required in kilowatts for an increase in incoming water temperature and the potential savings.

EES Software

Both groups used extensively the Engineering Equation Solver (EES) software in their work. This software is provided free-of-charge for teachers and students using the textbook *Thermodynamics: An Engineering Approach w/ version 1.2 CD ROM,* written by Yunus A. Cengel and Michael Boles. Temporary licensing allows students to use the software for the semester. The software contains tables of thermodynamic properties for many fluids and relieves students of having to make multiple interpolations through the tables to find properties. Additionally, the parametric nature of the software allows users to quickly study the effects of changing variables and increases understanding of the material.

Table 4. Estimated Savings Using an Economizer		
Temperature Increase (K)	Combustion Heat (kW)	Savings
0	100,032	$0
1	99,853	$32,313
2	99,673	$64,634
3	99,494	$96,966
4	99,314	$129,310
5	99,134	$161,665
6	98,954	$194,031
7	98,774	$226,408
8	98,594	$258,797
9	98,414	$291,197
10	98,234	$323,610

Benefits to Students

The benefits of project work such as this are several.

1. The students' exposure to real systems with real components in a fairly ordinary place as a hospital emphasizes that technology and, particularly, thermodynamics is everywhere. Certainly, these types of projects demonstrate to students the principles of thermodynamics in systems that are not just in a text book.

2. Much of industry currently places great importance on teamwork. While grouping students to do class projects is not a new or unique idea, it does build the soft or people skills that organizations desire. In an effort to evaluate teamwork, the students were asked to complete the teamwork rubric shown in Table 5. Out of a possible 45 points, the groups rated themselves at an average of 42.67 and 43 points. This high score is not particularly surprising given that nearly all the students are non-traditional, adult students who also have full-time jobs. In their jobs, the students are likely required to participate on teams and therefore have experience working cooperatively with other people. Of course, a comparison with traditional students would be interesting.

Table 5. Rubric Used by Students to Rate the Performance of Their Teams						
TEAMS student	**Aspects of Team Performance**	Never	Rarely	Sometimes	Usually	Always
Item	point value	1	2	3	4	5
A	My team respectfully listens to suggestions and ideas.					
B	My team plans our project actions.					
C	My team completes tasks within the project schedule.					
D	My teammates actively participate in team meetings.					
E	My team used electronic media to aid communication with each other.					
F	My team recognizes when additional technical help is needed.					
G	My team members take responsibility for accomplishing their assigned project tasks.					
H	My team works to ensure the team understands all aspects of the team project					
I	My team resolves disagreements in a reasonable, civil manner.					
	Subtotals					
	Total points					

3. Likewise, all organizations value effective communications skills. Again, while this idea is not new, projects that require written reports and oral presentations help to build those skills and these projects required both. In order to evaluate students on these important skills, Tables 6-8 show rubrics developed for the individual and group oral presentations and written research report respectively. Note that Table 8 was created using a template from the RubiStar website[2].While the written reports were evaluated by only one faculty member, the oral presentations were judged by 4 faculty members, three of whom are in engineering technology while the fourth is in leadership and supervision.

   Oral presentation group scores averaged 35 of 40 total points while the individual oral presentation average scores ranged from 23.5 to 26.5 out of a possible 30 points. For the written reports, the scores ranged from 17 to 26 points out of a maximum 28 points. Although the differences between the two groups were small, the members of one of the groups scored higher on all assessments. As a result, in future project assignments, the members of the two groups may be regrouped based on the rubric results.

Table 6. Rubric Used to Rate Individual Oral Presentations						
Ind	**Speaker:**	Never	Rarely	Sometimes	Usually	Always
Item	point value	1	2	3	4	5
A	The speaker spoke audibly, clearly, and distinctly					
B	The speaker maintained eye contact with the audience					
C	The speaker was prepared and relaxed and did not read the presentation to the listeners					
D	The language used was appropriate for a technical/professional presentation					
E	The content of the presentation was correct and the subject well covered					
F	The speaker answered questions honestly and directly					
Total points						

Table 7. Rubric Used to Rate Group Oral Presentations						
Group	**Aspects of Verbal Communications/Presentation**	Never	Rarely	Sometimes	Usually	Always
Item	point value	1	2	3	4	5
A	The presentation was well-organized					
B	The presentation held the listener's attention					
C	The presentation content was correct and addressed the assigned topic areas					
D	Transitions between speakers were smooth					
E	Visual aids used enhanced the presentation.					
F	Slide background was effective					
G	Graphics and pictures were used for clarification					
H	Slides were well designed – balanced, not too wordy					
Total points						

Table 8. Rubric Used to Rate Written Research Reports[2]				
CATEGORY	4	3	2	1
Organization	Information is very organized with well-constructed paragraphs and subheadings.	Information is organized with well-constructed paragraphs.	Information is organized, but paragraphs are not well-constructed.	The information appears to be disorganized.
Amount of Information	All topics are addressed and all questions answered with at least 2 sentences about each.	All topics are addressed and most questions answered with at least 2 sentences about each.	All topics are addressed, and most questions answered with 1 sentence about each.	One or more topics were not addressed.
Quality of Information	Information clearly relates to the main topic. It includes several supporting details and/or examples.	Information clearly relates to the main topic. It provides 1-2 supporting details and/or examples.	Information clearly relates to the main topic. No details and/or examples are given.	Information has little or nothing to do with the main topic.
Sources	All sources (information and graphics) are accurately documented in the desired format.	All sources (information and graphics) are accurately documented, but a few are not in the desired format.	All sources (information and graphics) are accurately documented, but many are not in the desired format.	Some sources are not accurately documented.
Mechanics	No grammatical, spelling or punctuation errors.	Almost no grammatical, spelling or punctuation errors	A few grammatical spelling or punctuation errors.	Many grammatical, spelling, or punctuation errors.
Paragraph Construction	All paragraphs include introductory sentence, explanations or details, and concluding sentence.	Most paragraphs include introductory sentence, explanations or details, and concluding sentence.	Paragraphs included related information but were typically not constructed well.	Paragraphing structure was not clear and sentences were not typically related within the paragraphs.
Diagrams & Illustrations	Diagrams and illustrations are neat, accurate and add to the reader's understanding of the topic.	Diagrams and illustrations are accurate and add to the reader's understanding of the topic.	Diagrams and illustrations are neat and accurate and sometimes add to the reader's understanding of the topic.	Diagrams and illustrations are not accurate OR do not add to the reader's understanding of the topic.

Benefits to Hospital

The hospital has received copies of all the project reports. In fact, the students' reports may likely become a resource for the hospital staff, helping to increase their understanding of the complex workings of the thermodynamic systems that they maintain and troubleshoot.

Conclusions

An engineering technology-industry collaboration is described including the Purdue College of Technology in Columbus/Southeast Indiana and the Columbus Regional Hospital in Columbus, Indiana. Two specific projects are described. Both projects involve the hospital boiler systems and focus on either (a) using an alternative fuel or (b) analyzing an economizer. Students were graded using rubrics on group and individual oral presentations as well as a written research report. Group members were also asked to rate the quality of the teamwork interactions within their groups using another rubric. While rubric results were good, identified trends within the scores could be used to reorganize the groups for future work.

References

1. Joe Fuehne and David Lenart, "Technology-Hospital Collaboration in Thermodynamics", *Proceedings of the 2004 American Society of Engineering Education Annual Conference & Exposition*, Salt Lake City, UT, June 20-24, 2004.

2. "Technology Criteria 2000: Criteria for Accrediting Programs in Engineering Technology Programs", Technology Accreditation Commission of the Accreditation Board for Engineering and Technology, Inc., November, 2002.

3. "How Steam Engines Work", Howstuffworks.com website, *www.howstuffworks.com*.

4. Rubistar website, *http://rubistar.4teachers.org/index.php*, High Plains Regional Technology in Education Consortium.

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