AC 2008-52: FIRE PROTECTION AND SAFETY MANAGEMENT: TWO PARTNERSHIP PROGRAMS

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Fire Protection and Safety Management: Two Partnership Programs

Abstract

Two four year engineering technology programs were recently developed and implemented at our university: 1) Safety and Fire Protection and 2) Safety Management. Safety and Fire Protection is a Bachelor of Science in Engineering Technology degree (BSET) degree while Safety Management is a Bachelor of Applied Arts and Sciences degree (BAAS). The BAAS degree was developed to allow community college graduates holding an Associate of Applied Science (AAS) degree rather than the Associate of Science (AS) degree the opportunity to continue their college education and earn a 4-years bachelor degree.

Introduction

This paper describes two engineering technology programs that were recently developed and implemented at our university: 1) Safety and Fire Protection and 2) Safety Management. Safety and Fire Protection is a four-year Bachelor of Science in Engineering Technology degree (BSET) while Safety Management is a four-year Bachelor of Applied Arts and Sciences degree (BAAS). The Safety and Fire Protection program was designed to satisfy the need for scientific and engineering knowledge in all aspects of fire in order to avoid human and physical losses due to the destructive nature of fire. In the United States and more specifically in the State of Texas, there is an immense deficiency on technical training in fire. In a recent fire conference in Beijing, China, there were hundreds of representatives from Europe, Asia and the Australian continent but only a handful from the United States. There are only five university programs in the field of fire protection in the U.S. Recent losses due to fire in the United States (12,000 lives and $11 billion dollars) are described in the report by The National Commission on Fire Prevention and Control, “Burning America”, Washington DC, 1973.

Safety Management deals with the development and implementation of procedures to avoid accidents in the workplace. The United States is a world leader in the field due to organizations that develop procedures and establish obligatory standards such as the Occupational Safety and Health Administration (OSHA), which is the main federal agency charged with the enforcement of safety and health legislation in the workplace.

The two programs are concerned with losses to society but their methodologies are completely different. Fire Protection is based on the application of the scientific principle to the study of fire phenomena while Safety Management deals with the application of laws and regulations to the prevention of human losses in the work place.

The State of Texas Legislature concerned about lack of training in fire protection established a tuition aid program for university students in the field of fire science. The Chief of the Houston Fire Department considering the scarcity of fire protection engineers in the Houston Area

requested the Chair of the Board of Regents of the University of Houston System to develop a program in fire protection engineering technology. The Engineering Technology Department at the University of Houston-Downtown (UHD) was assigned the task of developing the program, which was not an easy task considering the scarcity of model programs and the difficulties of recruiting qualified faculty. Thus, the Bachelor of Applied Arts and Sciences (BAAS) degree was designed to allow community college graduates holding an Associate of Applied Science (AAS) degree rather than the Associate of Science (AS) degree the opportunity to continue their college education and earn a 4-years bachelor degree. The Associate of Science (AS) degree is awarded by community college programs and is intended for transfer to a four-year college or university, usually with a major in the sciences, mathematics, or engineering while the Associate in Applied Arts and Sciences (AAS) degree is awarded to students who include more practical training in their program area and are allowed to reduce some of the general education requirements. This degree is for students who intend to enter the work force upon graduation and is considered a community college terminal degree. Our BAAS program is a terminal bachelor degree and was developed under the "Closing-the-Gaps" state goal of expanding higher education opportunities. Holders of the AAS degree find themselves in a difficult situation when they hold a position in industry that requires a bachelor's degree for promotion to upper levels, a situation in many fire and police departments. This situation is also common in the energy related sector of the Houston Area where high school graduates select a two-year terminal community college program (the AAS) to work in very demanding jobs with lucrative salaries. Some years latter, due to their success in industry they have the opportunity for career advancement. However, they find an obstacle: the lack of the bachelor's degree.

The government entities of the State of Texas became concerned with this situation and requested that the board of governors of the state universities develop bachelors programs (BAAS) to give employees in this situation the opportunity for progress in their careers. The president of the University of Houston-Downtown requested all departments to develop applied (BAAS) programs of high demand. The Engineering Technology Department developed and implemented the first such program in record time and is already graduating students.

Both programs are examples of partnership efforts between local community organizations and our university responding to community needs. Fire protection includes training for individuals responsible for design of systems to reduce losses due to fire; while safety management trains students to follow established procedures to avoid losses in the work place. Both programs are critical for stability and future development of Houston area industry.

This paper describes the two programs, the history of the programs, the partnership with the local community, and the modern educational technologies used to train students in the fields of fire protection and in safety. The characteristics, objectives, facilities and instructional methods of the Fire Protection program are presented with more detail than those of the Safety Management program because the latter one is in its initial stages of implementation. However the Fire Protection program can be seen as road map for future development of Safety Management at the University of Houston-Downtown.

The official academic names of the programs make the presentation of their specific characteristics difficult because the word Safety is included in both names while Protection is

not. For the purpose of this paper Safety and Fire Engineering Technology is referred as Fire Protection.

Program Objectives

The Fire Protection program (BSET) was established to develop fire protection engineering technology professionals that are scarce in the Houston Area. There are three types of students in the program: The first group is made of members of the fire services that take advantage of the Texas tuition exemption established for them by the state legislature. These students are familiar with the physical techniques to fight fires and come to the university to learn the scientific principles of fire protection in order to become well rounded professionals. The fire departments also give special consideration to these students at the time of promotion. The second group is composed of engineers in other branches of the profession such as civil, chemical, and mechanical engineers that seek a background in fire protection. Members of the group are typically rewarded by higher salaries and career advancement. It is important to observe that for these students it only takes around thirty semester credit-hours to complete the degree requirements because of their engineering background. The last group is composed of students that come in as freshmen or transfer from community colleges. Typically, they have some background in fire and want a degree in the field. Students in this group as well as the fire fighters are fascinated with the field of fire protection and come from families of fire fighters because it is well said that interest in fire protection "runs in the family".

Students of the program have gain national recognition and scholarships for outstanding performance in their studies. They also provide national exposure to the Fire Protection program in professional environments such as NIST, FEMA, and participation and presentations at professional conferences and symposiums.

There is a chapter of the Society of Fire Protection Engineers (SFPE) on campus that establishes contact with the society at local and national levels. The Houston chapter of SFPE meets on campus once a year to share professional information and attend student presentations.

The objective of the Safety Management program is to train students in the field of safety at the work place. These students seek the opportunity to become experts in the field of safety in the organizations for which they work. Furthermore, they have the opportunity to receive a bachelor's degree rather than been limited to holding an associate's degree.

The safety program graduated students for the first time in 2007 and is a very young program. As the program develops it will also develop student chapters associated with professional societies in the field.

Program Description: Fire Protection

The scarcity of faculty in the field of fire protection forced the faculty members of the engineering technology department to adopt creative alternatives. A strong relationship was established with the Worcester Polytechnic Institute (WPI), the academic institution with the highest reputation in fire protection engineering in the country, to get advice and training. The

department chair spent a summer at WPI studying fire dynamics, the curriculum of fire protection and conducting numerous interviews with the director of the program and other members of the WPI faculty. The cooperation and advice of WPI was critical for the development of the fire protection program at UHD.

Engineering technology programs are laboratory work intensive in order to provide students with practical experience. Developing fire laboratories that are called "burning houses" is close to impossible in an urban university such as UHD. Under the guidance and experience of WPI a critical decision was made: to develop a fire protection program based on computer simulation.

There were several factors that contributed to the successful implementation of the fire protection program. Further description of these factors helps to understand fire protection and its role in society, clarifies its methodology and indicates future developments for the profession and the fire protection program. The factors to be considered are herein described.

Performance-Based Fire Protection

There are two distinct approaches to fire protection: 1) Fire Codes and 2) Performance-Based fire protection. The best way to illustrate the difference between those two approaches is to use an analogy taken from the field of electricity. In designing the electric circuit for a residence the electrician follows codes that specify the minimum wire gages to be used for the circuits without performing analysis or considering other alternatives. This is code-based electric circuit detailing.

On the other hand, an electrical engineer will consider power requirements of the components of the circuit, run computer simulations using software tools and will reach an alternative that will satisfy power and safety requirements at minimum cost for the owner. This is performance-based electric circuit design. Performance-based electric circuit design is typically used for residential and commercial buildings and also for industrial plants and factories.

The analogy translates well to fire protection engineering. In code-based fire protection the different components of the building are selected according to fire ratings and codes specifying the time that the components will last under fire. But there is no consideration of alternative scenarios or conditions. This approach is economically and technically inefficient. Cost minimization without consideration of alternatives is an impossible goal. At the present time there are technologies and methods of analysis that can yield systems with improved fire performance at lower costs.

Performance-based is so common in other fields of engineering that it is difficult for engineers to understand that this is a recent approach in fire protecting. In performance–based fire protection the facility under consideration is analyzed under different fire scenarios using simulation to determine if the goal of protection of lives is accomplished[1].

Performance-based fire protection design of a room consists of the following steps:

- First, the geometry of the room including dimensions, windows and doors together with determination of the fire characteristics of all construction materials used for walls, ceiling, and floor must be defined.
- Second, the planed utilization of the room and its contents such as carpets, furniture, appliances, books, curtains and clothes must also be defined. The majority of contents in a residential room are combustibles, fuels that determine the fire load of the facility[2].
- Third, location and characteristics of fire sprinklers is determined.
- Fourth, possible fire scenarios and simulation of the different stages of the fire including flashover, the situation in which all combustible materials in the room different from the original fuel seem to explode at the same time, need to be considered.

Survival of the occupants of the room may be predicted using the results of the simulation. If the simulation indicates low probability of survival, the variables defining the behavior of the room can be modified to obtain satisfactory results[3].

Performance-based fire protection studies are used extensively in the analysis of fires with significant loss of lives to determine responsibilities and also to design better facilities and avoid repetition of tragedies. A good example of post-fire analysis performed by NIST is the incident in a night club in West Warwick, Rhode Island where ninety-six people died in a fast-moving fire. The simulations were used to show that most casualties would have been prevented with the installation of fire sprinklers.

NIST Building and Fire Research Laboratory

The Building Research Laboratory of NIST is an organization of the federal government with a mission: To promote U.S. innovation and competitiveness by anticipating and meeting the science, standards, and technology needs of the U.S. building and fire safety industries in ways that enhance economic security and improve the quality of life. And a vision: To be *the* source for creating critical solution-enabling tools (metrics, models, and knowledge) and promoting performance-based standards that are used by the U.S. building and fire safety industries to establish global leadership.

The results of this mission and vision are well presented by the Fire Dynamics Simulator (FDS) which is today the workhorse of fire protection in the United States and in many other countries[4]. It is difficult to find any other branch of engineering where its main tool of analysis and design is developed and maintained free of charge by the federal government. The Fire Protection program at UHD is based of FDS for all courses directly related to fire.

Fire Protection through Computer Simulation: FDS and Other Fire Models

FDS, the Fire Dynamics Simulator is a remarkable computer program that starting with the physical and chemical characteristics of the fuel and also taking into consideration the geometry and materials of the burning environment, tries to predict the behavior of the fire and present it in a graphical way that permits comparison with the real fire.

The idea that the dynamics of a fire might be studied numerically dates back to the beginning of the computer age. Indeed, the fundamental conservation equations governing fluid dynamics, heat transfer, and combustion were first written down over a century ago. Despite this, practical mathematical models of fire (as distinct from controlled combustion) are relatively recent due to the inherent complexity of the problem. Indeed, in his brief history of the early days of fire research, Hoyt Hottel noted "A case can be made for fire being, next to the life processes, the most complex of phenomena to understand" [5].

The difficulties revolve around three issues: First, there are an enormous number of possible fire scenarios to consider due to their accidental nature. Second, the physical insight and computing power required to perform all the necessary calculations for most fire scenarios are limited. Any fundamentally based study of fires must consider at least some aspects of bluff body aerodynamics, multi-phase flow, turbulent mixing and combustion, radiative transport, and conjugate heat transfer; all of which are active research areas in their own right. Finally, the "fuel" in most fires was never intended as such. Thus, the mathematical models and the data needed to characterize the degradation of the condensed phase materials that supply the fuel may not be available. Indeed, the mathematical modeling of the physical and chemical transformations of real materials as they burn is still in its infancy. In order to make progress, the questions that are asked have to be greatly simplified[6].

To begin with, instead of seeking a methodology that can be applied to all fire problems, engineers begin by looking at a few scenarios that seem to be most amenable to analysis. Hopefully, the methods developed to study these "simple" problems can be generalized over time so that more complex scenarios can be analyzed. Second, we must learn to live with idealized descriptions of fires and approximate solutions to our idealized equations.

Finally, the methods should be capable of systematic improvement. As our physical insight and computing power grow more powerful, the methods of analysis can grow with them.

Other Fire Models

In some courses in the Fire Protection program simpler models of fire are used to give students working knowledge of the variables determining fire behavior. To date, three distinct approaches to simulation of fires have emerged. Each of these treats fire as an inherently three dimensional process evolving in time. The first to reach maturity, the "zone" models, describe compartment fires. Each compartment is divided into two spatially homogeneous volumes, a hot upper layer and a cooler lower layer. Mass and energy balances are enforced for each layer, with additional models describing other physical processes appended as differential or algebraic equations as appropriate. Examples of such phenomena include fire plumes, flows through doors, windows and other vents, radiative and convective heat transfer, and solid fuel pyrolysis.

The relative physical and computational simplicity of the zone models has led to their widespread use in analysis of fire scenarios. So long as detailed spatial distributions of physical properties are not required, and the two layer description reasonably approximates reality, these models are quite reliable. However, by their very nature, there is no way to systematically improve them.

Figures 1 and 2 depict the simulation of a fire in a town house. Figure 1 shows development of smoke that is critical for survival and the dynamics of fire development. The development of the fire is tracked from small flames in a sofa, to flashover, where the town house seems to explode, and finally, the extinction stage of the fire.

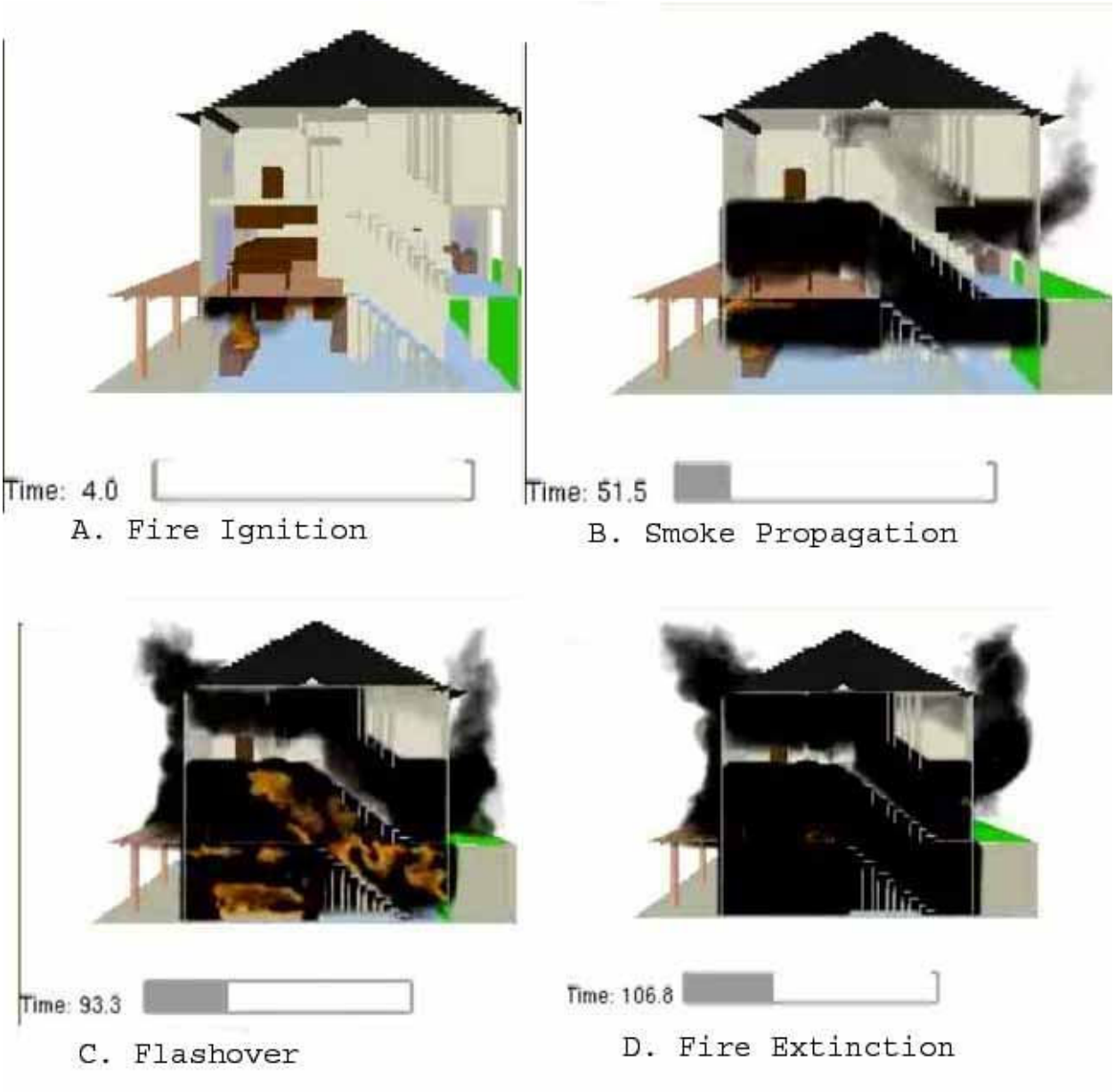

Figure 1. Simulation of a fire in a town house

Figure 2 shows the history of temperatures in the town house from ignition to extinction. Temperatures are high at the ceiling and low at the floor at the initial stages. At flashover the

temperatures are very high, around 300 degrees centigrade throughout producing ignition of at contents of the rooms.

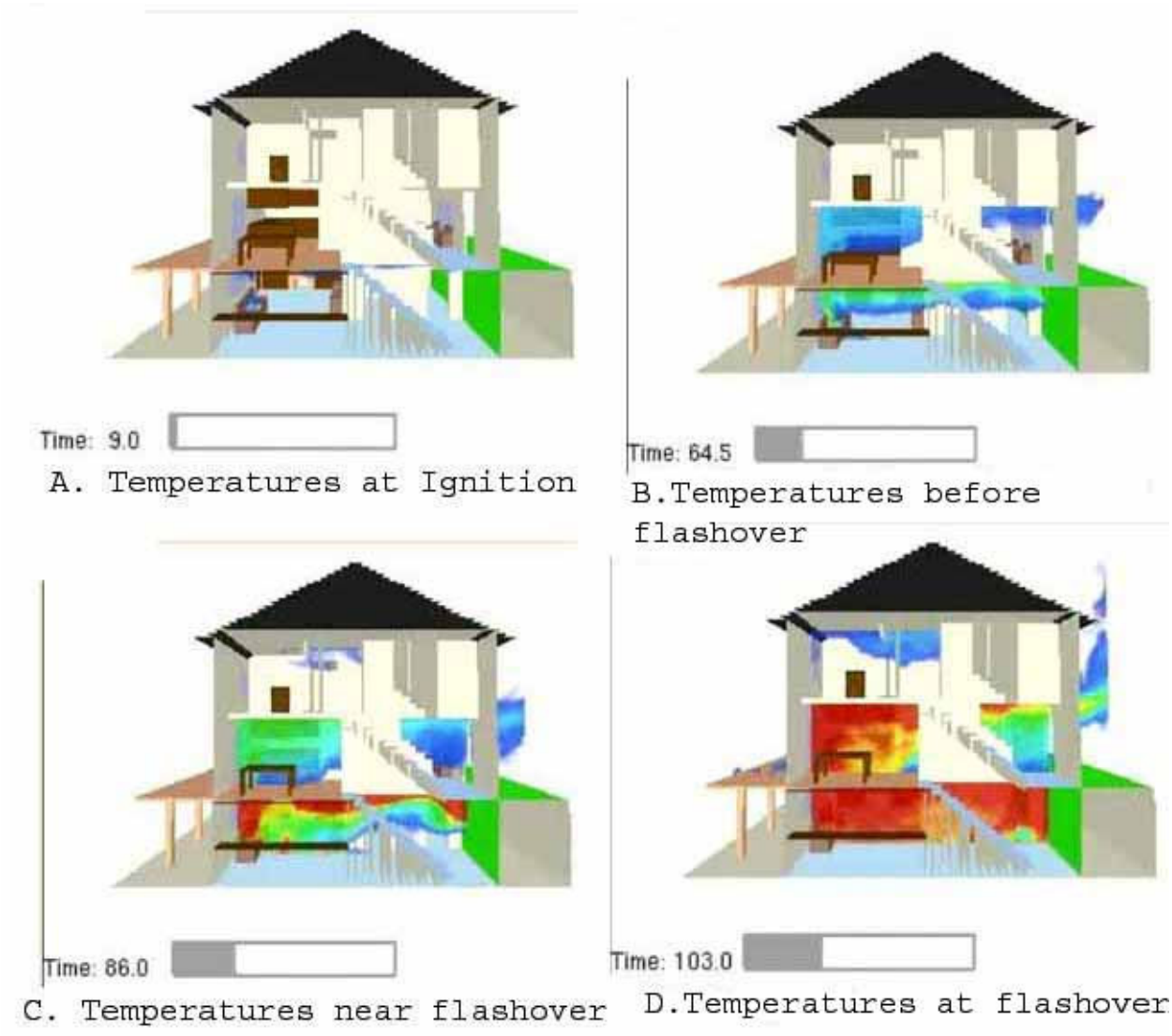

Figure 2. History of temperatures in the town house from ignition to extinction

The times in the figures are real times. They indicate for instance that at 51 seconds, less than a minute after ignition of the fire, the townhouse is completely filled with deadly smoke in the two lower floors which indicates the need to escape in less that a minute. Flashover occurs approximately at 1.5 minutes after ignition. At this stage of the fire there is no possibility of survival for the occupants.

Fire protection engineers have always been in demand by corporations, consulting firms, educational institutions, government bodies within the United States and demand around the world is constantly growing. Houston area petrochemical, oil refining, and energy industries have special safety and fire requirements due to their large concentration of installations, and

therefore, place a premium on Fire Engineering professionals. The Fire Engineering Technology program is structured to meet the needs of safety and fire personnel who desire a technical degree and professional advancement. It provides the graduate skills and knowledge of current trends in industrial safety, fire sciences and an overview of equipment operation in practice using computer simulations. In addition, graduates of this program are qualified for positions in fire departments and in industrial safety operations of petrochemical companies. All aspects of industrial safety and fire protection are included in the program courses. Fire Engineering Technology is based on scientific principles from several engineering disciplines, and combines thermodynamics, heat transfer, fluid mechanics, knowledge of the nature and characteristics of fire, with computer technology, to create highly sought after Fire protection professionals.

Fire Protection Engineering Technology (BSET) Requirements

Successful completion of the BSET requires the following courses:

General Education Core Requirements
ENGR 1400 PC Applications in Engineering
ENG 1302 Composition II
HIST 1305 US History to 1877
HIST 1306 US History after 1877
MATH 2401 Calculus I
PHYS 1307/1107 General Physics I with Lab
PHYS 1308/1108 General Physics II with Lab
POLS 2303 US Government I
POLS 2304 US Government II
PSY 1303 General Psychology
COMM 1304 Introduction to Speech Communication
ENG 3302 Business and Technical Report Writing
Fine Arts Fine Arts (three hours)
Literature (three hours, sophomore level or above)

Writing Proficiency Examination

Safety and Fire Engineering Technology Requirements:
Lower Division
CHEM 1307/1107 General Chemistry I with Lab
EET 1411 Electric Circuits with Lab
ENGR 2409 Engineering Mechanics with Lab
ENGR1402 Fire & Safety Hazard Recognition
ENGR1403 Fire Suppression & Detection Systems
ENGR 1404 Automatic Fire Suppression Systems
ENGR 1480 Occupational Safety Techniques
ENGR 2407 Surveying with GIS-GPS
ENGR 2410 Analysis of Engineering Networks

Upper Division
ET 3307 Applied Thermodynamics
ET 3308 Materials Science
ENGR 3311 Structural Analysis
ENGR 3308 Fluid Mechanics I
MGT 3301 Management of Organizations
ENGR 3302 Engineering Economics
ENGR 4370 Human Factors in Safety and Fire
ENGR 4410 Industrial Hygiene Instrumentation
ENGR 4420 Fire Dynamics
ENGR 4450 Industrial Safety
ENGR 4380 Security of Computing Systems
ET 4323 Technology Seminar

Electives (9 hours)
ENG 3302 and ET 4323 satisfy the W (writing) and S (to use of the skills learned in core courses to solve problems related to the major) application course requirements of the institution's General Education Program.

Safety Management (BAAS)

Students enrolled in the Safety Management program are exposed to the human and equipment aspects of safety. They are also trained in the ability to absorb new technologies generated by industry. The Safety Managements program taught by the Engineering Technology Department develops personnel able to apply the most modern technologies to assure the safety operation of current enterprises. As such, the program produces graduates who:

- Have a sound foundation in safety management, management of organizations, human factors, domestic terrorism, and industrial safety, hygiene and loss prevention.
- Are all-around individuals with strong social skill, able to work in team environments, competent in communication and information presentation, and with a strong sense of professionalism;
- Are committed to continuous improvement and lifelong learning.

The BAAS degree is intended for holders of the Associate in Applied Science (AAS) degree awarded by community or junior colleges. These programs extend for 4 or more semesters and include 60 semester credit hours, although some students lacking necessary freshman or sophomore courses require additional semester hours.

Safety Management (BAAS) Requirements

Successful completion of the BAAS in Safety Management requires the following courses:

General Education Core Requirements
ENG 1302 Composition II
HIST 1305 US History to 1877
HIST 1306 US History after 1877

COMM 1304 Introduction to Speech Communication
MATH 1301 College Algebra
POLS 2303 US Government I
POLS 2304 US Government II
Literature (three hours)
Natural Sciences (six hours)
Fine Arts (three hours)
Social/Behavioral Sciences (three hours)
Computer Literacy (three hours)

Other Basic Requirements
ENGR 3302 Engineering Economics
ENG 3302 Business Tech Writing
CJ 4306 Domestic Terrorism
MGT 3301 Management of Organizations

Writing Proficiency Examination

Safety Management Requirements:
Lower Division
ENGR 1402 Safety and Fire Hazards Requirements (fundamentals)
Upper Division
ET 4323 Technology Seminar
ENGR 4330 Systems Safety Management
ENGR 4350 Industrial Loss Prevention
ENGR 4370 Human Factors in Safety and Fire
ENGR 4410 Industrial Hygiene
ENGR 4450 Industrial Safety

Electives (18 hours, Approved by advisor)
ENG 3302 and ET 4323 satisfy the W (writing) and S (to use of the skills learned in core courses to solve problems related to the major) application course requirements of the institution's General Education Program.

Facilities

The programs operate within the facilities of the Engineering Technology Department. The department places great importance on efficiency in education. Classes meet once a week in sections of three and four hours depending on the credit hours of the course. The once a week arrangement requires only one trip per week per course to the university from the place of work. Considering that most students in the program work, the schedule minimizes the time and cost expenses of multiple trips.

All classes in the department meet in laboratories giving the opportunity to perform experiments and demonstration concurrent with the lectures. No time is wasted on trips to a different location. Furthermore, the utilization of space is optimal with combination of activities in the laboratory.

These laboratories are places to obtain real experience in the application of practical methods; they are also research laboratories for undergraduates

The computing facilities available to students and faculty in the two programs are outstanding. The computer requirements for the Fire Protection program are high because computer simulation of fires requires substantial computer power as noted above. Simulation of a one hour fire in a town house requires around one hundred hours of running time on a desktop computer of maximum capacity. More demanding fire simulations of buildings required several processors running in a parallel mode.

Supporting Organizations: Scholars Academy

The Scholars Academy is an exciting and innovative program at UHD designed for students who want to major in Computer Science, Mathematics, Engineering/Engineering Technology, and all areas of Natural Science. This competitive program is funded by the National Science Foundation, NASA, Office of Naval Research, UHD, US Army Research Office and the US Department of Agriculture. Academy Scholarships vary from $2,500 to $5,000 per academic year with additional summer stipends available for research participation. Students applying for admission to the Academy must be graduates of a college preparatory high school curriculum; have a minimum GPA of 3.0 in mathematics and science; have minimum SAT Math and Verbal scores of 450 each or THEA math, reading and writing component scores of 250 each; and be enrolled as full-time students majoring in one of the degree programs in the College of Sciences and Technology.

Supporting Organizations: SFPE and the Industry Advisory Board

The Fire Protection Engineering Technology program has an Industry Advisory Board composed of representatives of industry with backgrounds and interest in the field of fire protection. The faculty of the program keeps in contact with the Industry Advisory Board for advice on management of the program including course content, implementation of new courses and industry trends affecting the program.

Future Developments

The programs presented in this paper are young programs that are already graduating professionals working successfully in the Houston Area. The implementation of the program requires innovative methods and technologies such as the use of computer simulations to teach fire science. As Safety Management develops it is expected that new educational approaches will develop to help students and faculty improving the educational environment of the program. Appropriate instructional technologies will be implemented that will keep the students in contact with experienced instructors and at the same time optimize the results of the learning process. The University of Houston-Downtown, specifically the College of Sciences and Technology is providing all needed resources for an exciting future.

Conclusions

This paper describes two programs developed at the University of Houston-Downtown for the benefit of the safety and fire protection needs of the Houston Area. The Safety Management and the Fire Protection programs share the faculty, laboratories and facilities of the Engineering Technology Department. However they differ in methodology and fundamental principles.

Fire Protection is a program in engineering technology based on the fundamental principles of engineering science with strong emphasis on laboratory practical work. The laboratory experiments are a combination of computer simulation and small fire experiments. The computer simulation uses the FDS fire simulation system developed by NIST. Through experiments and simulations students get familiar with the relation between science, physics and chemistry, and practical fires. Historical fires are also studied to compare with the simulations. In summary, Fire Protection is a science based program.

Safety Management is based on a different approach. All instruction relates to established procedures to ensure a safe environment at the work place. Emphasis is on the organized and rigorous compliance with safety codes rather than on the scientific background of the codes. The programs are young but at the present time have graduated students that are contributing to industry in the Houston Area. The Society of Fire protection Engineers has provided a professional environment to assist in the growth of the program.

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