Teaching Fire Protection Engineering Within the Mechanical Engineering Curriculum

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Introduction

As Canada and other countries begin to introduce objective and performance-based building codes, which allow more flexibility in design, interest in fire protection engineering has increased. Fire protection engineers work in industry, research organizations and fire departments to prevent fires from occurring as well as to limit the consequences of fires that do occur. This is a multi-disciplinary area, relying on all branches of engineering, as well as other sciences. For example, a fire protection engineer should have a working knowledge of many areas, including heat transfer, combustion, structural engineering, fluid mechanics, chemistry and human behaviour.

To meet the need for individuals in this field, courses or programs in fire protection engineering have been developed. Many of these are full undergraduate or graduate programs. However, it is also becoming increasingly important to expand fire protection engineering education to programs in mechanical engineering and other traditional disciplines. For example, it is important for mechanical engineers who work in the design of building systems to have a working knowledge of fire protection engineering, so that they can develop effective systems for smoke control in buildings.

In order to integrate fire protection engineering within the mechanical engineering curriculum, several challenges need to be overcome. This paper will focus on how these challenges were addressed in a fire protection engineering technical elective currently offered in the Department of Mechanical Engineering at the University of Saskatchewan. The paper will first briefly describe the extent of fire protection engineering courses in Canada, along with the development of this course. The content of this course and the challenges to offering it at this university are then described, along with how I have addressed these challenges. This discussion will include a description of instructional technology used in this course and how partnerships with the local fire department and the university fire safety office have been developed in order to allow students to access the facilities and expertise of these groups. As I am developing my own fire science research laboratory on campus, future plans to integrate these facilities into my course will also be discussed. As other mechanical engineering departments may be interested in offering fire protection engineering courses in the near future, information on readily available print, internet and other resources that can be used in these courses will also be provided.

Fire Protection Engineering Education in Canada

Around the world, well-established fire protection engineering programs include those at Lund University in Sweden, the University of Edinburgh in Scotland, the University of Maryland and Worcester Polytechnic Institute in the U.S., and the Victoria University of Technology in Australia. Representatives from some of these programs published an article in 1995 that defines the general areas of engineering and specific courses, which they felt should be included in fire protection engineering programs[1]. The International Association of Fire Safety Science (IAFSS) maintains a list of links to these and other fire protection engineering education programs on their web site[2]. The association's web site also contains a link to its education subcommittee, which is developing a web site where educators can share material from their courses with instructors at other universities.

Fire protection engineering courses and programs were first offered in Canada during the 1980's, and the first complete fire protection engineering graduate program was offered at the University of British Columbia (UBC) in September 1994. Currently, there are four universities in Canada offering undergraduate or graduate engineering courses or programs in fire protection engineering: Carleton University, Concordia University, the University of Saskatchewan, and the University of Waterloo. These courses or programs are described in a recent article in *Canadian Consulting Engineer*[3].

Many of the provincial associations that license engineers in Canada are in the process of implementing continuing education requirements for their members. In the fire protection engineering area, technical societies offer short courses and other educational opportunities which practicing engineers can use to fulfill these requirements. For example, the Society of Fire Protection Engineers (SFPE) has been offering an increasing number of courses on the fundamentals of fire protection engineering. Over the last several years, the National Fire Protection Association (NFPA) has changed the format of their annual meeting, so that educational sessions feature relatively long presentations (e.g., 60 to 90 minutes), for which participants receive continuing education units.

History of This Course

This course has now been offered three times. In the Fall of 1999, I taught the course once a week as a part-time instructor at Concordia University in Montréal, while working at the National Research Council of Canada's (NRC's) National Fire Laboratory in Ottawa. I traveled to Concordia's campus in downtown Montréal once a week from Ottawa, for a lecture and for office hours. The students also traveled to Ottawa for a tour of NRC fire test facilities, and a guest lecture by one of my colleagues. During their visit, the class was able to witness one fire suppression test, and to see a wall specimen before and after a fire test. Twenty-seven students, 15 undergraduate and 12 graduate, took the course, some of which were practicing engineers. A summary of the content of this course and a discussion of its delivery can be found in an earlier paper[4].

In July, 2000, I moved to the Department of Mechanical Engineering at the University of Saskatchewan, where I have taught Introduction to Fire Protection Engineering twice as a Special Topics in Mechanical Engineering technical elective to our 3rd and 4th year students. As demand has been strong (the number of students taking the course has increased from 18 to 26, which is relatively high for one of our technical electives), the course has now been added to our list of regularly scheduled technical electives in the university calendar.

Course Content

For the most part, the topics covered in this course have remained unchanged during the three times it has been offered. As the content is described in detail in an earlier paper[4], and the focus of this paper is the delivery of the course at the University of Saskatchewan, the content will only be briefly described in this paper. The following overall objectives are communicated to the students in the course syllabus:

> "In general, students will learn the basics of fire science, including important theory from heat transfer, fluid mechanics, themodynamics and other fields. Students will learn how to use simple fire models to design fire protection systems for buildings, such as sprinklers, detectors and building construction features. They will also learn about the main fire test methods in use today, and how to analyze data from these tests."

The specific topics covered in the course are shown in Table 1. These topics have been chosen in order to provide the students with a broad overview of fire protection engineering. In the process of developing the course outline, I also examined the content of other fire protection engineering programs and the recommendations by the authors of the paper describing a model curriculum in fire protection engineering[1]. Most of the topics in the course are also presented in the same order as in the course text, *An Introduction to Fire Dynamics*[5], which is one of the few fire protection engineering textbooks available today. In addition to the course text, other references are used, such as Canada's National Building and Fire Codes[6,7], fire safety standards and guidelines used in industry[8,9], and research and engineering practice resources available on the websites of university, government and private fire research laboratories. In addition to the overall objectives, I also provide the students with a list of 27 specific objectives for the course, which I use to evaluate the performance of the students during assignments and exams.

Table 1. Topics Covered and Methods of Delivery Used in This Course

Topic	Methods of Delivery
Overview of fire protection engineering: • historical background • fire statistics • building and fire codes	Lectures Videotapes: • Prof. Torvi's fire science research • NRC research program
Combustion: • heat release rates of fires • combustion chemistry • flame temperatures, flammability limits	Lectures
Fire Testing	Lectures Videotape: • fire testing
Heat Transfer in Fires • conduction, convection, radiation • spatial separation between buildings • transient conduction heat transfer	Lectures Videotape: • *Setting Fires for Science*[10]
Fire plumes • fluid dynamics • response of detectors/sprinklers	Lectures
Human behaviour in fire	Videoconference guest lecture
Fire department operations and fire protection systems in buildings	Tours: • Saskatoon Fire Department • buildings on campus Videotape: • *Fires of Kuwait*[11]
Fire growth • piloted and spontaneous ignition of solids • steady burning and flame spread • preflashover and postflashover fires • fire resistant construction • computer fire models	Lectures Videotape: • fire test of mattress – from ignition to flashover
Smoke movement • characteristics of smoke • smoke detection • smoke control design calculations	Lectures
Objective-based building codes	Videoconference guest lecture

Challenges in Offering This Course

In order to integrate fire protection engineering within the mechanical engineering curriculum, several challenges need to be overcome. Much of fire science is still experimental and there are very few fire research and testing facilities, most of which are in government and industrial research laboratories. While I had access to one of the world's best fire research laboratories when I taught the course at Concordia University, I have limited facilities here at the University of Saskatchewan, as I am just beginning to equip my laboratory space. As fire science is multi-disciplinary, it is difficult to find the expertise in all areas within fire science outside of government research institutes and universities that offer compete programs in this area. This problem is magnified in a geographic location such as ours. For example, I am the only member of the Society of Fire Protection Engineers in our province, whereas Canadian cities such as Ottawa, Vancouver and Toronto, have their own local chapters. Much of the literature in this area is in specialized journals, which may not be available at all university libraries. For example, our university subscribes to only one of several major journals in this area. It should be noted that many of the challenges in offering this course are similar to those faced in integrating other emerging areas, which require specialized equipment and expertise, into the mechanical engineering curriculum. For example, many universities are beginning to add courses and programs in nanotechnology, which has meant hiring new faculty and adding new laboratory equipment.

Table 1 indicates some of the delivery methods I have used in the course, including lectures, videotape presentations, videoconference guest lectures and tours. For the remainder of this paper, I would like to describe how I have been addressing the challenges of teaching a course in fire protection engineering in our Department of Mechanical Engineering. This has involved different forms of instructional technology and partnerships with the local fire department and the University of Saskatchewan fire safety office. As the intent of this paper is to demonstrate how a course in fire protection engineering can be implemented in any mechanical engineering program, I will also provide information on resources that are widely available, which can be used in an introductory course in fire protection engineering.

Videotape

Fire science certainly leads itself to visual aids. However, from our own experience we know that there is also a difference between seeing a picture of a campfire and feeling the thermal radiation and sensing the smoke from a campfire. As mentioned in the description of the term this course was offered at Concordia University, having access to a fire research laboratory allowed me to have the students witness one fire test and to see the small and large-scale facilities used in other fire tests specified in industry. As I am just beginning to assemble some small-scale test facilities here at the University of Saskatchewan, I have had to rely on videotape of fire tests to help the students to gain an appreciation for these facilities and for the growth of a fire.

During the introductory part of the course, I show the students videotape of fire tests that I have been involved in during my research career, first as a graduate student at the University of Alberta, and then as a researcher at NRC. These include measuring the heat fluxes during a house explosion, full-scale testing of protective coveralls using an instrumented thermal mannequin, and determining the rate of growth of a mattress fire in a small room. The latter test also helps the students to gain an appreciation for the speed at which a fire can go to flashover, the stage at which everything combustible in a room will ignite, and all occupants of the room will almost certainly be dead. Therefore, I repeat this videotape later in the course when we discuss how to measure the energy released by a fire (the heat release rate) and the speed of fire growth. The students are also asked to calculate the heat release rate using fire test data on one of their assignments.

Videotapes, which illustrate research by my former colleagues at NRC and in other fire laboratories around the world, are also shown during the course. Areas of research include human behaviour and smoke movement. I also show the students two films: *Setting Fires for Science*[10] and *Fires of Kuwait*[11]. The former documents research conducted in Canada in the late 1950's, which is still used as the basis of regulations for the distance buildings must be spaced apart to avoid fire spread. A description of this research program can also be found in the fire science literature[12]. The latter film describes oilfield firefighting after the Gulf War, and also helps the students to gain an appreciation for the structure of large fire plumes.

While an instructor developing a new fire protection engineering course in another mechanical engineering department may not have been involved in full-scale fire testing during their career, there are a number of other resources that are readily available, which can be used to provide students with an appreciation of fire growth and fire tests. The National Institute of Standards and Technology (NIST) in the U.S. maintains a website[13], which includes still pictures, data and video of fire tests of common consumer products and other materials, including furniture and mattresses. These videos can be viewed in class or downloaded by students at their leisure. Assignment problems can also be developed which require the students to analyze the test data from the NIST website in the same way that test data from a standard fire test is analyzed in industry or a test laboratory. The two films discussed above[10,11] are also available for purchase from the National Fire Board of Canada and the IMAX Corporation, and therefore, can be included in a course in any mechanical engineering department.

Videoconference Guest Lectures

As mentioned in the introduction, fire science is a multi-disciplinary area. In order for students to learn about other areas of fire science from those that I work in, I have arranged videoconference guest lectures with former colleagues from NRC. We have used both the videoconference facilities at our university and those at NRC's Plant Biotechnology Institute (PBI), which is located about a five-minute walk from our engineering building.

Guest lectures dealt with human behaviour in fire and the transition to objective-based building codes in Canada and around the world. Both NRC researchers are internationally recognized in their particular fields. For example, Dr. Guylène Proulx, who lectures on human behaviour in fire, has participated in studies of the response of occupants during the incidents at the World Trade Center in 1993 and 2001. Both speakers forwarded copies of their presentations to me in advance, so that copies of their slides could be distributed to students. This was necessary, because it was difficult for the camera in Ottawa to show both the speaker and the screen with their slides at the same time. While the university's videoconference studio is set up as a classroom, the PBI facility was designed for videoconferences with about 10 people or less. Therefore, the camera could not pick up all of the students at the same time. Because many of the students would have to physically move to in front of the camera and microphone in order to be seen and heard by the guest lecturers, students were asked to save their questions for a question and answer session at the end of the lecture. Therefore, the guest lectures were closer to conference presentations than regular lectures.

After the videoconferences were completed during the first offering of the course at the University of Saskatchewan, the students were asked for their feedback using a survey, which was completed during the next scheduled lecture. Students were asked to quantitatively assess different features, and to provide written comments. They were asked about the effectiveness of the guest lectures, different technical aspects of the broadcast and organization of the lecture, and to compare the videoconference guest lectures with regular lectures. They were also asked for specific suggestions as to how to improve the videoconferences, and if they felt that these were worth continuing next year. Students unanimously agreed that these videoconferences were useful and should be continued. They agreed that having a copy of the speaker's slides was essential. They also provided suggestions, which could be incorporated into future videoconference presentations.

While instructors in other mechanical engineering departments may not have access to researchers specializing in human behaviour in fire, there may be a number of individuals in any community who can address the transition to objective-based building codes in the jurisdiction in which each particular university is located. Consulting engineers or building officials can speak to students about how the current building code is used in fire protection engineering design, and how any impending changes to building codes will affect local consulting and construction companies, building owners and building inspectors. Besides local engineering associations, technical societies, and building code authorities, organizations such as NFPA and SFPE may be able to provide assistance in locating individuals with particular expertise who would be willing to speak to students in a fire protection engineering course.

Partnerships with Other Fire Safety Organizations

In order for the students to learn about the importance of taking into consideration fire department operations when designing buildings, and to see first hand fire protection systems in the field, tours have been arranged with the City of Saskatoon Fire Department and the University of Saskatchewan fire safety office. The Saskatoon Fire Department has hosted the students at their main fire hall, and students have an opportunity to see the apparatus, training facilities and the 911 communications center for the city. They have also been able to see new technologies used in the fire service, such as thermal imaging cameras used to locate people and hot spots in buildings. While very few students would be expected to join the fire service after graduation, the tour affords the opportunity to remind the students of the importance of taking into consideration the needs of the fire department when designing a building. For example, the fire department has made some specific suggestions to students on useful design features of buildings. Seeing the apparatus has also helped the students gain an appreciation for the space that the fire department would need in front of a building should there be a fire. A similar tour could also be arranged with the local fire department for students in mechanical engineering departments at other universities.

The individual in charge of fire safety at the University of Saskatchewan has spoken to the students about the roles of their office, including conducting building inspections and testing fire safety equipment. This provides the students with an appreciation of how operating procedures in buildings are developed in accordance with local bylaws and relevant fire codes. The students are also taken to the main sprinkler control room in one of the larger buildings on campus in order to see the pumps and other equipment included in fire protection systems in large buildings. The students have also had an opportunity to tour the Canadian Light Source synchrotron facility, which is being built on our university campus. Part of this tour includes the mechanical rooms, and a brief discussion of fire safety equipment in this building, which is about the same size as a domed football stadium. Similar tours of fire protection systems on campus could also be arranged with fire safety departments at other universities.

Other Resources

In addition to these activities, the world wide web is also utilized extensively in this course. National fire laboratories, such as NRC and NIST now put most of their technical reports on their websites.[13,14] This has significantly helped to improve access to the fire science literature at universities, such as ours, that currently have limited collections in fire science. For example, besides the video, still pictures and fire test data mentioned above, NIST's website also contains a searchable database of the fire science literature. One of the other major parts of their site contains a description of a number of computer fire models developed at NIST, including reports outlining their theory, case studies, and sample results (including animations). A number of these models can also be downloaded free of charge from their site. Computer fire models will be discussed further in the section below on future plans for the course.

Assessment of the Course

So far, this course has only been assessed formally using our department's standard course and instructor evaluation form. As mentioned above, a survey was also conducted of the students in the class after the videoconference guest lectures during the first time the course was offered at the University of Saskatchewan. Feedback from these evaluations has been positive. Other informal assessment methods indicate that the course has increased interest among our students in the area of fire protection engineering. As mentioned above, the demand for the course continues to increase. By the fall of 2002, two of the students who have taken this course at the University of Saskatchewan will be enrolled in graduate programs with a fire science thesis research topic, while another student will have completed their second summer of work as a student research assistant in my fire science laboratory. Other students have begun inquiring about student internship or permanent positions with consulting engineering companies that specialize in the fire protection engineering area.

Conclusions and Future Plans for the Course

Although many challenges remain to be addressed in offering courses in fire protection engineering in mechanical engineering departments, advances in technology have made it easier to offer an introductory course in this area. While watching a videotape of a fire test is far different from observing a test first hand, videotape still gives the students an appreciation for the growth of a typical fire and the speed at which fire can severely affect people and structures. Videoconference facilities allow students to hear first hand from world-class researchers, and tours of local fire department facilities and campus buildings provide an appreciation for some of the factors that are important in designing fire protection systems. The world wide web has increased access to important information for students, researchers and practicing engineers, especially in locations that do not have extensive fire science holdings in their libraries.

This course is continuing to evolve. Suggestions made during formal and informal evaluations have been considered, along with ideas generated during my own self-assessment of the course. Developments in technology will soon allow the students to attend videoconference guest lectures in any room in our engineering building with a network connection. Ultimately videoconference and other technology may also allow us to partner with other universities with fire protection engineering programs in order to offer follow up courses in this area to interested students.

As this course becomes part of our regularly scheduled list of technical electives, we are also adding a laboratory component to the course. While some of the laboratory sessions will be used for tours and guest lectures, others may involve computer fire models. This could involve downloading the models from the NIST website and using these models to solve assignment problems. Information on possible laboratory exercises using these models can be found in Karlsson and Quintiere[15].

The laboratory portion of the course will also involve small-scale fire tests of materials. Currently I have equipment for conducting standard small-scale tests of fabrics used in protective clothing. As I am preparing applications for grants to purchase other equipment for my own fire science laboratory, I hope to be able to continue to increase the number of different small-scale fire tests that students will be able to witness first hand during this course. Most importantly, conducting experiments will provide students with opportunities to better appreciate the effects of fire (at a safe distance, of course).

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This paper is dedicated to the memory of my father, Allan Torvi, who passed away in April, 2001. He was a professor in the Department of Mechanical Engineering of The University of Calgary from 1969-1997, and was active in the Pacific Northwest Section of ASEE. His example as an engineer and as an educator has been and will continue to be an inspiration, not only to me, but also to countless former students and colleagues.

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