Design, Build, Test Project in Thermal Design

Don L. Dekker
Rose-Hulman Institute of Technology

ABSTRACT

Thermal Design is currently a required course for all senior mechanical engineering students. The course content includes heat exchangers, piping, pumps, fans, and non-steady flow. A project, the design of a heat exchanger, provides the focus of the course. The heat exchanger design has evolved over several years into the design of a heat exchanger to preheat the cold water entering an industrial facility.

During the first four weeks of the quarter, student groups of 3 to 5 students design a heat exchanger After their design is completed, the students buy materials for the heat exchanger construction. Then they pass their design and the materials to another group which builds the heat exchanger. The heat exchanger is then passed to a third group which tests the heat exchanger according to the testing instructions that the design group specified. The design group then compares the experimental performance with the expected performance, redesigns the prototype and submits a final report. The different parts of the heat exchanger design process are discussed in more detail in the rest of this paper.

This in-class project provides the students with experience in working in groups or teams, defining the design, designing, constructing a low-cost prototype, testing a prototype, and redesigning the "real" heat exchanger which would be used in the plant. This simulates the entire product realization process during a ten week quarter. It would be impossible to experience the entire product realization process in industry in only ten weeks. This is an example of university design projects providing an experience that industry cannot.

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INTRODUCTION

A new graduate should have the ability to size a radiator on a truck or car or some similar application. It was observed that students completing the heat transfer course could seldom do this. The goals of the Thermal Design course state:

> *"You should gain confidence in your ability to tackle an open-ended design problem in the heat transfer/fluid flow area and expect to solve it. You will also have an opportunity to take a heat exchanger through the product design cycle."*

In order to meet these goals, a project is used to provide a focus for the course content. This heat exchanger project has evolved over several years. At times an industrial application of a heat exchanger has been used as the project. The project description for spring 1998 is listed below. The flow rates and temperatures are changed every quarter so students have to design to the current values.

> It is desired to preheat the water coming into a plant by 20 degrees F. To simulate this you are to design, build, and test a heat exchanger. This heat exchanger is supposed to heat the water coming from a cold water line. Consider the nominal flow rate of cold water to be four (4) gallons per minute. This cold water is to be heated with hot heat transfer fluid. Consider the heat transfer fluid to be at 650 degrees F.

The development of this course, ME462, Thermal Design, was described at ASEE [1] and the International Conference on Engineering Design [2] in 1987.

HEAT EXCHANGER DESIGN

The students design their heat exchanger during the first four weeks of the quarter. Examples of several different heat exchangers and different configurations are shown to the students during the first class period so they will be able to discuss alternative designs. The heat exchanger design for the prototype is supported by lectures during the first four weeks of the class.

When it is possible, within the time constraints of a design project, it is a good idea to perform a brief "run-through". This "run-through" gets every one focussed and the participants begin to ask the right questions. The "run-through" is done by testing a previously built heat exchanger. After testing the heat exchanger, the instructor goes through the calculations to determine the experimental film coefficients, estimate what the film coefficients are from the equations, and predict the performance of the heat exchanger when using the high temperature heat transfer fluid. While these are being done on the overhead, each group is expected to calculate the values from their test. This three day experience provides the student groups with a quick pass through the entire design, testing and prediction of the final performance of the heat exchanger.

The students then must estimate the film coefficients, calculate the overall heat transfer coefficient, and estimate the size of the heat exchanger. They must perform the calculations for at least two different configurations. Each group must purchase the parts for its design. Having the student

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roups purchase the parts of their design provides a very real economic incentive to keep the cost low. In addition to the Design report, they must write construction instructions and testing instructions. The Design report contains their design calculations and the supporting evidence for their design.

CONSTRUCTION

The construction instructions and materials for construction are passed to another group, which builds the heat exchanger. This technique forces the design group to finalize their design and stop making design changes. It has been my experience that when this transfer of responsibility does not take place, the design group never stops "designing" and "fiddling around" with their design. If the construction group has any problems, they have to contact the design group and settle the differences. This provides the opportunity for meaningful communications to take place and it doesn't go through the instructor. The construction phase takes two weeks, although most groups are able to perform the required construction tasks in 4 to 6 hours.

TESTING

The device is then passed to a third group for testing. Although the heat exchanger is designed to be used with a heat transfer fluid as the hot fluid of about 600 degrees Fahrenheit, it is tested with hot water for safety and economic reasons. The testing takes place in a laboratory on a testing setup which was designed for testing heat exchangers. This test setup includes four RTD temperature probes and four digital readouts to measure the temperature in and the temperature out of both the hot and cold fluids. The setup also includes two variable area flow meters and four differential pressure gages to measure the pressure drop through the heat exchangers. The four differential pressure gages are two gages for low pressure drops and two gages for higher pressure drops. This test setup cost about $2500 for both the instrumentation and the assembly. this test setup has worked very well and has also been used as a demonstration in some other classes. It takes a group only about 30 minutes to test a heat exchanger, if it works well. One of the problems that is often encountered is leakage.

FINAL REPORT

The design group is then responsible for presenting and writing a comprehensive report which describes their design for a "real" heat exchanger which is to be used in the plant. This redesign portion is very important because it simulates the entire product realization process. This report also includes a comparison of the film coefficients which are obtained from the test results to the values of the film coefficients they used to design and size the heat exchanger. The final report also re considered.

The oral presentation is video taped. Each student must view the video tape and then write a one page memo which suggests improvements the student could make individually and improvements the group could make on their "next" presentation.

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This is done because our senior students are very busy, and it seems that if they can select their own groups then they can set meeting times more easily and start to work together effectively quite quickly.

Several things are shown in Figure 2. First of all, each student has a leadership assignment. For example, in the group, Penguins, Curtis is the "manager" during the design phase. Mary is in charge during construction, and Jay is the "manager" during the testing. Being the "manager" or being in charge does not mean doing all of the work, it means calling meetings and organizing that activity. In the case of the three person group, all students are responsible for the final report, whereas in four person groups, an individual is assigned to that task. The students also choose which task they will "manage". The figure also shows how the heat exchanger is "passed on". The heat exchanger which is designed by **Paragon** is then constructed by **Penguins,** and is finally tested by the group **Indecisive**.

Design Groups			**Construction Groups**			**Testing Groups**
Paragon Ht Ex		---->	**Penguins**	---->	---->	**Indecisive**
Heath		Design				
Robert		Construction				
Nellie		Testing				
Sam		Final Report				
Penguins	---->	---->	**Indecisive**	---->	---->	**Paragon Ht Ex**
Curtis		Design				
Mary		Construction				
Jay		Testing				
All		Final Report				
Indecisive	---->	---->	**Paragon Ht Ex**		---->	**Penguins**
Jason		Design				
John		Construction				
Brad		Testing				

Figure 1. Hypothetical Organization of the Design, Build, Test Assignments

Another unique feature of the course is the fact that the students are allowed to choose what proportion of their grade is made up of the three components of the class, tests and final, project, and homework. The test and final grade can vary between 35% and 60%, the project portion can also vary between 35% and 60%, and homework can vary between 5% and 15%. This gets the students

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vary between 35% and 60%, and homework can vary between 5% and 15%. This gets the students actively involved in their own education. Proportioning the grades this way is quite easy to do on a spreadsheet. The students make their selection during the tenth week of the quarter.

CONCLUSION

Each group had to design, build, and test a different heat exchanger. This technique made the student groups "stop designing" and pass the device on to the "shop" to build it. This also encouraged inter-group communication and let the group members see first hand the good and bad points of other designs. Students liked the realism of the design, build, test sequence. Seldom do students learn about heat transfer fluids, so using a heat transfer fluid to supply the heat source broadened their experience. This design, build, & test project provides students with a realistic done in this period of time if industrially sponsored projects are utilized. This academic project provides the students with an experience that is more complete and more efficient (in terms of time spent) than can be provided by a "real world" project.

BIBLIOGRAPHY

[1] Dekker, Don L., "Communication, Curiosity, Confidence, Creativity and Competence: Five Essentials in Thermal Design, ME 462", 1987 ASEE Annual Conference , Reno, Nevada

[2] Dekker, Don L., "Communication, Curiosity, Confidence, Creativity and Competence: Five Essentials in Thermal Design, International Conference on Engineering Design 1987, Boston, MA

BIOGRAPHICAL INFORMATION

Don Dekker, Professor of Mechanical Engineering, teaches Thermal Design at Rose-Hulman Institute of Technology. Some of the other courses he is involved with are Internal Combustion Engines, Mechanical Engineering Laboratory, Kinematics, and Fundamentals of Engineering Management. He has been active in ASEE and was Zone II Chairman and Chairman of the Design in Engineering Education Division. His Ph.D. is from Stanford, his Masters from the University of New Mexico and he earned his Bachelors from Rose Polytechnic Institute.

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COURSE ORGANIZATION

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