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CONCEPTS OF A PERFORMANCE-BASED BUILDING REGULATORY SYSTEM FOR THE UNITED STATES

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Notice

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Concepts of a Performance-Based Building Regulatory System for the United States

Report of the 1996 Activities of the SFPE Focus Group on Concepts of a Performance-Based System for the United States

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Abstract

The United States' building and fire communities have recently begun transitioning towards the implementation of performance-based building regulations and the use of performance-based fire safety engineering. As a means to facilitate discussion and gain insight as to the potential structure of a performance-based building regulatory system for the United States, and to help the Society of Fire Protection Engineers place the engineering aspects of such a system into perspective, the *SFPE Focus Group on Concepts of a Performance-Based System for the United States* was created in March 1996. This group, which represents a wide cross-section of the United States' building and fire communities, provided key input on such issues as why the United States is moving towards a performance-based system, how such a system might be structured, what components will be required for such a system to work, and what education and qualification issues need to be addressed. The conceptual framework for a performance-based system that was used as the basis of discussion, the comments received on that conceptual framework, and a summary of the focus group discussion and consensus on a performance-based system for the United States are provided.

Acknowledgment

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Executive Summary

The world-wide movement towards the implementation of performance-based building regulations and the use of performance-based fire safety engineering has recently drawn the United States into its wake. As a result, codes- and standards-making organizations, professional societies, trade associations, universities, research organizations, and others in the United States' building and fire communities have begun research, development, and education efforts on performance-based topics. To help assess the technological requirements for the United States to operate in a performance-based environment, the National Institute of Standards and Technology, Building and Fire Research Laboratory, awarded a grant to the Society of Fire Protection Engineers (SFPE) to study the issues.

The primary focus of the NIST-funded SFPE research effort is on engineering and technology. However, it was recognized that technology research and development must not occur in a vacuum, and that it is important to consider the broader issues of the building and fire communities. To help the SFPE gain insight as to how the building and fire communities in the United States viewed the potential structure of a performance-based regulatory system, and to help the SFPE place the engineering aspects of such a system into perspective, the SFPE created the *SFPE Focus Group on Concepts of a Performance-Based System for the United States* (hereafter referred to as "the focus group" or "the group") in March 1996.

The intent of the focus group was to obtain input from a wide cross-section of the United States' building and fire communities on the movement towards greater use of performance-based codes, standards and fire safety engineering and design methods in the United States. To initiate discussion, participants in the group were given background materials, a working concept for a performance-based system, and suggested definitions as bases. They were then asked to comment on the materials provided and to attend meetings to discuss the materials.

The primary objectives for 1996 were to discuss and gain consensus on five key issues:

1. Why does there appear to be such a strong movement towards performance-based codes in the United States?
2. Do we need a performance-based regulatory system for the United States, and what might it entail (i.e., what changes might be needed and are we ready to support those changes)?
3. What might the components of such a system be?
4. How might the components be developed, formatted, implemented and enforced?
5. What needs to be accomplished before widespread implementation and acceptance of such a system can occur?

To discuss these issues, two meetings of the focus group were convened during 1996: 25-26 April at the Doubletree Hotel in Arlington, VA, and 23 September at the Sheraton Ottawa Hotel in Ottawa, Ontario, Canada. The following consensus resulted:

- The United States needs to pursue a performance-based building regulatory system.

- A performance-based system for the United States will likely spawn from the present system, will include explicit policy level goals, functional objectives and performance requirements in the codes (to describe the level of safety that is desired), and will utilize both prescriptive solutions (as we currently have) and performance-based solutions as acceptable means to provide the desired level of safety.
- An initial step in the transition to a performance-based system will be to extract goals and objectives from the current codes (primarily by the codes- and standards-making organizations) and to quantify them.
- Policy level goals must be developed by all interested parties.
- Performance requirements need to be developed by consensus of those experienced individuals, professionals, and/or organizations who are qualified to translate verifiable goals and objectives into quantified terms.
- Tools and techniques to measure performance must be developed (the responsibility of many professionals, including the SFPE).
- Evaluation and design tools are to be developed by those with the expertise (e.g., the profession, academia and research organizations).
- The term validation means different things to different people, and for this reason, perhaps should not be used: the critical factor is confidence.
- An engineering guide for developing performance-based solutions needs to be developed (a task the SFPE has initiated).
- Engineering standards and practices (methods) need to be developed by, and gain the broad professional consensus of the scientific and engineering community. In essence, the scientific and engineering community not only develops the methods, but must agree to their validity before they can become widely accepted.
- Acceptance of engineering standards and practices within the regulatory system can be gained in one of two ways:

  (1) By having a critical peer review within the scientific and engineering community and a "reality check" by a broader community (such as might be gained through a broader consensus process similar to the NFPA process.)

  (2) When an engineering method has not received critical peer review by the engineering and scientific community, nor a "reality check" by the broader community, the burden of demonstrating the "acceptability" of the method is on the proposer of the method. Criteria for demonstrating the acceptability of an engineering method are to be provided in the code.
- Before the professional community and the broader community can identify where the gaps are, we need to know what we have.
- One clearly identifiable gap is the lack of data (specifically for the models).
- A common vocabulary and acceptable definitions need to be developed.

- The overall level of education needs to be raised for everyone in the building and fire communities, especially on performance-based code and design method issues.
- A short-term education goal is to determine what the current code requirements are (in terms of intent and objectives) and to explain why they are required.
- Another short-term education goal is to provide information on the basics and the conceptual background related to performance-based codes and fire safety design methods.
- A long-term educational goal is to provide applications-oriented education to all practitioners.
- Building and fire professionals, especially engineers, need a higher level of qualifications, a higher standard of ethics, and more accountability for a performance-based system to work.
- Good design documentation is mandatory for a performance-based system to work.
- The SFPE should be the facilitator in: a) defining the core competency requirements for those engaged in performance-based fire protection engineering and for those working with performance-based regulations, and, b) building relationships among allied professionals to validate competency (e.g., other engineering disciplines, building officials, architects, etc.).
- The SFPE needs to transmit the information to practitioners that their involvement is critical to the successful implementation of a performance-based system: they will make the difference.
- The SFPE needs to archive knowledge for a performance-based system, such as has been begun with the *SFPE Handbook of Fire Protection Engineering*.
- More outreach is needed to allied professionals to deliver the message of a systems approach to building (fire safety) design.
- Resources are needed for the SFPE and others to deliver on the above items.

This consensus has given the United States' building and fire communities a solid platform from which to build a performance-based building regulatory system. To date, the focus group consensus has played a role in the ICC Performance Committee's effort to develop a performance-based building code, in the development of educational publications and presentations on performance-based concepts, and in outlining technological requirements for the realization of performance-based fire safety engineering in the United States. The group continues to exist, and has agreed to meet periodically to discuss key issues of a performance-based system for the United States as they surface. No additional meetings have been scheduled at the time of this report.

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1.0 Introduction

Performance-based codes and fire safety engineering methods are the focus of significant discussion, research, and development activities worldwide. Among other reasons, this is a result of the large increase in knowledge in the areas of fire science and engineering over the past twenty years and of the societal and economic pressures to provide an acceptable level of fire and life safety in buildings at a reasonable cost.

While several countries have begun to use, or are developing, performance-based codes, many people in the United States and abroad have concerns about the availability of proven engineering and design methods for use within a performance-based code framework. Although many of the countries that are developing performance-based codes are also developing performance-based engineering and design methods, the codes are preceding the engineering methods, and the engineering methods have gone essentially unvalidated. There is also concern about the availability of qualified fire safety engineers to undertake performance-based designs, the availability of qualified authorities to review performance-based design, and the issue of liability related to performance-based design.

There are numerous interest groups that comprise the global fire and building communities. These include building owners and managers, architects, engineers, construction contractors, building officials, fire officials, product manufacturers, the insurance industry, and more. The Society of Fire Protection Engineers represents one segment of this community: fire protection engineers. As such, the SFPE represents the body of knowledge of fire protection engineering, and is an advocate for the profession and its technology within the greater community. In this role, the SFPE advocates the proper use of fire safety engineering principles and supports the implementation into practice of emerging fire safety engineering tools and methodologies that can benefit the greater fire and building communities.

Given this position, the SFPE found itself becoming increasingly involved in discussions and projects related to performance-based codes and fire safety design methods in the United States and around the world. The reasons for this are clear: for a performance-based system to be effective, there must be acceptable engineering practices available to support performance-based codes, and there must also be acceptable engineering tools and methods available to support the engineering practices.

To support the development of an overall performance-based system, the SFPE focused their efforts on the fire safety engineering areas: development of engineering practices (engineering practice documents) for use in fire safety design, and identification and evaluation of engineering tools and methodologies, developed by research and academia, that are intended for use in fire safety engineering practice.

To help the SFPE gain insight as to how the building and fire communities in the United States viewed the potential structure of a performance-based regulatory system, and to help the SFPE place the engineering aspects of such a system into perspective, the SFPE created the *SFPE Focus Group on Concepts of a Performance-Based System for the United States* (hereafter referred to as "the focus group" or "the group") in March 1996.

One goal was to obtain input from a wide cross-section of the United States' building and fire community on the movement towards greater use of performance-based codes, standards and fire safety engineering and design methods in the United States. This goal was met, with participants including representatives of the following organizations:

- American Institute of Architects (AIA)
- American Forest and Paper Association (AFPA)
- American Hotel and Motel Association, Safety & Fire Protection Committee (AHMA)
- American Society of Civil Engineers (ASCE)
- American Society of Heating, Refrigerating & Air-Conditioning Engineers (ASHRAE)
- American Society of Testing and Materials (ASTM)
- American Wood Council (AWC)
- Building Officials & Code Administrators International (BOCA)
- Building Owners and Managers Association (BOMA)
- Council of American Building Officials (CABO)
- Factory Mutual (FM)
- Fire Marshals Association of North America (FMANA)
- Gage Babcock Associates (GBA)
- Hughes Associates Inc. (HAI)
- Industrial Risk Insurers (IRI)
- Insurance Services Office (ISO)
- International Association of Fire Chiefs (IAFC)
- International Code Council (ICC)
- International Conference of Building Officials (ICBO)
- ITT Sheraton Corporation
- National Association of State Fire Marshals (NASFM)
- National Fire Protection Association (NFPA)
- National Fire Sprinkler Association (NFSA)
- National Institute of Standards and Technology (NIST)
- Performance Advisory Group (PAG)
- Portland Cement Association (PCA)
- Professional Loss Control (PLC)
- RJA
- Society of Fire Protection Engineers (SFPE)
- Southern Building Code Congress International (SBCCI)
- Underwriters Laboratories Inc. (UL)
- University of Maryland, Fire Protection Engineering Department(UM)
- United States Department of Energy (DOE)
- United States Fire Administration (USFA)
- United States General Services Administration (GSA)
- United States Nuclear Regulatory Commission (NRC)
- Wisconsin Electric Power Company (WEPCO)
- Worcester Polytechnic Institute, Center for Firesafety Studies (WPI)

In addition, representatives from a number of international organizations, actively involved in the development, application or enforcement of performance-based regulations or fire safety design methods in their countries, participated as well:

- Arup Fire, UK
- Australian Building Codes Board, Australia (ABCB)
- Building Industry Authority, New Zealand (BIA)
- International Council on Building Research Studies and Documentation, the Netherlands, (CIB)
- Department of the Environment, UK (DoE)
- Fire Code Reform Centre Limited, Australia (FCRC)
- Fire Research Station, UK (FRS)
- Fire Risk Consultants, New Zealand
- Glasgow Caledonia University, Scotland
- Loss Prevention Council, UK (LPC)
- National Research Council, Canada (NRCC)
- The Home Office, UK

Participants were given background materials, a working concept for a performance-based system, and suggested definitions as bases. They were then asked to comment on the materials provided and to attend meetings to discuss the materials. The primary objectives for 1996 were to discuss and gain consensus on five key issues:

1. Why does there appear to be such a strong movement towards performance-based codes in the United States?
2. Do we need a performance-based regulatory system for the United States, and what might it entail (i.e., what changes might be needed and are we ready to support those changes)?
3. What might the components of such a system be?
4. How might the components be developed, formatted, implemented and enforced?
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This report presents the working concept for a performance-based system that was used as the basis of discussion (Section 2) and a summary of the focus group meetings' discussion and consensus (Section 4). Attendance lists from the two meetings are provided in Appendices A and B.

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2.0 Working (Strawman) Document

As a means to provide background information and to stimulate discussion, the following (Sections 2.1 - 2.6) was sent to each focus group participant as a "strawman" document. The information outlines a three-component performance-based system, discusses the anticipated role of fire protection engineering and fire protection engineers in the system, and provides definitions that describe the concepts being discussed. The concepts and definitions are not new or radical, but are based heavily on concepts that are currently used in the United States, that are being discussed in the United States, or that are being used or discussed in other parts of the world (including Australia, Canada, England, New Zealand and the International Organization for Standardization).

A copy of the report on the 1991 Conference on Firesafety Design in the 21st Century, *Strategies for Shaping the Future*, was also provided as background material. The focus group participants were asked to note that the 1991 conference delegates produced a national goal that "by the year 2000, the first generation of an entirely new concept in performance-based building codes be made available to engineers, architects and authorities having jurisdiction...in a credible and useful form." It was also suggested that the focus group participants review the barriers to the acceptance of performance-based codes and fire safety design methods identified in 1991.

The focus group participants were then given the following instructions:

> What I ask from you is the following: Read the report on the Conference on Firesafety Design in the 21st Century, *Strategies for Shaping the Future*, to get a feel for the background issues. Then, read the documents that I have prepared on a performance-based system, its components and the definitions that describe them. Consider the document that I have prepared from your professional perspective. Address the questions that I have posed. Develop questions of your own. If you disagree with my framework or definitions, challenge them and propose alternatives.
>
> When you have done this, return your comments to me ... and I will copy and distribute them to the balance of the working group prior to the meeting on 25-26 April (please try to keep the total number of pages under 10). When we meet in April, we will discuss the system, the components and the terminology and definitions. Everyone will have the opportunity to address the group formally, if they choose, or simply participate in the discussion.

Most of the participants followed the instructions and responded with comments. (A summary of their comments can be found in Section 2, and the full comments can be found in Appendix A.)

2.1 Basic Components and Structure of a Performance-Based System

The current prescriptive- (or specification-) based building regulatory system consists primarily of a collection of codes and standards that describe how buildings should be designed, built, protected and maintained with regard to the health, safety and amenity of the general public. For the most part, this is accomplished using documents that prescribe (specify) both what is required for health, safety and amenity, and how these requirements are to be met. Is this the most appropriate system (framework) for a *performance-based system* as well? (Proposed definitions for words in *italics* can be found in Section 2.6.)

An alternate framework for a *performance-based system* is one that has three separate components:

1. Codes, which through *societal goals, functional objectives* and *performance requirements* reflect society's expectations of the level of health and safety provided in buildings (e.g., items such as acceptable access, egress, ventilation, fire protection, electrical services, sanitary services, etc.);

2. Standards and Practices, which are separate documents, adopted by reference, that describe *accepted methods* for complying with the requirements of the code(s); and,

3. Evaluation and Design Tools, which provide *accepted methods* for assisting in the development, review and *verification* of designs in accordance with *engineering standards* and *practices*.

If the above model is adopted, there will be a clear differentiation between:

1. The requirements of the code,
2. The acceptable means for complying with the requirements of the code, and
3. The acceptable means for demonstrating that the proposed solutions comply with the requirements of the code.

At a minimum, the code will explicitly state *societal goals, functional objectives* and *performance requirements*. *Acceptable methods* for meeting the requirements of the code may be included in, or referenced by the code. *Acceptable methods* may be specified (prescribed) solutions, or engineering standards, practices, tools and methodologies that can be used in an accepted manner for both design and *verification* of compliance.

Items to consider: Should *societal goals, functional objectives, performance requirements,* and *accepted methods* all be specified in a single document or should they reside in separate documents? Does this model achieve the intent of a *performance-based system* for the United States? If not, what is missing? If so, how do we transition to this system?

2.2 Prescriptive Codes and Performance-Based Codes

In general, a building code describes how a building should perform under normal and adverse conditions (e.g., fire) in meeting the health and safety needs of the community.

Prescriptive codes describe the desired level of performance for health and safety through a set of minimum requirements that are generic by occupancy. Examples include occupancy-based spacing requirements for detectors or sprinklers, a specified fire resistance rating for an interior wall, or the maximum travel distance to an exit. While these may be appropriate for a general minimum, the true objective of a stated requirement in a specific design situation can be lost.

For example, one may know the maximum permitted travel distance to the exterior of the building, but not know the extent of smoke spread within a building before the last occupant is expected to have escaped. Thus, if the intended objective of the travel distance restriction is life safety, it would be easy to state that the requirement has been met, but difficult to state that the objective has been met.

By contrast, performance-based codes describe requirements for health and safety through a set of flexibly defined performance objectives and functional requirements. Examples include broad-based statements such as:

- the objective of this requirement is to safeguard people from injury from the effects of fire while evacuating a building, and,
- installation of an automatic suppression system intended to control the development and spread of fire shall be appropriate to the building use and characteristics, the fire hazard, the height of the building and the size of the fire compartment.

In this case, the solution is not prescribed in the regulations. Rather, it is the responsibility of the designer to demonstrate that the proposed design meets the health and safety needs of the community by meeting the *functional objectives* and *performance requirements* of the code. This demonstration of compliance can be accomplished through the application of *accepted methods,* which are either deemed-to-satisfy (specified) solutions or *performance-based design* solutions. Performance-based design solutions utilize engineering standards, practices, tools and methodologies.

Items to consider include: Do the current codes clearly identify measurable goals and objectives? Whose responsibility is it to develop goals and objectives? Who determines required performance? Do current codes (and standards) actually fulfill the stated and perceived intent (goal)?

2.3 Standards and Practice Documents

For the purposes of this discussion, a *standard* is considered a consensus document that provides a set of rules, conditions, or requirements concerned with: definition of terms; classification of components; delineation of procedures; specification of dimensions, materials, performance, design or operations; description of fit or measurement of size; or measurement of quality and quantity in describing materials, products, systems, services or practices. Standards may be written in mandatory or non-mandatory language.

An *engineering standard* for example, could be defined as a *standard* written in mandatory language that relates specifically to an engineering analysis or design process or procedure. Prior to becoming a *standard,* such an engineering document could be used as an *engineering practice* (a pre-standardization document, developed within and accepted by a recognized engineering discipline, that relates specifically to an engineering analysis or design process or procedure related to the expertise of that discipline). An example of an engineering practice might be an engineering practice for the calculation of structural fire resistance. One might expect such a document to identify *accepted methods* for analysis and design, and include specific reference to material properties, dimensions and orientation, failure temperatures, effects of protective coverings, and other pertinent information.

A *performance-based system* requires *standards* of all types, including engineering analysis and design and component and system installation and maintenance. These will exist in performance-based format and prescriptive- (specification-) based format. For example, one *accepted method* for the design of automatic fire detectors may be NFPA 72, The National Fire Alarm Code® and another might be an *engineering practice* for performance-based design of fire detection systems that has been developed and accepted within the fire protection engineering community.

Similarly, a document that outlines an overall approach to *performance-based fire safety design* for buildings can also be considered an *engineering practice*. This is important, because although a *performance-based fire safety design* approach can be undertaken outside of a performance-based system (i.e., where no performance-based code is in place), a performance-based system must have at least one performance-based design approach, or engineering practice, to outline the process and procedure for complying with the requirements of the code. In the context of the *performance-based system*, a performance-based design approach provides a means to demonstrate that the health and safety requirements of a performance-based code are met by providing a process to evaluate design options against the *performance objectives* and *functional statements* using *accepted methods*.

Items that should be considered include: Who develops engineering standards and practices? Who evaluates them on their ability do perform their intended function (who validates them)? Who deems them to be acceptable? How are they included in the system such that, once accepted, they can be readily used?

2.4 Evaluation and Design Tools

Evaluation and design tools are *accepted methods* for assisting in the development, review and *verification* of designs in accordance with *engineering standards* and *practices*. Fire protection engineering tools and methodologies encompasses those equations, correlations, models and procedures used for engineering analysis and prediction of fire and fire related phenomena. Computer models used in fire and life safety analysis and design, for example, are considered fire protection engineering tools. So too are many of the equations and correlations found in the *SFPE Handbook of Fire Protection Engineering*.

The difference between an engineering practice and an evaluation and design tool is that an engineering practice provides the process and procedure to solve a global problem, and an evaluation and design tool is used to solve or verify components of the global problem in accordance with the engineering practice.

For example, if one wants to estimate the available time for safe egress from a particular building, one might well undertake a process that includes determining building characteristics and features, fuel loading and arrangement (contents, interior finish, etc.), and occupant characteristics, developing performance criteria (e.g., what renders the egress path unsafe), developing potential fire scenarios, evaluating protection alternatives and evaluating evacuation factors. A process such as this would be well-suited to an engineering practice for evaluation of safe egress time.

Within this process, it will be necessary to perform a number of specific analyses, such as estimation of fire growth and spread, estimation of smoke production and propagation and estimation of fire detector activation. For these analyses, specific tools, such as computer fire models, and methodologies, such as those outlined in the *SFPE Handbook* for estimation of fire detector response to a growing fire, may be applied.

Items to consider include: Who develops these evaluation and design tools? Who deems them to be acceptable? How are they validated?

There is also the question of who can be expected to properly utilize these tools. Must the user be a qualified *fire protection engineer*? It is important to note that the user may be a designer or a reviewer (authority). In addition, there is the question of when these tools are used. Should the code (or engineering practices) include these tools and methods within, or adopt them by reference?

2.5 The Role of Fire Protection Engineers and Others in the Process

Given that a performance-based system will be new to the United States, and that such a system will ultimately be more fire protection engineering intensive than a prescriptive-based system, the role of fire protection engineers in the performance-based system will likely increase. To help better clarify the role of fire protection engineers in the performance-based system, and why their role may be increasing, the following principles are currently being discussed within the SFPE:

- It is recognized that national, regional and local regulations establish the minimum levels for health and safety acceptable to society via building codes, standards and regulations.
- It is recognized that in a performance-based system, the minimum levels of safety acceptable to society will likely be presented in the form of *functional objectives* and *performance requirements* in building codes and standards.
- To adequately reflect society's needs, it is likely that performance-based codes and standards will be developed via a consensus process among a widely diverse cross section of society. (It is anticipated that the fire science and engineering community will be intimately involved in the translation of *functional objectives* and *performance requirements* into *performance criteria* that can be designed to or evaluated against using *accepted methods*.)
- As with other engineering disciplines (e.g., structural engineering), it is anticipated that performance-based codes (as with other building codes) will recognize acceptable fire protection engineering practices as suitable vehicles for achieving required levels of fire and life safety performance in buildings.
- Fire protection engineering tools and methodologies should be utilized in the engineering analysis and design of fire safety measures (performance-based or prescriptive) and reconstruction of fire incidents only where deemed acceptable by the fire protection engineering community.
- To attain *accepted* status, fire protection engineering tools and methodologies should have been widely challenged in a peer-review process (literature, conference proceedings, etc.), or have been developed in or received positive evaluations in a consensus process among qualified engineers, educators and researchers, and have been validated in their ability to generate outcomes consistent with those claimed by the developer when used in accordance

with the appropriate documentation. Safety and reliability factors that are included, or are required to be added, should be explicitly stated and based on accepted engineering theory, practice or statistics.

- The use of fire protection engineering tools and methodologies in the analysis or design of fire safety measures constitutes the practice of engineering.
- The identification, evaluation and selection of fire scenarios, for use in an engineering tool, methodology or practice, that are based on fuel characteristics, loading and arrangement, compartment characteristics (e.g., volume), environmental characteristics (e.g., ventilation), occupant characteristics and situation-related information, constitutes the practice of fire protection engineering.
- Fire protection engineering practices, including *performance-based fire safety design* approaches, should be developed by qualified fire protection engineers, educators and researchers.
- Those who engage in the practice of engineering should be engineers. Those who engage in the practice of engineering in fire related areas should be fire protection engineers.
- Those who engage in the practice of engineering in fire related areas should abide by the SFPE Canon of Ethics for Fire Protection Engineers.

What are the roles of other groups in the process: code developers, code authorities, fire authorities, the fire service, architects, other engineering professions, testing laboratories, insurance companies, educators, building developers and contractors, building owners and managers, researchers, others?

2.6 Working Definitions

Performance-Based System: A regulatory framework for the built environment that consists of 1) performance- or objective-based codes, 2) performance-, objective- and prescriptive-based engineering practices (standards), and 3) engineering tools and methodologies. The use of the word *performance* implies that the performance of materials and systems can be *verified* under the expected conditions. The use of the word *objective* implies that the expressed intent (objective) of materials and systems can be shown to be met under the expected conditions. (See also *performance requirements* and *functional objectives*.)

Performance-Based Code: A document that expresses requirements for a building or building system, in terms of *societal goals, functional objectives* and *performance requirements,* without specifying a single means for complying with the requirements. *Acceptable solutions* and *accepted methods* for demonstrating compliance with code requirements shall be referenced by the code. (This definition also applies to *objective-based code.)*

Societal Goal: Broad statement that reflect society's expectation of the level of health, safety or amenity provided in a building. These statements, although generally qualitative, should be stated in such a manner that compliance with the goal can be evaluated using *accepted methods.* (This is the statement in the code that reflects what we expect from the building.)

Examples include statements such as "insure public safety, health and welfare insofar as they are affected by building construction" [*The BOCA National Building Code*, 1993], "safeguard people from injury due to structural failure" [*The Building Regulations 1992*, New Zealand], "protect the occupants not intimate with the initial fire development from loss of life" [*The Life Safety Code*, NFPA, 1994], and "safeguard people from loss of amenity arising from the absence of adequate personal hygiene facilities" [*Draft Performance Building Code Australia*, ABCB, 1995].

Fire Safety Goal: A *societal goal* related to the level of fire safety expected in a building.

Functional Objective: A statement of how a building or its systems function to meet a *societal goal* for the building.

Examples include statements such as "buildings... shall be designed and constructed to support safely all loads, including dead loads, without exceeding the allowable stresses (or specified strengths when appropriate load factors are applied) for the materials of construction in the structural members and connections" [*The BOCA National Building Code*, 1993], "buildings, building elements and sitework shall withstand the combination of loads that they are likely to experience during construction or alteration and throughout their lives" [*The Building Regulations 1992*, New Zealand], and "a building is to be provided with safeguards to prevent fire spread so that occupants have time to evacuate to a safe place without being overcome by the effects of fire" [*Draft Performance Building Code Australia*, 1995].

Performance Requirement: A statement of the level of performance that must be met by building materials, assemblies, systems, components, design factors and construction methods in order for a building to meet the *societal goals* and *functional objectives*. (This statement should provide the basis for evaluating how the building design and features will meet the *societal goals* and *functional objectives*.)

Examples include such statements as "in order to inhibit the spread of fire within the building, surfaces of materials used on walls and ceilings shall offer adequate resistance to the spread of flame over their surfaces and shall have, if ignited, a rate of heat release which is reasonable in the circumstances" [*The Building Regulations 1985*, United Kingdom], "buildings, building elements and sitework shall have a low probability of causing loss of amenity through undue deformation, vibratory response, degradation, or other physical characteristics throughout their lives, or during construction or alteration when the building is in use" [*The Building Regulations 1992*, New Zealand], and "a material and an assembly must resist the spread of fire to limit the generation of smoke and heat, and any toxic gases likely to be produced, to a degree appropriate to the travel distance, the number and mobility of occupants, the building use and the active fire safety systems installed in the building" [*Draft Performance Building Code Australia*, 1995].

Performance Criteria: The metrics against which building materials, assemblies, systems, components, design factors and construction methods will be evaluated on their ability to meet specific *performance requirements*. (These criteria may be provided in the *code*, *engineering standards or practices*, or other *accepted methods* and references, and may be stated in terms of absolute values (threshold values) or ranges of values (e.g., between x and y, within one standard deviation of the mean, in the 95th percentile, etc). Several *performance criteria* may be applicable to any single design problem. *Performance criteria* may be situation dependent. A *performance criterion* should be a metric, but not the measurement tool.)

> Examples of how performance criteria can be referenced or expressed include "the deflection of reinforced concrete structural members shall not exceed that permitted by ACI 318" [*The BOCA National Building Code, 1993*], "the level of fire gases shall not be lower than 1.6 + (0.1xH) m, where H is the height of the room" [*Swedish Board of Building, Housing and Planning, Building Regulations 1994*], "limiting conditions for tenability caused by heat radiation: less than 2.5 kW/m^2 can be tolerated for over 5 minutes; 2.5 kW/m^2 can be tolerated for 30 seconds; 10 kW/m^2 can be tolerated for 4 seconds" [*Draft Fire Engineering Guidelines*, Australia, 1995], and "the smoke layer interface (shall be maintained) above the highest of either: the highest unprotected opening to an adjoining space, or 6 feet above the floor level of exit access open to the atrium for a period of 20 minutes" [*The BOCA National Building Code, 1993*].

Acceptable Solution: A solution that has been determined to comply with the *societal goals, functional objectives* and *performance requirements* of a *performance-based code*. These may be specific *prescribed/specified* solutions, provided in or referenced by the code, or *performance-based* solutions derived using *accepted methods* provided in or referenced by the code. (For example, current code provisions, if determined to comply, may constitute acceptable solutions.)

Accepted Methods: Any method, such as an *engineering standard* or *engineering practice*, or *engineering tool*, such as a computer fire model, that has been widely challenged in a peer-review process (literature, conference proceedings, etc.), or has been developed in or received positive evaluations in a consensus process among qualified engineers, educators and researchers, and has been validated in its ability to generate outcomes consistent with those claimed by the developer when used in accordance with the appropriate documentation. *Safety and reliability factors* that are included, or are required to be added, should be explicitly stated and based on accepted engineering theory, engineering practice or statistics.

> Examples of the use of acceptable methods include "the deflection of reinforced concrete structural members shall not exceed that permitted by ACI 318" [*The BOCA National Building Code, 1993*] and "each automatic sprinkler system required by another section of this Code shall be installed in accordance with NFPA 13, Standard for the Installation of Sprinkler Systems" [*The Life Safety Code*, NFPA, 1994].

Standard: A consensus document that provides a set of rules, conditions, or requirements concerned with: definition of terms; classification of components; delineation of procedures; specification of dimensions, materials, performance, design or operations; description of fit or measurement of size; or measurement of quality and quantity in describing materials, products, systems, services or practices. (These may be written in mandatory or non-mandatory language.)

Engineering Standard: A *standard*, typically written in mandatory language, that relates specifically to an engineering analysis or design process or procedure.

Engineering Practice Document: An engineering document, developed within and accepted by a recognized engineering discipline, that relates specifically to an engineering analysis or design process or procedure related to the expertise of that discipline.

Installation Standard: A standard relating to the installation of a material, product, component or system.

Safety Factor: An adjustment made to reflect uncertainty in the assumptions made, the tools and methods used, and the limiting value of a parameter or item being measured. (It should be noted that safety factors may be present in many components of an analysis or design. Careful attention should be given to both the lack of safety factors and the possibility that multiple safety factors are present.)

Reliability Factor: An adjustment made to reflect uncertainty in the reliability of a material, component or system to perform its intended function at the time it is required.

Validated: Has been demonstrated (proven) to meet the stated objective or intent through the use of *accepted methods.*

Verified: Has been demonstrated (proven) to meet the stated objective or intent through the use of *accepted methods.*

Performance-Based Fire Safety Design: An engineering approach to fire protection design based on (1) agreed upon *fire safety goals and objectives*, (2) *deterministic and probabilistic evaluation* of *fire scenarios*, and (3) a quantitative assessment of design alternatives against the *fire safety goals and objectives* using *accepted engineering tools, methodologies and performance criteria.*

Engineering Tools: Calculation techniques, *models* and related resources that can be applied to an engineering analysis or design.

Engineering Methodologies: Engineering analysis and design processes or procedures. (See also *engineering standard* and *engineering practice* document.)

Model: A structured approach to analyzing a problem, typically using a physical representation or mathematical relationship to represent or predict an outcome based on a set of definable input variables.

Computer Model: A model that has been adapted for use on a computer.

Fire Model: A *model* that is used for predicting one or more effects of well-defined fire.

Stochastic (Probabilistic) Fire Model: A *fire model* that treats fire growth as a series of sequential events or states. Mathematical rules govern the transition from one event to another (e.g., from ignition to established burning) and probabilities are assigned to each transfer point based on analysis of relevant experimental data, historical fire incident data and computer model results. (These models are often referred to as "state transition" models.)

Deterministic Fire Model: A *fire model* that represents the processes encountered in a fire by interrelated mathematical expressions based on physics and chemistry.

Room (Compartment, Enclosure) Fire Model: A *deterministic fire model* that represents the processes encountered in a room (compartment, enclosure) fire. (The enclosure boundaries, i.e., walls, ceiling, openings, etc. are additional input variables.)

Computer Fire Model: A fire model that has been adapted for use on a computer.

Zone (Control Volume) Model: A *room fire model* in which the mathematical expressions are solved for distinct and relatively large control volumes (zones). (Many *zone models* are limited to two zones: an upper 'hot' layer where hot gases and smoke are considered evenly distributed (homogenous) and a lower 'cool' zone that is typically considered free of smoke. Because *zone models* are typically limited to two zones, they can be readily converted to *computer fire models* that can operate quickly on small personal computers.)

CFD (Computational Fluid Dynamics) Model: A *deterministic fire model* that solves fundamental equations of mass, momentum and energy for each element in an enclosure space that has been divided into a three-dimensional grid of smaller units (cubes). (The application of a CFD model often results in the control volume (enclosure) being divided into a grid of several thousand (tens of thousands) units. This requires considerable computer power and computing time. CFD models are not generally available for use on personal computers.)

Fire Scenario: A set of parameters, circumstances and conditions that defines the initiation, development and spread of fire and fire effluents (combustion products) within a compartment, in many compartments or throughout a building, based on such factors as ignition sources, type, loading and configuration of fuel, compartment characteristics (e.g., enclosure volume, construction, contents and openings), active and passive fire and life safety systems, use of the compartment, building or structure, occupant characteristics, loading and location, and environmental conditions (e.g., seasonal characteristics, time of day, day of week).

Fire Protection Engineering: The application of science and engineering principles to protect people and their environment from destructive fire. It includes analysis of fire *hazards* and *risks*; mitigation of fire damage by proper design, construction, arrangement, and use of buildings, materials, structures, industrial processes and transportation systems; the design, installation, and maintenance of *active and passive fire and life safety systems*; and post-fire investigation and analysis.

Fire Protection Engineer: A fire protection engineer, by education, training and experience: (1) is familiar with the nature and characteristics of fire and the associated products of combustion; (2) understands how fires originate, spread within and outside of buildings/structure, and can be detected, controlled, and/or extinguished; and (3) is able to anticipate the behavior of materials, structures, machines, apparatus and processes as related to the protection of life and property from fire; (4) is able to use appropriate quantitative fire protection *engineering tools and methodologies* with an understanding of the techniques utilized with respect to assumptions, limitations and uncertainties; and (5) is aware of fire safety management requirements, including the role of fire prevention and the risks to building fire safety associated with construction, installation, operation and maintenance.

Engineering Judgment: The process exercised by a professional who is qualified because of training, experience and recognized skills to complement, supplement, accept or reject elements of a quantitative analysis.

Deterministic Evaluation: An *engineering methodology*, based on physical relationships derived from scientific theories and empirical results, that for a given set of initial conditions will consistently produce the same outcome within expected tolerances.

Probabilistic Evaluation: An evaluation based on a series of sequential events or states wherein mathematical rules govern the transition from one event to another and probabilities are assigned to each transfer point based on analysis of relevant experimental data, statistical data and *deterministic evaluation.*

Active Fire and Life Safety Systems: Fire and life safety systems that require electrical or mechanical power to activate, operate or perform their intended fire detection, suppression or control function. (Active fire and life safety systems include, but are not necessarily limited to, automatic and manual fire detection, alarm, signaling and communication systems, automatic and manual water- or chemical-based fire suppression and extinguishing systems, electrically or mechanically powered ventilation systems used for smoke management and/or control.)

Passive Fire and Life Safety Systems: Fire and life safety systems that do not require electrical or mechanical power to activate, operate or perform their intended fire detection, suppression or control function. (Passive fire and life safety systems include, but are not necessarily limited to, fire resistive construction of structural support systems (e.g., load bearing members) and barriers (e.g., fire and smoke walls and partitions), containment and drainage systems, and opening protection devices.)

Fire Related: Having to do with fire and its effects.

Flashover: The rapid transition from a localized fire to the combustion of all exposed surfaces within a room or compartment.

Hazard: An event that in a particular set of circumstances has the potential to give rise to unwanted consequences.

Risk: The potential for realization of an unwanted event, which is a function of the hazard, its probability and its consequences.

Prescriptive-(Specification) Based: Being *prescribed* or *specified* in terms of dimensions, materials or operation.

Prescribe: Lay down as a rule or course to be followed. [*Random House College Dictionary*]

Specify: State in detail. [*Random House College Dictionary*]

Performance-Based: Being described in terms of the measurable performance of a material, product, component or system.

Objective-Based: Being described in terms of an objective or intent to be achieved through the use of a material, product, component or system.

Safe Place: A place of safety within a building or within the vicinity of a building, form which people may safely disperse after escaping the effects of fire. (It may be a place such as a road, open space (including an appropriate roof space), or pubic space.)

Travel distance: The actual distance that needs to be traveled by a person from any point within a building to the nearest exit, having regard to the layout of walls, partitions and fittings.

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3.0 Summary of Comments on Working Document

This section provides a brief summary of the comments received on the working document. Copies of the actual written commentary, as provided by focus group participants, is available from the Society of Fire Protection Engineers. (Reading the participants' comments is highly recommended.) For ease of review, this summary is provided using the same headings as those in Section 2.

3.1 Basic Components and Structure of a Performance-Based System

The Framework:

The concept of separating the framework into distinct components including Codes, Standards and Practices, and Evaluation/Design Tools was welcomed. Standards and Practices and Evaluation/Design Tools were considered by many as interdependent, one being the subset of the other.

The Code

Care should be exercised in mixing goals, objectives and performance requirements together. Separation of these items is justified. More importantly, any referencing of *acceptable methods* in the Code, should be carefully considered. The marketplace changes, new technologies are introduced, and a true performance code should not be tied to prescriptive acceptable methods.

On Transition

Authorities Having Jurisdiction have a critical indirect influence on the system. Transitioning should include the AHJs. An increase in the use of equivalencies can be one method used during transition. As AHJs see an increased use in equivalencies, liability will become more significant. Implementation cannot occur until liability is resolved.

Related to the transition issue are education and qualification. These two items should be considered as part of the system of performance based codes. Particularly in the approval process, qualification and education are important to transition.

The Department of Energy emphasizes the use of published equivalencies (such as NFPA 101M) in order to reduce bureaucracy under the President's re-inventing the government plan.

3.2 Prescriptive Codes and Performance-Based Codes

Goals and Objectives

Fire loss history suggests that current standards do not achieve the "intended" goals. Current codes have qualitative goals/objectives through statements of intent and are not measurable. However, it does appear that prescriptive codes meet social objectives. Prescriptive codes, however lacking or however excessive, at least provide a benchmark for acceptability. There is some disagreement whether objectives can be quantified (see full comments of Nelson and Law). (The results are measurable, but as an extreme example, how does one compare 19th Century rates of fire death to today?)

A two tiered system will have functional objectives for a prescriptive code and performance objectives for a performance based code.

Most agree that setting goals and objectives should be accomplished through broad representation and include public representatives (regulators, code officials, engineers). (Setting the level of life safety in England is the province of the government and is a political process. However, quantification of deaths is politically difficult to endorse, therefore, a comparison type goal could be used.)

Property Protection

The current prescriptive codes appear to provide not only life safety, but also a level of property protection. If a performance code emphasizes only life safety, will building owners have false expectations of their property based on years of prescriptive code protection?

Goals and objectives should be stated considering property protection. The objectives may include or exclude property. (In England it is felt that government should not interfere with enterprise except in matters of health and safety. Therefore, property protection is left to the insurers.)

3.3 Standards and Practice Documents

Who Develops Standards and Practice Documents

The consensus is that development should be a multi-disciplinary approach: Engineers may spearhead the process, but other "governing" bodies should be included: ANSI, NFPA, manufacturers, consultants, and researchers who develop the tools.

There is a strong link throughout the various branches of fire protection. *Acceptable methods*, a subset of Standards and Practices, comes directly from research, follows through engineers and consultants and must be approvable by regulators. Therefore a strong argument can be made to support research: the front end of the acceptable methodology.

3.4 Evaluation and Design Tools

Evaluation and Design Tools were often "confused" with Standards and Practice Documents. The development of design tools, as with the development of Standards and Practice Documents, occurs through a process of research to engineering to regulation. In order to develop these tools, research becomes as important to the users as the regulations.

There is great variety in opinions on the subject of evaluation/validation. Several believe that we should not get stalled by waiting too long for validation of a tool, just as long as the tool is not overextended. The use of the tool will help determine what research and development is necessary. Also, use of the tools will uncover issues of maintenance and performance.

It is best to keep evaluation and design tools separate from the Code. Evaluation/Validation can become part of the acceptance procedure of an *acceptable method*. Testing laboratories may become a source for evaluation.

On the User

The user needs to be working in the field of fire protection and at least competent to use the tools. There is an argument to be made for accreditation through licensing, however, even some licensed may not be competent.

3.5 The Role of Fire Protection Engineers and Others in the Process

As stated in the previous section, the user of fire protection evaluation and design tools needs to be competent. This does not necessarily mean they have to be a fire protection engineer. For example, a licensed mechanical engineer, working for ten years in fire protection engineering, is likely to be fully qualified to design a smoke control system based on a performance based system. It is not necessary for him/her to be a licensed fire protection engineer.

Review agencies (i.e., AHJs) which do not have the necessary expertise on staff may find a suitable alternative in the use of outside experts (e.g., some form of peer review). (The use of performance- based design approaches will likely be limited in some jurisdictions. Thus, it would be unnecessary to have a fire protection engineer on staff in every jurisdiction.)

Several interesting questions arise from a contractors perspective:

- How will performance design influence the construction practice?
- Will the design be buildable? (Flexibility in design may not mean flexibility in construction.)
- Who will be accountable for the design?
- How will indemnification work?
- Will shop drawing approvals be different?

The comment was also made that some disputes, solved by the well-defined specifications prescriptive codes, will have to be addressed differently under a performance-based system (i.e., what will the AHJ use as the basis for evaluating alternative compliance options?)

3.6 Working Definitions

There was minor commentary on the definitions section. One common suggestion was to ensure that the definitions coordinate with ASTM and/or ANSI definitions.

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4.0 Focus Group Discussion

Two meetings of the focus group were convened during 1996: 25-26 April at the Doubletree Hotel in Arlington, VA, and 23 September at the Sheraton Ottawa Hotel, Ottawa, Ontario, Canada. The basis for discussion was the "strawman" document presented in Section 2. The primary issues discussed during the two meetings were:

1. Why does there appear to be such a strong movement towards performance-based codes in the United States?
2. Basic Components and Structure of a Performance-Based System
3. Prescriptive Codes and Performance-Based Codes
4. Standards and Practice Documents (Methods)
5. Evaluation (Verification) and Design Tools
6. Education
7. Qualifications

The following summarizes the discussion and consensus reached by the focus group on these issues. No significance should be placed on the order in which the bullets appear.

4.1 Why does there appear to be such a strong movement towards performance-based codes in the United States?

This discussion was intended to capture the essence of why the participants felt that the United States is moving towards the inclusion of performance-based codes, standards and fire safety design methods in its building regulatory system. These comments reflect the general feeling of the group as to what seem to be the motivating factors, what the resulting system might look like, and what remains to be done. Consensus on specific issues follow under subsequent headings.

Why are "we" doing this? What will be achieved?

- *To provide a better framework for communication* between the policy makers, the people who purchase fire protection services, systems, and materials, and the people who deliver fire protection services, systems, and materials.
- *To obtain a better understanding of what is being delivered.*
- *For cost effectiveness.* There is a perception of undue redundancy and cost in the present system, and a performance-based system would provide improved value by providing clear explanation of fire and life safety objectives.
- *To reduce economic impact on the community.* A performance-based system would likely include cost-benefit analyses and decision making for building design and construction.
- *Sustainable development.* To build safer buildings that last longer, provide better definition of what is being delivered for the cost, and strive for efficient use of resources over the life of the building.
- *To encourage the development of tools and techniques to evaluate building performance.* Performance tools and techniques will not only be needed for use in a performance-based system, but they can also be used to evaluate and improve the quality of prescriptive

requirements. As a result, not only will the estimated 5% of buildings that will benefit directly from performance-based design be addressed, but the other 95% of the buildings will be addressed as well.

- *To identify and target sectors of the built environment where the risk is higher.*
- *To identify and target sectors that deter growth and innovation in services, systems and materials.*
- *To allow architects and engineers more flexibility in the use of innovative designs, techniques, and materials.*
- *To maintain global competitiveness and respond to global market forces.* As global corporations look to locate, the regulatory environment will be an important factor in competitiveness of building design and construction.
- *To gain the recognition of fire protection engineering as a true engineering discipline and to achieve better fire protection engineering.*

How do we get there?

- One way may be to expand on the concept of using equivalency by introducing objective statements first, then transition to a "total" performance-based system.
- One needs to address the question, "Do people want a performance-based code or a performance-based option?"
- *Do not throw away what works.* Maintain and improve the current system and allow a performance-based option.
- *Provide an "integrated" system that retains the prescriptive and includes performance.*

Consensus was achieved on the "integrated" system approach, with the components including policy level goals, functional objectives, performance requirements, prescriptive solutions and performance-based solutions. A graphical representation of such a system is shown as Appendix D. Further discussion on the components can be found under subsequent headings.

What do the building and fire communities have to do, to have, to develop and to consider?

- *Examples of economic benefit would be useful.*
- *The development of an analytical tool to demonstrate the economic benefit would be useful.*
- *The development of tools and techniques to evaluate performance and to evaluate prescriptive requirements are needed.*
- *There is a need to address to concepts of acceptable risk and acceptable level of safety.*
- *There needs to be a linkage between those objectives extracted from our current prescriptive requirements and those that may be developed independently under a performance-based structure* (i.e., the "bottom-up" objectives and the "top-down" objectives). If this is not done, there may be incompatibilities.

4.2 Basic Components and Structure of a Performance-Based System

This issue focused on the "system" or "framework" for a performance-based regulatory system. Items that were considered under this issue included: Is a performance-based system needed? Does the "strawman" achieve the intent of such a system or framework? If not, what is missing? Should societal goals, functional objectives, performance requirements and accepted methods be specified in a single document or reside in separate documents? (Refer to the strawman model in Section 2 for definitions.) The following constitutes the consensus reached by the entire focus group on this topic.

- *A performance-based system needs to be pursued.* (As discussed in the *why* session, this would be an integrated system, maintaining what we have, and introducing the performance-based concepts listed below.)
- *A performance-based system will include goals, objectives, requirements and methods.* (These terms are based on the concepts of goals, functional objectives, performance requirements and accepted methods outlined in the "strawman.")
- *The term <u>societal goal</u> should be replaced with the term policy goal.*
- *The system will have a variety of goals and objectives.*
- *One starting point is the extraction and quantification of objectives from the existing prescriptive codes.* (Quantification is critical for evaluation/verification purposes.)
- *<u>Accepted methods</u> need to include an engineering guide for undertaking performance-based solutions and accepted/deemed-to-satisfy solutions.* (The former need to be developed and the latter is likely to be the current prescriptive requirements).
- *A "roadmap" for implementation of the system needs to be developed.* (A regulatory/regulator's tool for transitioning and implementing.)
- *A "users guide" for the system needs to be developed.* (For general use: now that we have this system, how do we use it?)
- *Common terminology and definitions need to be developed.* (Additional work is needed on the terminology and definitions proposed in the "strawman" document.)

4.3 Prescriptive Codes and Performance-Based Codes

This topic focused on the differences between prescriptive codes and performance-based codes. Items that the group considered included: Do the current codes clearly identify measurable goals and objectives? If not, how should they be developed, and by whom? Who determines the required performance (to meet the objectives)? The following constitutes the consensus reached by the entire focus group on this topic.

- *Current prescriptive codes seldom have explicit fire and life safety goals and objectives.*
- *Goals and objectives need to be developed by all affected interests.*

- *Performance requirements need to be developed by consensus of those experienced individuals, professionals, and/or organizations who are qualified to translate verifiable goals and objectives into quantified terms.*

  Although consensus could not be reached on a term to identify "who is qualified," there was clear consensus that the determination of performance requirements had to be done by those who have the expertise to translate the goals and objectives into quantified terms. Discussion indicated that this should be psychologists for human behavior, medical doctors for tenability or survivability criteria, fire scientists and engineers for fire related criteria, and the like.

4.4 Engineering Standards and Practice Documents

This topic focused primarily on engineering standards and practice documents (methods) that would be used for describing a process to be followed in achieving a solution. These are the analysis and design guidance documents (the "how is it done" documents), and do not include the evaluation and design tools (e.g., models) that are used within the analysis or design process. Items that the group considered included: Who develops engineering standards and practices? Who evaluates them on their ability to perform their intended function (who "validates" them)? How are they included in the system such that they can become readily used? The following constitutes the consensus reached by the entire focus group on this topic.

- *Engineering standards and practices (methods) need to be developed by, and gain the broad professional consensus of the scientific and engineering community.* In essence, the scientific and engineering community not only develops the methods, but must agree to their validity before they can become widely accepted.

- *Acceptance of engineering standards and practices within the regulatory system can be gained in one of two ways:*

  (1) By having a critical peer review within the scientific and engineering community and a "reality check" by a broader community (such as might be gained through a broader consensus process similar to the NFPA process.)

  This discussion included the commentary that the scientific and engineering community has the expertise necessary to develop engineering methods, but that they should not "operate in a vacuum" and develop methods that cannot be readily used or understood by the broader building and fire communities.

  (2) When an engineering method has not received critical peer review by the engineering and scientific community, nor a "reality check" by the broader community, the burden of demonstrating the "acceptability" of the method is on the proposer of the method. Criteria for demonstrating the acceptability of an engineering method are to be provided in the code.

  The discussion around this option focused on the need to allow engineers the flexibility to engineer solutions for which guidance documents may not exist, or in cases where the engineer wants to use an alternative approach that has not yet been peer reviewed. This option will only be truly effective, however, if there are acceptability criteria/factors in the code to assist enforcement officials in the review of such a method.

In essence, the engineering community must be the driving force behind development and "validation" of engineering methodologies. Traditionally, this is done through a peer-review process (e.g., refereed journals, refereed conference and symposia presentations, etc.) and subsequent acceptance and use in the wider community. An example might be a code reference (wide community acceptance) to an acceptable method for calculating the deflection of a reinforced concrete structural member (peer review and consensus of the scientific and engineering community). However, if such a reference is not included in the code, there needs to be a means by which to determine the acceptability of a proposed engineering approach to solving a problem (e.g., wording to the effect that "...alternative methods for meeting these objectives must consider...").

4.5 Evaluation (Verification) and Design Tools

This topic focused primarily on the evaluation and design tools that would be used within an engineering standard or practice document (method). These include such items as models, computer models, empirical equations, correlations, test methods and data. Items that the group considered included: Who develops these evaluation and design tools? Who deems them to be acceptable? Who "validates" them? Who can/should be expected to properly utilize these tools? How do we fill needed gaps? The following constitutes the consensus reached by the entire focus group on this topic.

- *Evaluation and design tools are to be developed by those with the expertise* (e.g., the profession, academia and research organizations).

- *The term validation means different things to different people, and for this reason, perhaps should not be used: the critical factor is confidence.*

  There are many parts to this issue, including the validity of the fundamental equations (correlations, assumptions, etc.), the validity of the software (in the case of a computer model), and the relationship to reality (does it accurately reflect what happens in "real life"). However, the bottom line seemed to be that the validity of any tool is a function of the confidence level of the developer, the user and the marketplace. If the developer can transmit a feeling of confidence in what the tool can do, the tool will be used. If the tool can be used with confidence in solving a problem, the marketplace will have confidence in its use. As with many parts of the transition to performance-based codes and fire safety design, education and communication will play a critical role in the acceptance of any tool as being valid for its intended use.

- *Acceptance of evaluation and design tools is a process that includes acceptance by the profession (critical peer review and professional acceptance), acceptance by the users (with knowledge of the tool's use, applications and limitations), and ultimately, acceptance by the marketplace, with the bottom line being confidence.*

  As with the discussion on validation, the real issue with acceptance is one of confidence by the developer of the tool, the user of the tool and the marketplace.

- *Before the professional community and the broader community can identify where the gaps are, we need to know what we have.* As the first step, it would be extremely useful to compile a complete inventory of all of the tools (in this case, primarily computer-based tools) that are currently available for evaluation and design. Such a list should include all pertinent tools, including fire science, engineering (of all types), medical, physiological, psychological, toxicological, etc.

The intent here would be to compile a complete list of what is available, and perhaps, provide some indication of use, application and limitations of each. It was suggested that this might be an appropriate role for the SFPE. Exactly what criteria would be included about the tools in such an inventory was not discussed.

- *One clearly identifiable gap is the lack of data* (specifically for the models).

  Although there was no consensus on what we should do, it was clear that the shortage of data is a critical factor in the "confidence" issue. It was suggested that this problem is bigger than any one group or organization, and that national or international policy/initiatives may be necessary to adequately address this shortcoming.

4.6 Education

To assist in the discussion of education, materials were supplied on the educational programs at the Victoria University of Technology (VUT), Melbourne, Australia and the Glasgow Caledonian University (GCU), Glasgow, Scotland.

In Australia, there is a concerted effort to educate a broad spectrum of involved persons in order to better work within a performance-based system. It was noted, however, that formal programs, such as those at VUT, are considered somewhat "elitist" by some due to limitations in the number of applicants that can be accepted into the program. To provide additional education, the Australian Building Codes Board is promoting the concept of a 4-day training module such as that used in the Netherlands (no documentation currently available on that program). There was some concern raised concerning this approach due to the limited amount of training that can be provided in four days. However, regardless of the different approaches, all agreed that education is needed, and more is better than less.

The GCU program is a B.Sc. program in Fire Risk Engineering. Given the movement towards a performance-based regulatory system, it was recognized that a better understanding of fire risk issues is needed by practicing professionals. This program is one attempt to address this area. Other discussion of U.K. educational programs included that of the National Core Curricula as developed by the Fire Service College, the Institution of Fire Engineers, and the Home Office. This program is aimed at increasing the education of related professionals, in this case, fire service officers, with regard to the technological issues related to a performance-based regulatory system (especially the fire safety design aspects).

The discussion of educational needs within the United States mirrored the international experience in that a wide range of educational services are needed. Although the U.S. has programs such as at Oklahoma State University, the University of Maryland and the Worcester Polytechnic Institute for engineers, much more needs to be done for the fire service, building officials, allied engineering and design professionals, and for the continuing educational needs of fire protection engineers. Efforts underway by the Society of Fire Protection Engineers were discussed and agreed to be a good start. However, the group felt that it would be beneficial for the SFPE to explore broader educational offerings, targeted at building officials, fire officials, and allied engineering and design professionals. The discussion resulted in the following consensus:

- *The SFPE should be the facilitator in defining the core competency requirements for those engaged in performance-based fire protection engineering and for those working with performance-based regulations.* It was felt that joint educational efforts with related organizations would likely be the best approach.
- *In the short term, it was felt that one educational goal is to help identify what the current code requirements are (in terms of intent and objectives) and why they are required, and transmit this information to building and fire officials.*
- *There is a need to provide building officials, fire officials, and allied engineering and design professionals with information on the basics of fire protection engineering and the conceptual background related to performance-based codes and fire safety design methods.* It was also discussed that engineers and AHJs need a better understanding of risk issues and how to deal with them in a performance-based system.
- *An educational goal for practitioners is to provide applications-oriented education.*
- Fire protection engineering education should look more closely at how other engineering disciplines work. (A discussion on the parallels to structural engineering was the basis for this comment.)
- *Fire protection engineers (and others involved in the design process) need to look at the process from a systems approach* (i.e., the building, the fire, and the fire safety systems interact together as a single system, and should be considered as such).
- *The educational offerings for engineers and allied professionals also need to discuss responsibilities and ethics related issues.* This was a result of discussion that one should not practice outside the area of one's expertise, and if an engineer claims that an engineering solution is valid, the engineer should take increased responsibility for that solution (there is less and less legal acceptance of hiding behind such claims as "it is all that the code required").
- *It was suggested that the key to increasing the knowledge-base, across the board, is to stop using ill-defined words to describe concepts, and start using full and complete sentences.* If the basic concepts are not well understood, then any subsequent educational efforts will be less fruitful. If the concepts can be better communicated, if the intent of a performance-based system becomes well-understood, then all subsequent educational issues will be easier to address.
- *None of the educational objectives can be met without both the resources and the vehicles to deliver the educational services.* Joint efforts with related organizations may be suitable vehicles; however, adequate resources still need to be found.

4.7 Qualifications

A critical point of discussion revolved around the question, "Who is qualified to undertake, review and accept performance-based designs?" In the present system, the qualifications of all participants do not need to be much more than the ability to read the codes and standards. In a performance-based system, all parties will need to understand the basic concepts, and some participants, such as fire protection engineers, may need a better understanding of a wider range of issues than they currently have. As the above discussion indicates, the group felt that many of these issues can be addressed through further education.

- *Until such time as the education levels in the broader community are raised to the levels discussed above, it was suggested that engineers and design professionals need to accept a greater level of responsibility and more closely adhere to the ethical requirement of practicing only in the area(s) of their expertise.* In addition, those engineers and design professionals practicing in the performance-based system, particularly fire protection engineers, will need to have a "higher" level of qualifications.

The reasons for the above are several, including the fact that performance-based fire protection engineering requires a much greater knowledge of a much broader range of fire protection engineering issues than more traditional code-based design approaches. Because an engineer who may be competent in performing code-based designs may not be as competent in performing engineering-based designs, there need to be more checks and balances. In the beginning, this will include more accountability and a higher level of adherence to professional ethics. Over time, the increase in education will help address the competency and qualification issues. These issues of ethics, responsibilities, and qualifications relate in strong measure to that of credibility: as a professional and as a profession. As one meeting participant pointed out, the fire protection community needs to raise their level of credibility in the broader building and fire communities because "lots of people have been practicing voodoo out there." Although this comment likely related to the mis-use of computer fire models, it also relates to the fact that fire protection engineering is still a relatively new engineering discipline, and has not yet gained the same status or respect as other engineering disciplines, such as structural engineering.

- *A short-term goal may be to provide some type of certification for those engineers qualified to undertake performance-based designs.* The intent of this would be to evaluate the competency of engineers for undertaking the more engineering-intensive analyses and designs that would be acceptable under a performance-based regulatory system.

As was pointed out in the April meeting, someone who has obtained a Professional Engineer license may have been qualified in a certain area at the time they became licensed, but after not practicing in that area for several year, may no longer be competent in that area. Some type of certification process may be able to deal with such a concern. (A potential model may be something like the ASME certification for those people who work with high-pressure vessels. Although one may be a mechanical engineer by education, and licensed as such, one still needs to become certified in the special area of high-pressure vessels.)

- *A requirement for complete design documentation in a performance-based regulatory system would help.* If the regulatory instrument clearly states (or references) requirements for design documentation, including the necessity to document such items as the range of applicability of an analysis or design (boundary conditions), the limitation(s) of any fire models used (computer-based or not), the level of uncertainty and means for addressing it (uncertainty or safety factors), and so forth, the credibility and "comfort level" of the AHJs and others, in the ability and competency of the engineers, will increase.

- *Fire protection engineers need to be more accountable for their analyses and designs.* It should not be acceptable to "hide behind" the code: the engineer should be accountable for the engineering performed. The engineer should understand the science and engineering principles behind the analysis and design methods used, and be held accountable for the proper application of those principles. This understanding and accountability should be reflected in the design documentation. (This discussion is a corollary to the ethics discussion summarized above.)
- *It was suggested that one way in which the fire protection engineering profession can gain additional credibility and respect is for the SFPE to become the primary resource for fire protection engineering information.* Following on the model of the *SFPE Handbook of Fire Protection Engineering*, the SFPE needs to archive and make available the fire protection engineering knowledge to work within a performance-based regulatory system. Cataloging the knowledge and making it available to others will greatly assist the profession's credibility.

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5.0 Summary

A focus group representing a wide cross-section of the United States' building and fire communities was convened to discuss concepts of a performance-based regulatory system for the United States. The group was given background material as the basis for discussion, and two meetings were convened to discuss and gain consensus on fundamental concepts. Over the course of the two meetings, the following consensus was reached:

- The United States needs to pursue a performance-based building regulatory system.
- A performance-based system for the United States will likely spawn from the present system, will include explicit policy level goals, functional objectives and performance requirements in the codes (to describe the level of safety that is desired), and will utilize both prescriptive solutions (as we currently have) and performance-based solutions as acceptable means to provide the desired level of safety.
- An initial step in the transition to a performance-based system will be to extract goals and objectives from the current codes (primarily by the codes- and standards-making organizations) and to quantify them.
- Policy level goals must be developed by all interested parties.
- Performance requirements need to be developed by consensus of those experienced individuals, professionals, and/or organizations who are qualified to translate verifiable goals and objectives into quantified terms.
- Tools and techniques to measure performance must be developed (the responsibility of many professionals, including the SFPE).
- Evaluation and design tools are to be developed by those with the expertise (e.g., the profession, academia and research organizations).
- The term validation means different things to different people, and for this reason, perhaps should not be used: the critical factor is confidence.
- An engineering guide for developing performance-based solutions needs to be developed (a task the SFPE has initiated).
- Engineering standards and practices (methods) need to be developed by, and gain the broad professional consensus of the scientific and engineering community. In essence, the scientific and engineering community not only develops the methods, but must agree to their validity before they can become widely accepted.
- Acceptance of engineering standards and practices within the regulatory system can be gained in one of two ways:

  (1) By having a critical peer review within the scientific and engineering community and a "reality check" by a broader community (such as might be gained through a broader consensus process similar to the NFPA process.)

(2) When an engineering method has not received critical peer review by the engineering and scientific community, nor a "reality check" by the broader community, the burden of demonstrating the "acceptability" of the method is on the proposer of the method. Criteria for demonstrating the acceptability of an engineering method are to be provided in the code.

- Before the professional community and the broader community can identify where the gaps are, we need to know what we have.
- One clearly identifiable gap is the lack of data (specifically for the models).
- A common vocabulary and acceptable definitions need to be developed.
- The overall level of education needs to be raised for everyone in the building and fire communities, especially on performance-based code and design method issues.
- A short-term education goal is to determine what the current code requirements are (in terms of intent and objectives) and to explain why they are required.
- Another short-term education goal is to provide information on the basics and the conceptual background related to performance-based codes and fire safety design methods.
- A long-term educational goal is to provide applications-oriented education to all practitioners.
- Building and fire professionals, especially engineers, need a higher level of qualifications, a higher standard of ethics, and more accountability for a performance-based system to work.
- Good design documentation is mandatory for a performance-based system to work.
- The SFPE should be the facilitator in: a) defining the core competency requirements for those engaged in performance-based fire protection engineering and for those working with performance-based regulations, and, b) building relationships among allied professionals to validate competency (e.g., other engineering disciplines, building officials, architects, etc.).
- The SFPE needs to transmit the information to practitioners that their involvement is critical to the successful implementation of a performance-based system: they will make the difference.
- The SFPE needs to archive knowledge for a performance-based system, such as has been begun with the *SFPE Handbook of Fire Protection Engineering*.
- More outreach is needed to allied professionals to deliver the message of a systems approach to building (fire safety) design.
- Resources are needed for the SFPE and others to deliver on the above items.

In addition, various general concerns also became apparent, including:

- There will be a reluctance by many to change the way we currently do business: all implications resulting from a change in our regulatory system should be considered up front.

- Although various organizations will have different parts to play in the transition, it will be best if the efforts are as coordinated as possible. Communication, cooperation, and collaboration will be essential.
- In the end, it will be the marketplace which will dictate the success or failure of the transition efforts. If the marketplace can realize definite benefits (e.g., reduced cost and increased flexibility), success is likely. If such benefits cannot be realized, success will be much harder to obtain.
- Additional research and development will be necessary before final implementation of a performance-based system for the United States. This will require resources that are currently in short supply. To procure these resources, multi-organization and/or multi-national cooperation may be required.

Regardless of the level of effort yet required, the consensus reached by the focus group has given the United States' building and fire communities a solid platform from which to build a performance-based building regulatory system. To date, the focus group consensus has played a role in the ICC Performance Committee's effort to develop a performance-based building code, in the development of educational publications and presentations on performance-based concepts, and in outlining technological requirements for the realization of performance-based fire safety engineering in the United States.

The focus group continues to exist, and has agreed to meet periodically to discuss key issues of a performance-based system for the United States as they surface. (No additional meetings have been scheduled at the time of this report.)

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ABSTRACT (A 2000-CHARACTER OR LESS FACTUAL SUMMARY OF MOST SIGNIFICANT INFORMATION. IF DOCUMENT INCLUDES A SIGNIFICANT BIBLIOGRAPHY OR LITERATURE SURVEY, CITE IT HERE. SPELL OUT ACRONYMS ON FIRST REFERENCE.) (CONTINUE ON SEPARATE PAGE, IF NECESSARY.)

The United States' building and fire communities have recently begun transitioning towards the implementation of performance-based building regulations and the use of performance-based fire safety engineering. As a means to facilitate discussion and gain insight as to the potential structure of a performance-based building regulatory system for the United States, and to help the Society of Fire Protection Engineers place the engineering aspects of such a system into perspective, the *SFPE Focus on Concepts of a Performance-Based System for the United States* was created in March 1996. This group, which represents a wide cross-section of the United States' building and fire communities, provided key input on such issues as why the United States is moving towards a performance-based system, how such a system might be structured, what components will be required for such a system to work, and what education and qualification issues need to be addressed. The conceptual framework for a performance-based system that was used as the basis of discussion, the comments received on that conceptual framework, and a summary of the focus group discussion and consensus on a performance-based system for the United States are provided.

KEY WORDS (MAXIMUM OF 9; 28 CHARACTERS AND SPACES EACH; SEPARATE WITH SEMICOLONS; ALPHABETIC ORDER; CAPITALIZE ONLY PROPER NAMES)

building codes; computer models; fire codes; fire protection engineering; fire safety; fire safety evaluation system; histories; International Standards Org.; life safety code; NFPA 101; performance based codes; risk analysis

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