Development of an Interdisciplinary HVAC Course

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ABSTRACT

The Building Construction and Contracting (BC) and Mechanical Engineering Technology (MET) Departments at Purdue University are developing innovative programs that target two rapidly expanding areas of specialization. Mechanical Contractors specify and install equipment for both commercial and residential spaces, while Maintenance Engineers operate and service the equipment on a daily basis. As part of the developmental effort, an existing HVAC course has been re-structured to focus on the unique technical requirements of these closely related careers. This cooperation takes advantage of the individual strengths of the BC and MET Departments and is provided as a working model for other institutions that may want to establish similar programs.

INTERDISCIPLINARY COLLABORATION

The demand for new buildings, both commercial and residential, was vigorous during the 1980's and remains strong today. This high level of construction activity has created a strong demand for qualified Mechanical Contractors who specify and install plumbing, electrical, and climate control equipment for indoor spaces. Once construction is complete, Maintenance Engineers operate and service the equipment on a daily basis. When the accumulation of buildings over the last 20 years is considered, it is not surprising that the job market for Maintenance Engineers is particularly robust. In fact, the Office of Manpower Studies in the School of Technology at Purdue University projects that Maintenance Engineering will be one of the fastest growing technical careers over the next 10 years.[2]

Mechanical Contracting and Maintenance Engineering may have been performed by skilled trades people in the past, but there are new and important trends that have greatly increased the scope and complexity of these tasks. Energy efficiency and environmental awareness are critically important and have strongly influenced how buildings are constructed and maintained. For example, computer-controlled "smart buildings" integrate communications, security, environmental control, and fire suppression into a single user--friendly package. One key feature is the ability to continuously monitor all mechanical systems for substantial savings of energy and money. This increased complexity has produced a need for undergraduates who have specific knowledge of mechanical equipment. The School of Technology at Purdue University has two options for students pursuing these challenging and exciting career opportunities.

The Building Construction and Contracting (BC) program has a Mechanical Construction Management (MCM) specialization option that provides expertise in mechanical construction management and mechanical cost estimating. BC students who select this option complete nine additional credit hours of courses in project management, scheduling, and estimating which are specific to mechanical construction. The MCM option emphasizes project management rather than the analysis of mechanical equipment. While all students recognize that the water in a hydronic system adds heat energy to an indoor space in the winter, few could calculate the required capacity of a pump or a boiler. To avoid this anticipated weakness, BC students in the MCM option complete the new HVAC course which is taught by the MET Department.

The converse is true for the Mechanical Engineering Technology program. The core MET courses are mostly analytical. A two course heat power sequence is particularly important for Maintenance Engineers because it includes a detailed energy-based analysis of equipment such as boilers, heat pumps and air conditioners. Despite this strong analytical background, potential Maintenance Engineers would benefit from an additional project management component in their course work. Much of a Maintenance Engineer's work involves project scheduling and management, yet these topics are not required for the MET curriculum.

Rather than the BC and MET departments addressing the shortcomings of their new programs on an individual basis, a cooperative effort could take full advantage of each department's strengths. BC students could benefit from MET expertise in mechanical systems such as pumps, fans, boilers, or heat exchangers. MET students could benefit from BC expertise in building codes, estimating, and project scheduling. A cooperative approach could also ease class scheduling or budgeting problems that can occur if only a small number of students from a single department take a class as a technical elective.

COURSE OVERVIEW

As a first step in the collaboration, BC students are enrolling in a new version of the MET Air Conditioning and Refrigeration course. The course has been re-structured to target a specific range of technical expertise. For example, Mechanical Contractors are typically not repairmen who make service calls to fix damaged equipment. As a result, soldering, brazing and other skills used by trades people are not emphasized. At the opposite end of the spectrum, Maintenance Engineers are typically not designers who develop the "next generation" of climate control equipment. The vital technical skills for both Mechanical Contractors and Maintenance Engineers lie somewhere between these two extremes. For example, it is important for these personnel to understand that changes in the dry and wet bulb temperature across the cooling coils of an air handler quantify the cooling capacity of the unit.

Air Conditioning and Refrigeration is offered in the spring semester of each academic year as a junior or senior level technical elective. There are typically about 15 students enrolled each time the course is offered. Although two semesters of heat power were required as a prerequisite, this requirement has been dropped to allow BC students into the course. The current prerequisites area two course sequence of general physics and mathematics up to and including integral calculus. This represents a significant deviation from more traditional HVAC courses that emphasize the thermodynamics of various cooling cycles.

Air Conditioning and Refrigeration has two l-hour lectures and one 2-hour laboratory each week. The lecture introduces concepts and methods of analysis that are subsequently explored in the laboratory. The textbook, "Principles of Heating, Ventilating, and Air Conditioning" by Sauer and Howell, is based on the Fundamentals Handbook published by The American Society of Heating, Refrigerating, and Air Conditioning Engineers.[3] The first part of the text reviews general thermodynamics and methods of HVAC analysis and the remainder describes different types of HVAC systems and equipment. The book contains 20 chapters, about twice the material that can be covered in a single semester. Homework problems are assigned from the end of each textbook chapter.

To emphasize the essential “hands-on” component of the course, it is taught in the Applied Energy Laboratory that is operated by the Department of Mechanical Engineering Technology. The front half has desks as in a typical classroom, but the back half contains test and measurement equipment. In addition to basic sensors for measuring temperature, pressure, and flow there are a number of pumps, fans, and refrigeration trainers for applications-based demonstrations and laboratory experiments. The principal HVAC equipment is a 800 ft^3 “environmental chamber” that was originally a meat locker. The chamber is instrumented for both temperature and humidity and directly linked to several types of climate control equipment. A forced air system, a hydronic system, and solar energy system can all be evaluated using the environmental chamber.

TECHNICAL CONTENT

As illustrated in Figure 1, Air Conditioning and Refrigeration has five segments. The broad topic areas include basic thermodynamics, system analysis, load estimation, and ducts and pipes. The final segment is a semester long group project. The course is arranged so that each important lecture topic is coupled with a related laboratory experiment. The percentage shown beneath each descriptor in Figure 1 indicates the amount of lecture and laboratory time devoted to the topic.

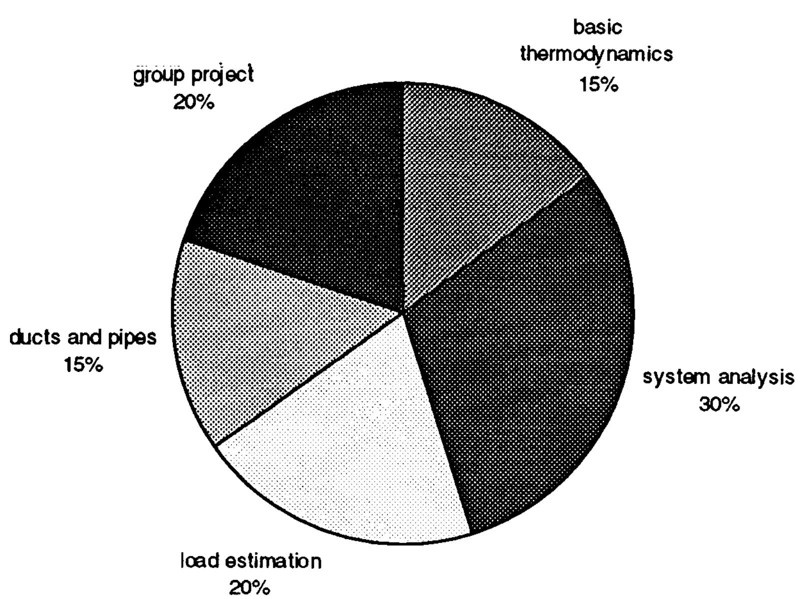

Figure 1. Most segments are discussed in lecture and reinforced with laboratory experiments.

Basic Thermodynamics

Air Conditioning and Refrigeration starts with a comprehensive review of fundamental thermodynamic principles. Basic fluid properties, such as pressure and temperature, are discussed first. The ideal gas law and thermodynamic tables are then used to determine other fluid properties, such as specific volume.

Conservation of energy and conservation of mass are introduced because they are the key tools for any energy-based analysis. Steady state heat transfer through walls and pipes is a special topic that is included because it helps determine heat gains and losses from a building. Several laboratory experiments demonstrate these lecture topics. In the first exercise, conservation of mass and energy are used to predict the final temperature of a hot and cold water mixture.

As indicated in Figure 1, the review of basic thermodynamics absorbs 15% of the class. While this may seem excessive, it is critical to have a firm grasp on the fundamentals before tackling more complex topics. It is also essential to account for differing student backgrounds. Basic thermodynamics may be remedial for MET students, but some of the topics may be new to BC students. Covering these topics in detail at the start of the course avoids problems later in the semester.

System Analysis

The largest segment of Figure 1 is system analysis, which is an energy audit of an HVAC system or a particular HVAC component. Figure 2 is a simplified schematic of a recirculating forced air system that helps illustrate this type of calculation. When the entire system is considered, the capacity of the air handler can be determined if the loads on the indoor space and the state of the outdoor air are available. Rather than evaluating an entire system, individual components can be assessed. For example, students check the efficiency of a heating coil in the Applied Energy Laboratory by comparing the change in air properties across the coil with the total electrical energy supplied to the heater. An efficiency significantly lower than the manufacturer's specifications may indicate that the heat transfer surface is degraded in some way. Calculations of this type are important to maintain an HVAC system at optimum levels. Knowledge of human comfort and indoor air quality are important peripheral information that guide a system analysis.

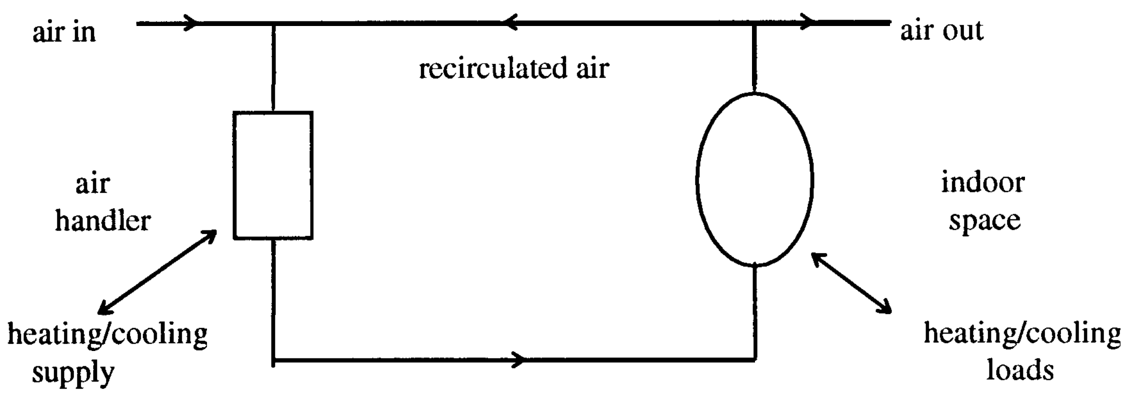

Figure 2. The analysis of a forced air system with recirculation is an important course topic.

Load Estimation

Figure 1 shows that 20 % of the course is dedicated to load estimation, which determines how much energy a building gains or loses over time. Heat transfer equations help estimate the heat gain or loss through walls, doors, etc. The energy developed by equipment and people are included when it becomes significant. Calculations are usually performed for winter conditions. Winter conditions are more appropriate than summer conditions because daily temperature fluctuations are smaller and a simplified analysis based on a steady state energy balance is appropriate. Computer-based load estimation is introduced, but there is not sufficient time to master a particular piece of software. The Transfer Function Method for load estimation, which has been adopted by ASHRAE, is discussed briefly. The primary goal of this segment is to provide a reasonable technical background for determining the heat gains or losses from a building. Computer software expertise can be gained on-the-job if it is needed.

Ducts and Pipes

The techniques for sizing air ducts are documented in nearly every HVAC text. However, as reported in "ASHRAE Insights", this important topic is frequently omitted. [1] The design of ducts and pipes is 15% of the MET Air Conditioning and Refrigeration course. Duct sizing is introduced using the Equal Friction method since the computations are fairly simple. Subsequent analysis uses either the Velocity Reduction or the Static Regain methods. As with the earlier load estimation segment, it is clearly understood that duct design problems are rarely solved manually. Computer software for duct design is introduced, but not covered in detail. The goal of this segment is to provide technical insight to supplement a computer based duct analysis. This segment also discusses pump and fan performance. A laboratory experiment explores flow as a function of system pressure.

Group Project

It is not possible to cover all the important HVAC topics during a 15 week semester. A group project helps students develop expertise in at least one focused area. A group project also introduces open ended problems, which are not possible in a typical laboratory experiment that comes with a detailed list of procedures. The projects are different each semester. In one instance, the entire class assessed air quality concerns at a plant that manufactures threaded fasteners for the automotive industry. In another instance, design groups evaluated and developed detailed plans for renovations to a solar energy system that is used for undergraduate laboratory experiments. Over 1/3 of the laboratory time, or 20970 of the entire course, is devoted to the group project.

CONCLUSIONS

An interdisciplinary HVAC course has been developed and offered to students in Mechanical Engineering Technology and Building Construction and Contracting at Purdue University. It differs from traditional HVAC courses because it is intended for Mechanical Contractors and Maintenance Engineers. Since both groups are users of technology rather than creators of technology, the number of design topics has been reduced and there is an increased emphasis on equipment assessment and specification. Particular attention was given to implementing course topics that will improve on-the-job performance.

BC graduates who become Mechanical Contractors will identify and manage complex climate control projects. Many of their technical challenges, such as sizing and specifying ducts or pipes, require considerable technical expertise. The new HVAC course provides mechanical project managers with a basic technical understanding of equipment analysis and load calculations and will increase the effectiveness of communications with the mechanical engineer and equipment manufacturer. In contrast, MET students who become Maintenance Engineers will operate modern buildings that contain automated energy management systems and climate control equipment. Energy efficiency is always a critical concern. Techniques for equipment assessment, such as calculating the bypass factor of a cooling coil, will help Maintenance Engineers recognize and solve potential equipment problems and reduce building operating costs.

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