Fire: Prescriptive and Performance Based Design

Joshua Reichert
Fire Protection and Paramedicine Sciences, Eastern Kentucky University, Richmond, KY, USA

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Definition
Best practices in the field of fire engineering are procedures that are accepted or prescribed as being correct or most effective.

Strategies for fire engineering is a plan of action designed to achieve an overall aim, usually life safety and property conservation.

Introduction
When architects and engineers collaborate on a new building, extension to an existing building, or renovation to a new building, fire and life safety is always a consideration. A specialty in the fire community that exists to assist with that is fire protection engineers. Fire protection engineering is a professional licensure governed by the state in which the person would like to be licensed in. To become a licensed professional engineer (PE), a person would need to complete a 4-year degree in engineering from an accredited engineering program, pass the Fundamental of Engineering (FE) exam, complete a state-determined number of years working under a licensed PE, and then pass the Principles and Practice of Engineering (PE) exam.

When designing fire protection and life safety for a building, engineers have two best practices in which to choose from: prescriptive design and performance-based design.

Prescriptive design is the design of fire protection features using codes and standards that have been developed for generic buildings. This could include codes and standards from organizations such as the International Code Council (ICC), National Fire Protection Association (NFPA), state and local codes and ordinances, state or local amendments to national codes such as ICC and NFPA, or even corporate codes and standards for fire protection.

The other best practice to design a building with fire protection features is a performance-based design (PBD). Utilizing PBD includes designing the fire protection features specifically for the performance and the functions of the building. To provided a level of safety that is equivalent or exceeds what would be provided using prescriptive design, PBD utilized engineering analysis.
Prescriptive Design

Prescriptive fire protection design is the practice of designing fire protection features per accepted and approved codes and standards. A prescriptive-based code or standard prescribes fire safety for generic use of application. Building codes have a long history in mankind as it has been recognized that responsibility needs to be put on to a building to ensure a level of safety to a building owner. The earliest building code is believed to have been written between 1955 B.C. and 1913 B.C. under King Hammurabi of Babylon. Once such building code written stated, “If a house fell and killed the owner of his child, then the building, or his child, would be slain in retaliation” (Foliente 2000).

King Hammurabi identified that buildings should be responsible for the quality of product being handed over to a person that many have no knowledge of buildings. While mankind has developed and punishments are less extreme, building codes have also developed. Within the United States, different codes and standards exist for use in prescriptive design. While the codes outline a set of rules that knowledgeable people recommend for others to follow. This is not law but can be adopted into law. A standard is the more detailed elaboration of how to meet the code. More specifically, a code tells you what needs to be done and a standard tells you how to do it. These codes and standards help a fire protection engineer develop a prescriptive strategy for designing fire protection.

The ICC was established in 1994 as a nonprofit organization dedicated to developing a single set of comprehensive and coordinated national model construction codes. The formation of the ICC was due to three separate nonprofit organizations which were developing separate sets of model codes to be used in the United States. The three separate organizations were the Building Officials and Code Administrator International, Inc. (BOCA), International Conference of Building Officials (ICBO), and Southern Building Code Congress International, Inc. (SBCCI). It was recognized one single organization was needed without regional limitation; hence the formation of the ICC was made a realization (ICC).

Currently, the ICC produced 15 different codes covering different concentrations. Pertaining to fire protection design, the most important codes published by the ICC are the International Building Code (IBC), the International Fire Code (IFC), the International Plumbing Code (IPC), and the International Residential Code (IRC) (ICC n.d.).

International Building Code – This code is the foundation for all codes from the ICC. It has been accepted by most jurisdictions within the United States as well as some jurisdictions internationally.

International Fire Code – This code is designed to meet the needs to address conditions hazardous to life and property from fire, explosion, handling or use of hazardous materials and the use and occupancy of buildings and premises. This code establishes minimum regulations for fire prevention and fire protection systems using both prescriptive and performance-related provisions.

International Plumbing Code – This code sets minimum regulations for plumbing systems and components to protect life, health, and safety of buildings’ occupants and the public. The IPC covers a range of topics such as backflow prevention, fixtures and fittings, water supply and distribution, etc. These covered topics are important when designing sprinkler systems for a building.

International Residential Code – This code is designed to address one- and two-family dwellings and townhouses of not more than three stories above grade. The IRC covers aspects of construction such as building, plumbing, mechanical, fuel gas, and electrical, which all play a role in fire prevention and fire protection of residential structures.

The National Fire Protection Association (NFPA) is also another organization that creates and publishes prescriptive codes, standards, and recommended practices. NFPA was formed in 1896 and has been devoted to eliminate death, injury, and property and economic loss due to fire and electrical and related hazards. NFPA, as
Performance-Based Design

Performance-based design (PBD) is the second practice that an engineer may use to design fire protection features for a building or process. The Society of Fire Protection Engineers (SFPE) has developed a strategy for performing a performance-based design for fire protection titled, *SFPE Engineering Guide to Performance-Based Fire Protection* (SFPE 2007).

SFPE was established in 1950 and incorporated as an independent organization in 1971. As of 2018, the society has over 4600 members and 92 chapters, including 17 student chapters worldwide. It is the mission of SFPE to “define, develop, and advance the use of engineering best practices; expanding the scientific and technical knowledge base; and educate the global fire safety community, to reduce fire risk” (SFPE n.d.).

In the guide, SFPE has developed a step-by-step guide to conducting a performance-based design.

**Step 1: Define Project Scope**
Defining the scope of a project should always be the first step in any design project. Without a well-defined scope, it is possible to not fully understand how to accomplish this project and cause errors that could cost money at later stages in the design process. Some of the information needed when defining the scope includes the constraints on the design and the project schedule, building construction and features desired, occupant characteristics, building characteristics, and applicable codes and regulations.

**Step 2: Identify Goals**
Once the objectives of the project are understood, it is easier to define the goals of the project. This should always include the levels of protection for people and property. Other considerations for a goal could be preservation of historical buildings or items, business continuity, and protection of the environment.

**Step 3: Define Objectives**
The objectives of the design project are the design goals with tangible values for evaluation purposes. This could include dollar value loss, loss of life, or any other impacts from a fire event.

**Step 4: Develop Performance Criteria**
This step includes developing the performance criteria that the design will be expected to meet. This is a further refinement of the design objectives and will include items such as tenability limits for life safety. The tenability limits will need to be well-defined and agree upon between all authorities and engineers to continue forward with the project.

**Step 5: Develop Design Fire Scenarios**
This step could include extensive research and a good understanding of the function of the building in which the fire protection features are being design for. By taking the building type and function into consideration, fire scenarios can be derived. This could include expected fuel packages, locations, peak heat release rates, growth rates, and products of combustion. An adequate amount of fire scenarios should be selected to ensure all possible worst-case scenarios have been tested against the fire protection design.
Step 6: Develop Trial Designs
This step is where the actual fire protection features are introduced. Consideration should be given to what the stakeholders and building owners would like within the building. This could include proposed fire protection systems, construction features, and operations. At this step in the design process, an engineering and all approving parties should determine and agree how the evaluation of each fire scenario to each trial design is going to occur. Typical evaluation techniques include hand calculation and computer fire modeling.

Fire protection hand calculations are widely known and used within the fire protection community. While hand calculations are quick and time-efficient, most are empirical correlations and have limitations. Hand calculations are also good for small-scale applications and become too difficult and tedious for large-scale buildings for a performance-based design.

Computer fire modeling has become revenant in the fire protection community for performance-based design. Computer fire models are usually divided into two categories, two-zone models and field models.

Two-zone models divide a computational domain into two zones, typically upper and lower layer within a compartment. Two-zone models have a low computational demand and can be more efficient on small scales but still have limitations. An example of a two-zone model is the Consolidated Model of Fire and Smoke Transport (CFAST), which is a free computer fire model maintained by the National Institute of Standards and Technology (NIST) (NIST n.d.-a).

Field models, also known as computational fluid dynamic (CFD) models, divide the computation into a user-specified number of zones. This allows for adjustments to the number of calculation zones; however, with an increased number of zones comes an increase in computational demand. Many field models exist in industry; one such is named Fire Dynamics Simulator (FDS) and is a free computer fire model maintained by the NIST (NIST n.d.-b).

Step 7: Evaluate Trial Designs
The next step in the design project is testing the chosen fire scenarios against the trial fire protection designs utilizing the chosen evaluation technique. The evaluation technique should provide analytical data that can be used to compare to the performance criteria.

Step 8: Determine if Design Meets Performance Criteria
Any trial fire protection designs that fail to meet the performance criteria for any of the fire scenarios can either be altered to change or increase fire protection features, or other means of fire protection must be considered. If any of the trial fire designs pass the performance criteria for all of the fire scenarios, this design can be deemed adequate to meet all the objectives of the project. However, it is likely none of the trial fire protection designs pass the performance criteria for fire scenarios, and this could be caused by restricting objectives, goals, or performance objectives, too severe of fire scenarios, or even incorrect use of the evaluation method. If no trial fire protection designs pass the performance criteria for all the fire scenarios, these possible restrictions may need to be readdressed, and the process starts over.

Step 9: Select the Final Design and Report
If there are more than one trial fire protection designs that pass the performance criteria for all fire scenarios, then one trial design will need to be selected. With more than one option, this allows the building owner to determine which design best fits their monetary and design needs. All steps of this performance-based design should be documented in a final report. This final report should be approved by additional engineers, authority having jurisdiction (AHJ), and all stakeholders.

Conclusion
Fire protection design is a field in which is very dynamic. New fire hazards and new building designs are always going to keep this field from remaining static. Fire protection professionals
have a few best practices and strategies to achieve adequate fire protection to provide life safety for occupants. The use of national and local building and fire codes provide a generic best practice and strategies to design the fire protection features. If buildings do not fit the mold of the generic codes, it may be more beneficial, or needed, for a fire protection professional to conduct a performance-based design. In order to do so, the fire protection industry has stabled some best practice and strategies in a step-by-step guide to insure success when conducting this type of design. Either strategy should ensure the objectives of the codes and standards are met to ensure things such as life safety, building protection, and environmental protection.

Cross-References

▶ Fire: General Concepts and Definitions
▶ Fire: Prevention, Protection, and Life Safety

References


Further Reading

