

PROJECT REPORT

YUAN-ZE UNIVERSITY, ZHONGLI CITY, TAIWAN

Verification and Validation of Fire Dynamics Simulator

Submitted by

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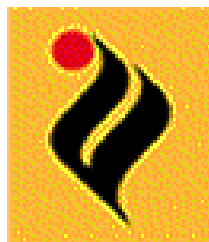
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July 2014**

DECLARATION

I hereby declare that the project work entitled “**Verification and Validation Fire Dynamics Simulaor**” is an authentic record of my own work carried out at **Yuan-Ze University, Taiwan** as requirements of six months project semester for the award of degree of B.E.-M.B.A.(Industrial Engineering), Thapar University, Patiala, under the guidance of Mr. C.S (Christian) Lin and Yug Dutt Chaudhary during January to July, 2014.

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It is certified that the above statement made by the student is correct to the best of our knowledge and belief.

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“To people, who make it possible to disseminate knowledge to enlighten the young and curious minds”

As I begin to reflect on the magnitude of my project report, I reminded of all the support, help and encouragement provided to me by all the members of FIRE PROTECTION ENGINEERING LABORATORY without their support my project won't be a success. I thank to the persons who inspired me to work and promoted this unique way of learning around their surroundings. When I begin to put on paper the feelings I have towards the people who have changed my heart, soul and thought, I am overwhelmed with emotions. If I put it in real terms, I would call it a splendid team effort that has helped me to end my training on high notes. My experience here has been very enriching. I sincerely hope that their guidance would be of great help to me in the future. I show my gratitude and thankfulness:-

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TUSHAR SINGLA

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"Theory without practice is a bird that never lands

Practice without theory is a bird that never flies."

ABSTRACT

My training started on 5th January 2014, I was introduced to my department i.e. Fire Protection Engineering Department. My mentor Mr.C.S (Christian) Lin and others familiarized me with the laboratory and kind of research carried out in their laboratory of fire protection engineering. My project was introduced to me which is verification and validation of fire dynamics simulator by reconstruction of a fire scene that occurred at Ala-Pub Taichung, Taiwan. Due to human carelessness and system errors fire mishaps take place which results in human lives.

- The need and importance of fire protection engineering was introduced to me. This field has always been neglected in India but it is very important as it costs human lives and property during a fire scene.
- Then I studied the manual of fire dynamics simulator + evac developed by NIST(National Institute of standards and technology,USA) to understand the basis of fire dynamics simulator and kind of programming used in FDS and how to analyse the output generated by the software.
- After going all through I started working on verification and validation of fire dynamics simulator under the guidance of other senior P.H.D students and my professor. I studied many research papers regarding the use and verification and validation of fire dynamics simulator and I represented one paper a week to my professor which helped me a lot.
- I attended all the lectures with the students of Yuan-Ze University regarding the fire protection engineering. It helped me a lot to develop basics of fire protection engineering.
- I also used to visit the fire protection department in Taiwan with my professor which helps the fire engineers to create awareness among the people of what to do in case of a fire.
- After the final results approved by my professor, he asked me to write a paper for the academic use (it will not get published) which helped me to understand how actual research is carried out.
- After qualifying it, I submitted my six months report to my advisor in Taiwan and my training got successfully completed.

Introduction-Yuan-Ze University



Fig1.Top View of the University

History

Established in 1989, Yuan Ze University may be young by traditional standards, yet it has been recognized as a model for newly emerging universities within the shortest period. As the first and the only university to win the National Quality Award in 2003, Yuan Ze received an award from the Ministry of Education for the Teaching Excellence Project in 2005. Successively, it has been designated by the MOE as one of the top 12 universities in Taiwan, receiving an award for the “Aim for the Top University and Elite Research Centre Development Project” since 2005. Granted with the highest honour in teaching, research and administration, Yuan Ze has become a marvel of higher education, in Taiwan.

In 2012, Yuan Ze University ranked 70th in Times Higher Education World University Rankings's top 100 universities under 50 years old category, and ranked within 350-400th place in its 2011-2012 World University Ranking category.^{[2][3]} Yuan Ze University is the only private education institute from Taiwan listed in Times Higher Education's top 400's ranking.

Courses Offered

Currently Yuan Ze has five colleges including the Colleges of Engineering, Informatics, Management, Humanities and Social Sciences, and Electrical and Communications Engineering. There are over 9,000 students with a 2:1 ratio between undergraduate and graduate students on campus. Aimed at housing key research centres in Taiwan, our Fuel Cell Centres and Communications Research Centres have integrated all resources and recruited talents in all engineering-related departments at Yuan Ze through support from the Top Universities Project. With the success of these two centres, Yuan Ze also places heavy focus on the promotion of overall teaching and research capacity. The College of Management has established the first EMBA program in Taiwan and all the courses in the Graduate School of Management are conducted in English to further connect our students to the international marketplace. The College of Informatics is the first college in Taiwan to adopt information as the core for its teaching and research. It has undergraduate and graduate programme in various fields of engineering listed below:

- (1) Department of mechanical Engineering
- (2) Department of chemical engineering and material sciences
- (3) Department of industrial engineering and management
- (4) Graduate school of Bio-technology and Bio-engineering
- (5) Graduate school of renewable energy engineering
- (6) Department of computer science and Engineering
- (7) Department of Information management
- (8) Department of information communication
- (9) Graduate school of social informatics
- (10) Biology and Bioinformatics Program

It also offers various other departments which are listed below:

- (1) Department of Foreign Languages and Applied Linguistics

- (2) Graduate School of Visual Arts and Management
- (3) College of General Studies
- (4) Department of social and Policy Sciences

Education and Culture

It emphasizes on practical experience with the integration between technology and social studies. The College of Humanities and Social Sciences is working closely with our College of General Studies to promote teaching and research in humanities, general education, and ethics.



Fig.2 Graduation Day

Giving top priority to students in the areas of teaching and counseling, Yuan Ze emphasizes education in both creativity and ethics. Moreover, we are active in the nation's pioneering "Classics 50 Reading Project," "Ye Sir Mentorship Program" and promote all types of activities that will enrich students' extracurricular studies. Founded by the Far Eastern Group, we have established close relationships with all of its subsidiaries to form an industrial and academia alliance. The internship plan for both domestic and international students can be fully realized through such a network. Based on the unique niche Yuan Ze has created, we provide added value to students and faculty members and expect ourselves to be the benchmark university in industry-academia collaboration.

The main theme of the University's development strategy emphasizes differentiation and internationalization. Through differentiation in curriculum design and research, we will create our distinguishing characteristics and brand; while in recruiting outstanding foreign faculty and potential international students with provision of favourable packages and scholarships/fellowships. The International Language and Culture Centre offers Mandarin and cultural programs for international students; hosts various cultural activities; and promotes cultural exchange on campus.



Fig.3 College Library



Fig 4. Students from all around the world resulting in great exposure

As the youngest and most energetic university of Taiwan's Top universities, we will continue to fully utilize our competitive advantages of "innovation," "quality," and "flexibility." We provide a challenging environment for students to enjoy learning, develop their potentials and surpass themselves; for faculty to devote themselves to inspiring and mentoring their students and the pursuit of truth and academic excellence; and for staff to promote the quality of service and fulfil personal growth

Infrastructure

The increased use of laptops and other portable devices on campus as well as an increase in learning mobility across locations around thThe increased use of laptops and other portable devices on campus as well as an increase in learning mobility across locations around the campus has fuelled the demand for campus wireless network facilities.

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Since Academic Year 2001, the Office of Library and Information Services has set out to deploy campus wireless network covering all Departments, classrooms, the University Library, administrative buildings, the activity center and campus to benefit faculty, staff and students of Yuan Ze University from the on-the-go Internet access on campus to facilitate their academic studies and research.

Wireless Network Architecture

Wireless Network Devices include:

- RADIUS Server
- Wireless Access Point (WAP) using 802.11b standards
- Network Connection Devices

All the laboratories in the university are well equipped with all the required instruments required for the undergraduate students as well as for the research students. The laboratories are designed in a way that student can spend most of the time in the lab. as all the facilities are available in the laboratory. Students can use expensive instruments to carry on their research and experiments. Whole campus is provided with wi-fi. Library of the university is very huge which can accommodate huge number of students and is fully air-conditioned. Over 10 thousand books are available in the library with more than 50 computers. One building in the institution got prize for the best architecture in Taiwan.



Fig5: Best architecture Design



Fig.6 Top view of the university

What is Fire Protection engineering?

Fire engineering is the application of science and engineering principles to protect people, property, and their environments from the harmful and destructive effects of fire and smoke. It encompasses **fire protection engineering** which focuses on fire detection, suppression and mitigation and **fire safety engineering** which focuses on human behaviour and maintaining a tenable environment for evacuation from a fire or it is concerned with the applications of scientific and technical principles to the dynamics, mitigation, and suppression of fire. This includes the effects of fire on people, on structures, on commodities, and on operations. The identification of fire hazards and their risk, relative to the cost of protection, is an important

aspect of fire safety design. In the United States **fire protection engineering** is often used to include fire safety engineering. Fire Protection Engineering as defined by the Society of Fire Protection Engineers (SFPE) is the application of science and engineering principles to protect people and their environment from the destructive fire and includes: analysis of fire hazards; mitigation of fire damage by proper design, construction, arrangement, and use of buildings, materials, structures, industrial processes, and transportation systems; the design, installation and maintenance of fire detection and suppression and communication systems; and post-fire investigation and analysis.

Dennis Nolan, Encyclopedia of Fire Protection, defines Fire Protection Engineering is the discipline of engineering that applies scientific and technical principles to safeguard life, property, loss of income, and threat to the environment from the effects of fires, explosions, and related hazards. It is associated with the design and layout of equipment, processes and supporting systems. It is concerned with fire prevention, control, suppression, and extinguishment and provides for consideration of functional, operational, economic, aesthetic, and regulatory requirements.

To summarize these definitions, Fire Protection Engineering is the practice of applying chemistry, physics, and engineering principles from mechanical, electrical, chemical, and civil engineering with additional education, training, and knowledge of fire dynamics concerned with the protection of life, property and the environment in the most economical and practical application.

Areas Of specialization of FPE

Now that we have defined Fire Protection Engineering, the individual who performs these tasks is a Fire Protection Engineer (FPE). Through education, training, and experience, this engineer:

- (1) is familiar with the dynamics and characteristics of fire and its products of combustion;
- (2) recognizes how fires originate, spread through structures, and can be detected, controlled, and/or suppressed; and
- (3) is capable of predicting the behaviours of various materials, structures, and processes to protect life, property and the environment.



Disciplines

The discipline of fire engineering includes, but is not exclusive to:

- Fire detection - fire alarm systems and brigade call systems
- Active fire protection - fire suppression systems
- Passive fire protection - fire and smoke barriers, space separation
- Smoke control and management
- Escape facilities- Emergency exits, Fire lifts etc.
- Building design, layout, and space planning
- Fire prevention programs
- Fire dynamics and fire modelling
- Human behaviour during fire events
- Risk analysis, including economic factors
- Wildfire Management

Fire protection engineers identify risks and design safeguards that aid in preventing, controlling, and mitigating the effects of fires. Fire engineers assist architects, building owners and developers in evaluating buildings' life safety and property protection goals. Fire

engineers are also employed as fire investigators, including such very large-scale cases as the analysis of the collapse of the World Trade Centres. NASA uses fire engineers in its space program to help improve safety. Few countries outside the United States regulate the professional practice of fire protection engineering as a discipline, although they may restrict the use of the title **engineer** in association with its practice.



Fig7: Balanced Fire Protection

History

Fire engineering's roots date back to Ancient Rome, when the Emperor Nero ordered the city to be rebuilt utilizing passive fire protection methods, such as space separation and non-combustible building materials, after a catastrophic fire. The discipline of fire engineering emerged in the early 20th century as a distinct discipline, separate from civil, mechanical and chemical engineering, in response to new fire problems posed by the Industrial Revolution. Fire protection engineers of this era concerned themselves with devising methods to protect large factories, particularly spinning mills and other manufacturing properties. Another motivation to organize the discipline, define practices and conduct research to support innovations was in response to the catastrophic conflagrations and mass urban fires that swept many major cities during the latter half of the 19th century

(see City or area fires). The insurance industry also helped promote advancements in the fire engineering profession and the development of fire protection systems and equipment.

In 1903 the first degree program in fire protection engineering was initiated as the Armour Institute of Technology (later becoming part of the Illinois Institute of Technology).

As the 20th century emerged, several catastrophic fires resulted in changes to buildings codes to better protect people and property from fire. It was only in the latter half of the 20th Century that fire protection engineering emerged as a unique engineering profession. The primary reason for this emergence was the development of the “body of knowledge,” specific to the profession that occurred after 1950. Other factors contributing to the growth of the profession include the start of the Institution of Fire Engineers in 1918 in the UK, and the Society of Fire Protection Engineers in 1950 in the USA, the emergence of independent fire protection consulting engineer, and the promulgation of engineering standards for fire protection.

Education

Fire engineers, like their counterparts in other engineering and scientific disciplines, undertake a formal course of education and continuing professional development to acquire and maintain their competence. This education typically includes foundation studies in mathematics, physics, chemistry, and technical writing. Professional engineering studies focus students on acquiring proficiency in material science, statics, dynamics, thermodynamics, fluid dynamics, heat transfer, engineering economics, ethics, Systems in engineering, reliability, and environmental psychology. Studies in combustion, probabilistic risk assessment or risk management, the design of fire suppression systems, the application and interpretation of model building codes, and the measurement and simulation of fire phenomena complete most curricula.

New Zealand was one of the first countries in the world to introduce Performance based assessment methods into their building codes in regard to fire safety. This occurred with the introduction of their 1991 Building Act. Professor Andy Buchanan, of the University of Canterbury, established the first post graduate and only course available in New Zealand, at the time, in fire safety engineering in 1995. Applicants to the course require a minimum qualification of a bachelors degree in engineering or bachelors degree in a limited list of science course. Notable alumni from the university of Canterbury include but is not limited to Sir Ernest Rutherford, Robert (Bob) Park, Roy Kerr, Michael P. Collins, John Britten and

many others. A masters degree in fire engineering from the University of Canterbury is recognized under the Washington Accord.

In the United States, the University of Maryland (UMD) offers the only ABET-accredited B.S. degree program in Fire Protection Engineering, as well as graduate degrees and a distance M.Eng. program. Worcester Polytechnic Institute (WPI) offers an M.S. and a Ph.D. in Fire Protection Engineering as well as online graduate programs in this discipline (M.S. and a Graduate Certificate). As of 2011, Cal Poly offers an M.S. in Fire Protection Engineering. Oklahoma State University offers an ABET-accredited B.S. in Fire Protection and Safety Engineering Technology (established in 1937), the Case School of Engineering at Case Western Reserve University offers a master's degree track in Fire Science and Engineering, and the University of Cincinnati offers an associate degree in Fire Science and a bachelor's degree in Fire and Safety Engineering Technology as distance learning options, the only university in the U.S. and Canada to hold this distinction.^[13] Other institutions, such as the University of New Haven, University of Kansas, Illinois Institute of Technology, University of California, Berkeley, Eastern Kentucky University, and the University of Texas at Austin have offered courses in Fire Protection Engineering or technology.

The practice of final fire sprinkler systems design and hydraulic calculations is commonly performed by design technicians who are often educated in-house at contracting firms throughout North America, with the objective of preparing designers for certification by testing by associations such as NICET (National Institute for Certification in Engineering Technologies). NICET certification is commonly used as a proof of competency for securing a license to design and install fire protection systems.

In Europe, the University of Edinburgh offers a degree in Fire Engineering and had its first fire research group in the 1970s. These activities are now conducted at the new BRE Centre for Fire Safety Engineering. The University of Leeds uniquely offers an MSc award in Fire **and** Explosion Engineering. Other European Universities active in the fire engineering are Luleå tekniska universitet, Lund University, Stord/Haugesund University College, University of Central Lancashire, University of Manchester, University of Ulster, University of Sheffield, University of Greenwich, London South Bank University, University of Wales, Newport, Letterkenny Institute of Technology in Ireland and Otto-von-Guericke-Universität Magdeburg and Bergische Universität Wuppertal in Germany, Vilnius Gediminas Technikal University in Lithuania.

In Australia, Victoria University in Melbourne offers postgraduate courses in Building Fire Safety and Risk Engineering as does the University of Western Sydney. The Centre for Environmental Safety and Risk Engineering (CESARE) is a research unit under Victoria University and has facilities for research and testing of fire behaviour.

Professional Registration

Suitably qualified and experienced fire protection engineers may qualify for registration as a professional engineer. The recognition of fire protection engineering as a separate discipline varies from state to state in the United States. NCEES recognizes Fire Protection Engineering as a separate discipline and offers a PE exam subject. This test was last updated for the October 2012 exam and includes the following major topics (percentages indicate approximate weight of topic):

- Fire Protection Analysis (20%)
- Fire Protection Management (5%)
- Fire Dynamics (12.5%)
- Active and Passive Systems (50%)
- Egress and Occupant Movement (12.5%)

Few countries outside the United States regulate the professional practice of fire protection engineering as a discipline, although they may restrict the use of the title **engineer** in association with its practice.

The titles *fire engineer* and *fire safety engineer* tend to be preferred outside the United States, especially in the United Kingdom and Commonwealth countries influenced by the British fire service. The Institution of Fire Engineers is one international organization that qualifies many aspects of the training and qualifications of fire engineers.

Definitions and Terms

Some more definitions of fire protection and of the terms related to it are given below:

- Fire Protection - A broad term that encompasses all aspects of fire and life safety, including building construction and fixed building fire protection features, fire suppression and detection systems, fire water systems, emergency process safety controls, emergency fire-fighting operations (fire department), Fire Protection Engineering (FPE), and fire prevention. Fire protection is concerned with preventing

or minimizing the direct and indirect consequences of fire on people, property, and programs. By extension, fire protection also includes aspects of the following perils as they relate to Fire Protection: explosion, natural phenomenon, and smoke and water damage from fire.

- Fire Protection Systems - Any system designed and installed to detect, control, or extinguish a fire; to limit fire damage; to alert occupants and/or the fire department that a fire has occurred; or to otherwise enhance life safety or property protection.
- Life Safety Systems: Any system designed and installed to alert occupants to a fire condition, provide sufficient capacity and a protected path for egress, provide structural stability, and provide passive defence against the spread of fire and its products. These include, but are not limited to, means of egress components, emergency lighting, exit signage, fire barriers, and structural fire protection.
- Maximum credible fire loss (MCFL): The damage to property and/or disruption to operations that would be expected from a fire, assuming that all installed fire protection systems function as designed; and the effect of emergency response is omitted except for post-fire actions such as salvage work, shutting down water systems, and restoring operations.
- Maximum possible fire loss (MPFL): The value of property (excluding land) and cost of operations disruption within a fire area, unless a fire hazards analysis demonstrates a lesser (or greater) loss potential. This assumes the failure of both automatic fire suppression systems and manual fire-fighting efforts.

Redundant fire protection: Fire protection measures implemented to mitigate the effects of fires or related perils in the event of a partial or total failure of the primary fire protection measures (e.g., two independent fire suppression systems to protect a high risk facility).

- Performance-Based Design: An engineering approach to design elements of a building based on agreed-upon performance goals and objectives, engineering analysis and quantitative assessment of alternatives against the design goals and objectives using accepted engineering tools, methodologies and performance criteria.

The most important tool of fire

protection engineers nowadays is **Fire Dynamics Simulator + Evacuation**. What is Fire Dynamics Simulator and Evacuation?

Fire Dynamics Simulator + Evacuation

Fire Dynamics Simulator (FDS) is a computational fluid dynamics (CFD) model of fire-driven fluid flow. The software solves numerically a form of the Navier-Stokes equations appropriate for low-speed, thermally-driven flow, with an emphasis on smoke and heat transport from fires.

Smokeview (SMV) is a visualization program that is used to display the output of FDS and CFAST simulations.

FDS+Evac is the evacuation simulation module for Fire Dynamics Simulator (FDS). The software is used to simulate the movement of people in evacuation situations. The evacuation simulations can be fully coupled with the fire simulations.

Fire Dynamics Simulator (FDS) is a computational fluid dynamics (CFD) model of fire-driven fluid flow. The software solves numerically a large eddy simulation form of the Navier-Stokes equations appropriate for low-speed, thermally-driven flow, with an emphasis on smoke and heat transport from fires.

FDS is free software developed by the National Institute of Standards and Technology (NIST) of the United States Department of Commerce, in cooperation with VTT Technical Research Centre of Finland. Smokeview is the companion visualization program that can be used to display the output of FDS.

The first version of FDS was publicly released in February 2000. To date, about half of the applications of the model have been for design of smoke handling systems and sprinkler/detector activation studies. The other half consist of residential and industrial fire reconstructions. Throughout its development, FDS has been aimed at solving practical fire problems in fire protection engineering, while at the same time providing a tool to study fundamental fire dynamics and combustion.

FDS is a computer program that solves equations that describe the evolution of fire. It is a FORTRAN program that reads input parameters from a text file, computes a numerical solution to the governing equations, and writes user-specified output data to files. Smokeview is a companion program that reads FDS output files and produces animations on the computer

screen. Smokeview has a simple menu-driven interface. FDS does not. However, there are various third-party programs that have been developed to generate the text file containing the input parameters needed by FDS. A fire protection design analysis is required for all designs and must address the fire protection requirements of the project. The fire protection design analysis shall be separate from other disciplines.

Fire Protection Provisions

Where applicable, discuss the following minimum fire protection provisions (include required vs. provided):

1. Building code analysis (i.e., type of construction, height and area limitations, and building separation or exposure protection)
2. Classification of occupancy,
3. Requirements for fire-rated walls, fire-rated doors, fire dampers with their fire-resistive ratings, smoke compartmentation, smoke barriers
4. Means of egress in accordance with NFPA 101, Life Safety Code (occupant loads, exit capacities, etc.)
5. Analysis of automatic sprinkler systems and other suppression systems and protected areas, including hydraulic analysis of required water demand,
6. Water supplies, water distribution, location of fire hydrants,
7. Smoke control methods and smoke control systems,
8. Fire alarm system (the type of alarm system and location of the fire alarm equipment),
9. Fire detection system (the type of detection system and location of detectors),
10. Standpipe systems and fire extinguishers,
11. Interior finish ratings,

12. Connection to and description of fire alarm supervising system.
13. Identify the various occupancies and hazardous areas associated with the facility,
14. Coordination with security and antiterrorism requirements,

This software is a combined agent-based egress calculation model and a Computational Fluid Dynamics (CFD) model of fire-driven fluid flow, where the fire and egress parts are interacting. It can also be used to calculate the egress problem without any fire-driven fluid flow calculation e.g., it can be used to simulate fire drills. It models the egress of the agents using continuous space and time, but the building geometry is fitted to the underlying rectilinear mesh. It uses simple rules and artificial intelligence to model the exit selection processes of the evacuees. It treats each evacuee as an individual agent, whose movement is treated by an equation of motion. This approach allows each agent to have its own escape strategies and properties. Agents experience contact forces and moments as well as psychological and motive forces and moments. The resulting equations of motion for the translational and rotational degrees of freedom are solved using the methods of dissipative particle dynamics. Thus, the model tracks the trajectories of the agents by using continuous time and space. FDS+Evac allows the modelling of high crowd density situations and the interaction between evacuation simulations and fire simulations. Evacuees are modelled as agents, which are moving in a 2D geometry representing the floors of buildings. The size of each agent is represented by three circles approximating the shape of the human body, see Fig.1. The definitions of the body size variables are also shown I in Fig.1. The body dimensions and the unimpeded moving speed of the default population types in the software are shown in Table1. The body walking speed and diameters are by default drawn randomly for each generated agent from uniform distributions, whose width is also given in the table. The body moving speed and diameter distributions are taken to be same as in the Simulex program for the Child, Male, Female and Elderly categories.

Agent movement model

The method of Helbing's group [1] is used as the starting point of the agent movement algorithm of FDS+Evac, where a so called "social force" is introduced to keep reasonable distances to walls and other agents. The software uses the laws of mechanics to follow the

trajectories of the agents during the calculation. Each agent follows its own equation of motion:

$Mdx_i(t)dt^2 = f_i(t) + \xi_i(t)$, (1) where $x_i(t)$ is the position of the agent i at time t , $f_i(t)$ is the force exerted on the agent by the surroundings, m_i is the mass, and the last term, $\xi_i(t)$, is a small random fluctuation force. The velocity of the agent, $v_i(t)$, is given by dx_i/dt . The software treats agents as a combination of three circles moving on a two-dimensional plane [2]. These circles approximate the elliptical shape of the human body, see Fig.1. The default body unimpeded walking speed and dimensions of different predefined agent types of the software are listed in Table 1. Note that the software uses stochastic properties for the characteristics of the agents. The offset of shoulder circles is given by $ds = R_d - R_s$. The definition of the other body size variables, R_d , R_t , R_s see Fig.1. The walking velocities and body sizes of the agents are occupant-salized by using them from uniform distributions, whose ranges are also given in Table 1.

Table 1
Body dimensions and unimpeded walking velocities in FDS + Evac.

Body type	R_d (m)	R_s/R_d (—)	ds/R_d (—)	R_t/R_d (—)	Speed (m/s)
Child	0.210 ± 0.015	0.3333	0.6667	0.5714	0.90 ± 0.30
Adult	0.255 ± 0.035	0.3725	0.6275	0.5882	1.25 ± 0.30
Male	0.270 ± 0.020	0.3704	0.6296	0.5926	1.35 ± 0.20
Female	0.240 ± 0.020	0.3750	0.6250	0.5833	1.15 ± 0.20
Elderly	0.250 ± 0.020	0.3600	0.6400	0.6000	0.80 ± 0.30

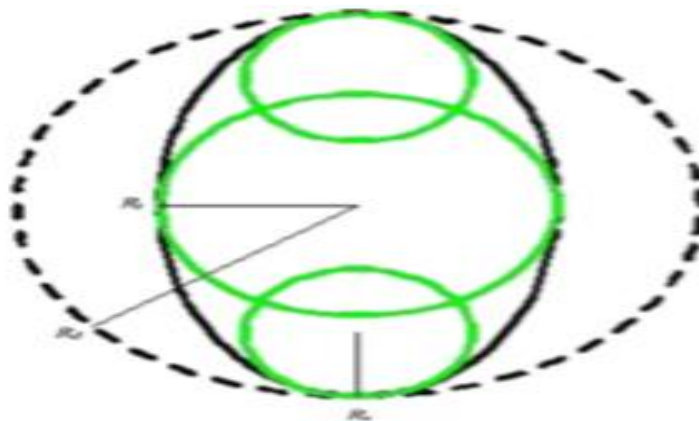


Fig1

FDS Governing Equations

FDS provides CFD calculations mainly based on LES (large eddy simulations). The governing equations of mass, momentum, energy are given as follows:

Conservation of Mass

$$\frac{\partial \rho}{\partial t} + \nabla \cdot \rho \mathbf{u} = \dot{m}^m$$

Conservation of Momentum (Newton's Second Law)

$$\frac{\partial}{\partial t} (\rho \mathbf{u}) + \nabla \cdot \rho \mathbf{u} \mathbf{u} + \nabla p = \rho \mathbf{g} + \mathbf{f}_b + \nabla \cdot \boldsymbol{\tau}_{ij}$$

Conservation of Energy

$$\frac{\partial}{\partial t} (\rho h) + \nabla \cdot \rho h \mathbf{u} = Dp/Dt + \dot{q}^m + \dot{q}_b^m + \nabla \cdot \dot{q}^n + \epsilon$$

Equation of State for a Perfect Gas

$$p = \rho R T / W$$

where p =pressure, ρ =density, T =temperature, $\mathbf{u} = (u, v, w)$ are velocity vectors, $\dot{m}^m$ =mass flow rate of per unit volume, $\mathbf{f}_b$ =external force vector(excluding), $\boldsymbol{\tau}_{ij}$ =viscous stress tensor, h =enthalpy; heat transfer coefficient, $\dot{q}^m$ =heat release rate per unit volume $\mathbf{g}$ =gravity vector, $\dot{q}^n$ =heat flux factor, ϵ = dissipation rate, R =universal gas constant and W is Molecular weight of the gas mixture.

Literature Search

The various journals studied and summarized based on verification and validation of the software by reconstruction of a fire mishap occurred in the past, available safe egress time (ASET) etc. are given below:

- Numerical Simulation of fire scene reconstruction at entertainment venues.
- Metallographic Analysis and Fire dynamics Simulation for electrical fire scene reconstruction.
- Smoke Transport Calculation during a wooden residential structure fire.
- Computer Simulation of Evacuation and Escape from a fire an entertainment Venue and Analysis of the effect of panic Psychology on Evacuees.
- Reconstruction of an Inn fire scene using the fire dynamics simulator program.

- Using fire Dynamics simulator to reconstruct a Hydro-electric power plant fire accident.
- Numerical modelling of fire dynamics behaviours for a five story building.
- Application of fire risk assessment system to verify on real fire case for factory buildings.
- Numerical Investigation of fire Dynamic Behaviour for a commercial building basement.
- Modelling of impact of fire on safe people evacuation in tunnel.
- Experimental study and numerical simulation of evacuation from a dormitory.
- Modelling an Air-Conditioner fire in a seminar room using FDS.
- Experimental study and numerical simulation of evacuation from a dormitory.
- Simulation of critical evacuation conditions for fire scenarios involving cables and comparison of different cables.

Modelling an Air-Conditioner Fire In a Seminar Room Using Fire Dynamics Simulator

In this study, we used Fire Dynamics Simulator to recreate and analyze a fire situation involving an air-conditioner that had occurred in the seminar room in Yuan-Ze University. In our simulations, the fire is initiated at the short-circuited air conditioner which we model as a constant heat rate burner surface. The position where the air-conditioner unit was installed is varied and its effect on the fire behaviour, smoke dispersion, visibility profiles and temperature profiles is studied. We then proceed to discuss the feasibility of safe evacuation of occupants in each case by comparing the RSET(Required Safety Evacuation Time) which is determined by experiential formulae and ASET (Available Safety Evacuation Time) as determined from the simulation. We expect that the results of this study will help building designers and safety engineers in recognizing and assessing the risk of fire from air conditioners in similar rooms with a fair amount of fuel load and adjusting their designs appropriately.

APPLICATION OF FDS

1. INTRODUCTION

Air conditioners pose a significant fire hazard in India. During the summer months, air-conditioners are operated at full capacity and often malfunction due to overloading, clogging of drainage or improper wiring. A cursory review of news-reports of recent air-conditioner related fires ([3]-[8]) reveal that fatalities are often a result of suffocation and toxic fume inhalation and sometimes, direct exposure to fire. According to a statistical study[9], fires caused due to air-conditioners account for \$ 23.8 million in property damage in the US alone. Eighty-six percent of air conditioning fires are ignited as a result of some type of mechanical failure or malfunction. The leading factor contributing to these mechanical failures and malfunctions is a short circuit (51%) or other electrical failure (22%) in the air conditioning unit. This study was motivated by a fire event that had occurred in the Seminar Room in the Yuan-Ze University. Although the fire remained confined and no one was injured or hurt, it prompted a re-evaluation of fire hazards that the AC installations pose in the institute. The seminar room has the dimensions of the typical classroom with one exit and no ventilation. The fuel load is primarily the wooden benches and table, which exhibited little involvement in the original fire as well as the simulations. As a result, even though the particular case of the seminar room is analyzed here, some of the qualitative results obtained may be applicable to classrooms, small stores, residential bedrooms, etc. For the purposes of the study we have used version 5 of the Fire Dynamics Simulator, a CFD code developed by the NIST (National Institute of Standards and Technology) laboratory in USA for simulating fires. FDS solves the Navier-Stokes equations for thermally driven flows in the low Mach number limit. [10] Turbulence is treated by the Large Eddy Simulation (LES) method and the classical Smagorinsky model[8] is adopted as the sub-grid scale model. (Direct Numerical Simulation is also possible with FDS, but we choose LES because of the considerable savings in computational costs.) The combustion model employed is based on the mixture fraction concept while the radiation heat transport is calculated by the Finite Volume Method. FDS has undergone extensive experimental validation by its developers as well as researchers (see[10]), with simulation results mostly being in agreement with the experimental data, with an error margin of 10 to 20 percent. For this study which involves a simple enclosure fire, therefore, we can use FDS simulations with a fair amount of confidence.

2. ESTABLISHMENT OF MODEL

The Seminar room is modeled as a 7 m X 6.5 m X 4 m room with a single exit door and an adjacent corridor 2 m wide. The walls are 0.2 m thick and the facing material is gypsum

plaster. The benches, table and podium are made of wood. Figure 1 below shows how the room appears in the Smoke view software that accompanies FDS. The red box represents the burning air-conditioner.

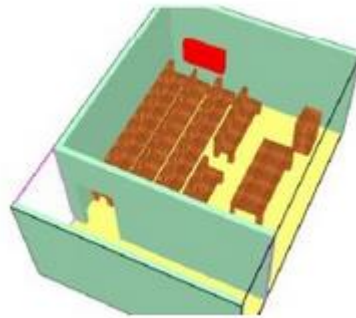


Figure 1: The Kraus seminar room. The ceiling and a wall have been hidden to facilitate viewing the interiors. The entire room is enclosed in a box whose dimensions are 9 m x 6.5 m x 4 m. To select an appropriate mesh size, we use the characteristic fire diameter D^* .

$$D^* = \left(\frac{\frac{dQ}{dt}}{\rho_\infty C_p T_\infty \sqrt{g}} \right)^{2/5}$$

- (1) D^* is evaluated to be 64.8 cm for this study. It is recommended that D^*/dx should range between 4 and 16 for reliable results[11], so we divide the mesh into 100 x 75 x 45 cells with $dx \approx dy \approx dz \approx 9\text{cm}$.

The ambient temperature is assumed to be 20 degrees, the ambient pressure is 101325.0 Pa, the initial velocity of the air is 0 m/sec and the smoke concentration is zero throughout the mesh at $t=0$. The door between the room and the corridor is open at $t=0$ and both ends of the corridor are exposed to ambient temperature conditions at all times. LES was chosen as the turbulence model with the Smagorinsky constant taken as 0.2. The burning air conditioner is represented as a burner surface with a constant heat release rate of 250 KW/m. Although there appears to be very little experimental work on electrical fires of this nature, this value was chosen as a conservative yet credible estimate of heat release based on suggestions of literature on the heat release rate of small burning objects [13].

The wooden seats were assumed to be composed of lignin, cellulose and moisture in a 7:2:1 ratio. Lignin is assumed to be incombustible, moisture evaporates to form water vapor and the decomposition of cellulose follows a two-step Arrhenius reaction, a simplified version of the model proposed by Bradbury et al.[12] The gaseous products released in pyrolysis were described by an aggregate chemical species $C_3.4H_6.2O_2.5$. [14]

Six different scenarios were considered with six different positions of the air-conditioner, shown in figure 2 below. The six simulations were run for 200 seconds, in batches of three simultaneously, and it took approximately 20 hours to run them on a quad-core 2.3 GHz Intel i5 processor.

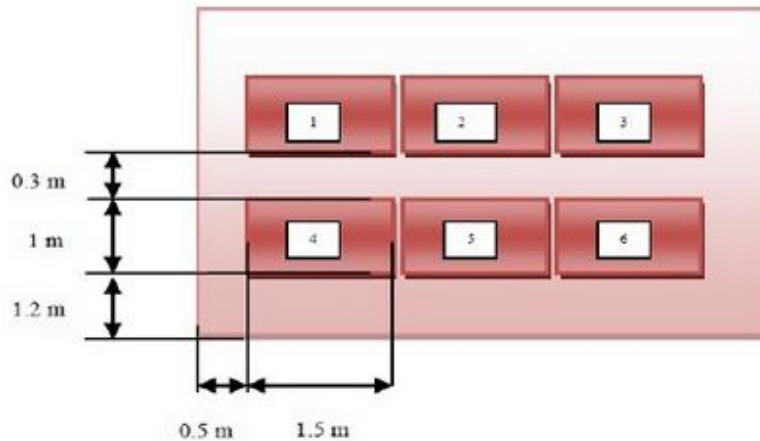


Figure 2: The 6 positions on the wall where the fire is initiated. (Not to scale) The original fire situation was akin to case 4.

3. RESULTS OF SIMULATIONS

3.1 Discussion of General Trends

In general, it is observed that for fires 1, 2 and 3, smoke and hot gases are strictly restricted to the upper layers. They exhibit near-identical behaviour. They do not spread, and from about $t=100$ sec, they begin to show signs of suppression due to the oxygen concentration falling below the critical limit (0.15) in the upper layer. By around $t=140$ sec, the fires are almost extinguished due to lack of oxygen. Although in the simulations, flames continue to appear after that throughout the room because the burner surface continues to release fuel gases even when not burning, that is unrealistic hence the results there on are rejected. Figures 3 and 4 from simulation 3 are representative of the situation.

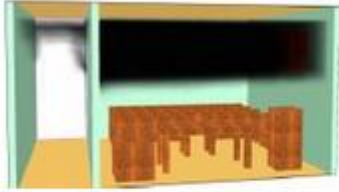


Figure 3: Soot Mass Fraction at $t=90$ sec
Smoke is strictly restricted to the upper layer

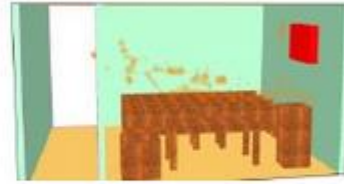


Figure 4: HRRPUV in the room at $t=137$ sec
Fire is extinguished owing to oxygen dearth

Fires 4 to 6 exhibit somewhat similar behaviour as well. The smoke layer is more diffuse than cases 1-3, because of the lower height and the smoke layer descends to lower heights as a consequence. The fires burn steadily throughout the simulation, without suppression, unlike in the previous cases. In Case 4 the fire is observed to be spreading briefly to the wooden seats as well.

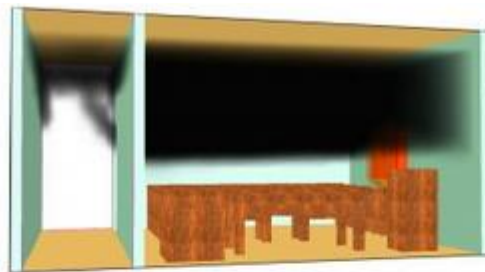


Figure 5: Soot Mass Fraction and HRRPUV at $t=170$ sec for case 5.

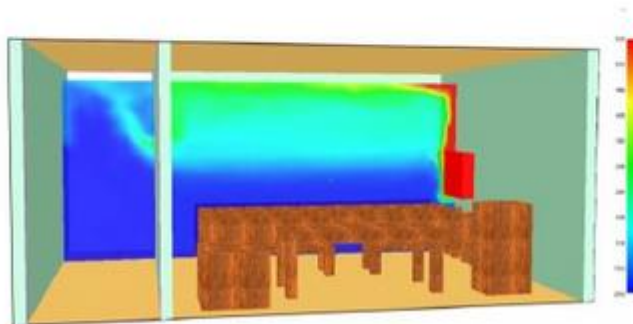


Figure 6: Temperature profile at $t=60$ sec for case 4 (profile plane $y=1$ m)

A peak temperature of around 500-600 degrees is reached near the surface of the air-conditioner in each case.

3.2 Calculation of ASET (Available Safety Evacuation Time)

Fatalities in fires are principally caused by a) toxic smoke inhalation b) exposure to high temperatures and c) light shielding effect of the smoke[15]. There is no data relating to the

toxicity of the gases yielded in AC fires. Since visibility relates to both light shielding effects as well as concentration of smoke present, so we will use a value of critical value of 20 m at the head-level to calculate ASET. From the statistics of height of Taiwanese males[16], considering the average of 1.68m and the dispersion, we will take a conservative 1.80 m as the characteristic human height for our study. After Mo Shan Jun et al[17], we will take the maximum tolerable temperature at the head-level to be 60 degrees Celsius. We calculated the volumetric average of visibility as well as temperature in the height range of 1.75-1.80 m in the room for every case. Since the distribution of temperature and smoke is observed to be almost uniform horizontally, this average is representative of the condition prevailing at the head-level of our characteristic human in the room. The averages are plotted against time and the ASET is calculated from the plots.

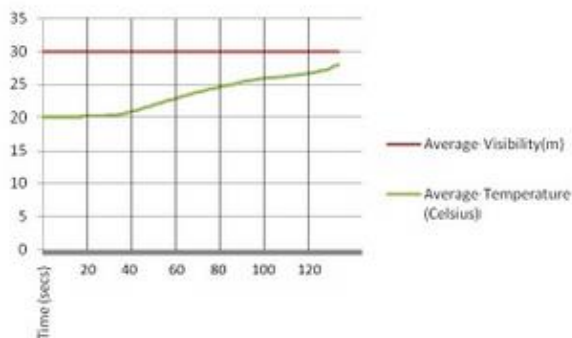


Figure 7: Visibility and temperature plot for Case 1

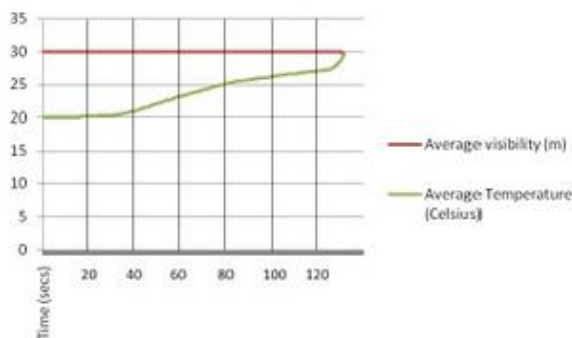


Figure 8: Visibility and temperature plot for Case 2

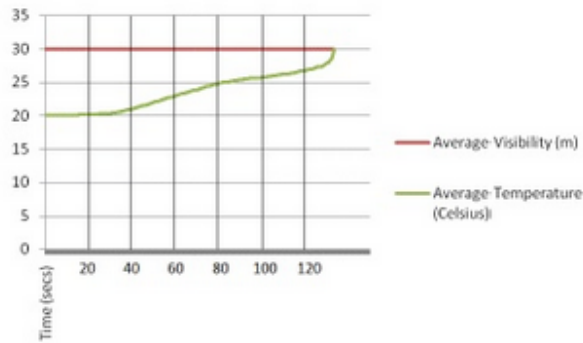


Figure 9: Visibility and temperature plot for Case 3

We observe that in cases 1 to 3, the volume-averaged visibility remains steady at 30 m until the fires are extinguished, meaning that the smoke layer does not descend to head-level. Thus there is no significant danger from toxic smoke inhalation or obscurity of vision. Since the temperature does not rise above a mild 30 degrees either, *the ASET in cases 1, 2 and 3 may as well be considered infinite.*

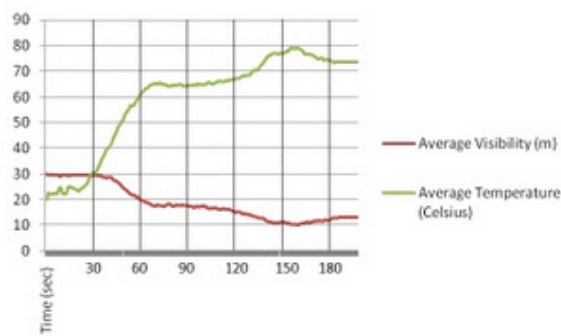


Figure 10: Visibility and temperature plot for Case 4

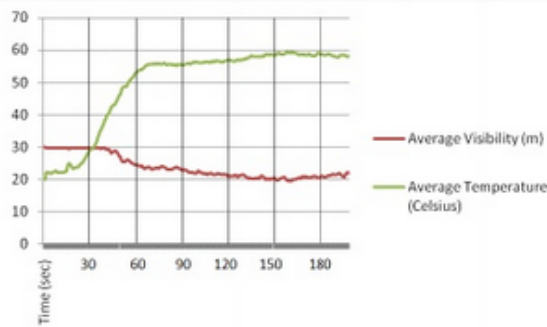


Figure 11: Visibility and temperature plot for Case 5

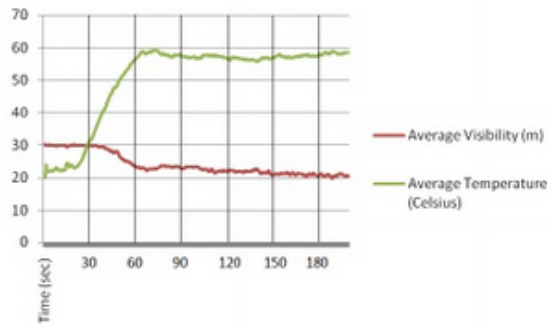


Figure 12: Visibility and temperature plot for Case 6

We observe that in cases 4 to 6, the temperature begins to rise sharply almost immediately since the plume of hot gases rises from below head-level. The temperature keeps increasing till it flattens at a peak of about 60 degrees for cases 5 and 6 and 80 degrees for case 4. Visibility remains steady until 40 seconds after which the smoke layer reaches head-level and visibility dips. The dip is more severe for case 4. From the plot data, we thus obtain the following ASET for each of the cases.

We observe that in cases 4 to 6, the temperature begins to rise sharply almost immediately since the plume of hot gases rises from below head-level. The temperature keeps increasing till it flattens at a peak of about 60 degrees for cases 5 and 6 and 80 degrees for case 4. Visibility remains steady until 40 seconds after which the smoke layer reaches head-level and visibility dips. The dip is more severe for case 4. From the plot data, we thus obtain the following ASET for each of the cases.

Case	Calculated ASET (secs)
1	∞
2	∞
3	∞
4	60
5	128
6	74

(Note: The large difference in ASET values between cases 5 and 6 does not stem from a large difference in fire behavior. Case 5 simply reached its plateau just below the critical temperature of 60 degrees.)

3.3 Calculation of RSET and feasibility of evacuation

RSET = Fire Detection Time + Pre-movement Time + Evacuation Movement Time

However since our simulation starts at a time where the entire AC is engulfed in fire and evacuation has started (door is open) we will consider only evacuation movement time in our calculations. We will make the simplifying assumptions that all the people within the room are in good physical health, they are uniformly distributed and they move with an equal and constant speed.

To calculate the Required Safety Evacuation Time we will use the following experiential formulae: [17]

$$V = k(1 - aD) \quad (2)$$

Here, k is a constant equaling 1.26 m/sec for horizontal exit routes, $a = 0.266$ and D is the occupant density in persons per m^2 . For our seminar room, the maximum capacity is 60 people hence $D = 1.32$ persons/ m^2 and $S = 0.8$ m/sec.

The effective evacuation distance is given by

$$S = (b + l) + X / x \quad (3)$$

Here, $(b + l)$ is the sum of the length and the width of the compartment is the longest possible distance that a person has to travel to reach the exit.

The term X/x is the added distance due to the passage of X persons through x exit routes. The passage of one person per second [18] has been observed in uncontrolled total evacuation drills in well-populated office buildings. So this term transforms the passage of each person into a walking distance of one meter. For our study S comes out to be 73.5 m.

Therefore, evacuation movement time is calculated as

$$T = S / V \quad (4)$$

The evacuation movement time comes out to be 92 seconds. Taking a factor of safety 1.5, RSET equals 138 seconds.

Thus, $ASET < RSET$ in cases 4, 5 and 6 and evacuation in these cases will expose occupants to the dangers of smoke inhalation and high temperatures. Safe evacuation is possible for cases 1, 2 and 3.

4. CONCLUSIONS

Through calculations of RSET and ASET for the seminar room, considering different cases, this study shows that installations of air-conditioner that are above door height are reasonably safe in case a fire breaks out due to equipment malfunction. This is because the smoke and hot gases are limited to the upper reaches of the room, the fire is soon suppressed due to lack of oxygen and the spread of fire to other objects in the room is quite unlikely. The almost identical behaviours of cases 1, 2 and 3 also showed that distance from the door does not affect fire behaviour at such heights. On the other hand, window AC installations at lower heights can pose quite a threat in case of a fire. They burn quite steadily, the fire may spread (as in case 4) and the layer of smoke and hot gases descends to heights where it can affect the occupants significantly. There is some difference between the behaviours of fires in cases 4, 5 and 6.

Fire 4, being placed directly opposite to the door and thus well-ventilated, burns more vigorously than the fires in cases 5 and 6, a fact clearly observed in the temperature and visibility plots. We also established that the original fire (case 4) could have caused injury to the occupants of the room, since $RSET < ASET$ for cases 4, 5 and 6. We see a large potential of further research in this area. Experimental work on the severity and toxicity of such fires need to be performed, so that more reliable and detailed simulation studies can be done and deeper insight can be gained.

Project

Academic Research Paper submitted to professor to get a better insight of how research is done.

Reconstruction Of Fire Scene At Ala-Pub

Abstract

Fire disasters frequently cause loss of life and property. Considerable valuable information regarding the thermal environment is also lost after the fires are extinguished. This study makes use of the fire dynamic simulator (fds) + evacuation software developed by NIST in liaison with VTT research centre, Finland to re-create the fire scene that occurred at the ALA-PUB in Taichung, Taiwan. The personnel evacuation time and time variants for various fire hazard factors of reconstructive analysis clarify the reason for such a high number of casualties. In this study people's velocity and evacuation time is changed and then the different results are obtained and analysed. Results obtained also matched closely with the actual fire scenario. The close comparison between simulation result and actual fire scene also provides fire prevention engineers, a possible utilization of FDS to examine the effects of improved schemes for the safety of buildings.

Introduction

In the event of fire occurrence at the entertainment avenues, the casualties/fatalities are generally more because these places are usually crowded. Some of the fire mishaps in the nightclubs are considered as the most deleterious incidents in the history. People at these avenues are not aware of the place; so evacuation takes a much longer time. For example, a

nightclub fire on 27th January, 2013 in southern Brazil killed at least 233 people and it is now reckoned to be the second most deadly fire mishap in the history of Brazil. On March 18, 1996 a fire incident at Ozone Disco club, Quezon City, Philippines ended up taking 160 lives. And on Dec 25, 2000 a fire incident (fire began elsewhere in shopping plaza & spread to disco) in Disco/Dance hall, Luoyang China killed 309 people.

Materials and Methods

Fire Simulation and Investigation

In this study, FDS+Evac [4] is used for the simulation or recreation of the actual fire scene to analyse the pedestrian evacuation time, CO concentration, temperature change smoke layer height with respect to time. Fire Dynamics Simulator (FDS) is a computational fluid dynamics (CFD) model of fire driven flow capable to simulate complex physical and chemical phenomenon associated with fire such as heat transfer, pyrolysis, combustion, radiation, turbulence, fluid dynamics and suppression. It is the work of NIST (National Institute of Standards and Technology, USA) in liaison with VTT Technical Research Centre of Finland. FDS+Evac considers each and every evacuee as a single agent, whose movement is considered by an equation of motion. FDS provides CFD calculations mainly based on LES (large eddy simulations). The governing equations of mass, momentum, energy are given as follows:

Conservation of Mass

$$\partial \rho / \partial t + \nabla \cdot \rho \mathbf{u} = \dot{m}^m$$

Conservation of Momentum (Newton's Second Law)

$$\partial / \partial t (\rho \mathbf{u}) + \nabla \cdot \rho \mathbf{u} \mathbf{u} + \nabla p = \rho \mathbf{g} + \mathbf{f}_b + \nabla \cdot \boldsymbol{\tau}_{ij}$$

Conservation of Energy

$$\partial / \partial t (\rho h) + \nabla \cdot \rho h \mathbf{u} = Dp/Dt + \dot{q}^m + \dot{q}_b^m + \nabla \cdot \dot{q}^n + \varepsilon$$

Equation of State for a Perfect Gas

$$p = \rho R T / W$$

where p =pressure, ρ =density, T =temperature, $\mathbf{u} = (u, v, w)$ are velocity vectors, $\dot{m}^m$ =mass flow rate of per unit volume, $\mathbf{f}_b$ =external force vector(excluding), $\boldsymbol{\tau}_{ij}$ =viscous stress tensor, h =enthalpy; heat transfer coefficient, $\dot{q}^m$ =heat release rate per unit volume $\mathbf{g}$ =gravity vector,

$\dot{q}^n$ =heat flux factor, ϵ = dissipation rate, R =universal gas constant and W is Molecular weight of the gas mixture.

In Agent movement model each agent follows its own equation of motion:

$$M_i \cdot d^2x_i(t)/dt^2 = f_i(t) + \xi_i(t)$$

where $x_i(t)$ is the position of the agent i at time t , $f_i(t)$ is the force exerted on the agent by the surroundings, m_i is the mass, and the last term, $\xi_i(t)$, is a small random fluctuation force. The velocity of the agent, $v_i(t)$, is given by dx_i/dt .

The structure and shape of human body is approximated by 3 overlapping circles depicting elliptical body shape as shown in Fig.1 and based on that unimpeded walking velocities used in FDS+Evac are given in Table1.

Table 1
Body dimensions and unimpeded walking velocities in FDS + Evac.

Body type	R_d (m)	R_s/R_d (—)	ds/R_d (—)	R_t/R_d (—)	Speed (m/s)
Child	0.210 ± 0.015	0.3333	0.6667	0.5714	0.90 ± 0.30
Adult	0.255 ± 0.035	0.3725	0.6275	0.5882	1.25 ± 0.30
Male	0.270 ± 0.020	0.3704	0.6296	0.5926	1.35 ± 0.20
Female	0.240 ± 0.020	0.3750	0.6250	0.5833	1.15 ± 0.20
Elderly	0.250 ± 0.020	0.3600	0.6400	0.6000	0.80 ± 0.30

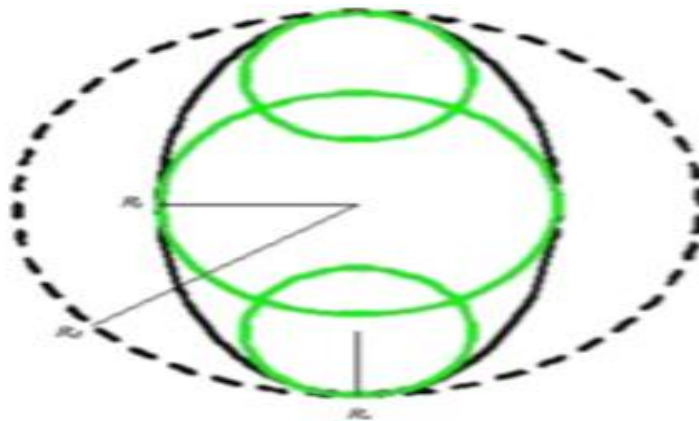


Fig.1 Illustration of the human body approximated by a combination of three overlapping circles.

Building and Fire Characteristics

The ALA PUB was a two storeyed building with a floor area of approximately 30 ping (99.17m²) and had only one narrow stair case which goes up to the second floor. More than 70 people had been packed into the small bar and there was only one exit gate on the ground floor (safety exit gate on the second floor was blocked) so evacuees on the second floor had to take the stairs to move out of the building through the front door. A dancer at the ALA Pub on Jhongsing Street accidentally set fire to the ceiling with his torch during a performance, triggering the blaze at about 1:30 a.m. and the insulation of ceiling was made of polyurethane (PU) foam. So because of excellent flammability characteristics of PU the whole bar was engulfed with fire in less than 3 minutes. The origination point of fire was on the second floor near the narrow stair case. In the figures from 2-4 different views of the building are shown. In fig.4 the red circle is showing the fire origination point and yellow circle is indicating the stare well where as in fig.5 the yellow circle is indicating main front door on first floor.



Fig.2 Image at the fire scene.

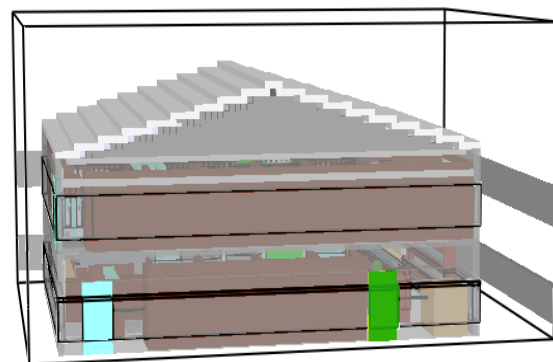


Fig.3 3-D model of the building



(front
view).

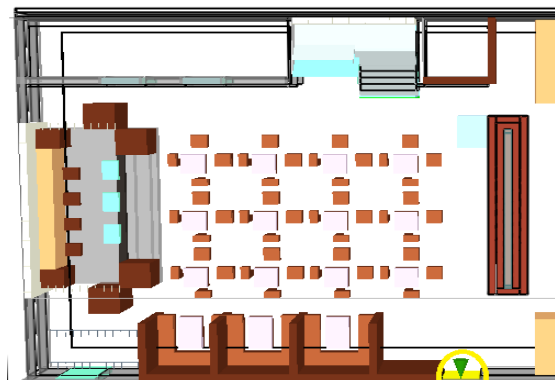


Fig.4 Inner top view of the building.
building.

Fig5. Top view of the first floor of the

The fire began near the stairwell; thus several people on the second floor could not escape, causing deaths of nine people and injuring 12. The time table of the progression of the fire progression is represented in the Table 2:

1:18 AM	Sparks Ignited the ceiling
1:29 AM	Fire spread rapidly across the ceiling
1:22 AM	Fire and smoke spread throughout the building
1:24 AM	Fire Bureau Informed
1:33 AM	Firefighters Arrived
2:13 AM	Fire Controlled

Table:2

Simulation Results and Analysis

In the fire incident of ALA PUB nine people lost their lives. Their bodies were found on the floor and it was evident that the fumes asphyxiated them. In this study the whole scene is reconstructed to closely analyse what actually happened in the incident and the simulation results were matched with actual incidents.

Velocity(m/sec)	No. of casualties	No. of people safely evacuated	First person died at (sec)	First person evacuated at (sec)
0.2	70	10	70.05	20.28
0.4	50	30	75.07	17.97
0.6	33	47	74.26	14.47
0.8	17	63	83.76	12.53
1.0	8	72	87.88	16.06
1.2	0	80	N/A	16.06
1.4	0	80	N/A	15.31
1.6	0	80	N/A	14.01
1.8	0	80	N/A	13.75

2.0	0	80	N/A	12.75
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Table3: Tau=0.7 Total No. of people=80 HRR= 800 KW/M² Random

Velocity(m/sec)	Tau	No. of casualties	No. of people safely evacuated	First person died at (sec)	First person evacuated at (sec)
0.975	0.5	11	69	85.4	13.55
0.95	0.5	9	71	82.23	13.6
1.0	1.0	13	67	82.93	13.86
0.97	0.7	12	68	82.23	13.75
0.9875	0.5	6	74	85.34	13.52
0.2	0.7	73	7	71.38	14.55

Table4: Total No. Of people=80 HRR= 800 KW/M² Random

In Table3 the simulation results are shown when velocity is changed by the factor of 2 and relaxation time is kept constant. The number of people/evacuees are 80 and heat releasing rate calculated is 800 KW/M² and motion of the people in the building is random. When the velocity is 0.2 m/s total number of casualties came out as high as 70 and when the velocity is set to be 2.0 m/s the total number of casualties calculated by the software came out to be 0. When the velocity is 1 m/s the total number of casualties that occurred comes out to be 8 which is close to our result and the velocity also lies in between the impeded velocities as shown in the table 1.

When relaxation time i.e tau is changed keeping the velocity same then it also shows a significance amount of change. When the velocity of agents was kept 1.0 m/s and tau was changed then variation in number of casualties was observed. When tau was kept 1.0 then total number of casualties increased by 5 as compared to the tau=0.7 . This shows that relaxation time is also an important factor during a mishap/evacuation scenario. Whenever the velocity of agents is kept in the range of impeding velocities of the adults the results obtained are comparable with the actual fire scenario.

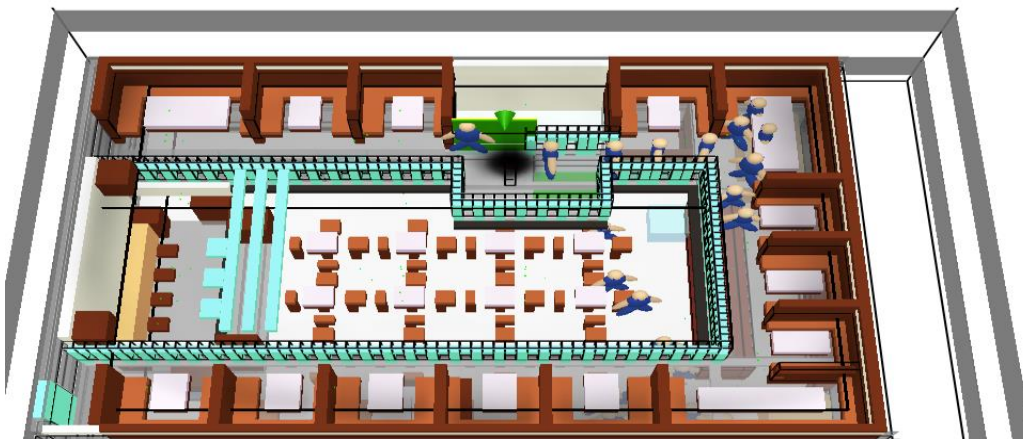


Fig5: People Evacuation at second floor

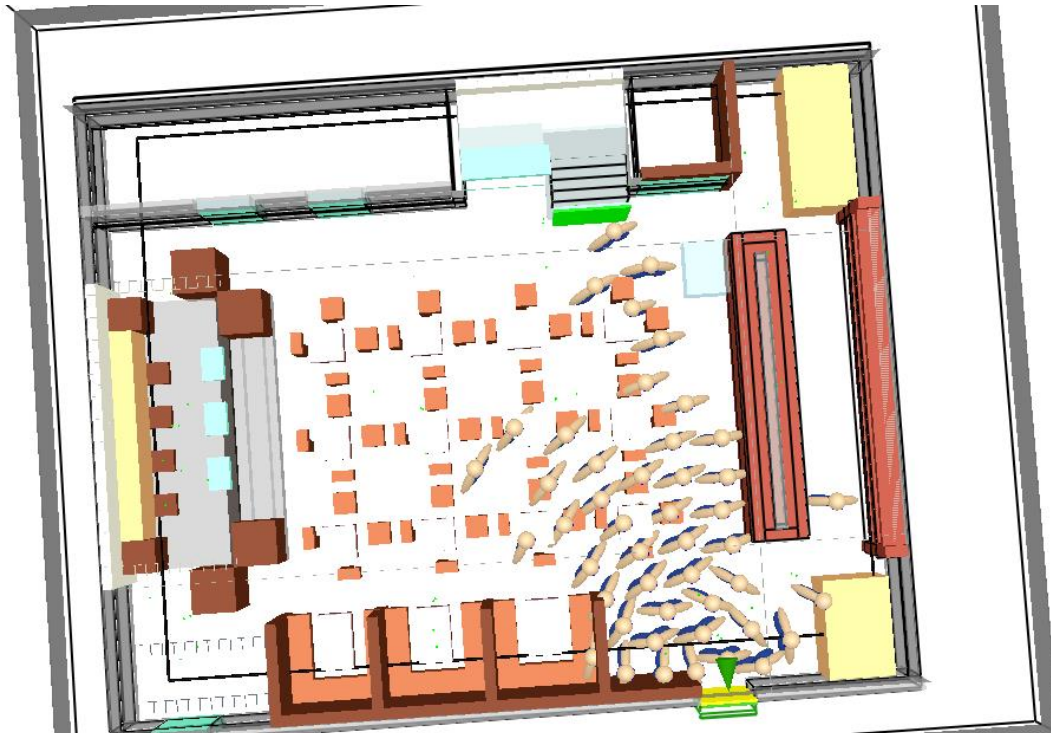


Fig6: People Evacuation at first floor

Conclusion

The most difficult task during a fire investigation is to reconstruct the fire scenario by using analysis to determine the cause of fire. The results of these investigations can be used as evidence. The FDS simulation results were combined with the evidence provided by the Fire Bureau and media reports to assist the researchers in reconstructing the fire scenario. The simulation results were fairly similar to the actual fire scenario, which demonstrates the effectiveness and value of the FDS in ensuring the fairness, objectivity and accuracy of fire investigations and forensic science.

Future Scope

Scientists and engineers are often asked to make predictions of the state of technology in the future and are usually laughably wrong. The best prognosticators get the trends right, but cannot possibly fill in the details. Think of Jules Verne predicting a trip to the moon, albeit in a projectile decked out in lavish red velvet, manned by champagne-sipping adventurers, and shot out of a giant cannon. Unlike Jules Verne, Fire Engineers dare only look 10 years into the future, rather than 100. In the Spring 2000 issue of *Fire Protection Engineering*, Howard Baum wrote a brief history of fire simulation in which he listed three major challenges facing fire modellers.

First, there are an enormous number of possible fire scenarios to consider. Second, fire engineers do not have either the physical insight or the computing power (even if we had the insight) to perform all the necessary calculations for most fire scenarios. Finally, since the “fuel” in most fires was never intended as such, the data needed to characterize both the fuel and the fire environment may not be available. Ten years from now, these issues will remain. Certainly the wide range of fire scenarios will persist, even widening due to the constant emergence of new materials and new architectural forms. Computing power will certainly increase, but not to the point of allowing for direct numerical solutions of the governing equations. As models focus in on the small-scale combustion processes in a fire, ever-more complex challenges will emerge that are, for now, neglected. Fortunately, there is hope. The reason is that models based on fundamental principles will improve automatically as computers get faster and the temporal and spatial resolution improves. In looking towards the future, fire engineers need to adopt fundamentally sound physical mechanisms that will retain an elegance and simplicity over time, that will shift us from empirical to deterministic descriptions of fire behaviour, and that will be useful to fire protection engineers and researchers alike. Using the NIST Investigations of the World Trade Centre collapse and the Station Nightclub fire, it became fairly obvious what needed to be done with FDS to make it an effective tool for reconstructing fires. Up to that point, FDS had been used by the FPE community for design applications, and to some extent forensic work, but the scope of the Investigations pushed the model to its limits. By 2005, it was clear that FDS was going to need a major overhaul, so we set about creating a new version (FDS 5) that would dramatically increase the flexibility and functionality of the model. The work proceeded along two broad fronts - the gas phase and the solid phase. In short, better combustion and better pyrolysis. Version 5 was released in 2007. It included a major overhaul of the input parameters and constructs. Over the next three years

improvements were gradually added, and in 2010, work began on FDS 6, which began beta testing in the fall of 2012.

The Road Ahead

Transport Equations[14]:

The core mass, momentum and energy transport algorithms within FDS are fairly robust and efficient, but up until the introduction of FDS 6, these algorithms exhibited over-shoots and under-shoots of scalar quantities in regions of steep gradients, a condition common to second order accurate finite-difference schemes. A new TVD (Total Variation Diminishing) transport algorithm for the density and species mass fractions has been implemented in FDS 6. The algorithm includes several different types of flux-limiting finite difference schemes that eliminate the excessive over and under-shooting in regions of steep gradients. One drawback of the new schemes, however, are that they require more CPU time per time step, and efforts are on-going for reducing the cost.

Potential Research Topic: Explore ways to increase the speed and decrease the memory requirements of the new transport schemes. Use the FDS Validation Suite to demonstrate equivalent or improved accuracy of the new algorithms.

The Pressure Solver:

FDS still need to improve the coupling of the pressure solver across mesh boundaries in a multi-mesh (often called "multi-block") simulation. Discontinuities in the pressure solution across these boundaries is currently the biggest speed bump to broader, more reliable use of the multi-mesh approach. The hope is to determine a computationally efficient way to perform this coupling that still permits the use of the direct pressure solver (CRAYFISHPAK) which is one of the primary reasons why FDS is fast. FDS 6 includes a way to tighten the tolerance of the pressure solution across multiple meshes by iterating the single mesh solutions, but this method is relatively slow.

Potential Research Topic: Improve efficiency of parallel version of FDS on very large computing clusters (100+ processors). Document scalability using conventional parallel computing terminology. Priority: High.

Combustion:

While working towards FDS 6, it became clear that the mixture fraction framework was becoming a limitation. It relied upon explicit assumptions about the fuel chemistry and the combustion reaction that resulted in inflexibility in the framework. Users and developers were locked into the assumptions without any easy method of redefining them other than re-writing portions of the input processing and combustion routines. Starting in FDS 6, a new lumped species framework has been developed to enable the user to have greater flexibility in specifying minor product species such as toxicants while still maintaining some level of computational efficiency. The new lumped species framework will be coupled with a more flexible combustion routine to enable easier exploration of reaction schemes.

Current Activities:

Led by Jason Floyd of Hughes Associates and Craig Weinschenk of NIST, they are moving towards a more general combustion formulation than previous versions. The method makes use of "lumped" species mixtures that reduce the number of species transport equations that need to be explicitly solved.

The new algorithms have been validated against experiments ranging from Kermit Smyth's Wolfhard-Parker burner to Craig Beyler's under-ventilated hood series to Bill Pitts' reduced scale enclosure tests. Work continues along these lines with the reduced and full-scale under-ventilated compartment experiments of Johnsson and Bundy at NIST.

Smoke Transport:

Recent large scale experiments conducted at NIST under US NRC sponsorship included measurements of smoke concentration that were substantially lower than predictions of both FDS and CFAST, the NIST zone fire model (US NRC, NUREG-1824). A possible explanation has been suggested by researchers at Hughes Associates, who have noted that significant amounts of smoke can be deposited on walls, an effect that is usually neglected by fire models. Starting in FDS 6, there is an optional soot deposition model implemented by Jason Floyd and Kris Overvault that uses empirical correlations to predict the rate of soot deposition onto walls.

Potential Research Topic: Reduced and full-scale experiments quantifying the mass of soot depositing onto surfaces. Experiments should isolate the various deposition mechanisms (thermophoresis, gravitational, and turbulent) to enable independent V&V of the specific

mechanisms. Priority: Medium

Potential Research Topic: Algorithms for the oxidation of soot deposited onto surfaces.

Priority: Medium

Potential Research Topic: Visualization techniques to shade surfaces based upon the amount of soot deposited. Priority: Low

Suppression:

Modelling gas phase suppression (flame extinction) is also a long term goal. FDS 5 has a simple, empirically based model of flame extinction based on the concept of the *lower oxygen limit* applied locally, grid cell by grid cell. Also available is the same concept for the fuel stream using the *lower flammability limit*. Validation work is on-going to test the simple model, and it is planned to also look at gaseous suppression agents and water mist.

Potential Research Topic: Identify and perform simulations of full-scale or reduced-scale experiments where the fire self-extinguished or was extinguished by a diluent or suppressing agent. The results could be added to a new chapter on Suppression in the FDS Validation Guide. Priority: High.

Modelling of ignition or re-ignition (deflagrations and backdrafts) is also a long term goal. The new lumped species approach will make possible development into these areas. It is noted that the low-Mach number limitations of FDS means that computations on flows that approach a detonation event will not be possible.

Potential Research Topic: Modelling backdraft experiments, noting that FDS currently lacks certain necessary physical mechanisms that would need to be developed in cooperation with us. Priority: Medium.

Pyrolysis and the Solid Phase:

Simo Hostikka of VTT, Finland, developed the basic framework for describing heat conduction and pyrolysis within bounding solids. The algorithm includes 1-D heat transfer through multiple layers of materials, and a generalized pyrolysis algorithm to allow for multiple materials undergoing multiple reactions.

The major hurdle in this area is still the availability of material property data. After 30 years of model evolution, there is now a fairly broad consensus on the basic approach for modelling solids within a fire model, but there remains the major hurdle of measuring the necessary

material properties.

Potential Research Topics: With an eye to the emerging trend of standardizing the measurement and interpretation of solid phase thermo-physical properties, demonstrate that we can, or cannot, model the decomposition and burning of various solids and liquids. For classes of solids that do not seem amenable to standardized measurement methods, suggest alternatives and demonstrate practicality and effectiveness. Priority: High.

Droplets, Particles, and the Dispersed Second Phase:

Code development in the areas of spray dynamics, spray heat transfer, and other areas related to dispersed second phases has been modest in comparison to the gas and solid phase efforts. Future areas of work include improved tracking of droplets and particles, improved radiative heat transfer to and from droplets and particles, and improved interaction between droplets and particles and the gas phase. These area would encompass the ability to have combusting particles (fire brands) and to better account for surface wetting, surface suppression, and surface penetration by droplets.

Potential Research Topic: Overhaul and simplify the droplet evaporation algorithm in the source code file part.f90. Currently, the heat and mass transfer is calculated droplet by droplet, but it would be more effective to process the droplets en masse rather than one by one. We need to also check the validity of the Claussius-Clapeyron evaporation model at temperatures ranging from ambient to flame. Priority: High.

Potential Research Topic: Improve modelling of dense water spray. Currently, water droplets do not interact each other. Priority: Medium.

Complex Geometry:

FDS has always been tied to structured Cartesian block geometries. Given that the zeroth-order specification of the heat release is often the best that can be expected from a fire model, the block geometries have not typically been viewed as a limiting factor. However, at a minimum, it is often a cumbersome process to input geometric information for something as simple as a cylinder. As we begin to tackle more challenging problems with FDS (fire spread, atmospheric flows) we are gradually being forced to account for second-order physical processes and we therefore require second-order numerical treatments at solid interfaces. For example, to first order the spread of wildfires is dictated by surface winds. In mountainous regions where these fires occur, the terrain is complex and simulations using stair-stepped

grids lead to spurious fluctuations in the wind field.

To address this issue engineers are experimenting with a new geometry module which creates a solid surface interface based on triangular facets as the primitive geometry element. The research needs in this area involve eliminating numerical diffusion of heat and mass in immersed boundary methods (IBM) without resorting to a formal cut cell method. Cut cell methods suffer from problems related to small unstructured cells that are inevitably created when a slanted surface interfaces with the Cartesian mesh. These cells cause time step constraints and stability problems unless they are merged with neighbouring cells. This merging process and all code needed for the unstructured geometry engine is inherently messy.

Potential Research Topic: Chimera (overlapping) mesh methods for heat and mass transport near complex surfaces. Priority: High (short term).

Potential Research Topic: Validate radiation model for complex geometry. Priority: Medium (short term), High (long term).

Active Fire Protection Systems:

In the 2006 workshop of The International Forum of Fire Research Directors (FORUM), the improvement of the ability to predict the impact of active fire protection systems on fire growth and fate of combustion products was identified as the most important research topic of the fire research community. Many of the future developments in FDS will focus on this topic. The issues affecting the modelling of fire suppression systems have already been addressed in the sections concerning combustion (modelling gas phase suppression) and Droplets, Particles and Dispersed Second Phase (description of water sprays). The modelling of water mist systems in particular should be addressed because they are rapidly becoming common. In addition to the basic physical sub-models of FDS, improvements are needed in the description of the suppression systems. For example, the simultaneous discharge from several sprinkler or water mist nozzles have effects on the pressure of the pipe system, and therefore on the mass flow of suppressant.

Potential Research Topic: In cooperation with VTT, Finland, better characterize the spray of fine mist and validate FDS for mist suppression. Priority: Medium.

Radiation

FDS version 1 used heat emitting particles to represent a fire. Radiation transport consisted of Monte-Carlo ray tracing from the particles to surfaces, essentially painting the radiative fraction of the fire on surfaces. Hot surfaces and hot gas layers were not emitters.

Early in the development of FDS 2 it was recognized that FDS was being used for conditions where the participation of surfaces and gases was important, and thus, a new radiation model was needed. The model that was eventually developed consisted of using RadCal (added by Jason Floyd while a NIST post-doc) to generate look-up tables of absorptivity and a Finite Volume Method radiation transport model (developed by Simo Hostikka of VTT). This approach consumes around 20% of the computational time and for the simpler versions of the combustion model generally performs well.

Ideally, engineers would prefer to compute absorptivity during the actual simulation rather than attempting to use look-up tables which do not readily support the needs of the more complex combustion models being developed. However, current validation efforts indicate that errors resulting from the use of the look-up tables are not large (indeed it is not clear if the errors are any larger than those in the experimental data we use for validation) so any new approach to generating absorptivity or radiation source terms should not consume significantly more time than currently used by the radiation transport. For example, RadCal could be called for each grid cell each time radiation transport is computed, but that would consume a tremendous quantity of resources.

Potential Research Topic: Examine the means to reduce the ray-effect.

Potential Research Topic: Determine a better way to define the radiation length scale or another way to calculate the 'path-mean' absorption coefficients from the narrow-band data.

High Performance Computing:

FDS[13] is written in Fortran 2003. Currently, there are two versions of FDS - serial and parallel. The serial version uses one process to compute the solution of the governing equations on one or more meshes, serially. This version cannot exploit multi-processor or multi-core architectures. The parallel version uses MPI (Message Passing Interface) to launch multiple processes on multiple machines. The advantage of MPI is that we can break up very large cases to reduce the run time and distribute the memory (RAM) among the different machines.

Recently (starting in FDS 5.4), Christian Rogsch of the University of Wuppertal in Germany implemented Open MP directives in FDS. OpenMP allows FDS to

run on a single machine but use its multiple processors and cores. This version is still being tested, but it is hoped that the OpenMP functionality becomes standard in FDS. At that point, both OpenMP and MPI can be used together to break up big jobs over multiple machines while at the same time exploiting multiple processing capabilities on each machine.

Potential Research Topic: Develop a strategy by which both OpenMP and MPI can be used on a cluster of dual processor/quad core machines. The end result would be rules for optimizing run times based on number of meshes, cells per mesh, number of machines, number of processes per machine.

Building Systems:

The International Forum of Fire Research Directors (FORUM) has identified the ability to determine the relationship between aspects of a building's design and the safety of building occupants as one of the top five research priorities. For whole building analysis, environmental control systems are a major contributor to the movement of toxic combustion products through a building. FDS 6 will be released with a first generation HVAC model as a first step in assessing the impact of HVAC systems on smoke movement. Further development will be needed to account for control system behaviour, transport delay of species, combustion within HVAC systems, deposition of aerosols, and to support modelling of in-duct, fire detection systems.

Potential Research Topic: Algorithms for determining the flow loss through filters exposed to soot, simple approaches to model duct heat transfer, computationally efficient approaches to model mixing and combustion processes within HVAC duct networks. Priority: Medium.

Potential Tool Development: User interfaces for developing the inputs to model complex HVAC networks.

Fire Toxicity:

In the context of FDS+Evac development we are planning to use the Fractional Effective Dose methods presented in the SFPE Handbook of FIRE Protection Engineering (Purser, 2008a). For these computations, we need a capability to define arbitrary toxic species as products of combustion. The concentrations of these species are usually so small, that they need not to be considered in gas transport computation (with possible exceptions).

Since some gases are produced in well-ventilated conditions and some in under-ventilated, it might be reasonable to let the user define if the gas appears in fixed proportion to major carbon carrying species, as discussed in Combustion section above. Assuming the CO model works, this would introduce under-ventilated products.

In FDS6, the FED/FEC algorithm will recognize the following species:

Asphyxiants: CO, HCN, Low O₂ and CO₂.

Irritants: HCL, HBr, HF, SO₂, NO₂, CH₂CHO (acrolein), CH₂O (formaldehyde), X (user defined)

Potential Research Topic: Yields of these species under different conditions, in relation to CO₂ or CO production.

We hope that the new coming versions of FDS+EVAC will help fire engineer's to analyse a fire scenario more precisely because FDS+EVAC has already played and still playing an important in understanding some fire mishaps that happened in the past and it is also used as a crucial tool for building risk free (from fire mishaps) structures and preparing a good evacuation route for the evacuee's in case of any fire. It's very important because in case of a fire many people lose their lives and there is a huge loss of property as well and it is always said that prevention is better than cure and FDS+EVAC has huge potential in making the buildings risk free.

Career Opportunities

Benefits and Opportunities

- **You'll have the power to make a difference!**

By becoming a fire protection engineer, you can make the buildings we live and work in safer for everyone.

- **You'll have money and job security!**

Fire protection engineers have significantly higher starting salaries than do college graduates with bachelor's degrees in many other fields. The median starting salary for a fire protection engineer is nearly \$65,000.

- **You'll be working with other talented people!**

Fire protection engineering is a team effort. As a fire protection engineer you may be

working on projects with experts in many different fields and backgrounds, from architects to contractors to designers.

- **You'll have lots of options!**

Fire Protection Engineers work everywhere: in big and small cities, urban areas and rural communities, even remote wilderness areas. Some work in business offices or classrooms, others in factories or research labs or onsite at a building location.

Where You can Work

A fire protection engineer fulfils a broad range of duties, all in some way related to fire. This can range from designing fire protection for a space station, to protecting treasures such as the U.S. Constitution, to ensuring that the occupants of a high-rise building are safe from fire. Fire protection engineers have always been in great demand by corporations, educational institutions, consulting firms, and government bodies around the world.

Fire protection engineers work in the following roles and industries:

- Consulting Engineering Firms
- Fire Departments
- Fire Equipment and Systems Manufacturers
- Government
- Hospitals and Health Care Facilities
- Insurance Industry
- Research & Testing Laboratories
- Universities & Colleges
- Entertainment Industry
- Forensic Investigations

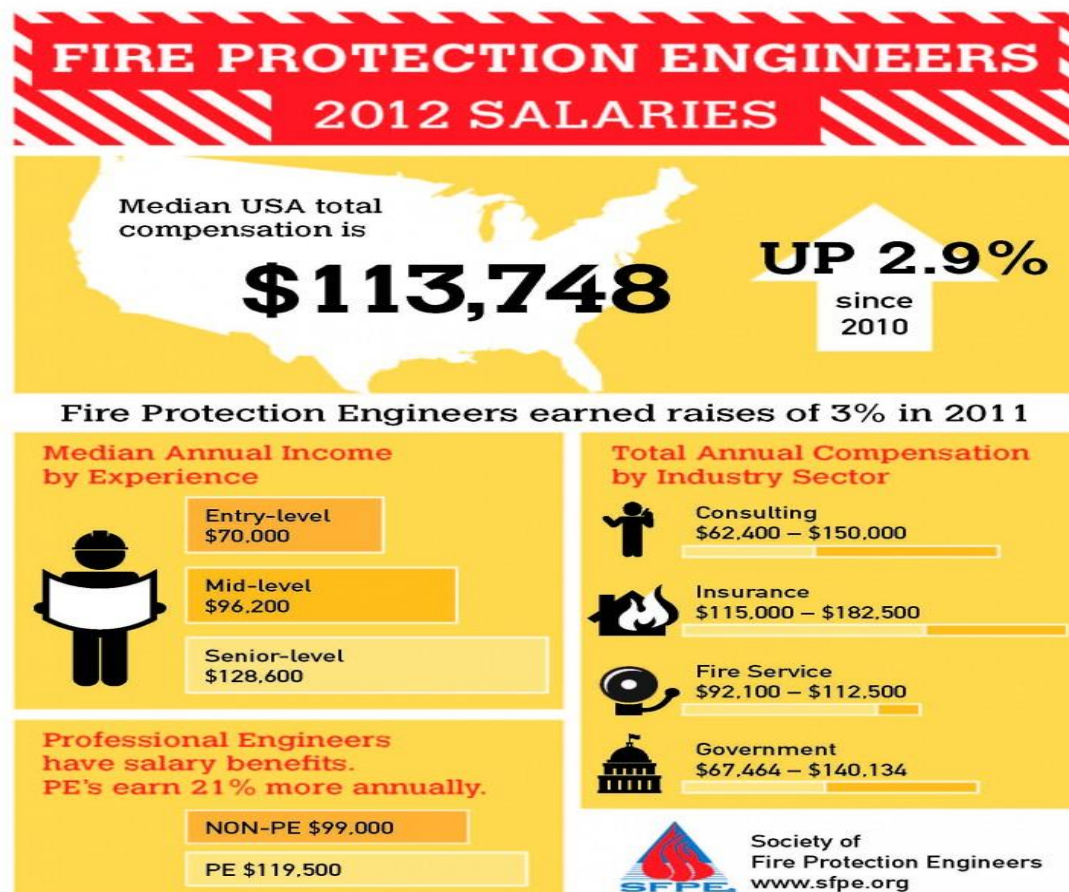
Awards and Competitions

Each year during National Engineering Week, the Society of Fire Protection Engineers sponsors the Fire Protection Award at the National Future City Competition.

The National Engineers Week Future City Competition is a program developed for sixth, seventh and eighth grade students to help them discover and foster interests in math, science and engineering. Students work in teams under the guidance of a teacher and a volunteer engineer mentor to design and build a city of tomorrow. They create cities on computers and then build three-dimensional, tabletop models to scale. Students also write brief narratives describing their city and must present and defend their designs at the competition before a panel of engineer judges who test the depth of the teams' knowledge.

Salary Facts

It pays to be a fire protection engineer. Not only does becoming a fire protection engineer bring the personal satisfaction of making the world safe from fire, but it provides competitive income.



In 2012, the Society of Fire Protection Engineers conducted a salary and benefits survey of the fire protection engineering profession. Data from this salary survey show that:

- Median income (including bonuses and overtime) for those working in fire protection engineering in 2011 was \$113,748, a slight (3%) since the previous survey was conducted in 2010.
- Median income (including bonuses and overtime) for engineers with 0-6 years of experience with a bachelor's degree was \$70,000 per year.
- Fire protection engineers with upwards of 15 years work experience earn the greatest salaries in the field. It is common for senior-level fire protection engineers to make over \$128,000 per year.

Generous benefits are another reason to choose a career in fire protection engineering. The vast majority of respondents receive medical benefits, dental benefits, flexible spending accounts, retirement plans, tuition reimbursement and bonuses.

Professional Profiles

Engineering Consultant:

Consulting engineers are often involved in the design of large buildings. Their role as part of the design team is to address fire safety concerns that arise during the design and construction of a building. In that role they work with engineers from other disciplines, as well as architects, technicians, and building owners and managers to protect against the threat of fire. The fire protection engineer is also often the liaison with government officials.

Fire protection engineering consultants also work with building owners to analyze existing buildings to determine fire safety criteria and design fire safety plans. After a fire has occurred, fire protection engineering consultants are often asked to perform an investigation to reconstruct the cause of the fire and carry out fire analyses of specific products. They are often called on to testify as expert witnesses in litigation.

Research:

Research within fire protection engineering is carried out by large corporations, fire equipment manufacturers, universities, government agencies, professional organizations, standard testing facilities, and insurance corporations. The research is conducted in every aspect of the field, from computer modeling of small fires to large-scale tests simulating fires in aircraft hangers, testing a broad range of consumer products from furniture to clothing. Fire researchers also study how people respond to fire and how this affects the ability of the fire protection systems

and personnel to perform in a crisis. An important part of fire protection engineering research is developing an understanding of all of the systems and human factors that go into protecting people from fire.

Profile: Erica Kuligowski

Erica Kuligowski is a Fire Protection Engineer in the Fire Research Division at the National Institute of Standards and Technology. Erica was introduced to the field of fire protection engineering during her 6-week Women in Engineering summer program at the University of Maryland, College Park. The program took place during the summer before her senior year. Erica was enrolled in two engineering classes and had the opportunity to learn about the various disciplines of engineering. The class's fire protection engineering demonstration involved the use of fire modeling to predict fire spread through a structure, and she has been excited about being an FPE ever since.

Erica developed an interest in human behavior in fire during her junior year of college after attending the 2nd International Human Behavior in Fire Symposium in 2001. As a graduate student, her research interests began to focus on human behavior in fires, people movement, evacuation and wayfinding systems, and computer modeling of fire evacuations. Prior to joining NIST in June, 2002, Ms. Kuligowski worked as a full-time Research Assistant and Teaching Assistant for the University of Maryland Fire Protection Engineering Department. While at Maryland, she researched people movement on stairs in cruise ships, directional sound as a wayfinding technique, as well as thesis research on the sensitivity and usability of current evacuation computer models. At NIST, Erica is involved in the study of the use of elevators in emergencies, the World Trade Center Investigation, and evacuation modeling. At the present time, much of her work involves data analysis from interviews of WTC survivors as well as the review, use and analysis of current evacuation models.

Education:	University	of	Maryland,	College	Park
BS	Fire	Protection	Engineering,		2001
MS Fire Protection Engineering, 2003					

Corporate Fire Protection Engineer:

Fire protection engineers are hired by corporations to protect the interests of the company from fire losses. In the corporate environment, the fire protection engineers works with engineers of other disciplines to make recommendations to the company for cost effective fire protection

solutions. It is the job of the fire protection engineer to ensure that the facilities, the employees and the work are safe from the threat of fire. This is done through design, inspection, review and modifications of the facility. Whether the hazard involves a high-rise hotel, large manufacturing facility, or an offshore oilrig, the threat to life and property are protected by fire protection engineers.

Many large companies employ a fire protection engineer. With the size and expense of modern commercial facilities, a single fire could risk the future of an entire company. Bethlehem Steel, Boeing, Chrysler, Dow Chemical, Eastman Kodak, IBM, Mobil and Scott Paper are just a few of the companies that employ fire protection engineers.

Profile: April Berkol

Providing for the safety of an entire hotel full of guests is a monumental responsibility, but what if you were responsible for more than 700 hotel properties in 64 countries! That is precisely the responsibility of fire protection engineer April Berkol.

Initially, April did not set out to be an engineer. It was until after her graduation that she decided to pursue her Master of Science degree in Fire Protection engineering at the Worcester Polytechnic Institute.

During her time as a student at WPI, she took advantage of the opportunities available to fire protection engineering students. She interned and held a co-operative work assignment with IBM. Her experience in that position, as a plant fire protection engineer, helped her develop the confidence to move on to positions of even greater responsibility.

After graduate school, she worked as a consulting engineer on a variety of projects including the Embassy Security Upgrade Program for the Department of State. In her present position she has the opportunity to travel to many interesting and exciting destinations throughout the world, inspecting and surveying hotels for life safety and structural aspects.

April's advice to students who are interested in a career in fire protection engineering is "once you have decided to become a fire protection engineer, get yourself the best education you can and accept internships or co-op assignments so you can see what types of jobs are out there. Talk to people who are active in their professional society (SFPE) to learn about their experiences and listen to their advice— you don't have to take it, but you may learn something from it!"

Appendix

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&EVSS XB=7,8.5, 9.4, 10.6, 1.5,1.6, IOR=+2, ID='FlightUpper',

FAC_V0_UP=0.4, FAC_V0_DOWN=0.6, FAC_V0_HORI=1.0,

HEIGHT=2.8, HEIGHT0=1.4, MESH_ID='STAIRS' /

&EVSS XB=8.5,10.0, 9.0, 10.4, 1.5,1.6, IOR=-2, ID='FlightLower',

FAC_V0_UP=0.4, FAC_V0_DOWN=0.6, FAC_V0_HORI=1.0,

HEIGHT=1.5, HEIGHT0=0.0, MESH_ID='STAIRS' /

&MESH IJK=90,60,1, XB= -1.0,17.0, -1.0,13.4,1.5,1.6, EVAC_Z_OFFSET=1.0,

EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='STAIRS' /

=====2¼Óà=====

&OBST XB= 7.00,8.60, 9.10,9.30, 3.20,4.40, SURF_ID='INERT',

EVACUATION=.TRUE., RGB=30,150,20 /

&DOOR ID='2FST', IOR=-2,

FYI= 'Comment line',

VENT_FFIELD='2fGrid2',

COLOR='YELLOW', EXIT_SIGN=.TRUE.,

TO_NODE='1FSTAIR',KEEP_XY=.FALSE.

XYZ= 8.0, 9.00, 4.00,

XB= 7.00,8.60, 9.40,9.40, 3.20,4.40 / ¶À'â½bÀY

&VENT XB= 7.00,8.60, 9.30,9.30, 3.20,4.40 SURF_ID='OUTFLOW',

MESH_ID='2fGrid2', EVACUATION=.TRUE./ Left Exit Fan 1¼Óªj³ù

&HOLE XB= 7.0,8.6, 9.00,9.30, 2.8,4.80, EVACUATION=.TRUE./

&ENTR ID='1FSTAIR', IOR=-2,

FYI= 'Comment line',

COLOR='GREEN',

XB= 8.60,10.0, 9.0,9.00, 0.4,1.6, /

=====

&EVHO ID= 'Evho_Fire',

FYI= 'Do not put humans close to the fire',

XB= 0.2,11.8, 2.8,7.0, 3.2,4.4 /

&EVHO ID= 'Evho_Fire1',

FYI= 'Do not put humans close to the fire',

XB= 0.2,7.0, 7.0,8.2, 3.2,4.4 /

&EVHO ID= 'Evho_Fire2',

FYI= 'Do not put humans close to the fire',

XB= 10,11.8, 7.0,8.2, 3.2,4.4 /

&EVHO ID= 'Evho_Fire3',

FYI= 'Do not put humans close to the fire',

XB= 0.2,6.8, 9.4,11.2, 0.4,1.6/

&EVHO ID= 'Evho_Fire4',

FYI= 'Do not put humans close to the fire',

XB= 10.2,11.8, 9.4,11.2, 0.4,1.6/

&EVHO ID= 'Evho_Fire5',

FYI= 'Do not put humans close to the fire',

XB= 11.80,12.80 , 02.80,08.40,0.4,1.6/

&EVHO ID= 'Evho_Fire6',

FYI= 'Do not put humans close to the fire',

XB= 7.00,10.20 , 09.30,11.40,3.2,4.4/

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&EVAC ID = 'Human1F',

NUMBER_INITIAL_PERSONS =20,

XB = 1.0,14, 1.0,11, 0.4,1.6

AVATAR_COLOR = 'BLUE',

KNOWN_DOOR_NAMES = '1FRIGHT',

KNOWN_DOOR_PROBS = 1.0,

PERS_ID ='Adult', / @¼ÓH¼Æ/

&EVAC ID = 'Human1Ffemale',

NUMBER_INITIAL_PERSONS =20,

XB = 1.0,14, 1.0,11, 0.4,1.6

AVATAR_COLOR = 'RED',

KNOWN_DOOR_NAMES = '1FRIGHT',

KNOWN_DOOR_PROBS = 1.0,

PERS_ID ='Adult', / @¼ÓH¼Æk

&EVAC ID = 'Human2F',

NUMBER_INITIAL_PERSONS =20,

XB = 1.0,14, 1.0,11, 3.2,4.4

AVATAR_COLOR = 'RED',

KNOWN_DOOR_NAMES = '2FST',

KNOWN_DOOR_PROBS = 1.0,

PERS_ID = 'Adult', / ¼G¼Ó¼H¼Æ

&EVAC ID = 'Human2FB',

NUMBER_INITIAL_PERSONS =20,

XB = 1.0,14, 1.0,11, 3.2,4.4

AVATAR_COLOR = 'BLUE',

KNOWN_DOOR_NAMES = '2FST',

KNOWN_DOOR_PROBS = 1.0,

PERS_ID = 'Adult', / ¼G¼Ó¼H¼Æ¼k

=====¼H-

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&PERS ID='Adult',

FYI='Male+Female diameter and velocity',

DEFAULT_PROPERTIES='Adult',

VELOCITY_DIST=0,

VEL_MEAN=0.2,

TAU_EVAC_DIST=0,

TAU_MEAN=0.7,

PRE_EVAC_DIST=1,PRE_LOW=3.0,PRE_HIGH=5.0,
DET_EVAC_DIST=1,DET_LOW=5.0,DET_HIGH=10.0,
TDET_SMOKE_DENS=0.1,
HUMAN_SMOKE_HEIGHT=1.60,
DENS_INIT=0.0,
OUTPUT_SPEED=.TRUE.,
OUTPUT_FED=.TRUE.,
COLOR_METHOD= 0 /

&PERS ID='Male1F',

FYI='Male diameter and velocity',
DEFAULT_PROPERTIES='Male',
VELOCITY_DIST=0,
VEL_MEAN=0.2,
TAU_EVAC_DIST=0,
TAU_MEAN=0.7,
PRE_EVAC_DIST=1,PRE_LOW=3.0,PRE_HIGH=5.0,
DET_EVAC_DIST=1,DET_LOW=5.00,DET_HIGH=10.0
TDET_SMOKE_DENS=0.1,
HUMAN_SMOKE_HEIGHT=1.60,
DENS_INIT=0.0,
OUTPUT_SPEED=.TRUE.,
OUTPUT_FED=.TRUE.,
COLOR_METHOD= 0 /

&PERS ID='Female',

FYI='Female diameter and velocity',

DEFAULT_PROPERTIES='Female',

VELOCITY_DIST=0,

VEL_MEAN=0.2,

TAU_EVAC_DIST=0,

TAU_MEAN=0.7,

PRE_EVAC_DIST=1,PRE_LOW=3.0,PRE_HIGH=5.0,

DET_EVAC_DIST=1,DET_LOW=5.00,DET_HIGH=10.0

TDET_SMOKE_DENS=0.1,

HUMAN_SMOKE_HEIGHT=1.60,

DENS_INIT=0.0,

OUTPUT_SPEED=.TRUE.,

OUTPUT_FED=.TRUE.,

COLOR_METHOD= 0 /

&PERS ID='Child',

FYI='Child diameter and velocity',

DEFAULT_PROPERTIES='Child',

VELOCITY_DIST=0,

VEL_MEAN=0.2,

TAU_EVAC_DIST=0,

TAU_MEAN=0.7,

PRE_EVAC_DIST=1,PRE_LOW=5.0,PRE_HIGH=15.0,
DET_EVAC_DIST=1,DET_LOW=5.00,DET_HIGH=10.0
TDET_SMOKE_DENS=0.1,
HUMAN_SMOKE_HEIGHT=1.20,
DENS_INIT=0.0,
OUTPUT_SPEED=.TRUE.,
OUTPUT_FED=.TRUE.,
COLOR_METHOD= 0 /

&PERS ID='Elderly',

FYI='Elderly diameter and velocity',
DEFAULT_PROPERTIES='Elderly',
VELOCITY_DIST=0,
VEL_MEAN=0.2,
TAU_EVAC_DIST=0,
TAU_MEAN=0.7,
PRE_EVAC_DIST=1,PRE_LOW=5.0,PRE_HIGH=15.0,
DET_EVAC_DIST=1,DET_LOW=5.00,DET_HIGH=10.0
TDET_SMOKE_DENS=0.1,
HUMAN_SMOKE_HEIGHT=1.60,
DENS_INIT=0.0,
OUTPUT_SPEED=.TRUE.,
OUTPUT_FED=.TRUE.,
COLOR_METHOD= 0 /

=====

Fire calculation output.

&BNDF QUANTITY='WALL_TEMPERATURE' /

Next line could be used to plot the evacuation flow fields:

&SLCF PBZ= 1.0, QUANTITY='VELOCITY', VECTOR=.TRUE., EVACUATION=.TRUE.
/

&SLCF PBZ=0.4, QUANTITY='VELOCITY', VECTOR=.TRUE., EVACUATION=.TRUE.
/

&SLCF PBZ=3.2, QUANTITY='VELOCITY', VECTOR=.TRUE., EVACUATION=.TRUE.
/

=====

&TAIL /

===== @æÂIçî¾Ü=====

COLOR=@æ½uÃC'â

IJK= XjBYjBZ@æÂI¾Æ

XB=X1,X2,Y1,Y2,Z1,Z2, DOMAIN½d³ð

SYNCHRONIZE=.TRUE. 'h«°ô@æ'P'B

&MESH IJK=90,72,45, XB=-1.0 ,17 ,-1.0 ,13.4 ,0.0 ,9.0 ,/ 0.20

=====¼ÒÀÀ@É¶i»Pαδ·½=====

=====

&TIME T_BEGIN=0,T_END=180/Á`¼ÒÀÀ-í¼Æ

&DUMP NFRAMES=465,/

NFRAMES=60 @É¶i-öçý¬°T_END/NFRAMES;Number of Frames of output
data;é¥X¼Æ¾Ü^{aoi},¼Æ

DT_RESTART=20 °C¼j20-íÀx|sRestartÀÉ;Restart core dump interval,restartÀÉ®×«Üαj

&MISC SURF_DEFAULT='out wall' ,THICKEN_OBSTRUCTIONS=.TRUE. ,TMPA=21. /

&BNDF QUANTITY='WALL TEMPERATURE'/¥iÂâ¥ÜWALL·Â«×

-----VENT-----

&VENT MB='XMAX' ,SURF_ID='OPEN' /model³q·³]©w

&VENT MB='XMIN',SURF_ID='OPEN' /

&VENT MB='YMAX',SURF_ID='OPEN' /

&VENT MB='YMIN',SURF_ID='OPEN' /

&VENT MB='ZMAX',SURF_ID='OPEN' /

&VENT MB='ZMIN',SURF_ID='OPEN' /

-----¿U¿N«Y¼Æ-----

/&REAC ID = 'ACRYLONITRILE'

/C = 3.

/H = 3.

/N = 1.

/HEAT_OF_COMBUSTION = 24500.

/IDEAL = .TRUE. /

&REAC ID='POLYURETHANE'

FYI='C_6.3 H_7.1 N O_2.1, NFPA Handbook, Babrauskas'

SOOT_YIELD = 0.10

N = 1

C = 6.3

H = 7.1

O = 2.1

CO_YIELD=0.0237

HEAT_OF_COMBUSTION=20000

IDEAL=.TRUE./

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REAC=REACTION

ID=PORPANE-^o1w³]¿U¿N¿İÄ³

-----αõ·½⁻S©Ê-----

&PART ID='FIREP', COLOR='BLUE', MASSLESS=.TRUE./·L²É³]©w

ID='FIREP';G²É¿l³]©w¿§ÃÑ§O²Ä,¹-° FIREP

QUANTITY='BLUE';G²É¿l³]©w¿§ÃC;â-°BLUE

MASSLESS=.TRUE.;G²É¿l³]©w-°µL½è¶q

&SURF ID='FIRE', HRRPUA=500 , COLOR='RASPBERRY', PART_ID='FIREP' ,
RAMP_Q='FIRE1 TS'/¥»®×"Ò³]©w-°500KW/m2

ID='FIRE';G³]©w^a«¥ó^aí±©Ê½è¿§ÃÑ§O²Ä,¹-°FIRE

HRRPUA=1000;G³]©w^a«¥ó^aí±¼öÄÄ©ñ²v¬°1000kW/m²,Heat Release Rate Per Unit Area

COLOR;G³]©w^a«¥ó^a§ÄC'â(¾p§@^a¥U55¶)

PART_ID='FIREP';G²É^al³]©w©I¥s^a§ÄÑ§O²Ä,¹¬° FIREP

RAMP_Q='FIRE1 TS';G¼öÄÄ©ñ²vÄH®É¶;ÄÜ^aÆ^a§^añ¬Ò;AÄÑ§O²Ä,¹¬°FIRE1 TS

&RAMP ID='FIRE1 TS', T=0 , F=0 /

&RAMP ID='FIRE1 TS', T=5 , F=0.04 /

&RAMP ID='FIRE1 TS', T=10 , F=0.10/

&RAMP ID='FIRE1 TS', T=15 , F=0.4/

&RAMP ID='FIRE1 TS', T=20 , F=0.55/

&RAMP ID='FIRE1 TS', T=40 , F=0.6/

&RAMP ID='FIRE1 TS', T=45 , F=0.85/

&RAMP ID='FIRE1 TS', T=50 , F=1.36/

&RAMP ID='FIRE1 TS', T=55 , F=1.50/

&RAMP ID='FIRE1 TS', T=58 , F=1.60/

&RAMP ID='FIRE1 TS', T=60 , F=1.62/

&RAMP ID='FIRE1 TS', T=65 , F=1.50/

&RAMP ID='FIRE1 TS', T=70 , F=1.36/

&RAMP ID='FIRE1 TS', T=75 , F=0.76/

&RAMP ID='FIRE1 TS', T=80 , F=0.36/

&RAMP ID='FIRE1 TS', T=85 , F=0.20/

&RAMP ID='FIRE1 TS', T=88 , F=0.1/

&RAMP ID='FIRE1 TS', T=930 , F=0.1/

ID='FIRE1 TS';G¼öÄÀ©ñ²v©I¥s□§ÃÑ§O²Å,¹¬°FIRE1 TS

T;G¼öÄÀ©ñ²v®É¶; F;G¼öÄÀ©ñ²v□§;²v

-----°_□öÄI-----

&OBST XB= 08.00,08.20 , 08.00,08.20, 4.40, 04.60,SURF_ID=
'FIRE'/2¼Ó»R¥x°_□ö0.002m3----B

/&OBST XB= 11.80,12.00 , 01.60,01.80, 4.40, 04.60,SURF_ID= 'FIRE'/2¼ÓROOM8
°_□ö0.002m3----CASE A1

&OBST XB= 00.40,14.20 , 00.40,11.20, 5.30, 05.35,SURF_ID= 'FOAM1'/2¼Ó□ÑªáªO«e

&OBST XB= 00.40,14.20 , 00.40,11.20, 5.35, 05.37,SURF_ID= 'CLOTH'/2¼Ó□ÑªáªO«e

-----Model-----

&OBST XB= 00.00,0.80 , 00.00,00.20, 0.00, 02.00,SURF_ID= 'out wall'/«eÀðªU1

&OBST XB= 01.80,10.6 , 00.00,00.20, 0.00, 02.00,SURF_ID= 'out wall'/«eÀðªU2

&OBST XB= 11.60,14.6 , 00.00,00.20, 0.00, 02.00,SURF_ID= 'out wall'/«eÀðªU3

&OBST XB= 00.00,14.6 , 00.00,00.20, 2.00, 05.40,SURF_ID= 'out wall'/«eÀðªW

&OBST XB= 14.40,14.60 , 00.20,11.40, 0.00, 05.40,SURF_ID= 'out wall'/¥kÀð

&OBST XB= 00.00,14.60 , 11.40,11.60, 0.00, 05.40,SURF_ID= 'out wall'/«áÀð

&OBST XB= 00.00,00.20 , 00.20,11.40, 0.00, 02.80,SURF_ID= 'out wall'/¥ªÀðªU

&OBST XB= 00.00,00.20 , 00.20,00.60, 2.80, 04.80,SURF_ID= 'out wall'/¥ªÀðW1

&OBST XB= 00.00,00.20 , 01.60,11.40, 2.80, 04.80,SURF_ID= 'out wall'/¥ªÀðW2

&OBST XB= 00.00,00.20 , 00.20,11.40, 4.80, 05.40,SURF_ID= 'out wall'/¥ªÀðWαW

&MULT ID='roof TOP1', DX=0.04, DZ=0.01, N_LOWER=0, N_UPPER=182, /roof TOP1¥ªÄä

&OBST XB= 00.00,0.2 , 0.0,11.60 , 5.4,5.5, MULT_ID='roof TOP1' , SURF_ID= 'STEEL R',SAWTOOTH=.FALSE. /roof TOP1

&MULT ID='roof TOP2', DX=-0.04, DZ=0.01, N_LOWER=0, N_UPPER=182, /roof TOP2¥kÄä

&OBST XB= 14.40,14.6 , 0.0,11.60 , 5.4,5.5, MULT_ID='roof TOP2' ,SURF_ID= 'STEEL R', SAWTOOTH=.FALSE. /roof TOP2

/&MULT ID='south', DXB= 0.04,-0.04 ,0.0,0.0, 0.01,0.01, N_LOWER=0, N_UPPER=170 /

/&OBST XB= 0.40,14.40, 0.00,0.2, 5.40,5.45, MULT_ID='south',SURF_ID= 'out wall' /

/&MULT ID='back', DXB= 0.04,-0.04 ,0.0,0.0, 0.01,0.01, N_LOWER=0, N_UPPER=170 /

/&OBST XB= 0.40,14.40, 11.40,11.6, 5.40,5.45, MULT_ID='back',SURF_ID= 'out wall' /

open

&MULT ID='south', DXB= 0.04,-0.04 ,0.0,0.0, 0.01,0.01, N_LOWER=0, N_UPPER=170 /

&OBST XB= 1.00,13.60, 0.00,0.2, 5.40,5.45, MULT_ID='south',SURF_ID= 'out wall' /

&MULT ID='back', DXB= 0.04,-0.04 ,0.0,0.0, 0.01,0.01, N_LOWER=0, N_UPPER=170 /

&OBST XB= 1.00,13.60, 11.40,11.6, 5.40,5.45, MULT_ID='back',SURF_ID= 'out wall' /

&OBST XB= 00.20,14.40 , 02.60,02.80, 2.40, 02.60,SURF_ID= 'STEEL R'/1F ç¼¼

&OBST XB= 00.20,14.40 , 08.20,08.40, 2.40, 02.60,SURF_ID= 'STEEL R'/1F ȷû¼Ù

&OBST XB= 11.80,12.00 , 00.20,11.40, 2.40, 02.60,SURF_ID= 'STEEL R'/1F ȷû¼Ù

&OBST XB= 00.80,03.00 , 00.60,0.65 , 2.40, 02.45,SURF_ID= 'STEEL2'/1F
ȷû¬W(°kŸÍªù«e)

&OBST XB= 00.80,03.00 , 01.60,1.65 , 2.40, 02.45,SURF_ID= 'STEEL2'/1F
ȷû¬W(°kŸÍªù«e)Room16

&OBST XB= 07.00,07.20 , 00.20,11.40, 5.80,5.85,SURF_ID= 'STEEL R'/«Î³» ȷû¼Ù

&OBST XB= 00.20,14.40 , 00.20,02.80, 2.60, 02.79,SURF_ID= 'out wall'/2¼Ó«efloor

&OBST XB= 11.80,14.40 , 02.80,11.40, 2.60, 02.79,SURF_ID= 'out wall'/2¼ÓŸk

&OBST XB= 00.20,07.00 , 08.20,11.40, 2.60, 02.79,SURF_ID= 'out wall'/2¼Ó«áŸª

&OBST XB= 07.00,10.00 , 08.20,09.40, 2.60, 02.79,SURF_ID= 'out
wall'/2¼Ó«á¼Ó±èªW¬Ó

&OBST XB= 10.00,11.80 , 08.20,11.40, 2.60, 02.79,SURF_ID= 'out wall'/2¼Ó«áŸk

&OBST XB= 07.00,10.00 , 07.00,08.20, 2.60, 02.79,SURF_ID= 'out wall'/2¼Ó»RŸx

/&OBST XB= 10.60,11.60 , 00.00,00.10, 0.00, 2.00,SURF_ID='STEEL1'/1F¬ªªù

&OBST XB= 00.00,00.10 , 00.60,01.60, 2.80, 04.80,SURF_ID='STEEL1'/2F-°kŸÍªù

&OBST XB= 00.80,1.80 , 00.00,00.10, 0.00, 2.00,SURF_ID='STEEL1'/1F-°kŸÍªù

-----1F Kitchen-----

&OBST XB= 06.80,07.00 , 09.40,11.40, 0.00, 02.50,SURF_ID= 'STEEL R'/1¼Ó¼Ó±è¥ª®Ç

&OBST XB= 10.00,10.20 , 09.40,11.40, 0.00, 02.50,SURF_ID= 'STEEL R'/1¼Ó¼Ó±è¥k®Ç

/&OBST XB= 10.00,10.20 , 09.20,09.40, 0.00, 02.20,SURF_ID= 'paper',EVACUATION=.FALSE./1¼Ó¼Ó±è¥k®ÇÂª«

&OBST XB= 00.20,02.20 , 09.40,09.60, 0.00, 2.40,SURF_ID='out wall'/1F-«á¥ªÃä´Z©ÒÀð1

&OBST XB= 02.20,03.20 , 09.40,09.60, 0.00, 2.00,SURF_ID='STEEL1'/1F-«á¥ªÃä´Z©Òªù1

&OBST XB= 03.20,04.20 , 09.40,09.60, 0.00, 2.40,SURF_ID='out wall'/1F-«á¥ªÃä´Z©ÒÀð2

&OBST XB= 04.20,05.20 , 09.40,09.60, 0.00, 2.00,SURF_ID='STEEL1'/1F-«á¥ªÃä´Z©Òªù2

&OBST XB= 05.20,06.80 , 09.40,09.60, 0.00, 2.40,SURF_ID='out wall'/1F-«á¥ªÃä´Z©ÒÀð3

&OBST XB= 02.20,03.20 , 09.40,09.60, 2.00, 2.40,SURF_ID='out wall'/1F-«á¥ªÃä´Z©Òªù1ªW

&OBST XB= 04.20,05.20 , 09.40,09.60, 2.00, 2.40,SURF_ID='out wall'/1F-«á¥ªÃä´Z©Òªù2ªW

&OBST XB= 06.80,07.00 , 09.40,11.40, 0.00, 02.50,SURF_ID= 'STEEL R'/1¼Ó¼Ó±è¥ª®Ç

/&OBST XB= 05.60,06.80 , 09.00,09.40, 0.00, 02.20,SURF_ID= 'paper',EVACUATION=.FALSE./1¼Ó´Z©ÒÂªª«

/&OBST XB= 00.40,01.60 , 09.00,09.40, 0.00, 02.20,SURF_ID= 'paper',EVACUATION=.FALSE./1¼Ó´Z©ÒÂªª«

/&OBST XB= 00.40,06.60 , 09.80,11.20, 0.00, 02.20,SURF_ID= 'paper',EVACUATION=.FALSE./1¼Ó´Z©ÒÂªª«

&OBST XB= 3.00,3.05 , 03.00,07.80, 4.6, 4.65,SURF_ID='STEEL1'/1F±¾¿O

&OBST XB= 3.50,3.55 , 03.00,07.80, 4.6, 4.65,SURF_ID='STEEL1'/1F±¾¿O

&OBST XB= 3.80,3.85 , 03.00,07.80, 4.6, 4.65,SURF_ID='STEEL1'/1F±¾¿O

&OBST XB= 10.20,11.80 , 09.40,09.50, 0.00, 2.00,SURF_ID='STEEL1'/1F-²º¥kÃäà1

/OBST XB= 11.00,11.80 , 09.40,09.50, 0.00, 2.00,SURF_ID='STEEL1'/1F-²º¥kÃäà2

/&HOLE XB= 10.40,10.80 , 09.40,09.50, 0.80, 1.40 /1F-²º¥kÃäàµj1

/&OBST PERMIT_HOLE=.FALSE. XB= 10.40,10.80 , 09.40,09.50, 0.80, 1.40
,SURF_ID='GLASS-1',DEVC_ID='1F-W001'/1F²º³j¥kÃäàµj-1 }

/&DEVC ID='1F-W001', XYZ=10.6,09.30, 01.20, QUANTITY='TEMPERATURE',
SETPOINT=600., INITIAL_STATE=.TURE. /.FALSE.

/&HOLE XB= 11.20,11.60 , 09.40,09.50, 0.80, 1.40 /1F-²º¥kÃäàµj2

/&OBST PERMIT_HOLE=.FALSE. XB= 11.20,11.60 , 09.40,09.50, 0.80, 1.40
,SURF_ID='GLASS-1',DEVC_ID='1F-W002'/1F²º³j¥kÃäàµj-2 }

/&DEVC ID='1F-W002', XYZ=11.4,09.30, 01.20, QUANTITY='TEMPERATURE',
SETPOINT=600., INITIAL_STATE=.TURE. /.FALSE.

&OBST XB= 10.20,11.80 , 09.40,09.50, 2.00, 2.40,SURF_ID='table'/1F-²º¥kÃäà²W

&OBST XB= 11.80,11.90 , 09.40,11.40, 0.00,
02.40,SURF_ID='table',EVACUATION=.FALSE./1F-¼p©Ð¥kÃäà¥kÀð*

/&OBST XB= 10.40,11.60 , 09.60,11.20, 0.00,
02.40,SURF_ID='paper',EVACUATION=.FALSE./¼p©ÐÂøª«

/&OBST XB= 12.00,12.80 , 09.40,11.40, 0.00,
02.40,SURF_ID='paper',EVACUATION=.FALSE./&Øª«

&OBST XB= 14.00,14.40 , 02.45,02.50, 0.00, 2.40,SURF_ID='CABIN3'/°sÂd¥k

&OBST XB= 14.00,14.40 , 08.65,08.70, 0.00, 2.40,SURF_ID='CABIN3'/°sÂd¥ª

&OBST XB= 14.00,14.40 , 02.50,08.60, 2.00, 2.04,SURF_ID='CABIN3'/°sÂd1*

&OBST XB= 14.00,14.40 , 02.60,08.60, 1.46, 1.50,SURF_ID='CABIN3'/°sÂd2*

&OBST XB= 14.00,14.40 , 02.60,08.60, 0.80, 0.84,SURF_ID='CABIN3'/°sÂd3*

&OBST XB= 11.80,12.80 , 02.80,08.40, 0.00, 1.40,SURF_ID='CABIN3'/§aÂi

&HOLE XB= 12.00,12.60 , 03.00,08.20, 0.20, 1.20, / §aÂi

/&OBST XB= 13.00,13.40 , 02.80,04.80, 0.00,
1.40,SURF_ID='paper',EVACUATION=.FALSE./¶Ç³æ

/&OBST XB= 13.00,13.40 , 06.80,08.20, 0.00,
1.40,SURF_ID='paper',EVACUATION=.FALSE./¶Ç³æ

&OBST XB= 14.20,14.25 , 02.50,08.60, 2.10, 2.25,SURF_ID='GLASS-1'/°sÂd1°s²~

&OBST XB= 14.20,14.25 , 02.60,08.60, 1.55, 1.70,SURF_ID='GLASS-1'/°sÂd2°s²~

&OBST XB= 14.20,14.25 , 02.60,08.60, 0.90, 1.05,SURF_ID='GLASS-1'/°sÂd3°s²~

&OBST XB= 12.20,12.40 , 03.00,08.00, 1.50, 1.70,SURF_ID='GLASS-1'/§aÂi°W°s²~

&OBST XB= 11.00,11.80 , 07.40,08.40, 0.00, 0.80,SURF_ID='GLASS-
1',EVACUATION=.FALSE./§aÂi«e°s²~

/&OBST XB= 11.00,11.80 , 05.40,06.40, 0.00,
1.00,SURF_ID='paper',EVACUATION=.FALSE./§aÂi«eÂª«²º

/&OBST XB= 11.00,11.80 , 03.40,04.80, 0.00,
1.00,SURF_ID='paper',EVACUATION=.FALSE./§aÂi«eÂª«¥~

/&OBST XB= 12.60,12.80 , 07.00,08.00, 1.50, 1.70,SURF_ID='paper'/§aÂi°WÂª«

/&OBST XB= 11.80,12.00 , 02.80,03.80, 1.50, 1.70,SURF_ID='paper'/§aÂi±WÂøª«2

&MULT ID='1F floor', DY=0.2, DZ=0.2, N_LOWER=0, N_UPPER=6, /1F¼Ó±è

&OBST XB= 08.50,10.00 , 9.00,09.20 , 0,0.2, SURF_ID= 'STEEL1', MULT_ID='1F floor'/
, SAWTOOTH=.FALSE. /1F¼Ó±è

&MULT ID='2F floor', DY=-0.2, DZ=0.2, N_LOWER=0, N_UPPER=4, /1F¼Ó±è

&OBST XB= 07.00,08.50 , 10.20,10.40 , 1.60,1.80, SURF_ID= 'STEEL1', MULT_ID='2F floor'/, SAWTOOTH=.FALSE. , /2F¼Ó±è

&OBST XB= 07.00,10.00 , 10.40,11.40, 1.50, 01.60,SURF_ID= 'STEEL1'/¼Ó±è5

&OBST XB= 13.00,14.20 , 00.20,02.00, 0.00, 01.40,SURF_ID=
'FRIDGE',EVACUATION=.FALSE./1F 'B½c1

&OBST XB= 13.00,14.20 , 08.80,11.40, 0.00, 01.40,SURF_ID=
'FRIDGE',EVACUATION=.FALSE./1F 'B½c2(«á±)

&HOLE XB= 13.20,14.00 , 00.40,01.80, 0.20, 1.20 /1F 'B½c1

&HOLE XB= 13.20,14.00 , 09.00,11.20, 0.20, 1.20 /1F 'B½c2

/&OBST XB= 13.00,14.20 , 00.20,02.00, 1.80, 02.40,SURF_ID=
'paper',EVACUATION=.FALSE./1F 'B½c1

/&OBST XB= 13.00,14.20 , 08.80,11.40, 1.80, 02.40,SURF_ID=
'paper',EVACUATION=.FALSE./1F 'B½c2±WÂøª«

/&OBST XB= 13.00,14.20 , 08.80,11.40, 1.80, 02.40,SURF_ID=
'paper',EVACUATION=.FALSE./1F 'B½c±WÂøª«(«á±)

/&OBST XB= 07.00,10.00 , 10.40,11.40 , 0.00,1.40 SURF_ID=
'paper',EVACUATION=.FALSE./Âøª«(¼Ó±è±U) END

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