Designing a HVAC Demonstrator - an ASHRAE Undergraduate Senior Project

Richard L. LeBoeuf, Gregory Spaulding
Kansas State University at Salina

The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) provides funds for undergraduate senior projects to encourage students to pursue ASHRAE-related careers. As a result of this grant program, the mechanical engineering technology (MET) seniors at Kansas State University have designed and built a Heating, Ventilation and Air-Conditioning (HVAC) Demonstrator that will be used to demonstrate the interrelationship between thermodynamics and HVAC processes. The apparatus will be used to demonstrate airflow, inlet heating and humidification, air cooling, and air reheating. The demonstrator includes computer data acquisition and control using modern virtual instrumentation software. This apparatus will be an invaluable resource in our Thermodynamics and Heat Transfer course as well as in our Industrial Instrumentation and Controls course.

The Senior Design Project courses in mechanical engineering technology at Kansas State University (KSU) consist of a two-course sequence. In the first semester, students generally clarify the project requirements and perform a preliminary design. In the second semester, the design is finalized and fabrication and testing take place. This project required students to develop a sound background in mechanical design, fluid thermal system design, as well as, electronic instrumentation and control. This senior project tied much of the material from students' previous course work together, including that of thermodynamics, fluid mechanics, instrumentation and control. In this respect, the project truly represents a 'capstone' design project.

Introduction

Funding for senior design project courses, which have become especially common in engineering technology programs, can be difficult to obtain. Finding a project that has many elements of mechanical engineering technology and can be permitted to span an entire academic year is often difficult. Although the senior project courses at KSU traditionally have been industrial projects funded by industry, the ASHRAE Undergraduate Senior Project Grant Program was attractive because it could encompass many aspects of students' course work, require a significant amount of learning, and last up to an entire academic year.

Prior to the year the senior project grant was procured, ASHRAE sent a proposal solicitation to the college in September. The deadline for proposals was in December and notification of approval was given by ASHRAE in March of the following year. Since a laboratory component had just been added to the Thermodynamics course (now called Thermodynamics and Heat Transfer), this project was viewed as a perfect way to develop essential laboratory equipment while providing seniors the opportunity to gain experience in HVAC along with mechanical design, instrumentation and automated data acquisition. This project fit into the higher priority of the Grant Program which is to support projects that involve building working models, test equipment, experimental teaching aids, and laboratory experiments.

The senior project course sequence at KSU includes a one credit hour (two contact hours per week) course in the fall semester and a two credit hour (four contact hours per week) course in the spring semester. A preliminary design and clarification of project requirements was achieved during the first semester. The second semester activities were dedicated to design refinement, demonstrator construction, and computer integration. During the first semester, team members met two times per week for one hour each meeting. Time was used to set project parameters, weekly goals, task assignments, and to assess progress. In addition to the organized team meetings, each team member utilized individual time to complete the task assignments, weekly goals, and to familiarize themselves with HVAC principles and equipment.

Each student was required to maintain a project notebook containing three sections:

A log of all course activities recorded by hand along with the date of entry.

All written progress reports and other material assigned by the instructor.

Copies of all reference materials collected as an individual during the semester including a bibliography, as well as photocopies of all magazine articles, book chapters, flowcharts, program listings, etc., produced during the semester.

Students were required to supplement written progress reports with an oral progress report once per month. A design review was given in a presentation to the mechanical engineering technology faculty and invited HVAC experts at the end of the first semester. The students were required to contribute equally to the reports written for ASHRAE and to the oral presentations of their results at the end of each semester. The final presentation included a demonstration of the final unit. As is the tradition of the MET faculty, the entire college was invited to the final project presentation and demonstration of the finished demonstrator. This provides faculty and staff outside of the MET department the opportunity to see the fruits of their labor.

First Semester Results

Six students were registered for the senior project, so dividing out a group for this project was not necessary. Initially all six students were set to work identifying all of the anticipated tasks and their expected duration and optimum start and stop dates. This information was entered onto a project management chart which was refined during the first month of the project. The hardest part of this process for the students was getting familiar with the HVAC system and the instrumentation and data acquisition equipment necessary to build an outstanding demonstrator. The tasks identified by the students at the beginning of the first semester included:

Identify project tasks;
Put tasks on a project manager;
Study HVAC systems;
Select, order and test instrumentation software and hardware;

Identify components and locate vendors;
Prepare rough sketches and detailed drawings of the system;
Prepare the fall report and presentation;
Check and rework the design;
Order components;
Fabricate the demonstrator;
Test and debug the demonstrator;
Prepare the final report and presentation.

A major challenge for the group was identifying components and a layout since few requirements for the demonstrator were given by the instructor. Since the equipment list in the proposal was guided by features of commercially available HVAC demonstrators, the instructor imposed the following requirements for the system:

It must use computer data acquisition and control using virtual instrumentation software;
It must be able to operate as an open loop or closed loop duct system;
It must have casters for mobility and be able to fit through the doorway of any classroom.

Additional requirements added during the semester included:

Use visual measurement devices along with the computer data acquisition;
Operate as a heat pump (i.e., operation for heating or cooling).

During the first semester, the group accomplished the following tasks:

Examined existing refrigeration demonstrators;
Discussed the design with refrigeration equipment vendors and HVAC instructors;
Studied the refrigeration cycle;
Selected the refrigerant;
Selected and purchased instrumentation software and hardware;
Designed the demonstrator cart;
Selected components of the heat pump system;
Designed the duct work;
Identified locations of all sensors in the system;
Derived the thermodynamic equations for the refrigeration cycle and determined how they would be used in conjunction with the virtual instrumentation software for displaying heat or work.

With completion of the preliminary design the team placed the percent completion of the project at fifty percent. The percent complete figure was predicated on the assumption that the design was two thirds of the project and fabrication was one third. At the end of the first semester, the design and fabrication were considered to be seventy-five and zero percent complete, respectively. The cart design and schematic of the refrigerant flow resulting from the first semester activities are included in Appendix A.

Second Semester Results

In this portion of the course, which had twice as much contact time as the first, the students finalized the design and fabricated and tested the demonstrator. Typically the most difficult aspect of this part of the project was resisting the urge to begin fabrication and component purchasing before finishing the design work. Frequent design reviews took place at the beginning of the semester to finalize the design.

In this portion of the project the team became acutely aware of the time constraints and the requirements of completing the project. With these issues looming over them, the team saw the necessity to take action to expedite the project. One of the actions taken was to divide the project into sub-systems to parallel the development process. The sub-systems were:

Cart
Duct work
Electrical / Computer
Refrigeration system
Documentation

Each sub-system had one or two students who were responsible for that sub-system. The division of the project occurred fairly natural, each student seemed to gravitate toward particular sub-system. This division was encouraged by the faculty to more closely model a "real life" working environment, where projects are divided among several employees.

After dividing the project into sub-systems the students established interface specifications for each of the sub-systems. By establishing these interface specifications, the students could push all sub-systems ahead in parallel, knowing as long as they adhered to the interface specifications the sub-systems could be successfully joined together downstream.

Another action taken by the team early in the second semester was a review of the resources required to complete the project. This list was compared to the available resources within the team, two voids were discovered by this review. These two resource voids were:

A lack of adequate electrical expertise
A lack of skills for the assembly of the components of the refrigeration system

To fill the void of inadequate electrical expertise two electronic engineering technology (EET) students were invited to join the original group of six MET students for the second senior design project course. The EET students provided support for the data acquisition, control and signal conditioning requirements of the project. This arrangement also provided a "real life" model, where mechanical and electrical disciplines collaborate on the project design. This arrangement also provided the team members with a broader exposure to other disciplines.

The second resource void, the lack of skills for the assembly of the refrigeration system, was filled by seeking out and enlisting the talents of a local expert. This expert found the project interesting and provided the resources to complete the task and instruction on the techniques used.

One of the biggest stumbling blocks for the members of the team was making decisions when there was a lack of information. The team members appeared to be most comfortable working on traditional classroom problems, where all of the information was given and they were left to solve for the correct answer. In this design project not all of the information was know and there were numerous solutions and numerous correct answers. The team members were uncomfortable making the educated guesses necessary to move the project ahead. The faculty found in necessary to nudge the team members through several of these situations. This nudging would typically progress in the following manner. The team members would be directed to gather all of the available facts. The team would then be encouraged to locate sources of expertise such as other instructors and suppliers technical support. Armed with the facts, input from experts , and their own expertise the team member were lead to a decision necessary to keep the project progressing.

The team worked through everything including, tight schedules and budgets, the reality of working with other team members, suppliers lead-times and backorders, and fabrication errors. The results of the second semester were presented to the campus community and invited HVAC experts at the end of the semester.

Grading

The grade each student received each semester was determined by considering the following factors:

Contribution to the presentation;
Progress reports;
Notebook;
Cooperation/involvement;
Completion of required work;
Contribution to the project in and out of class.

Of these factors, cooperation/involvement in the project was the most subjective to grade. The observations of the instructor were corroborated by the students through the use of a confidential self and peer review form which each student was required to fill out for themselves and for each of the other team members. The instructor also used the form for each of the team members. Results of the review of the instructor and students were remarkably similar including even the written comments. A copy of the form is given in Appendix B. Required work included assignments given by the instructor (as project manager) for the purpose of keeping the project moving forward.

Conclusions

The ASHRAE Undergraduate Senior Design Project Grant Program enables a group of engineering or engineering technology seniors to develop a working model, test equipment, experimental teaching aids, or laboratory experiments involving an ASHRAE related topic.

Grants may be for a project lasting one quarter or semester or for a project that spans an entire academic year. If time permits, the project scope can be tailored to cover many aspects of mechanical engineering/technology as was done in this project. This project resulted in a group of seniors not only becoming familiar with ASHRAE and HVAC systems, but also with a number of transducers and their application in automated data acquisition and control system.

This project required the students to develop sound background in mechanical design, fluid thermal system design, as well as, electronic instrumentation and control. In this respect, this senior project served to tie much of the material from their previous course work together, including that from the following courses: Thermodynamics, Fluid Mechanics I & II, Electric Power and Devices, and Industrial Instrumentation and Controls. In this respect, the project truly represents a 'capstone' design project.

Appendix A. Cart and refrigeration cycle layouts.

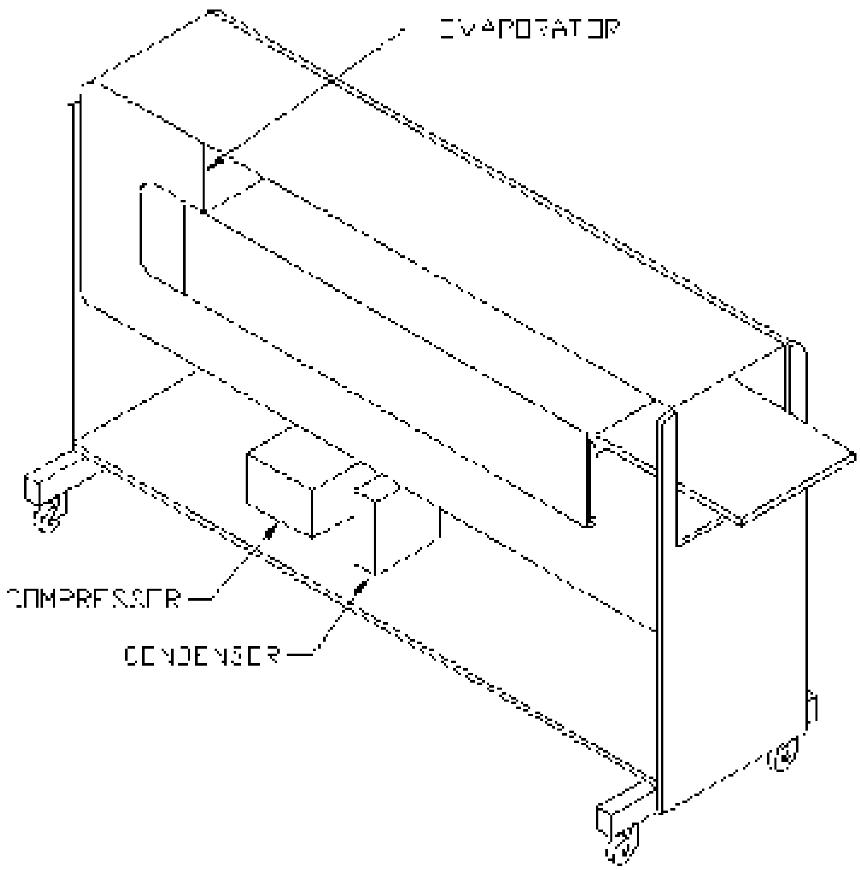

Figure A.1. Cart layout.

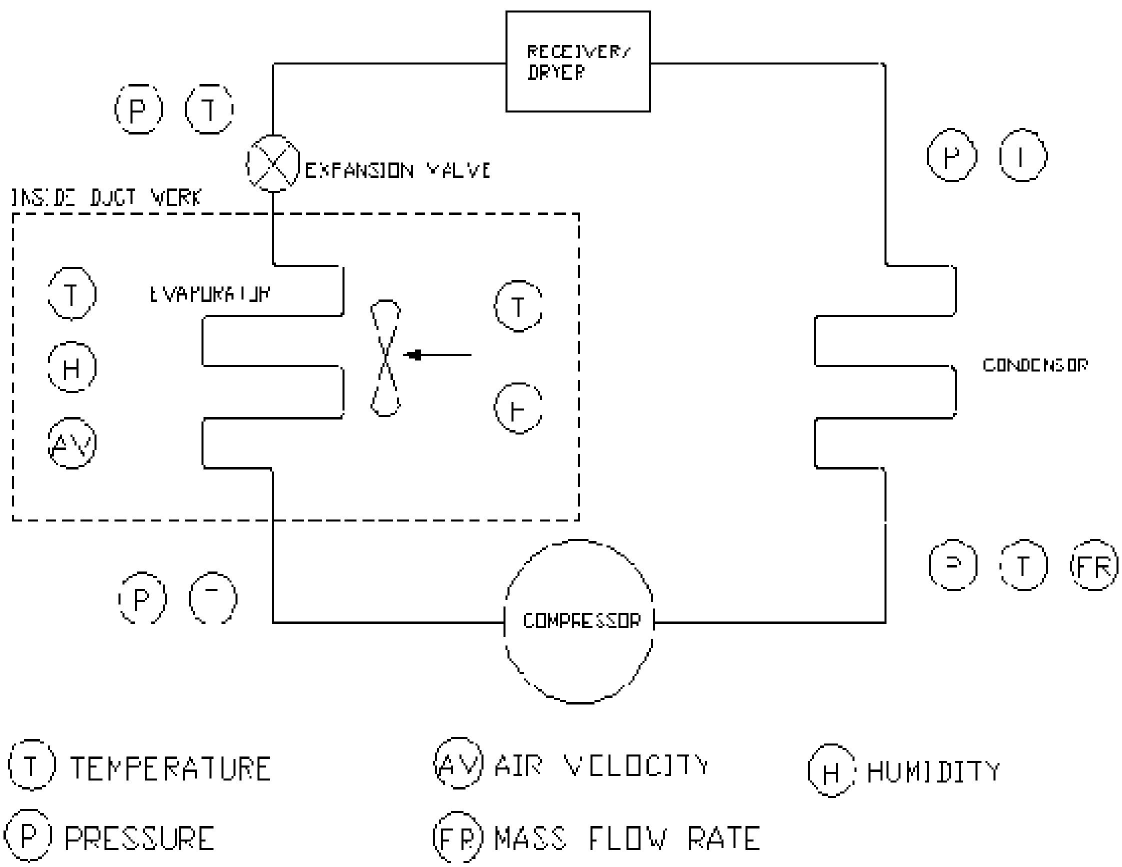

Figure A.2. Refrigeration cycle layout with sensor locations identified.

Appendix B. Self and peer review form

KANSAS STATE UNIVERSITY-SALINA
MET 462 & 464 SENIOR DESIGN PROJECT I & II
Self and peer review form

NAME:

STUDENT BEING EVALUATED:

Complete the following information to critique your own or another individual's performance. Be as truthful as possible and write out any specific strengths and/or weaknesses in the space provided. You may leave some categories blank if you feel you do not have sufficient information.

For each of the following categories, rate yourself or your peer from 0 to 5, where 5 is the best rating. You may add written comments if you wish.

CATEGORY	**SCORE**	**COMMENTS**
Communication skills	0 1 2 3 4 5	
Demonstrated leadership	0 1 2 3 4 5	
Demonstrated cooperation	0 1 2 3 4 5	
Decision making abilities	0 1 2 3 4 5	
Technical competence	0 1 2 3 4 5	
Creativity	0 1 2 3 4 5	
Reliability	0 1 2 3 4 5	
Attitude	0 1 2 3 4 5	
Trustworthiness	0 1 2 3 4 5	
Loyalty	0 1 2 3 4 5	
Individual effort	0 1 2 3 4 5	
Completes tasks	0 1 2 3 4 5	

Significant strengths:

Significant weaknesses:

Other comments:

RICHARD L. LEBOEUF is an assistant professor in mechanical and electronic engineering technology and Head of mechanical engineering technology. He received B.S. degrees in electrical and mechanical engineering and a Ph.D. degree from the State University of New York at Buffalo. He has published papers in the areas of instrumentation as well as fluid mechanics and turbulence. His most recent research activities involve computer based instrumentation and control. E-mail: leboeuf@mail.sal.ksu.edu.

GREGORY SPAULDING is an assistant professor in mechanical engineering technology. He has B.S. and M.S. degrees in mechanical engineering from Kansas State University. He is a former owner and chief engineer at a pharmaceutical dispensing company. His interested are mechanical and electromechanical design; areas in which he holds two patents. E-mail: gspauld@mail.sal.ksu.edu.