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Engaged in Thermodynamics – Bringing it to Industry and the Classroom

Dr. Patrick A. Tebbe, Minnesota State University, Mankato

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Abstract

This paper will discuss an on-going NSF-CCLI grant that addresses improvements in student pedagogy and educational materials for the engineering thermodynamics curriculum by completing development of the Engaged in Thermodynamics website. The material is based on actual engineering facilities and equipment. They expand on the case study concept by including skills-based problems that can be used in place of traditional homework problems but written in the context of the real-world environment. The material also includes additional design problems based on design methods and actual solutions at real facilities. Accompanying supplementary and background information promotes increased inquiry-based or student-centered learning, better addresses student real world expectations, and leads to an increase in overall student engagement. This paper will first discuss the major activity during the previous year, which was working with industry professionals to correct and expand the technical content. Industry professionals were identified with experience that spanned the topics of the Engaged in Thermodynamics material. Secondly, the paper will discuss the current year's activity of exploring innovative and creative uses of the Engaged in Thermodynamics material. Engineering educators are being recruited to create case studies of how the material can be used with different pedagogical approaches. Examples of possible case studies will be presented in the paper; such as flipped classroom use and problem based learning.

I. History of the Project

The Engaged in Thermodynamics project was originally supported in 2005 by a NSF-CCLI Phase 1 grant with the purpose of improving student engagement in thermodynamics and related courses. The material concept was a textbook supplement that could be used with any of the major engineering thermodynamics textbooks on the market. By providing information linking the thermodynamic theory to the real world applications it was believed students would be more engaged and would gain an improved understanding of the material. This information was structured in the form of engineering scenarios; descriptions of real world facilities with in-depth information on the equipment, processes, and personnel present. Along with this narrative information skill based problems were structured based on the actual equipment and its operating data. Design based, or open-ended, problems were also created based on past or future design challenges within the facilities. It was decided early in the project that an electronic or web based format was the best option for the material.

Initially a single scenario was created based on the combined heating and cooling plant on the Minnesota State University, Mankato campus as a proof-of-concept. Later the material was expanded to include multiple sites. This allowed additional systems and components to be included in the information and problems. The intent was to span sufficient real world sites to allow all of the engineering thermodynamics topics to be addressed.

The Phase I results indicated that the Engaged in Thermodynamics material did improve student's overall engagement. The assessments also indicated that there was a link between student performance and engagement[1]. Further assessment during Phase 2 demonstrated that the impact was highly dependent on how the material was used and what the overall course format was. However, student feedback was consistent in viewing the most interesting aspect of thermodynamics as the "real-world" connection[2]. Additional research questions have been generated concerning the role of student motivation and engagement in class as well as how readability and material formatting affect student impact.

II. Description of the Engaged in Thermodynamics Material

The current format has been reached through repeated student evaluations and redesigns and can be found at http://cset.mnsu.edu/engagethermo. The bulk of the material is taken from the actual sites and manufacturer information for components. Skill-based problems use values and units found in the actual sites. Each problem is directly linked to the relevant background information. This can often mean using measurement units, acronyms, and in some cases equations that are not covered in a traditional thermodynamics course. The list of current topics addressed in the material is shown in Table 1.

Table 1: Topics covered in Engaged in Thermodynamics [3].

Locations	Minnesota State University, Mankato Facilities Plant The College of New Jersey Cogeneration Plant Faribault Energy Park Monticello Nuclear Generating Plant
Systems	Steam Turbine Power Plant Gas Turbine Power Plant Combined Cycle Plant Cogeneration Generator Sets Centralized Heating and Cooling Plant Military Tanks (Drivetrains)
Components	Boiler Chiller Cooling Tower Steam Turbine Gas Turbine Diesel Engine Fuel Cell

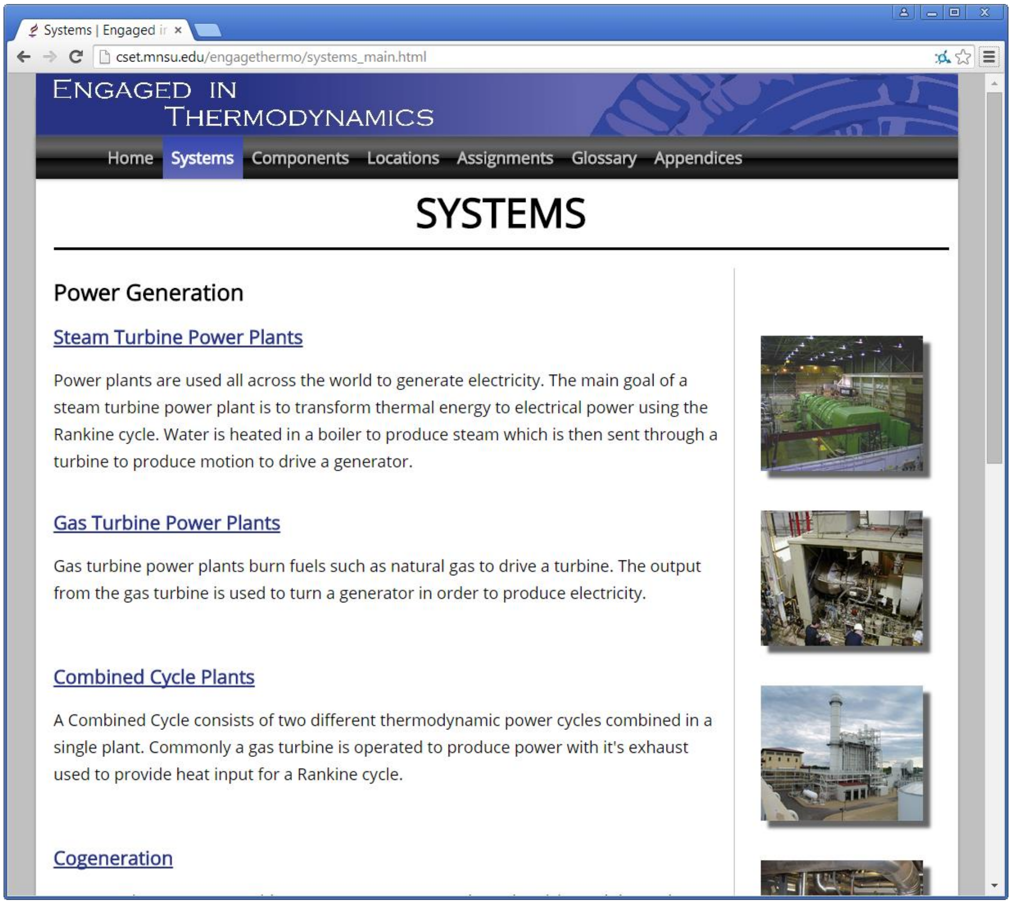

Figure 1: The main Systems page from the Engaged website showing a few of the options available. Each can also be selected through the drop down menu.

The overall site is designed to allow multiple paths to information by dividing it into three main categories: Systems, Components, and Locations. Each is heavily cross linked. A Location page will describe the basic systems and components present but will focus on the overall purpose and application of those systems (i.e. how they meet the needs of that specific location). A System page will describe a general type of system, for instance a co-generation system (Figure 1). It will delve deeper into how the system works regardless of where it is. The Component pages are the building blocks for the systems. Each component described could be employed in multiple types of Systems and at multiple Locations. Links are provided between all of these pages so students who start at one point can follow their interests to broader or more in-depth information.

For each System, Component, or Location page a right sidebar has been developed to provide additional information (Figure 2). This can include links to external information that may help understanding, such as an animation of a gas turbine; definitions that may not commonly be used in a thermodynamics course, such as ton of refrigeration; or links to interesting stories that have a connection but may not be directly related to the material on the page, such as an ASME article on boiler explosions. The overall intent is to provide as much opportunity for the student to explore and learn while not making the page or information overwhelming.

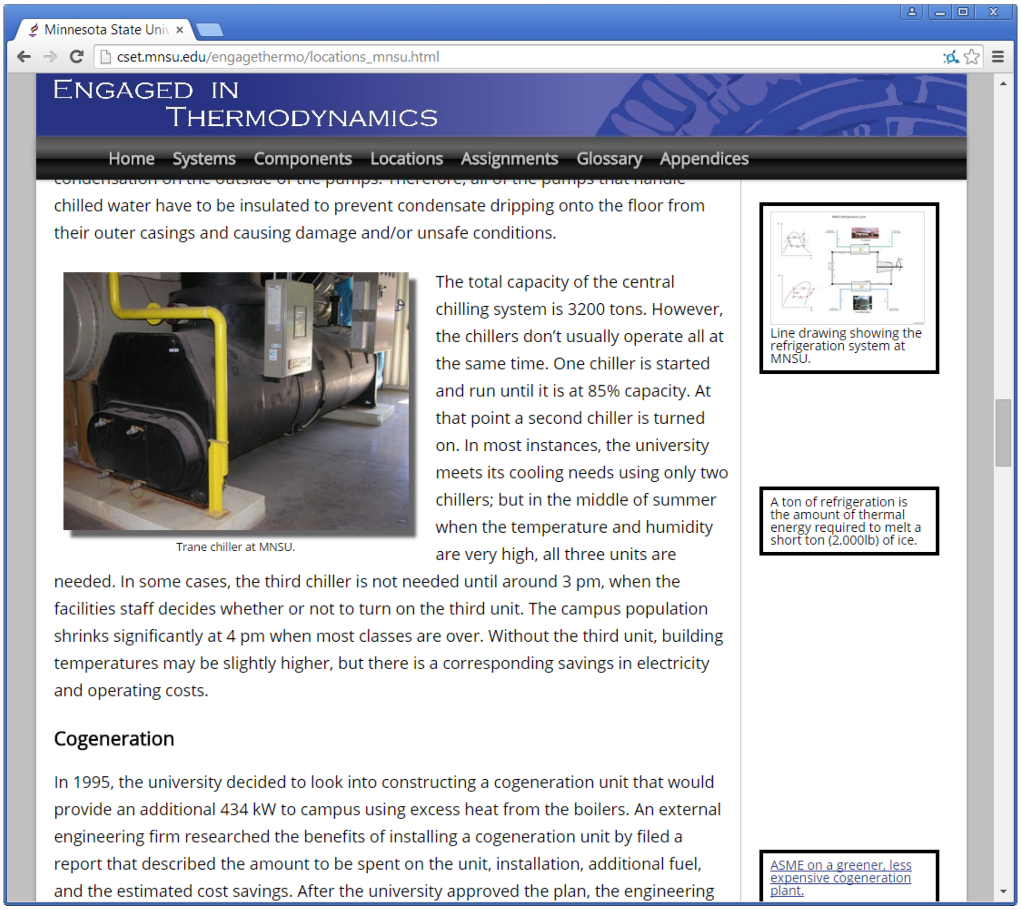

Figure 2: Example of a Location page with right sidebar.

III. External Evaluation of the Material

As previous papers on this project have mentioned, the readability of the material plays a large role in how students interact with it. While extensive work had already been done on the technical content and website organization, this phase of development focused more on the technical communication aspects. Early in the project it was determined that student developers lost their independent student perspective within weeks and started viewing the material as "experts". Therefore, a graduate student from the Technical Communication program was brought in to do a complete review and editing of the material. Having someone with no engineering background review the material provided great insights into how the material was being communicated.

Next, industry experts were brought in to provide a technical critique of the material. To address all the various aspects and topics, four experts were selected in the following areas (for this paper the experts and the respective firms they work for will remain anonymous):

1. Design consultant in the area of combined heating and cooling plants, as well as co-generation plants.

2. Design engineer in the area of diesel engine design and amateur historian of military tank history.
3. Professor of nuclear engineering and power industry consultant.
4. Design engineer in the area of commercial refrigeration system design.

The four experts were asked to review different portions of the material specific to their expertise and return initial written comments. While several technical suggestions were made there were also some more general comments. A summary of these comments (strengths, weaknesses, and recommendations) is given below in Table 2. Several of these items have already been addressed. Of special note is the inclusion of new line drawings for some of the Systems and Locations (Figure 3). These allow a better overall understanding of how the many components connect. Line color is used to distinguish between different working fluids present.

Table 2: Summary of expert review comments on material.

Strengths

- There is a good overview of systems students are likely to encounter in their careers.
- The provided Glossary is a good aid to the reader due to the technical "jargon" that is present in these fields.
- The sidebar links to additional information help provide further understanding.
- The assignments drive home the key and important concepts.

Weaknesses

- The material jumps from being general to site specific. This may confuse readers into thinking that every site is like the one described.
- The Condenser and Evaporator sections are oversimplified. They ignore the numerous types of heat exchangers used in industry.
- Only R-134a and R-123 are mentioned as possible refrigerants. Additional options should be presented.

Recommendations

- Add more information on how and why a refrigerant is selected.
- Line drawings of components should be included with actual photos.

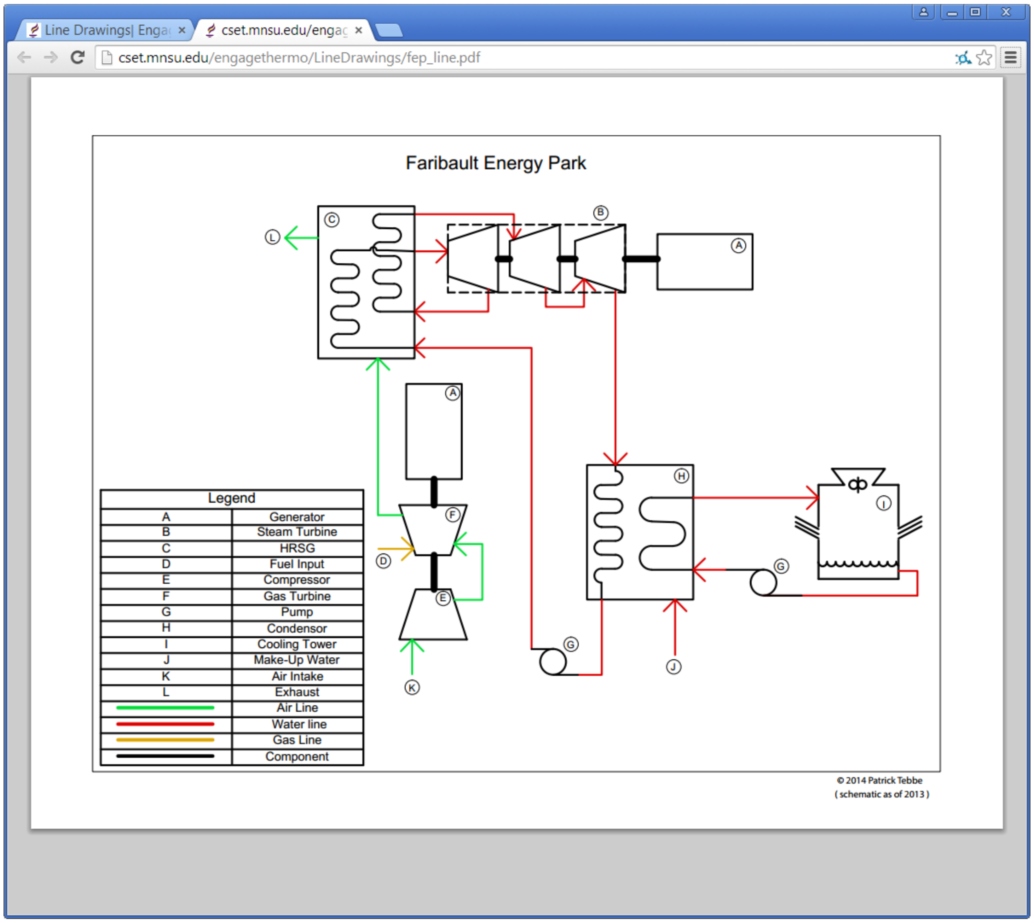

Figure 3: Example of a new line drawing. In this case, for a combined cycle plant.

IV. Pedagogical Approaches and Future Work

Since its inception the Engaged in Thermodynamics material has been designed to be flexible. It is not intended to be used in only one pedagogical manner. Rather, it is intended to be used as a tool that can be applied in different ways to promote student motivation and engagement. There are many definitions of engagement used in education. With regard to how material is taught the work of Smith et al.[4] provides a good overview of cooperative learning and problem based learning. Another approach is to focus on motivation as a determining factor for engagement. Herman et al.[5] highlight several course aspects that can be used to assess intrinsic motivation including purpose, autonomy, relatedness, and competence. Using just these two papers' descriptions, there are many ways the Engaged in Thermodynamics material could be used to address engagement and motivation. Two possible examples will be described.

Many students view the thermodynamics material as dry because they do not see the connection to the real world and their interests. Introducing topics with the real world equipment and locations in the Engaged material directly addresses the intrinsic motivation aspects of purpose and relatedness. As a simple example, students can be presented with a campus steam boiler as an application of first law principles (purpose). If these calculations are done correctly there is a possibility of not having enough hot water for dorm showers (relatedness). The project team is now working on short video clips that highlight and explain the system and location information on the website. These will be posted to a YouTube page devoted to Engaged in Thermodynamics. The short videos will provide another avenue for course integration, particularly suited to online or hybrid formatted courses.

Besides skill-based problems, the Engaged material also includes open-ended design problems called Plant Assignments. For instance, one problem involves the selection of a new chiller unit based on performance and the different refrigerants used. In essence there is no "right" answer and there are many considerations beyond simple thermodynamic energy calculations. These problems are ideal for structuring problem based or cooperative learning activities around. The problems are based on actual real world issues encountered by engineering professionals at the locations studied. Also, the Engaged material is currently structured for self-directed learning allowing students to proceed quickly to new information within the site and through outside links.

Currently, collaborators are being sought who will develop lesson plans that employ the Engaged in Thermodynamic material. These could take different forms, involve different teaching pedagogies, and be of short or long duration. It is intended to make these lesson plans available through the website for others to use or adapt.

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