Fire Safety Engineering Development at Department of Mechanical Engineering University of Indonesia

Yulianto Sulistyo Nugroho
Fire Protection Engineering and Management
Department of Mechanical Engineering University of Indonesia
Kampus UI Depok 16424
Ph. (021) 7270032, Fax. (021) 7270033
E-mail: yulianto@eng.ui.ac.id

Abstract

Fire in buildings and industrial facilities remains one of the greatest challenges in building and industrial operations. The direct economic loss from building fires in industrial and residential buildings for many countries is estimated to reach about 0.2%. In general, the field of fire protection engineering is considered still in the stage of relative immaturity compared to other branches of engineering. However, this general view has motivated new advancement through advanced research activities in fire science and engineering. Due to progress in fire safety technology, economic and social reasons, building codes in many countries around the world are shifting from prescriptive-based to performance-based. This development requires a great need for fire safety professional to act as agents of change, both in respect to the technology and the design of building and industrial operations. This paper describes the general trends in fire safety engineering, fire research and postgraduate university-level education in fire protection engineering and management at Department of Mechanical Engineering University of Indonesia.

Keywords: Fire safety, fire protection engineering and management, performance-based fire protection system

Introduction

Fire in buildings and industrial facilities cause human suffering and materials losses. The direct economic loss from building fires in industrial and residential buildings for many industrialized nations is estimated to reach about 0.2% of the gross domestic product (GDP). However, when some other costs of fire relevant to fire safety program were included, particularly incremental building costs and the cost of fire services and insurance, the total cost of fire to the nation was found to approach about 1% of the GDP [1]. Comprehensive data on economic loss from fires in Indonesia is still very limited; yet, one may consider the loss figure is within a comparable range or higher, since we must also count the destructions resulted from forest fires. These statistics are excluding the pain and suffering of anyone who might in any manner be touched by a destructive fire or the indirect business losses and bankruptcies that often occur as a result of large fires.

Every community has firefighters, both career and volunteer, whose responsibility it is to respond to these emergencies. Firefighter is the basis of the efforts to control the spread of fire and to mitigate against the loss of life and property from fire and similar emergencies. There is another group of professionals dedicated to the prevention of damage and loss of life from fire - fire protection engineers. Their work complements that of the firefighter and their main focus is both the prevention of fires before they start and limiting the consequences if they have already begun. They design building features, analyze activities in those buildings and research materials and products to prevent fire hazards and limit its destructive effects. They use the basic tools of engineering and science to help protect people, property, information, and organizational operations from the effects of fire and explosion [2].

Despite the great loss from fire accidents in Indonesia, effort to build the capacity of personnel in fire safety / fire protection engineering is limited, and mainly focused in the area of fire fighting techniques. As far as the author knowledge, the subject of fire safety – fire protection engineering is attached to one or two modules in university-level- engineering education. In School of Architecture and Civil Engineering, fire safety is introduced in Building Physics module. Meanwhile, in School of Chemical and Mechanical Engineering, fire safety is discussed in Combustion module. In fact, until recently there is no formal education on fire protection engineering at university level (undergraduate –S1 or postgraduate-S2) has been introduced in Indonesia.

This paper describes the general trends in fire safety engineering, fire research and postgraduate university-level education in fire protection engineering and management at Department of Mechanical Engineering University of Indonesia.

2. General Trends in Fire Safety Engineering

This paper starts by reviewing general trends in area of fire safety engineering including fire safety research and publications as well as fire safety engineering education in some leading universities around the globe.

Firstly, this paper considers progress and dissemination of fire research. The field of fire protection engineering is considered still in the stage of relative immaturity compared to other branches of engineering (Civil, Mechanical, Chemical engineering etc.). However, this general view has motivated new advancement through advanced research activities in fire science and engineering. In fact, trends in fire safety / fire protection engineering practices have been motivated by the accrual and dissemination of fire research through scientific journal and reference books . Readers who are interested in finding the latest research information, development and advancement in fire safety areas can gather the information from the following scientific journals:

- Fire Safety Journal
- Fire and Material
- Journal of Fire Protection Engineering
- Journal of Fire Science
- Combustion and Flame
- Proceeding of Combustion Institute
- Fuel
- Journal of Loss Prevention in the Process Industries
- Fire Technology
- Journal of Applied Fire Science
- NFPA Journal, etc

and some reference books:

- Society of Fire Protection Engineering Handbook (2004)
- NFPA Handbook (2003)
- Drsydale, D., An Introduction to Fire Dynamics, 2nd Ed. (2003)
- Rasbach DJ, et al., Evaluation of Fire Safety (2004)
- Zalosh, RG., Industrial Fire Protection Engineering (2003)
- Buchanan, A., Fire Engineering Design Guide (2001)
- Brabauskas, V., Ignition Handbook (2004), etc.

Better understanding and new development on fire phenomenon, fire dynamics, fire growth and spread, fire modeling, protection method (both passive and active), fire risk analysis, fire safety management, human behavior in fire etc., has provided an improved basis for evaluating the hazards due to fire, and has potentially given the engineer new tools to perform his / her job [3]. Beneficiaries of new progress in fire research would be the designers and regulators in examining alternative code compliant approaches through quantitative engineering analyses, and fire investigator through the application of "fire modeling" or quantitative methods to the reconstruction of actual accidental fires for the purpose of settling litigation claims. In addition, safety of the public should be benefited by better understanding of "evacuation modeling" for large enclosed public facilities such as large shopping mall, supermarket, airport and underground facilities.

The trend in fire safety research is also try to gain better understanding to traditional but remain the leading cause of household fire, "the cooking fire". Manzello, et al., (2003) [4] carried out an experimental studies on the interaction of a liquid droplet with a pool of hot cooking oil. The impaction process was recorded using a high-speed digital camera at 1000 frames per second. The initial droplet diameter was fixed at 3.1± 0.1mm and all experiments were performed at room temperature (20^{o}C). The impact Weber (*We*) number of the water droplets was fixed at 200. As the water droplet impacted the hot peanut oil pool, it fragmented, and ultimately produced a vapor explosion. Experiments were also performed applying methoxy-nonafuorobutane to hot peanut oil with similar impact *We* number. Dramatic differences were observed when methoxy-nonafuorobutane droplets were used. At peanut oil temperatures above ≈ 180^{o}C, methoxy-nonafuorobutane droplets did not result in a vapor explosion. Currently methoxy-nonafuorobutane is being screened as a potential fire suppressant.

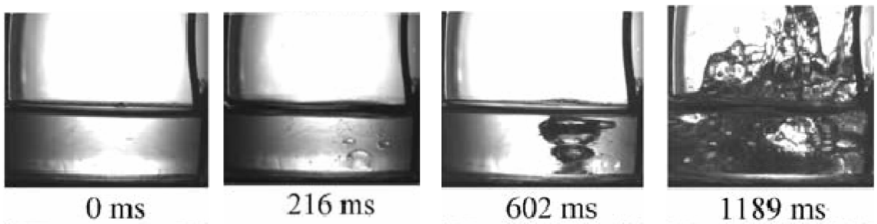

Fig. 1 Time elapsed images of distilled water droplet impingement (*We* = 200) on a heated peanut oil pool at 220^{o}C [4].

Nowadays, many countries are moving towards *performance based* building codes which state objectives and performance requirements, and allow any form of construction which meets those requirements. SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Building [5] is an example of a guide which can be used for the development and evaluation of designs of fire protection measures. This is to support the development of alternatives to prescriptive-based code requirements, or to evaluate the building fire safety design as a whole. Performance-based design of fire protection systems may offer a number of advantages over prescriptive-based design [5].

a) Performance-based design specifically addresses a building's unique aspects or uses, as well as specific stakeholder needs and considers those of the broader community where appropriate.
b) Performance-based design provides a basis for development and selection of alternative fire protection options based on the project's needs (e.g., in the case that the code-prescribed solution does not meet the stakeholders' needs).
c) Performance-based design allows the safety levels provided by alternative design options to be compared. Comparing options provides a mechanism to determine what level of safety, at what cost, is acceptable.
d) Performance-based design requires the use of a variety of tools in the analysis, bringing increased engineering rigor and resulting in innovative design options.
e) Performance-based design results in a fire protection strategy in which fire protection systems are integrated, rather than designed in isolation.

A comprehensive performance-based engineering approach may provide more effective fire protection to address a specific need, in addition to improved knowledge of the loss potential. The steps in the performance-based analysis and the conceptual design procedure for fire protection design is given in Fig. 2.

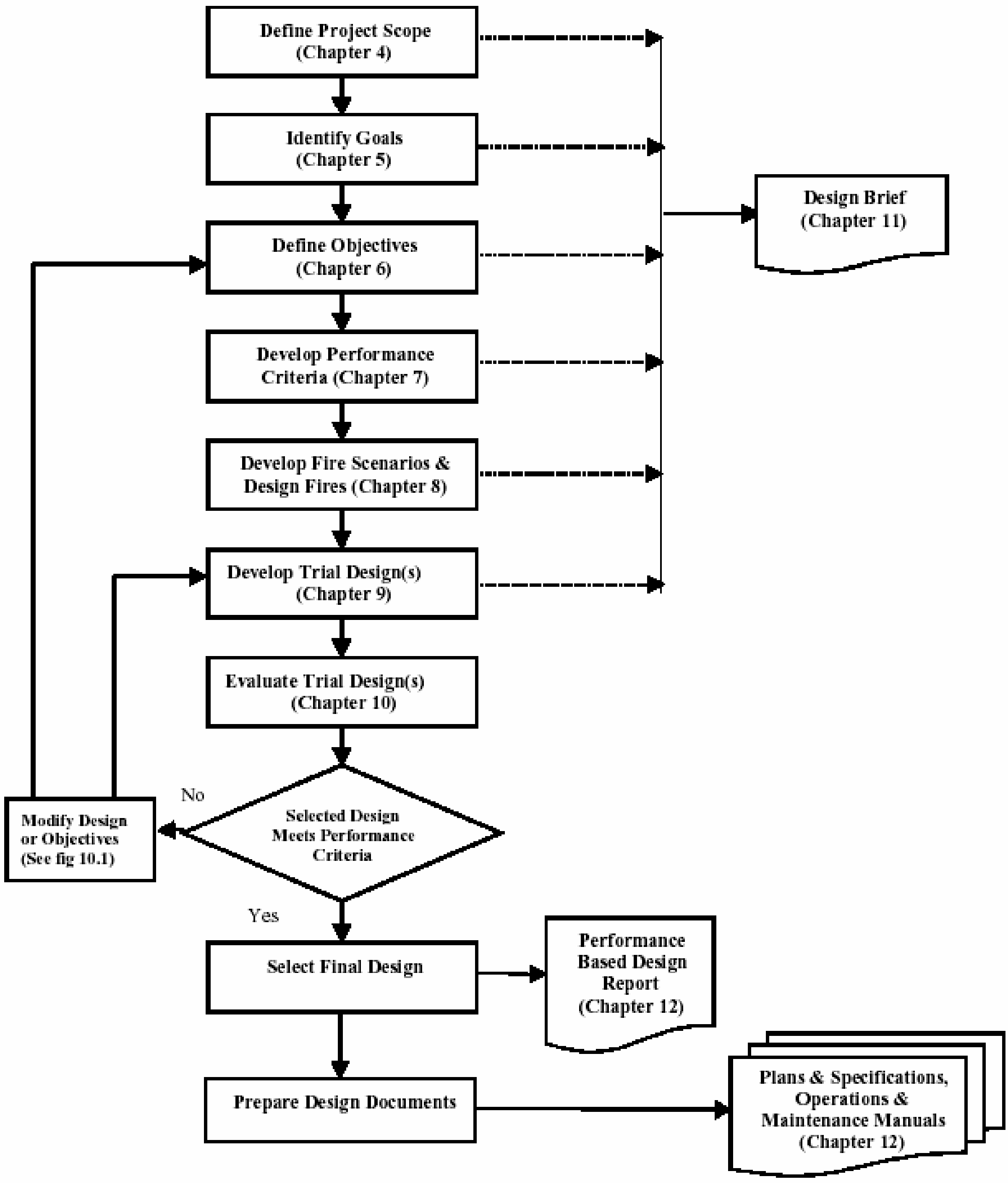

Fig. 2 Steps in the Performance-Based Analysis and the Conceptual Design Procedure for Fire Protection Design. Chapters in the above chart are referring to chapters in Ref. 5.

Secondly, this paper describes the introduction of fire protection engineering education at university level. Fire is a complex system which is more complicated and less technically developed than problems that define other branches of engineering. This is also reflected by the fact that fire safety engineering education at university level have only emerged in the last 32 years. A Master's Degree program in fire protection engineering was begun at the University of Edinburgh in 1973. In 1979, Worcester Polytechnic Institute began a similar program followed by M.S. programs at the University of Maryland (1990) and the Victoria University in Australia (1992) [3]. Other efforts are also underway in various universities to bring advanced scientific knowledge to the education of fire protection engineers. Some of these include the University of Leeds (BEng/MEng Fire Engineering), the University of Ulster, University of British Columbia, , the University of Canterbury (New Zealand), Lund University (Sweden), and Hong Kong Poytechnic, and several universities in Japan.

With the introduction of new, synthetic materials throughout the workplace, the commercial and industrial facilities, and the home, the hazards have become much more widespread, and the risks to life and property are now much greater, particularly in view of the size and complexity of buildings being built to serve all sectors of society such as high-rise buildings, shopping malls, industrial plants, etc. This has motivated the need for advanced formal education in fire protection engineering to enrich engineers and professionals holding engineering degree or its equivalents with skills to assess fire hazards and develop creative engineering solutions to reduce the risk of fire losses at large commercial and industrial facilities.

3. Fire Safety Research at Department of Mechanical Engineering University of Indonesia

Fire related research activity at DTM-UI was started in early 1990’s when the Department received laboratory equipments for its new campus in Depok. The new equipments include bomb calorimeter for measuring calorific value of combustible materials, thermal conductivity apparatus, radiation heat transfer apparatus, calorimeter and Bunsen burner equipment for studying (pre-mixed and non-premixed) flame characteristics and effects of different fuel characteristics.

By mid-90’s to recently, research activities in the area of combustion engineering and fire safety at DTM-UI got new impetus by returning staffs holding PhD degree from abroad. Their research interests cover fire safety related subjects including ignition of gaseous fuel, flame propagation, spontaneous ignition of solid combustible materials, advanced heat transfer, flame stability and extinguishment, and computational fluid dynamics. New laboratory equipments have been developed and some are still under-development such as adiabatic technique for spontaneous combustion testing apparatus, combustion-step apparatus, fire calorimeter and bubble-modeling of smoke movement. These apparatus are equipped by on-line data logging systems. Some results of the research works are explained below:

a. <u>Assessment of spontaneous combustion properties of coal using adiabatic oxidation method</u>
In nature or in bulk sizes of coal piles, the low-temperature oxidation reaction is considered slow, in that it could take days or even months to reach a critical temperature for ignition. In such cases it can be assumed that there is limited heat exchange between the coal and direct surroundings. The increase of coal temperature is caused by heat generated during the oxidation process. This phenomenon can be considered as the adiabatic oxidation process, because the heat transfer between coal and direct surroundings are close to zero. The author assesses the liability of low rank and high rank coals to spontaneous combustion using an adiabatic oxidation method. The results show that sub-bituminous coal are extremely reactive to oxygen and have higher propensity for self-heating compared to bituminous coal (Fig. 3).

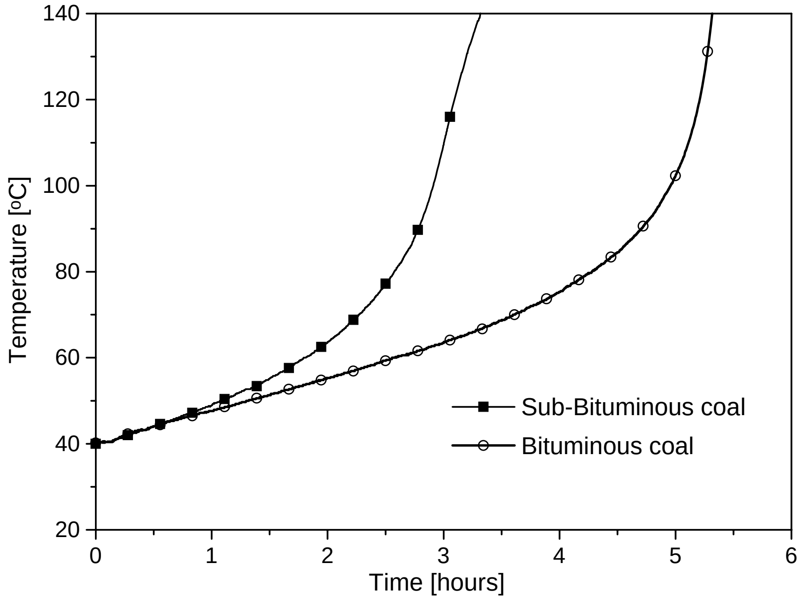

Fig. 3. The temperature - time records for bituminous and sub-bituminous coal samples.

b. Assessment of heat release rate of wood product using cone calorimeter

This work was carried out in a prototype of cone caloriemeter apparatus to measure the heat release rate by materials during fire. This new apparatus is capable to measure other important parameters including reaction to fire performance, time to ignition, critical heat flux, and rate of mass loss. Fig. 4 shows the effect of sample thickness on heat release rate patterns for Medium Density Fibreboard (MDF) sample at a constant heat flux of 27 kWm^{-2}.

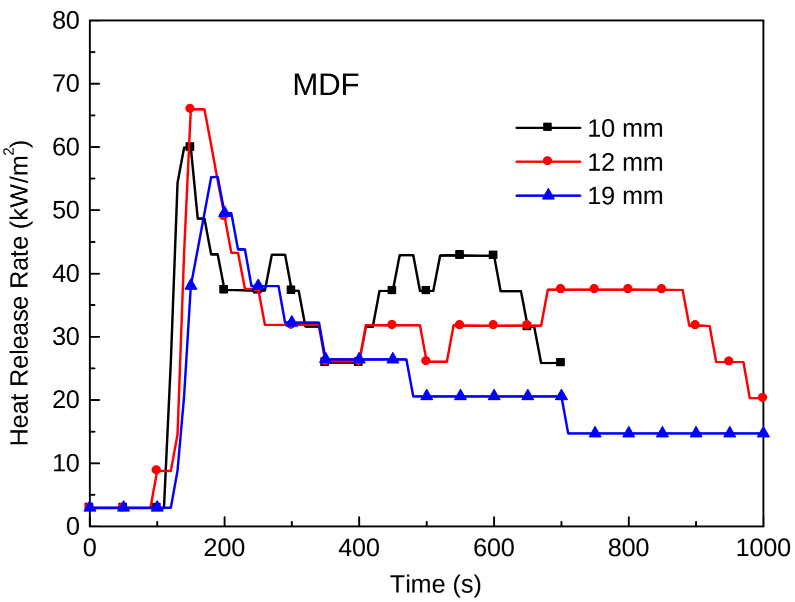

Fig. 4. Effect of sample thicknesses on heat release rate patterns for MDF.

4. Post-graduate program (Magister Teknik) in Fire Protection Engineering and Management at University of Indonesia

The Magister Teknik (MT) in Fire Protection Engineering and Management (FPEM) was developed as a responds to increasing need of fire safety professional in the industrial and building sectors, risk management and insurance sectors, design and construction consultants, researchers, regulator and decision maker at central and regional government. The MT-FPEM program is coordinated by the Department of Mechanical Engineering University of Indonesia.

The graduate of the MT-FPEM program is expected to have a set of skills in (i) identification of fire hazard, (ii) identification of fire protection strategies, (iii) identification of cost-effective solutions, and (iv) using related information to design and conduct laboratory scale fire research and or field studies, to analyze the outcomes and to withdraw crucial conclusions and recommendation. The graduate is expected to be able to give some contribution to fire safety scientific society by publishing their research works.

The above program outcomes could be achieved by structuring the curriculum into (a) background modules: research design, engineering mathematics, computation, and safety engineering and management; b) fundamental modules: fire dynamics, fire protection system (passive and active), risk management, and laboratory experimental; (c) applied modules: the economics of fire protection, evaluation of fire safety, fire modeling; and (d) seminar and thesis. The total credit number of this program is 40 credits. The detail structure of the curriculum and the credits of individual modules is given in Table 1.

Table 1. Structure of the MT-FPEM curriculum

Semester	Modules	Credits
I	Research design and methodology	2
	Engineering mathematics	3
	Computation	3
	Safety engineering and management	3
II	Risk Management	3
	Fire Dynamics	3
	Fire protection system	3
	Engineering measurement and laboratory experiment	2
III	Evaluation of fire safety (*electives*)	4
	Economics of fire protection (*electives*)	4
	Fire modeling (*electives*)	4
	Human behavior in fire (*electives*)	4
IV	Seminar	3
	Thesis	7

The development process of the MT-FPEM curriculum and its syllabus was supported by valuable documents related to curriculum of Master program in Fire safety at some leading universities abroad. The other crucial consideration in setting the syllabi for each module is the availability of the textbooks and supporting scientific publications. One of the main textbook of this program is An Introduction of Fire Dynamics written by Prof. Dougal Drysdale of University of Edinburgh. In a rare opportunity, the author had a chance to meet Prof. Drysdale at his fire laboratory in Edinburgh. Although the meeting was quick but it has a great impact in the spirit of Fire Protection Engineering program at S2 level in Department of Mechanical Engineering University of Indonesia.

The MT-FPEM at University of Indonesia was finally begun last year (in August 2004). The current students are mostly have Bachelor degree in engineering background (chemical, mechanical and civil engineers) and Bachelor degree in Public Health. In years to come, the MT-FPEM program should be attended by wider participants, not only engineers holding chemical, mechanical and civil engineering degrees, but also professionals in the areas of architecture, electrical and telecommunication engineering, risk management and insurance, petroleum and gas engineering, transportation, human behavior and health.

A constructive discussion on the subject of fire safety professional development and the MT-FPEM program with all participants of the SNTTM 5 - 2006 will benefit the development of this program in particular, and the improvement of societal safety in general.

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