A little-known discipline is helping to improve fire safety around the world and women are playing a key role.

Fire Protection Engineers HELP SAVE LIVES

By Laurel M. Sheppard, SWE Contributing Editor

Fires cost the American economy approximately $128 billion each year, with over $8 billion in direct property damage. The annual human toll is also high — about 4,000 lives and 25,000 injuries. One important group of professionals dedicated to preventing such loss of life and property are fire protection engineers (FPEs). Although not as well known to the public as firefighters, these engineers play an important role in public safety.

Typical fire experiment used to test the Sensor-driven Fire Model under development at NIST. This model is designed to use signals from building sensors to predict the size and growth of fires in buildings.

Education Options

There are only several schools in the United States that offer fire protection engineering. The University of Maryland offers the only ABET accredited undergraduate FPE degree as well as master's degrees. Oklahoma State University offers a bachelor's in engineering technology that combines the disciplines of fire protection and safety, making this the only degree of its type.

Worcester Polytechnic Institute (WPI) offers a special five-year program option in which the student earns two degrees — one is an ABET accredited Bachelor of Science in one of the traditional engineering disciplines, such as mechanical, civil, chemical or electrical engineering. The other is a Master of Science in fire protection engineering. In 1979, WPI started the first master's degree FPE program in the U. S., and is the only university to offer both the master's and doctorate in this discipline. The University of New Haven also has a fire science department that offers several degrees, including an unaccredited bachelor's in fire protection engineering.

Other countries have recently added or expanded FPE programs. The Fire Safety Engineering College in the country of Oman opened its doors in 1997. Affiliated with the University of Central Lancashire, United Kingdom, the college offers two programs in fire safety and well engineering. Students can specialize in fire safety, fire safety management, fire safety engineering or fire engineering.

"Although our first batch of fire safety engineering students were all male," says Susan Trevor-Roper, assistant dean, "we do have several female students in the well engineering program. We hope to have some females in the fire program within the next year." The College also has several women on the well engineering faculty.

In 2002, Carleton University established Canada's first research chair in fire safety engineering with a grant of $1.2 million from the National Science and Engineering Research Council of Canada, and Forintek Canada Corporation. This chair will focus on research in the field of fire performance of wood frame buildings, and will also be conducting research

TABLE 1
Where to Learn Fire Protection Engineering*

- Carleton University *(Canada)*
- Delaware Technical and Community College
- Fire Safety Engineering College *(Muscat, Oman)*
- Hong Kong Polytechnic University *(Hong Kong, China)*
- Illinois Institute of Technology
- Lund University *(Sweden)*
- Oklahoma State University
- Seneca College
- Science University of Tokyo *(Japan)*
- South Bank University *(England)*
- Swiss Federal Institute of Technology *(Switzerland)*
- University of British Columbia *(Canada)*
- University of California at Berkeley
- University of California at Davis
- University of Canterbury *(New Zealand)*
- University of Central Lancashire *(England)*
- University of Edinburgh *(Scotland)*
- University of Greenwich *(England)*
- University of Leeds *(England)*
- University of Maryland
- University of New Brunswick *(Canada)*
- University of New Haven
- University of Ulster *(Northern Ireland)*
- Victoria University of Technology *(Australia)*
- Worcester Polytechnic Institute

**this is not a complete list; some of those listed only offer courses*

on human behavior in fire. In addition to the research, the chair will lead the development of a Ph.D. graduate program in fire safety engineering, the only one of its kind in Canada.

Several women recently enrolled in this program. Ineke Van Zeeland, a civil engineer with the Codes & Engineering division of the Canadian Wood Council, previously worked for six years at Forintek Canada Corporation's fire research laboratory. She is currently engaged in part-time studies toward a Ph.D. Another part-time student pursuing her M.S. degree is Susana D. Chui, a registered professional engineer, specializing in life safety and building code.

Table 1 lists schools that offer degrees or courses in fire protection engineering. Since there are a limited number of schools, distance education has made courses available to practicing engineers who want to stay current with the technology. This option also gives engineering students at non-FPE schools the chance to take an FPE course or two to see what it's all about. Two women took advantage of this option while attending Illinois Institute of Technology. Anne Guglielmo, a civil engineer, earned a minor in FPE by taking two distance-learning courses. Katie Brady, a mechanical engineering major, also plans to take such courses as part of her undergraduate program.

Most schools will accept transfer credits for these types of specialized courses taken at other universities. These out of major courses or technical electives count toward a degree in one of the traditional disciplines. WPI has been delivering FPE courses via distance learning since 1993. The University of Maryland is starting a distance graduate program in FPE in the fall of 2003.

The Society of Fire Protection Engineers (SFPE) has also launched a career task force to help recruit more people into the field by reaching out to high schools, technical schools, community colleges, and the fire service. Another strategy is to promote FPE courses to other disciplines — including architects, contractors and other similar groups. In addition, the University of Maryland has established a scholarship program for volunteer firemen.

Making a Social Impact

The percentage of women enrolling in FPE is often higher than other disciplines, ranging from 22 percent to 30 percent, depending on school and degree level. Women find FPE attractive because it makes a direct and tangible contribution to society. "FPE is so closely related to saving lives that you feel like you are making a significant difference in your own community," says Kathleen Almand, P.E., executive director of SFPE. "There is also a real technical side to an interest in people — studying human behavior in fire."

"FPE is more of a 'caring' profession than

Fire Safety Pioneer Becomes **First Female to Join SFPE**

In 1979 Margaret Law became the first woman to join SFPE. In 1952 she earned a degree in physics from the University of London. A British native, she also was the first woman to be on SFPE's board of directors. Until 1974, Law worked for the fire research station in the United Kingdom, eventually becoming a principal scientific officer. She then joined Arup to act as an adviser for fire engineering on projects designed within the firm. Early projects included the Exchange Theatre, Manchester; Centre Pompidou, Paris; Stansted Airport, U.K.; Kowloon Bay Port in Hong Kong and Shanghai Bank, Hong Kong and the Lloyds Building, London. All were innovative and ground-breaking in their application of fire engineering to building design.

Law has been a great influence on the firm and building industry. Her early work at the Fire Research Station, which she joined in 1952, included developing a design method to prevent fire spread from building to building. This method is still used today in the British building regulations. Prior to this, the rules had not been significantly updated since the Great Fire of London in 1666. Law also developed a correlation that related the performance of fire-protected steel in real fires to the standard furnace test. In some academic circles this is known as "Law's Law". Law is the author of Technical Paper No. 5, which later became the basis for the exposure requirements in the United Kingdom regulations and NFPA 80A.

One of her first projects at Arup in 1974 was to develop and write a methodology to allow bare external steel structures: a need driven by the fashion for weathering steel. This work has since been used on numerous other projects where prediction of compartment fires and external flame projection has been essential in the design process. Her work was also accepted by the United States' building codes, and she was cited by the Engineering News Record as being "among the many men who serve the best interests of the construction industry".

Law has devoted considerable energy to obtaining acceptance of fire engineering principles within codes and standards, both in the U.K. and Europe. In the U.K. she was instrumental in developments that culminated in fire engineers achieving chartered status through the Institution of Fire Engineers. She has continued to develop her work and influence building design throughout the world, including the Chep Lap Kok and Kansai International Airports in Hong Kong and Japan.

Law was appointed a Member of the Order of the British Empire by Queen Elizabeth II. She also became the first female Fellow of SFPE in 1993 and a year later received the society's highest honor, the Guise Medal, in recognition of her technical achievements. This award is named after Arthur Guise, who singularly developed dry chemicals for fire extinguishing agents. Other recognition from the fire industry has included a visiting professorship at the University of Greenwich, a visiting researcher at the Science University of Tokyo, and various awards from the Institute of Structural Engineers and other organizations.

To celebrate her retirement and mark her contributions, Arup published 29 of Law's most influential papers as a single book, titled *Some Selected Papers by Margaret Law,* in 2002. They represent work that she did over the full span of her career from the 1950's to the end of the century. The book is available from Arup's website at www.arup.com. In his forward, Arup's Deputy Chairman Turlogh O'Brien said, "...this book...will be of great value to current and future fire engineers for many years."

other engineering disciplines because it helps protect lives," agrees David Lucht, director of the Center for Firesafety Studies at WPI. This is what Erica Kuligowski, a fire protection engineer at the National Institute of Standards and Technology, likes the most about her job. "From a technical standpoint, the problem of fire is challenging and an exciting one to find solutions," she says, "But from a practical standpoint, we are working together to save lives." Adds Doreen Moore, a fire protection engineer at Colorado Springs Fire Department, "I love working for this department since I am helping the citizens and providing a safer environment for them to live in."

According to Lucht, FPE also requires exceptional communication and listening skills, which women seem to adapt well to. "You definitely have to be people-oriented and be able to deal with all kinds of people," says Lori Dinney, a consulting engineer at Code Consultants who enjoys interacting with her clients. Moore also believes having a sense of customer service helps diffuse tense situations and also is important for interviewing fire victims.

People skills are even more critical when corporations are global in nature. "I deal with individuals from other countries and other cultures," explains Denise Brown, a graduate from Oklahoma State's program and a consulting engineer at The RCE Group, "and it seems that the more adept you are at wanting to learn through communication, the more respect individuals will have toward you. Even if you speak a different language, you can always find something to point to and talk about. People skills are something that can benefit you more than you know."

Despite the downturn in the economy, the supply of FPEs is well below the demand. "I've been in FPE for nearly 40 years," says Lucht. "It has always been this way, during all kinds of economic situations." Jim Milke, associate chair of the department of fire protection engineering at the University of Maryland, points out that those graduating in 2001 had two to five job offers. Despite the economy, in 2002 each student still had several job offers.

Salaries are also quite attractive, in the high 40's for those with bachelor's degrees and sometimes signing bonuses of an additional $5,000 to $10,000. Those with master's degrees can receive in the vicinity of $50,000 to start. A 2001 survey by the Society of Fire Protection Engineers showed that 25 percent of respondents earned $100,000 or more, including bonuses, with 20 percent earning between $70,000 and $79,000. The median salary including bonuses for a bachelor's and master's degree was around $77,000, which jumped to $90,000 for a Ph.D. Consulting firms typically offer the highest pay.

TABLE 2
Who Hires Fire Protection Engineers?*

- Arup Fire
- Boston Fire Department
- Code Consultants, Inc.
- Colorado Springs Fire Department
- ConocoPhillips
- Dallas Fire Department
- Engineering Planning & Management
- FM Global
- Gage-Babcock & Associates, Inc.
- Gamewell
- General Signal Building Systems
- General Services Administration
- Global Fire Engineering
- Grinnell Corporation
- Harrington Group
- HSB Professional Loss Control
- Hughes Associates, Inc.
- Intel Corporation
- International Conference of Building Officials
- IBM
- Kidde Fenwal
- Lockheed Martin Aeronautics Co.
- Los Alamos National Laboratory
- Mountain Star Enterprises
- MBS Fire Technology
- National Fire Protection Association
- National Institute of Standards & Technology
- NASA
- NSF Office of Polar Programs
- Other fire departments
- Pittway Safety Systems
- R.W. Sullivan, Inc.
- Rolf Jensen & Associates
- Schirmer Engineering
- Southwest Research Institute
- Starwood Hotels and Resorts
- 3M
- Underwriters Laboratories
- U.S. Coast Guard
- U.S. Gypsum Corporation
- U.S. Navy
- Varley-Campbell & Associates, Inc.
- Veterans Administration
- Westinghouse Hartford
- Westinghouse Savannah River Company

**this is not a complete list*

A Diverse Career

As Table 2 shows, fire protection engineers are found in almost every sector of the work force. Responsibilities vary widely, depending on the job and industry. Some FPEs perform fire safety evaluations of building and industrial complexes to determine the risk of fire losses and how best to prevent them. Others design systems that automatically detect and suppress fires and explosions, as well as fire alarm, smoke control, emergency lighting, communications and exit systems. FPEs also perform research on materials and consumer products. Some work involves computer modeling of fire and smoke behavior. Investigating fires or explosions, preparing technical reports or providing expert courtroom testimony in civil litigation cases are other opportunites.

Fire protection engineers also work at large corporations overseeing the design and operational fire safety of complex manufacturing facil-

Phoenix Fire Department intentionally burns a house for a training video developed in conjunction with BFRL to educate fire fighters about the hazards of structural collapse.

ities and global business networks. Elisha Lau, a fire protection engineer at Lockheed Martin Aeronautics Co., approves plans for new construction, fire protection sprinkler systems, and alarm systems. "I am responsible for making sure that new designs meet the requirements of applicable codes," explains Lau. "Whenever I get a submittal for a sprinkler system, I have to check the hydraulic calculations to make sure that the system will work in the event of a fire." Within just three months of being hired, Lau played a key role in the incident command system in two HAZMAT incidents at her facility.

In addition, FPEs work for insurance companies, surveying major facilities and performing research, testing and analysis. Lori Dinney, a P. E. with a master's in FPE from WPI, was previously a loss control property manager for Hanover Insurance. Her duties included training the loss control representatives who performed the field surveys for commercial/industrial occupancies in the identification of fire protection measures. Dinney also conducted sprinkler plan reviews for the insured to confirm that the plans met compliance with the applicable codes.

Fire protection engineers can be found at all levels of government. At the National Institute of Standards and Technology, several women are working in research. Erica Kuligowski, a fire protection engineer hired in 2002, works for Dr. Kathy Notarianni. Dr. Notarianni is a group leader in the Building and Fire Research Laboratory. Kuligowski works on a variety of projects involving fire fighting technology, smoke detectors and sprinkler systems, smoke management, analysis and prediction of fires, and standards. She is also completing her master's degree in FPE at the University of Maryland, and is investigating how people evacuate buildings and ways to make buildings safer and easier to evacuate.

Well over 25 percent of FPEs are hired as consultants. Dinney is now a project consultant with Code Consultants Inc., where she is responsible for the development of fire protection concepts used in the design of construction projects for both new and existing buildings. "This work involves conducting engineering evaluations of alternative or equivalent methods and concepts for meeting code issues in projects," explains Dinney. "I also perform plan reviews of construction documents."

Interesting jobs are also available in trade associations, testing laboratories, and at colleges and universities. Colleen Wade, a FPE at the Building Research Association of New Zealand (BRANZ) and a graduate of WPI, participated in the peer review of the design for Wellington's new national museum, Te Papa. The building's design, which includes several large atria and floors that open to each other, presented a challenge to the fire protection engineers regarding smoke spread and evacuation times. A computer simulation helped determine the best escape routes and demonstrated the effectiveness of using fans to blow air into some of the building's protected escape routes to clear away smoke.

Fire in two-story home used to test performance of current smoke alarms by researchers at BFRL.

A Family Limk

Family members often influence women who select FPE as a career. For instance, consultant Brown's entire family was involved with the local volunteer fire department in some way. "Coming from a family of six brothers, and being the only girl, I decided to join our local fire department," she says. "But it wasn't until my parents fought with a school board regarding means of egress and fire code violations in my own Catholic school that I became interested in FPE. My father handed me a copy of the book, *To Sleep with the Angels,* which vividly describes the fire at Our Lady of the Angels Catholic School outside of Chicago. At the age of 14, it infuriated me to know that so many code violations and inadequate fire protection features led to the deaths of so many innocent children and teachers."

Lau's stepfather is a captain in the Tulsa Fire Department. Through this connection, she was able to visit one of the fire department's female safety officers on the job. Although Lau originally wanted to become a safety engineer, she was later offered a position in Lockheed Martin's fire department after spending the summer before graduation in the company's environment, safety and health department. "I decided to give FPE a shot because I had learned so much about it in school," Lau says, "I am really glad I accepted this position because I really enjoy it."

Others become interested in a more roundabout way. After receiving her undergraduate degree, Lori Dinney became interested when an insurance company was looking for a chemical engineer to work in the fire protection field. Later she worked at an insurance company located near WPI and decided to attend graduate school there. NIST's Kuligowski became interested during her junior year of high school, when she attended a Women in Engineering six-week program at the University of Maryland that exposed her to FPE. Colorado Springs Fire Department's Moore chose FPE after taking a fire prevention class at the junior college she attended. Her current supervisor is a graduate of her alma mater, Oklahoma State.

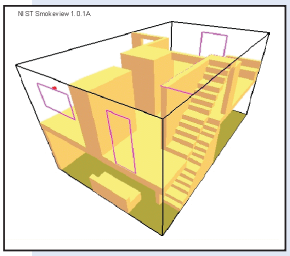
Society Leads the Way

The Society of Fire Protection Engineers (SFPE) was established in 1950 and incorporated

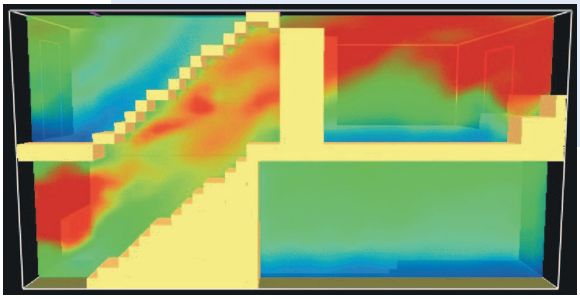
FIRE RESEARCH AT NIST

At the National Institute of Standards and Technology, the technology of fire protection is advancing through research conducted by the Building and Fire Research Laboratory (BFRL). BFRL studies building materials; computer-integrated construction practices; fire science and fire safety engineering; and structural, mechanical, and environmental engineering. Products of the laboratory's research include measurements and test methods, performance criteria, and technical data that support innovations by industry and are incorporated into building and fire standards and codes.

A key research thrust of BFRL is fire loss reduction, which involves the development of advanced fire service technologies, advanced measurement and prediction methods, and reduced risk of flashover.



BFRL's Smokeview software provides a computer simulation of the 1999 Cherry Road fire in Washington D.C., as well as a representation of the residence.



BFRL is partnering with the materials industry to enable the development of new materials and flame retardants used in mattresses and upholstered furniture, is researching environmental sensors/control systems that actively redirect air flows in and around the room of fire origin, is developing fire detectors that can be connected directly to local fire departments, and is investigating localized fire suppression systems in high risk locations.

BFRL is also: developing a data base of material properties and a model for the thermal performance of fire fighter protective clothing; working with fire alarm manufacturers to demonstrate timely delivery of fire condition information to responders before they arrive; evaluating the capabilities of thermal imagers to provide quantitative information on fire hazards; developing a computational model to predict interaction of structures with wind-driven fires; assessing the capabilities of acoustic sensing to determine weakness in roof structures; and developing a standard method to determine the performance characteristics of durable agents for protecting structures from fire.

Because new fire safety technologies are needed that only can be achieved by more accurate measurement methods, BFRL is conducting fundamental experiments to expand the knowledge for numerically simulating and visualizing real fire phenomena and is using molecular dynamic models and chemical kinetic studies to investigate ignition, flame spread, soot formation and extinction of the condensed phase, and the chemical and physical mechanisms of fire retardants and suppressants. Numerical simulation and computational fluid dynamic models of transport processes are being expanded to encompass higher accuracy radiation, droplet and sprays, as well as models and semi-empirical sub-models of phenomena at the fuel/flame interface. New instrumentation and test methods are being developed to support these models, and reference data are being produced against which predictions can be compared.

In September of last year, NIST's BFRL began its $16 million, 24-month federal building and fire safety investigation to study the structural failure and subsequent progressive collapse of several World Trade Center (WTC) buildings following the terrorist attacks of 9/11. The study of WTC Buildings 1 and 2 (The Twin Towers)

as an independent organization in 1971. The Society has approximately 4,000 members in the United States and abroad, and 52 regional chapters, 10 of which are outside the United States. In 1997, Kathleen Almand, a registered professional civil engineer, became the first woman and the first engineer to become executive director. Prior to joining SFPE, Almand had over 20 years of experience in the planning and management of marketing, research and education programs in the not-for-profit construction sector in the U.S. and Canada. She received her engineering education at the University of Ottawa, Canada.

Bed fire about two minutes after ignition with a match sized flame. The mattress industry is working with NIST on defining the problem and finding a solution to prevent deaths caused by such fires.

Almand's mission was to move the Society to align more strongly with the profession, changing the focus of the Society from the art and sciences to science and practice. This change is reflected in the many programs and publications SFPE offers, such as the various engineering guides and technical reports. Educational programs include short courses on various technical subjects ranging from risk assessment to new developments in building codes and standards.

The Society also supports the development of the annual professional engineer licensing exam in fire protection and the grading of those exams under the auspices of the National Council of Examiners for Engineering and Surveying. In 2002, a new specification was approved for the P. E. exam in 2004 that reflects the changes in the profession. The percentage of the questions on the exam that covers building systems has approximately doubled, while the percentage of questions on water-based suppression systems

and WTC Building 7 is focusing on the building construction, the materials used and all of the technical conditions that contributed to the outcome of the WTC disaster. Computer models are being used to recreate and analyze fire conditions in the towers in order to yield an estimate of the total heat release rates.

Additional research is being conducted in BFRL's Safety of Threatened Buildings Program. This research will provide guidance and tools to assess and reduce future vulnerabilities; will produce the technical basis for cost-effective changes to national practices and standards; and will better prepare facility owners, contractors, designers, and emergency personnel to respond to future disasters, natural or intentionally initiated.

One woman FPE making significant contributions to this effort and at BFRL in general is Dr. Kathy Notarianni, a registered professional engineer and leader of the Integrated Performance Assessment Group in the Fire Research Division. Dr. Notarianni's work has focused on issues relating to smoke detection, water-based suppression, design of engineered systems, and fire model validation. Her interests are in developing engineering methodologies and decision analysis models of use to practicing engineers and/or policy makers in industry and government.

Dr. Notarianni supervises a group of 12 scientists and engineers and has served as the lead principal investigator on a number of important projects. She also has participated on several NFPA committees and mentoring of young people through local and national programs. She recently authored a new chapter in the SFPE *Handbook of Fire Protection Engineering.*

Dr. Notarianni

She recently completed her Ph.D. in mechanical engineering and public policy at Carnegie Mellon University. As part of her dissertation research, "The Role of Uncertainty in Improving Regulation: A Case Study in Fire Protection," she has proposed a methodology for the quantitative treatment of variability and uncertainty in performance-based engineering analysis. This effort will assist architects and engineers in the design process, and assist code officials by increasing confidence in accepting a performance calculation.

Dr. Notarianni is also an active member of the Society of Fire Protection Engineers (SFPE). She currently serves on the technical committee that wrote the U.S. Performance-Based Engineering Design Guidelines. Dr. Notarianni has served as chair of the SFPE Committee on research, and editor of the "Research Today" column in the *SFPE Bulletin.* She represented SFPE on a national coalition of engineering societies working to advance pre-college mathematics and science education in the United States. She is a member of the National Fire Protection Association, serving on the technical committee on fire risk assessment methods.

Dr. Notarianni has received awards from the Department of Commerce and the Society of Fire Protection Engineers for superior performance and leadership. In 2002, she was elected Fellow of SFPE. She has served on a task force to study future directions of the fire research program at NIST and on the strategic planning committee for the Building and Fire Research Laboratory. Before earning her doctorate, she held a B.S. in chemical engineering and a M.S. in fire protection engineering from Worcester Polytechnic Institute and a M.S. in engineering and public policy from Carnegie Mellon University.

was reduced by approximately 50 percent. The percentage of the exam that is dedicated to hazard and risk analysis and the fundamental principles that support hazard and risk analysis (fire science and human behavior) has approximately tripled, which indicates that fire protection engineering as a discipline has matured.

"Human behavior is an emerging discipline and how humans respond to fire is becoming an important part of engineering design," explains Almand. "For instance, how loud should alarms be, where and what color exit signs should be, how wide stairways need to be, and how long it takes to exit the building are just a few of the design parameters related to human behavior." SFPE is writing an engineering guide that quantifies human response and offers a three-day fire alarm system course that discusses human behavior.

The events of 9/11 made SFPE a focal point for the general public and engineers, as well as increasing awareness of the field. "For the first time, the general public had a better understanding that there is a separate engineering discipline," says Almand. "In fact, even many structural engineers were not aware of our discipline before 9/11." SFPE also played a key role in the WTC investigation. Many of the teams formed by the American Society of Civil Engineers included SFPE members who also made significant technical contributions.

Women's Accomplishments Recognized

Although SFPE's current female membership is only 3 percent, several major awards went to women in 2002. This is consistent with the Society's history, as evidenced in the sidebar on page 53. Dr. Kathy Notarianni (see page 56) was elected Fellow, and Jane Lataille, P. E. received the D. Peter Lund Award. This award honors the first executive director of the society and recognizes significant contributions to the advancement of the professional recognition of the fire protection engineer. Lataille is honored for her many and varied contributions, including her many years as chair of the SFPE engineering licensing committee. She spearheaded the effort for recognition of the P.E. license for FPE in many states. She was the editor of the first edition of the reference manual for the P. E. exam, and a major contributor to its recent edition.

As a long serving member of SFPE's publications committee, Lataille was a major advocate for the enhanced quality of SFPE's new publications program. In 1998, she recognized the role that a state of the art practice-oriented magazine would have in gaining recognition for the

Test burn to study effects of intentional burning of oil spills in marshland environment.
Photo, courtesy of NIST.

NASA BRINGS SPACESUIT TECHNOLOGY TO FIRE FIGHTING

Although fire protection engineers usually work on buildings and facilities, fire research may also involve investigating the flammability of fabrics and require assistance from other types of engineers. NASA's Johnson Space Center (JSC) — together with the Houston Fire Department, the Department of Defense, Supercritical Thermal Systems (formerly Aerospace Design and Development), Oceaneering Space Systems, ILC Dover, and Lockheed Martin — are developing a prototype protective suit that could double the time a firefighter can battle a blaze before needing rehab to cool off. The current suits permit firefighters to work a maximum of 20 minutes. The Department of Defense develops heat stress models to test and evaluate materials. After the NASA contractors build mockups for the volunteer firefighters to evaluate, the contractors then build prototypes for field tests and certification for compliance with minimum firefighter standards.

The advanced firefighter suit uses a number of technologies that also protect space-walking astronauts. These include new outer garment fabrics and active cooling inner garments that can allow longer exposure to temperatures of up to 260 degree C (500 degrees F), while protecting the firefighter from building up metabolic heat stress.

Among the concepts the team is exploring is the use of cryogenic supercritical air in the backpack. "This system is at a hand-built prototype stage and shows a lot of promise," says Tico Foley, one of the NASA investigators. "Basically, the current firefighter carries compressed air in a backpack (these were developed at JSC following the Apollo Moon Landing). The new concept uses very cold air in a thermos bottle called a Dewar in the backpack. A liquid cooling garment, similar to the ones astronauts use in their spacesuits, picks up the metabolic heat from the firefighter's body and carries the heat to a heat exchanger in the backpack. The heat exchanger is similar to a radiator in a car."

Several women FPEs were involved in developing this prototype of an advanced firefighter suit.

An advantage of using cyrogenic air is that such air is both denser and at a lower pressure than ambient temperature compressed air, so a lighter weight tank can contain twice as much air at the same total weight. "We are also looking at new materials for bunker gear outershell and insulation, based on what we have learned when looking for better space suit materials," says Foley. "And we are adapting space suit tailoring concepts for bunker gear in order to achieve better mobility." Although experimental fabrics are being tested for the outer suit, these materials are very expensive so other options are being investigated.

The primary challenge is to design a suit that takes into consideration all three critical parameters that determine how long a firefighter can work: fire heat, body heat, and air supply. "You cannot establish adequate protection for any of these three unless you address all of them together," says Foley. Another major concern for firefighter safety is communications.

The development team has identified 40 additional areas from which space suit technology can potentially add improvements to structural firefighter protective gear. These include: integrated helmets; improved gloves with better dexterity, thermal protection, mobility, and tactility; radiant heat protection (current structural firefighter suits only provide conduction and convection heat protection); and ergonomic evaluation for best fit. The integrated helmet would have a built-in duplex digital radio, bone-conduction headset for noise reduction, infrared imaging to search for fire victims, biodata and temperature sensors, and readouts on the status of its life support system. Current efforts are focusing on developing better gloves.

Another key challenge is obtaining the right type of information. Most of the information has come from detailed incident reports following firefighter fatalities, and from the subjective stories from firefighters. What is missing is good information about injuries, mishaps, close calls, etc. that contains the appropriate details; for instance, whether the firefighters were wearing their gloves or not when the injury occurred. Lacking this information makes it harder to determine what improvements are needed. For more information, contact Tico Foley at: phone 281-483-2996; fax: 281-244-5773; or tico.foley@jsc.nasa.gov.

A demonstration of the Supercritical Air Mobility Pack (SCAMP).

profession, and was a tireless contributor to the initiation of *Fire Protection Engineering* in 1998. Lataille now serves on the editorial board and is a frequent contributor.

Lataille is currently a fire protection engineer at the Los Alamos National Laboratory and a past president of the Connecticut Valley chapter of SFPE. She has received SFPE's Hats Off and President's Awards. Lataille continues to volunteer in the NSPE Mathcounts Program to encourage young people to join the engineering profession. SFPE also has established an informal mentoring program with women members to mentor students. Other outreach programs for women and minorities are being considered.

An Evolving Field

The FPE field has changed considerably over the last several decades. Deaths from fire in the U.S. have dropped by some 50 percent since the landmark report, *America Burning*, was published in 1973. Today, computer modeling, new

materials and fire-suppression agents, new approaches to design, and new regulatory practices are transforming the way engineers look at fire safety in buildings and vehicles. Environmental regulations will continue to impact what fire suppression materials can be used. For example, because of its negative effects, Halon 1301 is now rarely used. FPEs also must continue to deal with changes in building and fire codes since they are updated on a regular basis.

Computers will continue to have a major impact on FPE technology. "As computers expand in capability, so will the field of FPE," says NIST's Kuligowski. "I expect our computer models of both fire and people movement will become more accurate and become integrated to encompass the entire fire situation."

Code Consultants' Dinney also believes that advances in modeling will help in her company's arguments for equivalent levels of safety. In other words, although a proposed concept is not specifically code compliant, it may be equivalent or better than that which is specifically stated by code. These concepts are backed up with engineering models and methodologies. "If code officials agree with the concept, this helps save clients a lot of money," says Dinney.

In the aftermath of 9/11, human behavior has become more of a priority, especially in regard to evacuation from buildings. "If our main concern is life safety, we must not only stop the spread of fire, but also move the people away from the threat of smoke and heat into an area of safety," says Kuligowski. Adds the University of Maryland's Milke, "Human behavior is the key to performance-based analysis and is based on assumptions of what people will do. In our FPE program we have a lecture on this topic and we have begun a research project on human behavior as it relates to residential fires."

The adoption of performance-based codes will continue and should be completed within the next several years. SFPE has already published an engineering guide to design and analysis using these codes. "This publication expands opportunities for the profession," says SFPE's Almand. "Building design will be based on the performance objectives of the owner as well as the prescribed safety levels in the codes. FPEs will become integrated into the design team and be involved in the design from the start. This engineering approach to fire safety is more cost effective and provides better fire protection."

"Performance-based design is not an arcane procedure but a proper engineering approach," adds Margaret Law, SFPE's first female Fellow. "It is a process...that can be applied equally to a project design, a rule, a code or a product."

Global recognition of FPE is also increasing as SFPE establishes more chapters overseas. Over 20 percent of its members are from other countries and this segment is growing. "However, our challenge is to make young people more aware of these opportunities," says Almand. "Fire protection as a career is one of engineering's best kept secrets and we'd like to change that." ■

The Society of Fire Protection Engineers

The Society of Fire Protection Engineers was established in 1950 and incorporated as in independent organization in 1971. It is the professional society representing those practicing the field of fire protection engineering. The Society has approximately 3500 members in the United States and abroad, and 52 regional chapters, 10 of which are outside the US.

The purpose of the Society is to advance the science and practice of fire protection engineering and its allied fields, to maintain a high ethical standard among its members and to foster fire protection engineering education.

The Society supports the development of the annual Professional Engineer licensing exam in fire protection and the grading of those exams under the auspices of the National Council of Examiners for Engineering and Surveying. Several volunteer committees and task groups work under the Society's auspices on technical projects to further advance the state of the art.

The Society's activities include a series of educational seminars and short courses, technical symposia and conferences, books and publications, designed to advance the state of the art of fire protection engineering and provide technical information to the fire protection community. The Society publishes a bimonthly newsletter, a peer reviewed quarterly Journal, and a quarterly technical magazine, *Fire Protection Engineering*.

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The Society of Women Engineers

Founded in 1950, the Society of Women Engineers stimulates women to achieve full potential in careers as engineers and leaders, expands the image of the engineering profession as a positive force in improving the quality of life, and demonstrates the value of diversity.

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