A Research Agenda for Fire Protection Engineering

The Society of Fire Protection Engineers

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Executive Summary

On October 21 & 22, 1999 the Society of Fire Protection Engineers hosted a workshop to develop a research agenda for the fire protection engineering profession. The 70 attendees came from around the world and from all segments of fire protection engineering practice: consulting, insurance, education, research, manufacturing, enforcement and facilities management.

Fire protection engineers are the link between fire research and its application in the built environment. In this capacity, fire protection engineers have a unique perspective on where fire research is needed. The workshop attendees identified research priorities in four areas:

- Increased utility of risk concepts. Workshop participants noted that consideration of the probabilistic aspects of fire could yield significant improvements by better focusing fire protection resources where they are most needed. An improved understanding of the aspects that affect individual and societal risk acceptance is desired. Also, a framework is needed to apply risk analysis in fire protection design.

- Increased understanding of fire phenomena. Workshop participants identified that research is needed in such areas as heat release rates from fires in buildings, fire detection, and fire suppression. Workshop attendees also emphasized that an improved understanding in this area alone is not sufficient; the results of research must be translated into practice, such as by the development of readily usable models.

- Human behavior. Workshop attendees noted that better considering human behavior in fire would lead to improved fire protection designs. An increased understanding of human behavior and psychology would help fire protection engineers better predict how and when building occupants react to fire cues, such as smoke and alarms. It was also noted that not all people behave the same, and an understanding of how human behavior varies is needed.

- Data. Workshop participants expressed a strong need for data, with known confidence, in all areas considered in fire protection design: reliability data, human behavior, product, failure, near-miss, etc. This data would form the input to fire hazard or risk calculations. Increased availability of data would lead to improved, more cost efficient designs, increased reliability and a better understanding of financial losses and the costs of fire protection. Workshop attendees also stressed that data must be readily available.

Workshop attendees also gave their perspectives on the necessary components of a plan for implementing the research agenda. They noted that a champion is needed, that funding should come from private/public sector partnerships, and that collaboration, including international collaboration, will be necessary. The latter point is particularly true since several of the research areas identified will require input from outside of the traditional fire protection community.

Completion of the research identified in this research agenda will contribute towards improved fire safety and reduced fire related costs.

Acknowledgements

This research agenda is the product of all of the participants in the SFPE Research Agenda Workshop. Their time and effort in developing this agenda is greatly appreciated. A complete listing of all of the workshop participants can be found on page 47.

A steering committee oversaw the development of this agenda, framed the discussions at the workshop and provided the seed crystal for the agenda itself. Their selfless contribution of time and talent was instrumental in the success of the workshop and the quality of the agenda. The steering committee was comprised of the following members:

- James Quiter (chair), The RJA Group
- Philip DiNenno, Hughes Associates
- Paul Fitzgerald, FM Global
- John Hall, National Fire Protection Association
- David Lucht, Worcester Polytechnic Institute
- James Milke, University of Maryland
- Robert Schiffiliti, R.P. Schiffiliti Associates
- J. Kenneth Richardson, Ken Richardson Fire Technologies
- Robert Weber, Clark County, NV

There were five breakout groups at the workshop. Breakout group leaders facilitated discussions that led to the content of this agenda and kept their groups focused. The breakout group leaders were:

- Paul Heilstedt, Building Officials and Code Administrators, International
- Michael O'Hara, The Mountainstar Group
- Matti Kokkala, VTT Building Technology
- Paul Shipp, USG Corporation
- Robert Schiffiliti, R.P. Schiffiliti Associates

Keynote presentations were given by:

- J. Joseph Moakley, U.S. House of Representatives (Massachusetts, 9th District)
- James Quiter, The RJA Group
- Paul Fitzgerald, FM Global
- John Nutt, Ove Arup & Partners & Chair, Fire Code Reform Centre

Morgan Hurley, SFPE Technical Director, served as overall project manager. Additional staff support was provided by Kathleen Almand, SFPE Executive Director, Brian Meacham, SFPE Research Director and Judy Fantle, SFPE Administrative Assistant.

The National Institute of Standards & Technology provided financial support (Grant No. 60NANB8D0047) and secured the Department of Commerce facilities where the workshop was held.

Introduction

"Fire protection engineering" is the application of scientific and engineering principles to protect people and their environment from destructive fire. As the primary appliers of fire protection research, fire protection engineers form one of the principal links between researchers and the end users of fire protection technology.

Fire protection engineering utilizes fire prevention, passive and active fire protection measures, and evacuation strategies to provide the safety required by society at a reasonable cost. Other strategies such as fire safety education, training and fire service response are also used, although other professional groups such as the educational, environmental and legal communities are more active in these areas.

Every profession must strive to find better, more cost effective methods to achieve its goals, and fire protection engineering is no exception. However, there are limited resources available to finance fire related research, which makes it necessary to ensure that the research that is conducted will have the greatest impact. Fire protection engineers, as the primary appliers of fire protection technology, have an understanding of the areas where technology development is most needed.

On October 21 & 22, 1999 the Society of Fire Protection Engineers hosted an international workshop to develop a research agenda for fire protection engineering. The 70 attendees came from around the world and from all segments of fire protection practice: consulting, insurance, education, research, manufacturing, enforcement, and facilities management. The purpose of the workshop was to identify research needs of the fire protection engineering community.

Throughout the world, there are changes occurring that will facilitate the timely implementation of research results. The acceptance of performance-based fire protection engineering is becoming more widespread. Several countries have adopted or are in the process of adopting performance-based fire protection engineering methodologies, including Australia, New Zealand, the United Kingdom and the Nordic countries[1]. In the U.S, a performance-based option has been included in the National Fire Protection Association's *Life Safety Code*[2] and a new *International Performance Code*[3] is expected to be completed shortly. Additionally, the Society of Fire Protection Engineers has published a performance-based fire protection engineering design guide[4] to facilitate the implementation and use of these performance codes.

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[1] Meacham, B. "The Evolution of Performance-Based Codes and Fire Safety Design Methods," *NIST-GCR-98-761*, National Institute of Standards and Technology, Gaithersburg, MD: 1998.
[2] NFPA 101, *Life Safety Code*, National Fire Protection Association, Quincy, MA: 2000.
[3] International Code Council. *International Performance Code*, International Code Council, Falls Church, VA (under development).
[4] Society of Fire Protection Engineers. *The SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings*, Society of Fire Protection Engineers and National Fire Protection Association, Bethesda, MD: 2000.

WHY RESEARCH IS NEEDED

The innovation gained through research can be implemented to reduce direct and indirect fire related costs, improve life safety, improve international competitiveness and facilitate regulatory reform. Improvements are needed in many areas:

- **Improved Life Safety.** Fire death rates among the elderly and physically and mentally disadvantaged populations are disproportionately high. Changes are occurring in the demographics of the population that will exacerbate this problem. People are living longer, and the elderly will constitute a larger percentage of the population. Accessibility laws will lead to a greater integration of physically and mentally disadvantaged into the built environment. In the U.S., the overall fire death rate relative to population is among the highest in the industrialized world.[5] Additionally, fire injury rates can be several times greater than death rates, with approximately five times more injuries than deaths annually in the U.S.[6]

- **Reduction of fire related costs**. The cost of fire and fire protection – combining spending to prevent or mitigate losses with human and property losses – within developed (G7) countries, constitutes a large percentage of gross domestic product[7]. For example, despite dramatic loss rate declines over the past century, the total cost of fire in the USA is particularly high, estimated at $100 to $200 billion a year[8], or over 2% of the gross domestic product.

- **International Competitiveness**. In Europe and the Pacific Rim, fire protection is typically 2-3% of construction cost.[5] In the U.S., this cost is higher, as approximately 5% of every U.S. construction dollar is spent on built-in fire protection[8]. This high cost of fire protection in buildings is passed on to product costs, which can have a negative effect on competitiveness with countries where the cost of fire protection in buildings is lower.

- **International trade**. The cost in the U.S. of meeting fire safety product standards, including testing to demonstrate compliance, is estimated at more than $25 billion per year[8]. Multi-national firms face this cost repeatedly in global markets with varying standards. Less reliance on prescriptive, pass-fail standards will allow producers to test once and sell anywhere. However, development of harmonized, performance-based testing standards requires research, data, and tools to demonstrate equivalence of tests and to convert test results between systems.

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[5] Wilmot, R.T.D. (Ed.), "United Nations Fire Statistics Study,", London: World Fire Statistics Centre, September 1998.
[6] *Fire in the United States*, United States Fire Administration, 10th Ed., 1995.
[7] Tudhope, H., "International Fire Losses" 1985-1987, *Fire Prevention*, May 1989.
[8] Hall, J., The Total Cost of Fire in the United States Through 1995, NFPA Fire Analysis & Research Division, Quincy, MA, March 1998.

- **Regulatory reform**. The industrialized world is adopting performance-based codes for fire safety design. Performance-based design requires engineers to seek out and appropriately apply engineering tools not contained within the codes. Uncertainties in predictions from these tools are often undocumented, and appropriate safety factors often have not been identified or substantiated. Without a strong scientific foundation, which is developed through research, designs with weak scientific underpinnings may be developed and implemented. These may be less expensive, but possibly less safe and no more innovative.

- **Protection of the Environment**. Fire can have a detrimental impact on the environment by introducing toxic or hazardous materials. Products used for fire protection, such as fire suppression agents, must continue to meet changing environmental requirements. Research can be used to identify fire protection measures and products that are environmentally benign.

In a myriad of ways, fire protection engineers would benefit from additional science and tools that would help them advance safety, reduce construction costs, and support innovations in product and building design. Fire protection engineering technology is changing to favor explicit calculation and scientific demonstration of fire performance over prescriptive approaches.

It is therefore essential that the research base for fire protection engineering be strengthened. Current resource limitations demand that this be done efficiently and effectively. This research agenda identifies the research that is most needed by the fire protection engineering community to make meaningful gains in the areas identified above.

Workshop Summary

The workshop was held for 1-1/2 days, beginning in the morning of October 21, 1999. Following welcoming remarks and a summary of workshop goals, keynote presentations were given by Joseph Moakley, U.S. Congressman representing Massachusetts' 9th district, James Quiter, Senior Vice President of the RJA Group, and John Nutt, ex Chair of Ove Arup & Partners and Chair of the Fire Code Reform Centre. These presentations were intended to help participants focus their thoughts on research needs and the benefits of fire research. Participants were then divided into five breakout groups. Each breakout group was comprised of a cross section of the workshop attendance. Each breakout group met three times, and each meeting had a different goal.

The first time that breakout groups met, participants were asked to brainstorm fire protection problems that they had encountered in the course of their work. In the second meeting of the breakout groups, research needs were identified that would help overcome the problems identified.

Following the second meeting of the breakout groups, the plenary session was reconvened. A keynote presentation was given by Paul Fitzgerald, Executive Vice President of FM Global on the benefits of fire research to business and on how those benefits are often long in coming and difficult for businesses to recognize. The breakout groups then met for a third and final time on the morning of the second day to prioritize the needs that they identified and give their perspectives on implementation of the research agenda.

The workshop concluded with a plenary session where each of the breakout group chairs presented the research needs that their group identified as the highest priorities. The results of the breakout group discussions were summarized and agreement reached on the highest needs. The workshop attendees identified four primary areas where research is most urgently needed:

- Fire phenomena
- Human behavior
- Risk
- Data

Forms were given to workshop participants for them to evaluate the impact, cost, feasibility and timeframe for the research needs identified at the workshop. These forms were completed after the workshop and returned to the workshop host.

The next four chapters of this research agenda summarize the discussions at the workshop regarding the research needs in each area. Each chapter concludes with a table that lists the research needs identified. The tables also summarize the results from the evaluation forms.

Risk Management

The engineering community generally recognizes risk as a product of probability and consequence. However, risk is much broader than this simple equation suggests, for example, addressing issues of uncertainty.

Fire protection engineering has typically focused only on the consequence (or hazard) part of risk. To bring about significant cost-benefit improvements in fire protection engineering design, and to better focus fire protection resources where they are needed most, it is necessary to apply risk management. Using risk management in fire protection engineering practice requires definition of the level of risk that society is willing to accept and a risk management framework.

Society is willing to accept a certain degree of risk. However, exactly how much risk society finds acceptable is unknown. Compliance with prescriptive codes and standards is intended to provide an "acceptable" level of safety. However, as more detail and new requirements are added to prescriptive codes, it becomes more difficult to explicitly define what is considered an acceptable risk.

Reduced risk tends to mean increased cost. Less risk is typically viewed favorably. However, as risk decreases, the costs involved in providing still lower risk eventually become unacceptable. Determining what level of risk is acceptable to society involves finding where the balance occurs between how much society is willing to pay to avoid risk, and the risk itself. Additionally, risk acceptance is not universal – some communities may be willing to accept a higher level of risk, and others may be less willing to pay for a lower level of risk. Moreover, the costs and risks often fall on different people, and this further complicates the search for a single value for acceptable risk.

Present application of performance-based design typically focuses on measuring "equivalency" to individual code or standard provisions. However, without specific risk targets, equivalency determinations can result in an inconsistent level of safety. People may interpret the intent of a provision differently. Similarly, judgement is needed to select the appropriate fire scenarios in order to test a proposed alternative design. A less severe scenario can result in a less safe design being considered acceptable; similarly, a scenario that is too severe might result in a design that is not cost effective.

One workshop participant noted that "it is not possible to incorporate society's perception of acceptable risk into design, particularly as perception of 'acceptable risk' varies." Determining what constitutes an acceptable risk will require the input and concurrence of public policy makers. Since definition of risk involves deciding how much loss is acceptable, this can be a politically challenging task. However, lessons can be learned from other industries, such as the automobile and aircraft industries.

Once an acceptable level of risk is known, it will become necessary to design to meet this level of risk. This will require the development of a risk analysis framework that considers the risk exposure and the costs, both initial and lifecycle, of any protection methods used.

The development of a risk analysis framework for fire protection would bring many benefits. In addition to maximizing cost effectiveness of fire protection designs by designing to meet the risk that is acceptable to society, a risk analysis framework would allow consideration of the effectiveness of fire protection designs as a complete system. The contribution of individual components (such as active and passive systems, the fire service, fire prevention, and fire safety education) could be considered collectively.

As risk analysis has been applied in other engineering disciplines, one can look to these disciplines as a starting point. The risk analysis tools used in other engineering disciplines can be evaluated for their applicability to fire protection engineering, and possibly modified accordingly.

Research Needs: Risk Management

Research Need	Benefits	Impact on Need (1 = no impact; 5 = high impact)	Cost (1= high cost; 5 = negligible cost)	Feasibility (1 = very difficult; 5 = simple)	Time (1=5 or more years; 5 = 1 or fewer years)
Determine what level of risk is acceptable to society, and how acceptable risk varies from community to community.	• Understand the level of safety society desires, and the costs of providing this level of safety. • Understand how much society's risk acceptance varies in different communities.	4	2	3	2
Develop a risk management framework to describe the fire/building/people interaction and impact of system operation success or failure.	• The ability to provide the level of safety that society requires at the most reasonable cost. • The ability to balance the strengths and weaknesses of individual components of a fire protection strategy.	4	3	3	2

Fire Phenomena

A common issue in the breakout groups was that "gaps in current design methods result in excessive conservatism."

An understanding of fire phenomena forms the foundation upon which engineered fire protection is based. Consideration of the effects of fire on people, buildings, property or the environment first begins with consideration of the types of fires that might be expected and how those fires would behave (fire growth, heat release rate, smoke production, etc.). While there are significant opportunities for improvement in design that would result from research in other areas, strengthening the knowledge base in fire phenomena would lead to improvements in all designs.

Current predictions of fire phenomena are too often based on rules of thumb, extrapolation from small scale testing or expensive large scale testing. While these methods are based on a significant body of experience, the margin between predictions and actual behavior is often unknown, and the applicability of these methods to new fire hazards, new technologies, and any changes in the future, cannot be assumed.

Fire development is typically categorized into three regimes: growth, full development and decay. Typically, fire growth is assumed to be proportional to time squared. While this method has been used successfully for quite some time, it is based on limited testing and may not apply to all configurations. In some cases, more scientifically grounded predictions are possible where test results from burning individual pieces of furniture can be aggregated and balanced against the available ventilation.

Methods of predicting heat release rates from fully developed fires are relatively well established where the enclosures are approximately the size of a common office. However, these methods do not hold well for larger or elongated enclosures. The ability to predict heat release during the decay period is very limited, but the decay period is typically of little consequence for fire protection design.

Methods currently exist for predicting the response of detectors, but these methods are limited to thermal detectors that are installed under horizontal, unobstructed ceilings. Prediction methods are needed for detectors that are installed in other geometries. Also, smoke detector response is typically predicted assuming a temperature rise necessary for operation, a method that does not have a strong scientific basis. While these methods have worked reasonably well, a more detailed understanding would be beneficial such that detection system design and performance could be better matched with design objectives.

In the area of fire suppression, there has been a fair amount of research into halon alternatives and water mist; however, a quantitative understanding of fire suppression is still lacking in most areas. The minimum water application rates from sprinkler systems, which are the most widely used suppression systems, to achieve fire suppression or control are unknown in all but a limited number of cases. Research is needed to better predict suppression system efficacy.

However, a greater understanding of fire phenomena in itself is not sufficient. It is necessary to transfer knowledge gained through research into fire protection engineering practice through the development of models and other tools. A greater understanding of fire phenomena which is readily applicable through models will lead to better and more cost effective fire protection.

Research Needs: Fire Phenomena

Research Need	Benefits	Impact on Need (1 = no impact; 5 = high impact)	Cost (1= high cost; 5 = negligible cost)	Feasibility (1 = very difficult; 5 = simple)	Time (1=5 or more years; 5 = 1 or fewer years)
Heat release rates (fire growth & fully developed fires)	• Better prediction of fire protection performance • Stronger underpinning of fire protection designs • Better predictions of the effects of fire • Improved protection of people and property	4	1	2	2
Suppression system effectiveness	• Better prediction of suppression performance • Suppression system designs could be more closely matched with expected fire characteristics • Improved protection of people and property	4	2-3	2	2
Response of fire detectors (smoke, heat, flame, etc.) to different fire signatures	• Better prediction of detector response • Detection system designs could be more closely matched with expected fire characteristics • Improved protection of people and property	2	3	3	3
Smoke movement from low energy (smoldering) fires	• A better understanding of a type of fire that can be difficult to protect against	2	3	3	3
Investigate the impact of fire and fire protection on the environment	• Reduced environmental damage from fire and fire protection	2	3	3	3

Research Needs: Human Behavior

A participant in one of the breakout groups noted that "fire protection system designs assume that people will leave buildings in the event of fires. However, this often does not happen; … we need to design for these actions." Similar remarks were made in each of the other breakout groups.

Designs that are based solely on fire behavior, equipment performance, and materials response overlook a significant factor that can often by the key to the outcome of a fire: human behavior, human performance, and human response. To provide better life safety, it is necessary to better understand the actions that people will take in response to a fire.

The decisions that people are likely to make in response to a fire and the reasons for those decisions are not well understood. Most designs are based on the assumption that people would leave immediately after being notified of a fire. However, research has shown that people frequently take other actions before evacuating, such as investigating, notifying others or looking after family members.

While there is a significant body of research on movement speed during evacuation, there is little understanding of how to predict pre-movement times, i.e., the time from the onset of hazardous conditions to the time when occupants begin evacuation. These pre-movement delays have been significant in many cases. Increased understanding of human behavior and psychology is needed to better predict how and when building occupants react to fire cues, such as smoke and alarms, and what actions they take upon recognizing a cue.

The fire environment can also impact human behavior. People may become impaired or incapacitated from exposure to toxic fire products. Decreased visibility thorough smoke can affect decision making. While there is knowledge concerning the impact of combustion products on human capability, survivability, and behavior, most of it is based on animal testing for lethal effects. Sub-lethal health effects, effects on behavior, and animal-to-human conversions are among the points not now well understood.

Considering human behavior in design is complicated by variations in the behaviors of different people. People in family settings may put the safety of other family members above their own. People with mobility or sensory limitations might react differently than people without impairments. People might have varying degrees of consciousness, particularly where they could be expected to sleep. These occupant factors, and their implications on design, need to be better understood.

As with fire phenomena, increased understanding of human behavior in fire must be quantitative and predictive. Readily available models will be needed to facilitate the consideration of human behavior in engineered fire protection system design. An increased understanding of human behavior in fire will lead to more efficient life safety systems, thus providing necessary protection at acceptable cost.

Research Needs: Human Behavior

Research Need	Benefits	Impact on Need (1 = no impact; 5 = high impact)	Cost (1= high cost; 5 = negligible cost)	Feasibility (1 = very difficult; 5 = simple)	Time (1=5 or more years; 5 = 1 or fewer years)
Human behavior in fire, including responses to cues, pre-movement decision making and the impact of fire products (heat, gasses, etc.) on behavior.	• Better understanding of how people will react to fire and the actions that they will take • Better understanding of how people are affected by exposure to fire and fire effects	5	3	3	2
Develop design methods based on human behavior in fire situations.	• Egress system design could be matched to the expected actions that people might take • Improved life safety designs	5	3	3	2

Research Needs: Data

Each of the breakout groups expressed concern with the paucity of data that is available to fire protection engineers. Statements made included: “A significant amount of fire testing is conducted; however, the results from these tests are not readily available,” and “forensic research is needed to capture performance data of real fires.”

Data forms the input to engineering tools and calculations. Data is needed to assess how products and materials would behave in fires. Reliability data is needed for fire protection systems. Forensic data is needed to learn more about how fires are started and for feedback regarding failures and successes. Human behavior data is needed to learn more about what types of people can be expected in different occupancies, and what types of actions they might take that could lead to fires or alter the course of fires.

There is currently a significant amount of testing conducted to evaluate products. However, the data resulting from these tests are often unavailable or proprietary. In the absence of readily available product data, engineers are faced with applying engineering judgement or making assumptions regarding how products might behave. Mechanisms must be sought to remove proprietary concerns, or incentives must be created to promote the sharing of product data.

Fire protection systems are not always operational. A fire protection system may be unavailable due to accidental shutdown or maintenance. A fire protection system may be available, but might still not perform as intended. Data is needed regarding availability and reliability of fire protection systems so engineers can better predict their dependability. Additionally, data is needed to learn how the performance of systems change with time and to gain a quantitative understanding of the effects of inspection and maintenance at different intervals and depths. With improved knowledge of reliability and availability, redundancy could be provided where it is needed, and not provided where a component is sufficiently dependable.

Forensic data is needed to provide feedback from fires. An increased availability of forensic data would give additional opportunities to learn which strategies work well and which strategies don’t work well. Forensic analysis could also be used to gain additional insights into frequencies of fire ignitions in different occupancies. While there is considerable useful fire incident data available, the level of detail on all but the largest fires typically falls well short of engineering needs. The full range of scientific investigative techniques are applied to only a few major fires each year, leaving unanswered questions about the details that are provided on many fires. More detail is needed on smaller fires and investigation that is more thorough would be valuable for most fires. Particularly of interest are small fires that would have become large but for mitigating factors.

While many forms of data are needed, all data must be readily available and have known limitations. Workshop attendees suggested establishing a central contact for fire data. This central contact point would not need to physically house data, but could index data that is contained in other locations. Workshop attendees also identified a need to maintain data in such a manner that it can be used with confidence, which would fall to all who collect or store data.

Research Needs: Data

Research Need	Benefits	Impact on Need (1 = no impact; 5 = high impact)	Cost (1= high cost; 5 = negligible cost)	Feasibility (1 = very difficult; 5 = simple)	Time (1=5 or more years; 5 = 1 or fewer years)
Develop a data reporting/collection method such that reliability, failure, near miss, product, and occupant data, with known confidence and limitations, is available to the design community.	• Allow engineers greater access to data • Better prediction of the performance of individual components • Improved protection of people and property	4	2	3	2
Investigate how installations vary from design.	• Better prediction of as-built performance • Improved protection of people and property	3	2-3	2	2
Data collection from post fire analysis.	• Increased feedback from failures and successes • Help overcome gaps in data stemming from proprietary concerns	4	4	4	4
Improve collection of system reliability data from maintenance and inspection	• Better prediction of how components could fail and how frequently failures occur • Improved protection of people and property	5	3	4	3
Determine the effects of aging on equipment performance.	• Better predict how fire protection performance changes over time • Improved protection of people and property	5	2	1	1
Better monitor and manage systems and components that affect building performance.	• Changes that would adversely impact fire protection performance could be avoided (changes in occupancy, changes to fire protection system components, etc.) • Improved protection of people and property	4-5	2-3	3-4	2

Summary & Conclusions

The fire protection engineering community has identified research needs in several areas: Research is needed to apply risk concepts in fire protection design. A better understanding of fire phenomena and human behavior in fire is needed. There is also a need for data in all areas considered in fire protection engineering design.

Realization of the research needs identified in this agenda will allow fire protection engineers to achieve a number of societal benefits: improved life safety, reduction of fire related costs and improved environmental protection. Additionally, others stand to benefit from an increased understanding of the physical world – product manufacturers, building owners, insurers, the fire service and the public at large.

Implementing the research agenda will not be easy. It will require a significant financial investment and several years to achieve it. Presently, there are a number of organizations involved in research, including both private companies and governmental agencies around the world. Each of these organizations will have a role to play in implementing the research agenda.

Many stand to benefit from the results of the research identified in this agenda. Therefore, it is not reasonable to depend only on the organizations now involved in fire research to conduct the necessary research with the resources they currently have available. Collaboration and partnerships will be crucial to the success of implementing this agenda.

Additionally, a champion will be needed to coalesce the diverse interests that will need to come together to ensure successful implementation of the agenda. This champion will need to advocate the agenda, break down inter-organizational barriers, and oversee and monitor completion of agenda topics.

Realization of the research agenda will be no small undertaking. However, the benefits far outweigh the costs. Implementation of the research agenda will bring about significant improvements that will improve safety and reduce fire related costs.

Why Engineers Need Fire Research to Better Serve Society

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INTRODUCTION

"Fire protection engineering" is the application of scientific and engineering principles to protect people and their environment from destructive fire. As the primary appliers of fire protection research, fire protection engineers form one of the principal links between researchers and the end users of fire protection technology.

Fire protection engineering uses a number of strategies to provide the safety required by society at the most reasonable cost. These include:

- Hazard and risk analysis,
- Building design, construction, and arrangement,
- Design, installation and maintenance of fire detection and suppression and detection systems, and
- Post-fire investigation and analysis.

Fire protection engineers are but one of a number of professional groups that are involved with fire safety. Other allied professional groups include building owners and managers, building and fire officials, the fire service, product manufacturers, and the educational and legal communities. Society ultimately faces the burden caused by unwanted fire, and each of these groups has a role to play in reducing this burden.

The fire burden can be felt in a number of areas: life safety, costs of fire losses, costs associated with protecting against fire, and environmental damage. To make significant progress in reducing the fire burden requires research and the application of research. However, it is important to take a measured approach towards research, as there is a limited funding base to finance research. Such an approach should prioritize which research would have the greatest impact towards reducing the fire burden.

THE FIRE BURDEN

The fire burden is felt in a number of areas. Each is discussed in detail below.

Life Safety

In 1986, the average annual fire death rate among 15 industrialized nations was 14.4 per million population.[1] In the United States, the fire death rate was slightly higher, at a total of 5850 or 24.4 per million in 1986 and 4585, or 17.4 per million in 1995.[2] While this represents almost a 30% decrease in the U.S. over ten years, the fire death rate per million population in the U.S. is still two to three times that of several European nations.[2]

In the U.S., several population groups have a disproportionate share of the death rate. Children less than five years old have double the death rate of the entire population. Adults over 60 years of age also have a fire death rate higher than the general population.[2] As the percentage of older people living in the U.S. is expected to increase over the coming years, and this age group has a higher than average fire death rate, the aging of the population may exert a negative pressure on the decreasing trend of the overall death rate.

Within the United States, the majority of fire deaths, 74%, occur in homes,[2] with the vast majority of residential fire deaths occurring in one- and two-family homes. Vehicle fires constitute approximately 10%[2] of the fire deaths and outdoor fires constitute 4%[2]. Only roughly 7% of the fire deaths occurred in commercial settings, where the majority of fire protection attention is presently focused.

Conclusions that can be drawn from these statistics include: (1) the fire death rate in the U.S. is worse than the average of industrialized nations, and (2) there are forces that will make it more difficult to continue the downward trend in fire deaths. Research can help engineers find methods of protecting people that can be used to lower fire death rates. The use of this research would improve life safety for everyone.

Fire related costs

In 1994, the average direct cost of fire losses in several industrialized countries was 0.2% of their respective gross domestic products. In the United States, the 1997 total direct dollar loss was approximately $8.5 billion[3], or 0.15% of the gross domestic product. This figure includes fire damage to structures, contents, vehicles, machinery, etc., and does not include dollar losses associated with lost business or market share.

However, the total cost of fire in the U.S., including direct losses, indirect losses, and the cost of fire protection, insurance and fire departments, is estimated at a staggering $100 – 200 billion per year[4], or approximately 2% of the U.S. gross domestic product.

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[1] Tudhope, H., "International Fire Losses" 1985-1987, *Fire Prevention*, May 1989.
[2] "Fire in the United States," U.S. Fire Administration, 10th Edition, 1998.
[3] Karter, M. "1997 Fire Loss in the U.S.," NFPA Journal, National Fire protection Association, September/October. 1998, pp. 72 – 82.
[4] Wilmot, R.T.D. (Ed.), "United Nations Fire Statistics Study," World Fire Statistics Center, London: September, 1998.

Research can help engineers find cost effective methods of protecting people and property that can decrease the total cost of fire. The use of this research would increase the quality of life for everyone by lowering the total amount spent on fire and fire protection, freeing those financial resources for other uses.

International competitiveness

The average cost of installing fire protection into buildings in several industrialized countries ranges from 2-4% of the total construction cost. In the U.S., this cost ranges from 2.5% for housing to 12% for private, non-residential structures.[4] This cost differential of fire protection in buildings is passed on to the cost of products and services of the organizations that inhabit those buildings, which can impact international competitiveness.

Research can be used to identify methods to decrease the cost of built-in fire protection. The application of this research would help reduce the building cost differential among industrialized countries, which would facilitate international competitiveness.

International trade

Many products that are used in the built environment require fire performance related testing. Active and passive fire protection products require testing to demonstrate their capabilities. Other types of products require testing to ensure that they do not negatively impact fire behavior in the built environment.

Typically, the tests associated with having products approved vary slightly from country to country. This requires manufacturers to conduct a number of similar, but different, tests on a single product to market it in the global marketplace. The cost associated with conducting this testing is estimated at $25 billion per year.[5] These testing-related costs are passed on to the consumer as increased product costs.

Research can be used to develop scientifically based, performance oriented test methods for products and materials. The implementation of these test methods would allow for different countries to select different pass-fail criteria in accordance with their own desired level of safety, but make it necessary for a manufacturer to only test a product once. Where performance-based design is used, different pass-fail criteria could be specified by the designer depending on the hazards of the building.

Environmental protection

Both fire and fire protection measures can have a detrimental impact on the environment. Uncontrolled fires in manufacturing, production or storage facilities can release hazardous products of combustion into the air. Runoff from fires and fire fighting systems can release

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[5] Hall, J. "The Total Cost of Fire in the United States Through 1995," NFPA Fire Analysis and Research Division, Quincy, MA, March 1998.

hazardous substances. Also, fire suppression agents, such as Halon, CO_2, and emerging substitutes can impose environmental or health hazards of their own.

Research can be used to identify improved methods of property protection to mitigate the risk or hazard of fire. Research can also be used to find environmentally benign fire protection methods and agents. The application of this research would result in improved environmental protection.

APPLICATION OF RESEARCH

Traditionally, research results were applied through modifications to prescriptive codes and standards. Unfortunately, the time lag between research completion and the application of research through code modification was often very long.[6]

The time lag resulted from overcoming a number of barriers before the research results could be incorporated into the relevant code or standard. These steps have been described as:[6]

- Research, i.e., conducting and completing the research
- Technology transfer
- Application, typically to support code equivalencies or deviations
- Awareness by those outside of the fire protection engineering community
- Acceptance within the building community
- Approval by incorporation of the research into the relevant code

It is noteworthy that the research results would typically be applied prior to final acceptance through code equivalencies, however, this practice only allowed for limited application of the research.

Some examples

Three examples illustrate the impact of research on the practice of fire protection engineering and the speed that research results can be applied. These examples are sprinkler hydraulic calculations, smoke control, and replacement of Halon.

Prior to the 1970's, pipe sizes in sprinkler systems were selected based on pipe schedules. These schedules listed the maximum number of sprinklers that could be supplied for a given pipe size. Application of these pipe schedules required only minimum consideration of the water supply. The ability to perform sprinkler system hydraulic calculations, which would allow pipes to be sized based on the available water supply, dated to 1905.[7] However, hydraulic calculation methods were not included in NFPA 13 until the 1970's, and the pipe schedule method was not eliminated until the 1990's.[6]

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[6] Quiter, J. "Fire Research and Its Impact on the Building Code," in *Proceedings of the Conference on Firesafety Design in the 21st Century*, Worcester Polytechnic Institute, Worcester, MA: 1991.
[7] Williams, G. & Hazen, A. *Hydraulic Tables*, John Wiley & Sons, New York: 1905.

Calculation of smoke development and smoke spread has been the topic of basic research and applied research for many years. In the late 1960s and early 1970s, significant work was done on smoke spread within malls by researchers in the UK. Butcher and Parnell wrote a book on smoke control in the late 70's[8], and Klote and Milke have published several books and articles, including *Design of Smoke Management Systems*[9], in the years since. In the late 1980s, this information was incorporated into recommended practices [10, 11], and in the early 1990s was introduced as code into the *Uniform Building Code*. Similar language will also be included in the Year 2000 edition of the *International Building Code*.

There are still issues that need to be resolved regarding design of smoke control systems. The appropriate fire source needs to be better quantified, although there is limited, although growing, information regarding expected fire sizes in various occupancies and layouts. The reliability of the equipment and the overall system needs to be better understood. Building construction methods, including anticipated leakage of walls and barriers, and their impact on smoke management system performance needs further study. Other areas that could use further research include the responsiveness of the overall system and its individual components and how the quality of construction of the mechanical systems impacts performance.

With regard to smoke, there are several areas where further information is needed. They include information on the smoke hazard associated with various types of fires, smoke production from fire sources, including species yields, and how people are affected by smoke, including toxicity and visibility.

The recent work regarding Halon replacement shows a much faster progression. Several years ago, the problem of ozone depletion was noted as an environmental issue. A political solution was reached that eliminated production of Halon over time. This action created a need to replace Halon systems with another viable protection method. The response was a significant amount of money, energy, and time. As a result, several new products and methods have been developed.

Why is it that the Halon replacement project moved so quickly whereas research and its application on automatic sprinklers and smoke control has moved so slowly? A primary reason is that an externally induced (political) time factor was placed on the overall development of new materials and systems. This caused a direct financial impact and an immediate need for development of research and application of that research. This external inducement was not present for smoke control research or automatic sprinkler research. Rather, the only inducement in those cases was better fire protection methods and products. Some means of developing the "carrot" may be necessary to move research forward more quickly.

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[8] Butcher, E. & Parnell, A. *Smoke Control in Fire Safety Design*, London, E. & F.N. Spon: 1979.
[9] Klote, J. & Milke, J. *Design of Smoke Management Systems,* American Society of Heating, Refrigerating and Air Conditioning Engineers, Atlanta: 1992.
[10] *Recommended Practice for Smoke-Control Systems*, NFPA 92A, National Fire Protection Association, Quincy, MA, 1996.
[11] *Guide for Smoke Management Systems in Malls, Atria and Large Areas*, NFPA 92B, National Fire Protection Association, Quincy, MA, 1995.

Changes are now occurring that will allow for expedited implementation of research results. The acceptance of performance-based fire protection engineering is becoming more widespread. Several countries have adopted or are in the process of adopting performance-based fire protection engineering methodologies, including Australia, New Zealand, the United Kingdom and the Nordic countries[12]. In the U.S., two performance-based codes have been published or will be published soon: a performance option in the National Fire Protection Association's *Life Safety Code*[13] and a new *International Building Performance Code*[14]. Additionally, the Society of Fire Protection Engineers published a performance-based fire protection engineering design guide[15] to facilitate the implementation of these performance-based codes.

While the acceptance and implementation of performance-based codes will not overcome all of the barriers listed above, it will eliminate some of the barriers and shorten others. Additionally, preparing guidance on the application of research, an activity that the Society of Fire Protection Engineers presently has underway in several areas, will further aid the acceptance of fire research results.

However, performance-based codes bring with themselves new challenges that point to a need for further research. There are gaps in the knowledge base that will affect the widespread acceptance and implementation of performance-based codes. These gaps occur in many areas that would be considered in performance-based design, such as prediction of time dependent heat release rates, prediction of detection system response, prediction of suppression system effectiveness, and prediction of available safe egress time or required safe egress time.[16]

While the absence of a detailed understanding in these areas will not in itself form a barrier to the implementation of performance-based codes, it will hamper the realization of the full cost effectiveness of performance-based codes. Where a detailed understanding of a given phenomenon does not exist, a reasonable estimation may be made. However, these assumptions should be conservative enough that the final design is robust.

Conservative assumptions have the advantage of adding additional assurance to the final design, but also bring the disadvantage of added cost. These added costs become increasingly large where a number of conservative assumptions have to be made during the development of a single design. A more detailed understanding would enable the uncertainty associated with a prediction to be reduced, such that a "conservative" assumption would be closer to an average predicted value, thus reducing cost while maintaining an equivalent level of safety.

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[12] Meacham, B. "The Evolution of Performance-Based Codes and Fire Safety Design Methods," *NIST-GCR-98-761*, National Institute of Standards and Technology, Gaithersburg, MD: 1998.
[13] NFPA 101, *Life Safety Code*, National Fire Protection Association, Quincy, MA: 1999.
[14] International Code Council. *Interim Report of the ICC Building Performance Codes Committee*, International Code Council, Falls Church, VA: 1999.
[15] Society of Fire Protection Engineers. *The SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design Draft for Comments of Buildings*, National Fire Protection Association, Quincy, MA: 2000.
[16] Dinenno, P. "State of Fire Safety Engineering Design Technology," in *Proceedings of the Conference on Firesafety Design in the 21st Century*, Worcester Polytechnic Institute, Worcester, MA: 1991.

Another advantage that performance-based design brings is the ability to compare different strategies to achieve a set of fire safety goals. Where different strategies are equally effective in meeting those goals, obviously the most cost effective option would be selected. However, this brings an additional benefit: the ability to apply knowledge gained through research to reduce costs in otherwise seemingly unrelated areas.

For example, an improved understanding of human behavior during egress could lead to reduced uncertainty in an egress analysis, which would lead to a smaller factor of safety applied to the egress estimation. A smaller factor of safety applied to the required safe egress time could be used to allow for a larger available safe egress time. A larger available safe egress time could be used to offset the use of furnishings that might otherwise not be acceptable, while maintaining an acceptable level of safety. The number of other similar examples is literally as broad as the mind of the engineer who is performing the design.

CONCLUSION

An increased research base will allow for the simultaneous realization of a number of benefits: improved life safety, reduction of fire related costs and improvement of environmental protection. All professionals involved in fire safety stand to benefit from an increased understanding of the physical world – fire protection engineers, product manufacturers, building owners, insurers, the fire service and the public at large.

Designing for Fire

Dr John Nutt,
Chair, Fire Code Reform Centre Australia
ex Chair, Ove Arup and Partners

Introduction

My colleagues and I are designers, active in the construction industry in a number of countries. What we want to see and what we need are consistent global standards in design, which are transparent, universal and readily understood. Without this, differences lead to errors and inefficiencies. If the rules are flexible so that innovation is encouraged, then design encourages export and trade in both directions because good design creates a competitive advantage.

To achieve innovation, we need to be at the forefront of our activities. Design firms have to be supported by a professional community where research is encouraged, and where the risks are defined, controlled, and understood. That research has to be incorporated into the regulations and standards so that flexibility permitted while maintaining public safety. That requires participation in the preparation of the regulatory framework to achieve transparent and flexible rules.

Let me tell you a story which illustrates this point. One of our special skills is fire engineering. Our firm works throughout the world. I happen to believe that a proper understanding of fire engineering will bring revolutionary changes to the way buildings are planned, designed, and operated.

> *"I am often asked by governments to demonstrate the benefits of research and I do so by quoting an anecdote which involved fire engineering and my own firm. Margaret Law who headed Fire Engineering in Arups for many years and who will be known to many of you, used Arups to introduce many of her innovative ideas into practice.*
>
> *One such was the 'fire and island' fire protection concept in the design of large non compartmentalized airport terminals. She had developed her ideas when researching on London Heathrow Terminal 3, and with Paula Beaver, her successor at Arups, applied them to Stansted, London's new third airport. When the international competition for Osaka's new airport at Kansai was called, those ideas were incorporated into the winning entry by European architect Renzo Piano whom Arups were assisting as engineers. Clearly good exciting architecture and engineering was an important aspect of achieving success in that competition but inherent in the planning were certain aspects which were unique in our design.*
>
> *I then ask my questioner "Where do you think the steel for the building was manufactured?" Japan is noted for its immense steel production capacity. It was fabricated in the North East of England, and shipped to Japan. Why? Because the*

designers built using techniques with which they were familiar. That suited the British manufacturers. The Japanese steel industry was very good in other ways, but they were not price competitive in the steelwork of the winning competition design. It was the architectural design and the innovative engineering which won the competition, but the real beneficiaries were the steelworkers on Tyneside in the industrial heartland of Britain.

I have experienced that situation throughout my engineering career. The Sydney Opera House was designed by Danish Architect, Jorn Utzon. A million beautiful ceramic tiles clad the roof and were supplied by the Swedish manufacturer Hoganas. British firms supplied steel, Austrian firms, the stage machinery, French firms, the building cranes."

Design is an important tool in the export of a manufacturer's building products. With that underlying thought let me return to the theme of this conference.

Design

The process of design is to prepare for construction the intentions of the project initiator, satisfying the functional, economic, and operational requirements of the user, while meeting the social, safety, health and amenity criteria of the community. The language of design comprises drawings and written specifications. As in all engineering design, there is an appropriate balance struck between economy and risk, social purpose and function. The developer expects value for money, the community requires that its standards are adhered to.

Design Framework

The design framework therefore comprises two parts:

- A statutory part comprising laws, regulations standards and other rules, and
- A contractual part which incorporates planning, cost budgets, design, specifications, schedules, and quality assurance procedures.

The designer has to transmit intentions to many participants in the construction and approval processes, so definitions and meanings must be clear. All sets of construction documents call up other reference documents to avoid ambiguity and avoid the need to repeat commonly used material in many different contracts. Each variation to a standard increases the risk of misunderstandings and errors. Designers want a common set of reference documents which have wide industry usage and acceptance. A common and transparent language is necessary.

Statutory Requirements

The designer has to understand the statutory framework in which work is carried out, and there are two parts to the definition and application of the rules:

- The criteria contained in the regulations, and
- The application and approval process by which compliance is achieved.

From our experience on the variability across national boundaries, the approval process is the most difficult and restrictive.

The suite of rules are the publicly available documents which the community uses to define its requirements, generally to a set of minimum criteria for public health, life safety, and amenity. But it frequently extends beyond that to embrace consumer protection, (as is the case of serviceability criteria in design codes, limitation of deflections and so on), occupational safety and health, sometimes social goals (e.g. access for the disabled, the protection of property in an unknown or undefined manner like in fire regulations), political goals (as for energy efficiency). None of these are inappropriate, but the contents of each part of this hierarchy is often ill defined.

I won't dwell here on the approval process which incorporates accreditation, responsibility, accountability, audit, penalties and compensation provisions, but in many ways compliance with these exerts a greater influence on the designer than the technical criteria because the application of the rules is not what it appears to be.

Hierarchical Framework

The laws, regulations and standards provide a hierarchical structure within which the contract documents of drawings, technical specifications, schedules and bills are produced. Designers need a clear framework.

With the world wide trend towards the adoption of performance based codes, the process will become more confusing unless there is a transparent logical and universal framework in which to operate. Prescriptive and deemed - to - satisfy regulations provide speed and certainty of achieving approval, but have been found to lack flexibility. Their accuracy and applicability will also diminish as buildings change in planning and structural characteristics.

On the other hand, performance criteria defined by stated objectives provide flexibility, and in many instances, significant savings in construction costs. However, lacking a specified compliance path, incorrect validation procedures may be used. The prospect of error is greater. Designers need a logical hierarchical framework so that transparency is brought about. That Five Level Nordic framework is shown and has been adopted in a number of jurisdictions.

The Laws define the national goals of the building regulations - public health, life safety, amenity, social and political goals. The Regulations give a set of functional objectives and compliance procedures.

A typical statement of function might be that for structural performance there should be no collapse, the structure should be serviceable throughout its life, avoiding excessive deflections, having durability and so on; there should be property protection, certainly of a neighbors property, and perhaps of the building itself. What do these statements mean in real terms which designers can use. Performance criteria should provide this, giving for example, the quantified levels of risk.

National standards and Codes provide the deemed-to-satisfy methods, and following the theme of this conference, the loading codes, the material codes would be called up here. These provide the speed and certainty which the designer needs in the majority of designs. But for non-standard situations, an alternative compliance path is required, and for performance regulations, verification methods have to be agreed.

Approval Process

The approval process comprises application, assessment, decision, compliance, dispute resolution, and regulation support. In a changing technical and political world, unless adequate resources are directed to the maintenance of the regulatory framework, it will date and become restrictive and inapplicable.

It is not surprising to observe a great deal of variation in the building regulations, standards and codes of practice of different countries as regulations and standards are influenced by historic connections, local legislature, trading activities and cost of set up and maintenance of the regulatory framework.

Cost Structure of Buildings

There is one more point I wish to make which relates to the commercial environment in which a designer works - the cost of the project. Risk and economy go hand in hand. There are always pressures on the designer to reduce the cost of a building. A good designer achieves that without compromising the other attributes required - safety, functional efficiency, social statements and so on. A study of construction costs shows where the real economies can be achieved. Although these costs relate to Australia, they are more or less applicable elsewhere.

For every $100 which a developer or owner pays for a building, $50 relate to the direct construction cost and $50 to the cost of land and finance in about equal proportion ($25 each). Of the construction cost, $10 relates to the structural frame, $20 to the building envelope, and $20 to building services (electrical reticulation, lighting, air conditioning/heating, and lifts). The greatest savings can result from efficiencies in the time related costs, and in the operating costs of the building services. The latter is not relevant here. If the time from project initiation to delivery can be minimized, there are substantial benefits to be achieved which will exceed the savings resulting from refinements of analysis. The design and approval period is on that critical time line. Time which results from unnecessary complexity of the regulatory or approval process adds significant cost to a project. Therefore the converse applies.

The reduction of costs through refinement of structural analysis is not as cost effective as the economies relating to speed and familiarity. If procedural simplification can be brought about, cost saving will result.

Examples in this category are:

- Clarity of definition to reduce errors or rework
- Shorten familiarization effort and time to adapt from one design jurisdiction to another,
- Keeping the regulations and standards simple and transparency,
- Providing procedures so that alternative compliance paths are acceptable,

- Mutual recognition of other national codes with due account for geographic factors through the adoption of a common global system,
- Mutual accreditation of computer software,
- Consistency of units of measurement.

Innovation and Risk

Fire engineering research has the potential for introducing the greatest changes into the way buildings have been designed.

Innovation is at the very heart of commercial success. Innovation is the injection of creative ideas in a framework of careful risk minimization which is the essential ingredient of excellence. Each successful designer has a personal formula for achieving excellence, but invariably it comprises two parts, a creative part and a systematic procedural part. Without both, a design is unlikely to be successful.

Innovation, by definition, brings new and at times, untried, approaches to a project with greater risk. However, risk cannot be minimized without judgement, judgement cannot be gained without experience, and experience requires the knowledge gained from research and application to projects. Separate the technical issues from the decisions, and little innovation will be achieved. The control of risk is fundamental to innovation. The community is intolerant to failure. Litigation and the judgements of the courts have supported the consumer. Fear of litigation is the greatest deterrent to innovative ideas.

Where public safety is involved, changes have to be carefully introduced. Governments are responsible for the definition of public safety through regulation. As long as regulations are based on subjective judgements, changes will be slow or not at all. Each individual regulator has a wealth of bad experiences based upon poorly understood circumstances.

Funding of Research

In Australia the construction industry spends only 0.13% on research and development to improve its products and productivity. This is not the case in manufacturing or the resource industries. Why is this so little?

In construction, it is difficult for the various sectors of the construction industry to capture the benefits - builders work to defined documents and receive little for technical improvements; consultants who design and specify products also do not; owners are remote from the construction process and few have an understanding of the issues. In the absence of public pressure, there is little specific incentive for governments to give research high priority. The public, which is the ultimate beneficiary, is too far removed from the decision making process.

A recent study in Australia reported by the CSIRO has shown that construction industry savings have greater effect on the Gross Domestic Product than any other industry sector, more than, for example, business services, public administration, or road and rail transport combined. The flow on effect magnifies the savings in the construction industry to achieve a benefit for the whole community of about two and a half times that saving.

The changes in the funding mechanisms which have occurred, not only in Australia, but in other countries, requires that the research organizations themselves have to articulate the case for financial support for their work, and actively seek it from sources who will benefit from it. This paper's intent is to relate fire engineering science to the industry it serves, particularly the construction industry, and give, by way of a case study, a successful example of how industry supported an ambitious fire engineering research program when no obvious or captive sponsor appeared available.

A Case Study of Fire Research Sponsorship

In Australia in the late 1980s, there was political concern about the escalating costs of building construction and the onerous restraints which the building regulations were perceived to impose on all attempts to introduce flexibility into the approvals procedures.

Numerous surveys were conducted which identified many of the blockage points. There are probably parallels between the conditions which existed in Australia, and those which I suspect exist in the USA now. Briefly, the deficiencies were identified as:

- Building Approval procedure problems
- Procedures lacked transparency
- Too many local variations
- Overly bureaucratic
- Restrictive building code
- Too complex for small /medium projects
- Poor funding for updating maintenance.

Fire regulations, constituting 70% of the Building Code of Australia (BCA), were identified as the largest single technical restraint to the cost effective planning of new buildings and the renovation of old buildings.

Building Regulation Review Task Force

A **Building Regulation Review Task Force** (BRR) was established jointly by all Australian governments to improve the building regulations. I was appointed Chairman. It ran for two years and reported in 1991.

Its main recommendations can be summarized as follows:

- Building Regulations should be overseen by a joint government / industry Board Australian Building Codes Board, (ABCB) with an industry Chair
- Adequate funds should be allocated to the preparation and maintenance of an efficient regulatory system, to be raised by a levy on all non-domestic construction,
- Building Control procedures should be improved by:
    - Preparation of a Model Code of Approval,
    - Introduction of Private Certification as an alternative to local government certification,
    - National accreditation of Building Surveyors (Certifiers)

- A Project Insurance Scheme

- A performance based Building Code of Australia
- Fire research to underpin the performance code
- Simplified Housing regulations.

Those recommendations, 19 in all, with the exception of the funding levy, have been implemented.

Australian Building Codes Board (ABCB)

The leadership of the Australian Building Codes Board has been exceptional. It has wide representation, its achievements have been outstanding, it has adopted a cooperative approach with industry, it is well led and staffed, and it has a plan for an orderly change.

The Building Code of Australia has been written in performance format and issued in 1996, being gazetted a year later. It is recognized as an excellent document, and has achieved wide acceptance. The benefits on a national scale are apparent now.

However, without the levy for the maintenance of the ABCB programs, the amount of money available for fire engineering research was limited. Governments looked to industry to commission the necessary work, while industry was looking to government. The restraint to successful improvement was scope and scale. Unfortunately, the construction industry was an ineffective lobbying body. There was therefore no independent champion of the ongoing reform process.

There were three alternatives:

- Do nothing and wait for 20 years,
- Wait for overseas research,
- Establish an industry/government partnership.

Fire Code Reform Centre

It was to overcome this problem and delay that the **Fire Code Reform Centre** was established. The **strategy** behind the foundation and operation of the Fire Code Reform Centre (FCRC) was to bring together all major participants in the fire industry in Australia, and through a **cooperative non-profit effort**, undertake and manage the research to underpin codes and regulations for the industry.

The FCRC has many unique characteristics. It is an independent organization. It undertakes its own fundraising. It is a **partnership** between industry and government, undertaking the best research, and adopting an **engineering approach** to the outcomes. It brings together competing industries like timber, steel and concrete in a common cause.

Researchers, regulators, practitioners, industry groups, fire services, and building owners have taken part in formulating the research program, raising the funds, directing the contracts, and interacting with industry. The strategy has been to focus fire research in Australia on an achievable goal to compensate for the low level of construction industry research, to spend the available funds on gaining the maximum benefit, and to raise funds by approaching selected groups in industry for sponsorship

The group **ran a campaign to promote itself** and its activities. It commissioned a **business plan** with the small amount of funds which it had available. It set out in detail its **research program**. It developed a **work plan**, and **costed the research**. The research organizations committed themselves to forming a **consortium** so as to offer the best available resources in Australian in a non-competitive arrangement.

Funding

The plan costed the input from the researchers at **discounted rates** so that **sponsors** were seeing a commercial benefit not readily achievable by other means. It co-opted industry identities on an **honorary basis**. The consortium received some financial support and pledges from industry on startup, but what was required was a **sponsor of substance** who would underpin the program and permit the establishment of a corporate vehicle. That came from the newly established **Australian Building Codes Board (ABCB)** which was established in 1992 to implement reforms to the **Building Code of Australia**.

The ABCB had a limited amount of funding available which could be directed towards research. The FCRC mounted a campaign to direct that towards fire reform. The Chair of the ABCB came from industry and could see the problem and recognized the potential benefits. He was instrumental in obtaining ABCB support on the condition that substantial support was given by industry. With that pledge, a **fund raising campaign** was launched.

At the 30 June 1999, a total of US $ 3.5 million since inception has been raised. The Government, through the Australian Building Codes Board (ABCB) has contributed US $1.7 million. The FCRC has raised the remainder from other sources, mostly from industry. To date, this has resulted in industry funding of $1 for every $1 contributed by government. Support has taken forms other than cash contributions. The research organizations with whom the contracts have been placed are undertaking the work at discounted rates, because they are universities, other government organizations. One industry research organization is contributing significantly in kind in addition to its cash contributions. The cash value of the total research program, excluding in kind contributions, is budgeted at US $6 million. In addition, the value of the in kind and discounted rate contributions at the completion of the program will be nearly US $2 million.

FCRC Organization

The **Fire Code Reform Centre Ltd.** has been established as a non profit company limited by guarantee. It is controlled by an **honorary Board of Directors** comprising representatives of **Nominating Sponsors**, an independent Chairman, and an invited representative of the fire services. Nominating Sponsors are those who contribute **US $65,000 annually**.

A pragmatic leadership directs the work of the Centre. The Board comprises sponsor's representatives and distinguished industry identities. The Centre is run frugally and tightly controlled. There are one and a half staff - a part time consultant Technical Director and

Business Manager. A Research Supervisory Committee monitors the individual projects and provides a linkage to the commercial and regulatory world.

The FCRC Research Program **commenced in November 1994** and research contracts have been commissioned as funds become available. That **FCRC Research Strategy** was devised to

- Establish a format for a performance BCA,
- Produce Fire Engineering Guidelines which could for the basis for Building Approvals,
- Study special issues relating to Fire Performance of Materials, combustibility, and FRLs,
- Develop the Risk / Cost Methodology to underpin the performance BCA,
- Develop deemed - to - satisfy alternatives to those existing in the BCA,
- Produce a fully engineered Fire Safety Engineering Design Code.

FCRC Quality Assurance

The high quality of the work is maintained by peer review. A Mid-term Review of the overall FCRC Program was carried out by a team of international experts in 1998 and a detailed review of the Risk Assessment project was completed in March 1999. The reviewers, experts in fire research, fire engineering practice and fire codes, came from Australia, USA, Sweden, Canada and Finland.

FCRC Technical Controls

Control of the research contracts is administered by a Part time Technical Director (Mr. Richard Custer), and a full time Business manager (Mr. Claude Eaton). A Research Supervisory Committee contributes to the work on a volunteer basis, and Technical Working Groups are engaged to supervise individual research projects.

FCRC Outcomes

The FCRC program of research has delivered fire engineering science and technology to the Australian Buildings Code Board (ABCB), the regulatory authority, to bring about changes to the Building Code of Australia. (BCA).

Since the new BCA has been written in performance terms in 1997, the **FCRC Fire Engineering Guidelines** have become the preferred method of compliance for industry practitioners and approval authorities. In Australia, as far as can be determined, every major building project has benefited from the use of the FCRC Guidelines to develop cost effective alternatives to the prescriptive requirements of the BCA.

FCRC Shopping Center Research and Testing

Due to the demand and the potential for significant savings at a time of high development activity, a research project was carried out to make recommendations on the fire safety design of low rise large area sprinkled shopping centers. Large scale tests were undertaken and recommendations made . This will be launched soon as a Design Guide.

Substantial benefits of the core program will be delivered progressively. More than 60 preliminary and final reports and journal publications have been produced to date many of which are already available to interested parties. Arrangements are being made to make them available through an international network of fire engineering societies.

FCRC Achievements

The acceptance of the performance-based fire engineering by industry in Australia has been encouraging. The demand for fire engineers has risen dramatically (fifty fold) in the last 5 years as a result of the research, education and training programs, and the recently introduced performance based BCA, all activities closely connected to the work of the FCRC.

The prime objective has been implemented. There is now strong support for Australian projects and services using the technology developed and underpinned by strong research establishments. Australia is helping to shape the next generation of world codes, talented overseas researchers have been attracted to Australia to participate in the programs, and the spirit of innovation is alive and well.

The FCRC Research Plan will deliver a Fire Safety Engineering Design Code in 2001, based upon new research and large scale fire testing and will incorporating best available fire engineering technology.

ABCB - FCRC Cooperation

The close cooperation between the FCRC, the ABCB, and industry provides a mechanism for regulatory change which is firmly founded on practice requirements, while maintaining the current high levels of safety required by the Australia community.

Conclusion

The Centre is unique. As far as we are aware, it represents the only comprehensive, integrated program of applied research in the world specifically directed to the improvement of a nation’s prescriptive building regulations and the development of verification procedures of an alternative performance based approach.

Before I conclude I would like to draw your attention to Unifire99, the FCRC organized conference to be held in Sydney next month to maintain the dialogue with industry, and to promote the work of the Centre so as to disseminate knowledge.

The lasting benefit to Australia of doing the work there is that it maintains researchers in universities and research establishments who are at the forefront of fire engineering research, and who are able to support Australian consultants and contractors in the design of innovative buildings at home and overseas.

Ultimately, that will flow through to new products which can be manufactured for export.

Acknowledgments.

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The research consortium comprises : BHP Research, Melbourne; CSIRO Division of Building, Construction and Engineering; Scientific Services Laboratory, ACS; University of Technology Sydney; and Victoria University of Technology.

Fire Research Strategies - A Business Rationale

Paul M. Fitzgerald, P.E.
Executive Vice President
Factory Mutual Research

Good afternoon ladies and gentlemen.

It is a great pleasure to be here this afternoon. I have been asked to share with you the rationale why Factory Mutual Research and it's parent company, FM Global believes investing in fundamental fire research is a good investment, especially at this point in time. Before I start, I have to comment that I was on the program planning committee for the workshop. Unfortunately, I had to miss the final meeting when the program and speakers were selected. There is a great lesson in this. Previous to that final meeting, I – along with the other planning committee members – had been enthusiastically volunteering others to give a talk. Miss one meeting and all of a sudden you find yourself being volunteered instead of volunteering someone else.

That said, I'm glad to have this opportunity – and for a good reason. By accepting the invitation to talk about our business rationale for having invested in fire research for well over a century, I found myself thinking back on what we had accomplished over the years and where we planned to go in the future. It was certainly satisfying to review the progress that we all have made and the very positive contribution Factory Mutual Research's efforts have produced. It was also satisfying to reflect on the very positive impact our research efforts have had on our business and for our customers – to say nothing about the public at large. But perhaps the most rewarding aspect of preparing these remarks was the opportunity to think about our plans for future and to do so with an acute focus on the business justification for our very substantial investment in fundamental research.

So, I would like to give you a complete Business Overview if our approach. In doing so, I would like to try and answer three questions. These questions are:

- Why fire research at Factory Mutual Research has been and continues to be extremely valuable as a business strategy?

- The characteristics of business-supported research and the benefits it can bring by using our experience and future plans as an example.

- How we can move ahead with a focused national agenda for fire research using the business model as a guideline.

At the end of our discussion, I would be pleased to answer any questions you may have.

To start, I think it would helpful if I defined what it is that I will call 'research' from here on. The word 'research' is often applied to any activity that involves burning something with a thermocouple or two present. At Factory Mutual Research, we think of our programs of being one of two types: long term or fundamental research; or short-term testing projects. Let me use the following definitions:

- Definitions

  - Long Term Research: That which has as its objective the development of scientific knowledge from which standardized Testing and solid engineering practice can be developed.

  - Short Term Projects and Testing: Research directed toward resolving a few – often only one – specific problems or issues.

These two approaches – both quite valid depending on the needs – have very different characteristics as it pertains to length of the effort, commitment and perhaps most significantly, uncertainty of payback. Let me characterize long and short term research this way:

- Long Term Research: Is characterized by prolonged investment often over many years. Failure to achieve desired ends is a common outcome.

- Short Term Projects and Testing: Generally involves a finite time period and well defined expenditures for at least the initial testing period and failure is not an accepted outcome.

From a pure business perspective, it is pretty clear that the chances of payback are better with a short-term, pure testing project. There are certainly better prospects for instant gratification with such efforts and less risk of exceeding budgets for gaining a desired result. Therefore, in any business environment, a researcher such as myself has to understand two basic facts of corporate life about both types of research:

- Long Term Research: Is often criticized by management, investors and even other employees who are interested more in today's financial performance than tomorrow's promises.

- Short Term Projects and Testing: Are usually appreciated more because the results are available and thus it is perceived as creating value in today's market by producing immediate solutions to and resolution of customer problems.

So why would a business invest in long term, fundamental research? It has higher risk. It takes longer. It has uncertain costs? Customers may not appreciate it. Financial markets may not appreciate it. It may not solve an immediate – or even long-range – problem. As I consider the above, I sometimes wonder myself why we should invest in it. But it turns out there is justification for such investments. I think the following would apply to any technical organization but I am sure that it applies to fire research and testing:

- Long Term Research: Despite the uncertainty, risk and time for payback, long term research is the only way in which a technical business can consistently create value for its customers.

- Short Term Projects and Testing: Satisfaction – while often appreciated results are delivered – fades quicker because solutions are usually not flexible enough to permit extension of that knowledge to other applications.

We believe that both kinds of programs are necessary and produce useful results. Certainly, we have engendered a lot of customer satisfaction by being able to quickly resolve a specific problem for them through one to a few empirical tests. In some cases, use of existing empirical databases can enable application of past test results to similar but slightly different problems faced by other customers. In addition, in many cases, a quick test program is the most efficient way to resolve a wide variety of potential problems or issues. And of course, standardized tests allow direct use of information in codes, standards and engineering tools.

By contrast, long range research requires a business to strategize its investment. That's how we got started in fire research. I thought it might be helpful to review why FM Global's predecessor property insurance companies developed a fire research capability, and in particular, why we invested in and committed to fundamental research over 35 years ago.

Our History:

Our investment in research began shortly after the Civil War. Our initial investment was primarily driven by an underwriting concern that a large insured fire loss might break the bank. Remember that at this time, the industrial age was producing bigger factories, construction was largely combustible and conflagrations were not uncommon. Perhaps most significantly, automatic sprinkler development was truly in its infancy. Added to that was the fact that all property insurance contracts were 'Fire Insurance Policies' and even as coverage expanded a bit, the largest losses were still fire losses. Small wonder then, that for over a century, we focused almost entirely on fire and explosion.

Our first 'research' investigation looked into the cause of textile machine fires. After having favorable experience for the first thirty years of our existence, the frequency of fires began to increase. This investigation led to the discovery that the cause was the new use of a very flammable liquid to clean the machine. The flammable liquid was gasoline. At that time, gasoline was considered to be an unimportant waste product of lamp oil refining. While this investigation hardly involved breakthrough technology, we learned two important lessons: first, what the direct cause of the increased fire frequency was which was the objective of the investigation; and second, and definitely more lasting, the understanding that even basic technology could change suddenly and silently, resulting in increased exposures and losses.

In the1870's, we began to evaluate sprinklers to determine if we could recommend them to policyholders. When sprinklers were shown to be an extremely effective tool in limiting fire spread, we began to recommend them to policyholders. Where you have sprinklers, you need water and subsequently, we began to do fundamental research in hydraulics in order to assist in the design of public water supplies. In fact, many of the engineering practices used today to design public water supplies were developed by Factory Mutual engineers in the 1880's and '90s.

As sprinklers and water supplies became more available during the early 1900's and manufacturing technologies widened in scope, we found it wasn't just adequate to hook the sprinkler system up to the water and hope for the best. In addition to the hardware and water supply, we found we needed to know how much water was needed to control a particular fire scenario. Our objective was to develop the ability to design or evaluate sprinkler protection systems for particular customer activities. This resulted in our conducting full-scale fire testing and developing sprinkler and other suppression system for the entire family of industrial occupancies. We also instituted the study of losses to determine what the actual sprinkler system had discharged in controlling fires both successfully and not so successfully.

Following World War II, storage occupancies became a particular problem. Both loss experience and individual test results demonstrated that a typical warehouse with wall-to-wall combustibles and ever increasing storage heights presented an extremely challenging occupancy. Working with the industry over the next two decades, we developed several sprinklers – including the standard spray sprinkler – designed with an eye for protecting storage occupancies. With the need to build ever increasing larger fuel arrays to evaluate this protection, however, we also discovered that full-scale testing was becoming increasingly more expensive.

In 1963, with the immense help and guidance of Professor Howard Emmons, the Board of Directors of Factory Mutual Research approved the concept of investing in fundamental research directed at understanding the enormously complex issue of fire. The following year we started a fundamental fire research group housed at the then National Bureau of Standards. With this change, much of our large-scale fire testing began to change from being specifically geared to an individual solution to more or less proving (or disproving – this knife cuts both ways) a scientifically developed concept.

Has It Been It Worth It?

Defining the value of research has always been a dilemma for those of us who believe in it and believe that any company that uses or requires a technology to succeed. Recently, the National Science Foundation undertook a survey of corporations to determine what, if anything, were the drivers in their research and development work.[1] This review discovered six predominant drivers why corporations do fundamental research. They were

- To Generate New Sources of Wealth
- A Corporation's Technology Depends On the Science Behind It
- It Improves the Recruiting of Talented, Creative Staff Throughout the Organization
- It Can Lead To or At Least Create the Promise of Great Discoveries of Proprietary Value
- It Helps the Corporation Benefit From the Spillover From the Technology Revolution
- At the End of the Day, Research Is Perceived to Pay Off

[1] Hicks, Diana; National Science Foundation Contract No. SRS-99617459 Published by the Industrial Research Institute, Inc. 0895-63-8/99, (1999)

Time only permits discussion of four of these areas. The two I won't dwell on are 'Improves Recruiting' and 'Great Discoveries of Proprietary Value'. Certainly the existence of an effective, long-term research program is a major attraction when recruiting top quality technical people. Our technical employees take great pride on the achievements of the organization and they communicate that to others. As for making discoveries of great proprietary value, the kind of information that Factory Mutual Research produces is only of value when it used in engineering applications. That means the information has to be transferred to others in the form of advice, reports and proposals to Codes and Standards bodies. Thus, the output from our proprietary research cannot remain proprietary for long.

The other areas are fertile, however, and have and continue to contribute to our business success.

1. <u>To Generate New Sources of Wealth</u>: This should seem to be an obvious output of any fundamental research. In today's world, however, this vision is significantly different from most current corporate initiatives. Downsizing, re-engineering, mergers, knowledge management and most of the other current corporate hot buttons are predominantly geared toward extracting maximum value from the products and services in provided by the existing business. Long-term research often doesn't provide a financial payback for years.

   While it is common to think of 'wealth' as increased profits and market value, I would also offer up the paradigm that knowledge is also a measurable form of wealth. Using that knowledge in the conduct of the enterprise's business should result in improved products or services and especially, produce improved decision making for the enterprise. This advantage can be used many ways:

   - To manage enterprise risk far more effectively;
   - To be able to anticipate the competition and therefore move more proactively than they can move;
   - To be more effective in strategic planning in all technical areas;
   - To be anticipate a customer's changing needs; and, very importantly; and
   - To be able to spread this increased knowledge into other areas of the enterprise's business and enhance operations in unaligned areas.

   In our case, having a research capability has brought us in contact with materials, products, technologies and affiliations that would not exist otherwise. As a result, we can and have been able to achieve these advantages in many situations.

2. <u>Technology Depends on Science</u>: Long-term research is invariably involved in searching for scientific truths to allow for wide understanding of physical phenomena and proper application of the results. As we have seen, however, testing and problem-solving research is interested predominantly in an immediate, usually very limited result that addresses a specific problem or issue. Short-term research is necessary, of course, and the results from tests and experiments can provide insight into the fundamental nature of a particular problem. Despite its value, however, total reliance on research that does not deal with the fundamental nature of the problem is inadequate. There are at least three major shortfalls with an approach based on point-by-point test results:

First, it is a very expensive way to do research. Test-by-test research obviously involves an attempt to draw an empirical circle around an objective or problem by having a number of data points (and possibly a large number of such points) to provide a level of confidence in the final ‘result’. This can be costly – and especially so in fire research where fire dynamics often dictates testing at larger scale. Unless there is a good understanding of where a program is going, I can testify that the costs for such programs can be prohibitive.

Second, running repetitive experiments varying one or two conditions per experiment takes time. In fact, while one of the leading raps against fundamental research is time to completion, once completed it usually leads to a more universal application of results. Empirical research programs are not so blessed. A generalized result may not respond to future changes in a particular technology. Certainly our nation’s fire record has ample evidence of a major losses which have occurred because of a change – often perceived to be minor – in a building or specific occupancy.

Third, if a scientific solution does not exist, the danger of there being more gaps in application technology increases. This is probably the most telling argument. We cannot afford such gaps to develop if life and property losses are to continue to be minimized.

Hick’s NSF study also provided some interesting data on the relationship of science and technology in the citations in patent applications. Historically, most ‘prior art’ citations were to previous patents. In the last decade, however, an increasing percentage of patent citations referred to the scientific literature and not prior art. For example, in this most revealing exercise of technology development, the growth of prior art references to scientific publications is increasing at a rate of over three times that of references to patents. While part of this increase is no doubt attributable to better data base searches and to Patent Office diligence in assuring full disclosure, it nevertheless highlights that fundamental research is increasingly finding it’s way into application.

3. Spillover From the Technological Revolution: This finding is based on the precept that most of the knowledge gained doing long range research is not generated by the business doing the research. Consider that in 1998, the National Science Board estimated that about $50B of research was done and made available to the public.[2] This research includes not only the research done by the government, but also by universities, public grantees and non-profit organizations like Factory Mutual Research. In fact, only about 8% of the papers published in the scientific literature during last year were from corporate research scientists.

   Taking advantage from the work done by others is critical. Furthermore, an organization that does not engage in fundamental, long-range research may find themselves at a serious disadvantage to those that do. There are several reasons for this. For example, a non-research organization:

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[2] National Science Board, *Science & Engineering Indicators – 1998*; National Science Foundation, Arlington VA, 1998 (NSB 98-1).

- Would not have the scientists who as a matter of their work tend to find and bring valuable information, data and knowledge into the organization.

- Even if they come by valuable research information, they would not have the skilled staff that a research organization has to appreciate it's value and importance. In other words, there would be a very high probability that the information would go unused or even worse, be used inappropriately thereby damaging the organization's results.

- Almost certainly, they would not be able spin the information and knowledge they have into new products and services.

- Finally, they would probably not have access to networks of research organizations and individuals who could be of assistance in helping solve problems and plan future improvements in their product and service base.

Of all of the reasons for doing long term research, this may be the single greatest advantage to a business. It is becoming increasingly more difficult to make major technological breakthroughs. Instead, most research outputs are incremental gains rather than giant leaps for mankind. Because all businesses have limitations in human and financial resources, knowledge must be obtained from all sources and used appropriately. This is where the 'spillover' concept is critical. In a knowledge age and especially an age that is increasingly technical, being able to access the world's available knowledge and use it for the business competitive advantage is essential for long-term survival in many – if not all industries – if the organization is to survive.

4. <u>Research Pays</u>: At the end of the day, there has to be a payback to a business for its investment in research – and especially long-term research. Unfortunately, proving that long-term research pays is difficult. Intuitively, one would think that investing in a solid, strategically aligned research effort would always be in the best interests of the business. If we are asked for examples companies where we most think this is true, it is likely that we would think of the high tech, pharmaceutical or biotech industries as proof. On the other hand, with industries such as basic metals, electronics or diversified chemicals – all of which experienced technology breakthroughs decades ago – it is more difficult to conceive of such advantages.

   Certainly there is evidence and data (albeit a lot of it is several decades old) that suggests research 'pays'. In the high tech industry, surveys of patents and scientific reputation of companies indicated that the tighter the linkage between research and market value, the better the average return on a stock investment. Specialty chemical companies also have a significant – ~25% – better market-to-book value where this tight link of science-to-patent exists than in companies in which the link is weak. Even accountants are paying attention to research as they attempt to 'value' knowledge capital to include it on their books. Assuming that all of these valuations are classified as assets, we might soon have arguments as to the value of research.

The above are fun to talk about and compare one to the other. On the other hand, financial and competitive measures are just one way to prove 'research pays'. Today, organizations like

Factory Mutual Research are evaluating other ways in which it may pay. The most commonly used terminology in establishing and managing research program portfolios for specific targets is called ‘value creation’. Using value creation, the research organization attempts to emphasize value, not ‘beating the competition’ or ‘improving shareholder value’. It tends to focus more on the customer by bringing new and superior products or services to them, even if increased revenues aren’t huge. In many cases, small advances can result in quantum leaps in perceived value and that can lead to one of the most critically sought after objectives of any business – namely, customer loyalty.

The value equation should be brought to bear on the next generation fire research. We don’t have ‘buyers’ in the traditional sense of the word but we do have ‘customers’. In fact, we have a monster customer base – it’s called the general public. This customer base will be looking for us to provide buildings and other occupied spaces that are economic, attractive, durable and yes, safer from fire. If we can achieve this, we will provide enormous value to this critically important constituency and that will build the incentive for investment into fundamental fire research.

Factory Mutual Research’s Strategy

Long-term research has to be directed at creating either financial or customer value for an organization. The best chance the organization has that its research will be successful is if it is tightly tied to the overall corporate strategy of the enterprise. And that is certainly true for us.

In many ways, we are at one of those watershed periods where a company has to strategically adapt to a new world. There have been many recent changes in our business. For example, traditional fire insurance policies are now more accurately described as ‘Property Insurance’ policies because they routinely cover such perils as wind, flood, earth movement, etc. Fire and explosion, once 80% of our loss experience, are as likely to be less than 40%. Clearly, if this is where the dollars are being lost, Factory Mutual Research must strategically widen its area of research interest if there is inadequate work being done in these areas.

We are in the process of broadening our research into four areas:

- Fire and Explosion Protection: This has long been our focus and it will continue to be a strategically critical research area. In other words, while we may look into other areas, we will still continue our work in this crucial area.

- Materials: Increasingly, we are finding newer materials being used in many applications replacing materials where we had a strong legacy of knowledge about those materials. Where once we would have only focused on flammability, our research will know consider all of it’s properties – mechanical, resistance to corrosion, strength as well as flammability.

- Structures: There have been dramatic changes is the design of most industrial and commercial buildings. The many advantages in terms of cost, functionality and speed of construction – to say nothing about performance-based design – make it likely change will continue well into the 21st century. The performance of some of these buildings against the perils of wind, earth movement and other extraordinary loadings has not been adequately researched. We are looking into these areas and building relationships to take advantage of as much prior knowledge as possible.

- Reliability Engineering: At the heart of most manufacturing process lies some form of control systems. These systems often have well-defined technical data on such as things as the failure rate of components. Failure of a component doesn't necessarily define the failure of a system. On the other hand, proper operation of a system doesn't necessarily guarantee an incident could not occur, especially when human element is factored in. In either case, the consequence of an event given certain failure modes also has to be defined and our research is attempting to develop criteria that can be used by system manufacturers and designers as well as risk analysts.

Suggestions for Moving Forward

I believe that the process Factory Mutual Research is currently using – a process that parallels in many ways how other organizations conduct research – can also be used as a guide to develop a national research strategy needed to develop the knowledge, tools and information necessary to support quality performance-based Codes and Standards. For example:

- Follow A Typical Business Model: Develop an overall strategy – even a full-blown Strategic Plan – that identifies realistic visions and <u>very specific</u> goals that everyone – buyer, designer, insurer, fire service and manufacturer – can buy into. We have tried to do this before in the 80's and 90's but to a large extent, progress has been more on an individual researcher than coordinated basis. This strategy has to be specific and down to earth so that organizations that do research can understand and bite off that they may be best qualified to do or could contribute to.

  In addition to very specific goals, the strategy should identify the infrastructure needed to support the gradual emergence of performance-based codes and standards. Key among the infrastructure needs is to agree on a common language in for data management, engineering models and test protocols. If this very fundamental foundation is not built, we run a very real risk of creating a modern-day Tower of Babel. Progress will be definitely slowed down while technical arguments rage over which tests are the best or the most accurate or the most appropriate for this material or that application. If you don't think this will happen, then you haven't been a student of the twenty-year history of debates within the fire research community over different protocols and technologies. At the core of many of these are classic apples and oranges comparisons of very different end results.

- Do Fundamental Research: As I discussed earlier, in our work, we approach our research from a fundamental view. We want understand the basic underlying science of a particular investigation. In the end, this leads to lower overall cost, improved technology and a better understanding of where to go next. It also increases the chances of doing the research once because we would have a better chance of doing it right. This rationale has to be applied here. We have come a long way in fire research in the past 50 years but the world does not stand still. We need better understanding of the science of flammability and suppression if we expect manufacturers and fire protection companies to develop safer materials and better protection systems.

To accomplish this, we need to reinforce the scientific peer review processes in place today. Because of the scarce number of truly qualified researchers in North America, we need to involve all global scientists in an objective network of competent reviewers. The review should not only be of scientific papers but also proposed test instruments and new protocols if these are to be used in any Code or Standard application. In short, to be successful, we need to establish an infrastructure that has the highest level of integrity and does not allow for the introduction of substandard tests or protocols that meet a particular vested interest's needs.

- Consciously Strategize to Create 'Spillover': Although we didn't define it this way at the outset of launching our new programs, Factory Mutual Research certainly tried to create as much 'Spillover' as possible to accelerate the speed and minimize any duplication in the work that we have done. We have established liaisons with other research centers focused on Structures (wind, earthquake), Materials (flammability, corrosion, restoration of property) and Reliability Engineering. On reflection, I would say that in many ways we did the same thing in the mid-60's when we worked closely with NBS and Dr. Emmons on their research while at the same time starting our own fire research program. Fire research crosses most scientific and engineering disciplines and in this area in particular, I would posit that there are many opportunities for synergy and 'spillover' from other disciplines to ours and they should be tapped.

- Establish Networks of Research Institutions and Keep Them Well Advised of What Is Needed and What Has Been Done: Realistically we need to face one very limited fact of life and that is that no private research organization will drop what it is doing to support a national effort. I will candidly admit that Factory Mutual Research will not and cannot afford to do that no matter how noble a particular national research initiative may be. That said, however, it may be that if we are aware of other programs and data needs, there may be opportunities to piggyback additional instrumentation or collect additional data points on a program we are conducting and provide that to other investigators with minimal impact on our cost or cycle time. By networking all researchers, we will also minimize the chances of duplication and possibly promote better cooperation in the development of standardized instruments, data definitions and test protocols. There are models for this level of cooperation in medical research and these models can serve as a basis for establishing similar networks for fire research.

- Communicate, Communicate and Communicate: Finally, let's keep in touch with each other. Over the years I have attended many symposia or conferences and when it is over, we all run back to our work places until it is time for the next symposia or conference where we wonder what happened to all the great ideas from the last one. I think that networking, establishing 'Centers of Excellence' if that's the right approach and peer review systems can all contribute to promoting better cooperation and exchanges among researchers and practitioners but there has to be a continuous day-to-day forum as well. Every business strategy includes a communication strategy. Very clearly, we need to devise one as well.

Summary:

I want to thank you again for the opportunity to be here today and share with you some of the background why Factory Mutual Research exists and how we go about defining and prioritizing our research. While we are sort of unique in what we choose to research into, we are clearly not unique in the way we approach it. I think that our approach – in fact, the approach of most businesses – can be adapted to a national approach. If we are successful in launching such an effort, we stand ready to participate as we seek to improve the fire safety of future generations of buildings and the people who occupy them.

Workshop Attendees

Name	Organization
Vytenis Babrauskas	Fire Science & Technology, Inc.
Mike Balch	Australian Building Codes Board
Carl Baldassarra	Schrimer Engineering Corp.
John Bender	National Association of State Fire Marshals
Craig Beyler	Hughes Associates
Jim Beyreis	Underwriters Laboratories, Inc
Jason Boren	Bechtel
Robert Boyer	Edwards Systems Technology
Doug Brandes	Duke Power
Murray Cappers	J&H Marsh and McLennan
Larry Maruskan	US Fire Administration
Geoff Cox	Building Research Establishment
Dick Crouse	American Petroleum Institute
Richard Custer	Custer-Powell, Inc.
Tom Daly	Hilton Hotels
Robert D’Angelo	U.S. Army
Mr. Ron de Veer	Queensland Department of Communication & Information
Dougal Drysdale	University of Edinburgh
Ken Dungan	Risk Technologies, LLC
Fred Emerson	Nuclear Energy Institute
William Erny	American Petroleum Institute
Lenny Farelo	Intel Corporation
Paul Fitzgerald	FM Research Corp.
Jay Fleming	Boston Fire Department
Arnold Garson	Cerberus Pyrotronics
Casey Grant	National Fire Protection Association
LT Andy Grenier	U.S. Coast Guard
John Hall	National Fire Protection Association
Rich Hansen	U.S. Coast Guard
Paul Heilstedt	Building Officials and Code Administrators, International
Wayne Holmes	Hartford Steam Boiler Professional Loss Control
Tom Jaeger	Gage-Babcock & Associates
Marc Janssens	Southwest Research Institute
Robert Jonsson	Lund University
John Klote	American Society of Heating, Refrigeration and Air Conditioning Engineers

Bill Koffel	Koffel Associates
Matti Kokkala	VTT Building Technology
Bruce Larcomb	Building Officials and Code Administrators International
Larry Little	Commonwealth Scientific and Industrial Research Organization.
Dave Lucht	Worcester Polytechnic Institute
John MacGreggor	Building Industry Authority
Robert Malanga	Union Camp Corporation
Chris Marrion	Arup Fire
John McFassel	U.S. Army Aberdeen Test Center
Joseph Messersmith	Portland Cement Association
Fred Mowrer	University of Maryland
Frederick Mulhaupt	Fire Protection Research Foundation
Bijan Najafi	SAIC
Harold Nelson	Hughes Associates
David Notley	SAIC
John Nutt	Ove Arup & Partners
Michael O'Hara	MountainStar Enterprises
Jim Quintiere	University of Maryland
Jim Quiter	The RJA Group, Inc.
Ken Richardson	Ken Richardson Fire Technologies, Inc
Mickey Reiss	The RJA Group, Inc.
Robert Schifiliti	RP Schifiliti Associates, Inc.
Jim Shields	University of Ulster Fire SERT Centre
Paul Shipp	USG Corporation
Nathan Siu	Nuclear Regulatory Commission
Warren Stocker	Safeway Inc.
Kuma Sumathipala	American Forest & Paper Association
Harry Taback	J&H Marsh & McLennan
William Tangye	Southern Building Code Congress, International
Ian Thomas	Centre for Environmental Safety and Risk Engineering
Jon Traw	International Conference of Building Officials
Beth Tubbs	International Conference of Building Officials
Bob Weber	Clark County Nevada
Dave Wechsler	Union Carbide
Jack Woycheese	Gage-Babcock & Associates