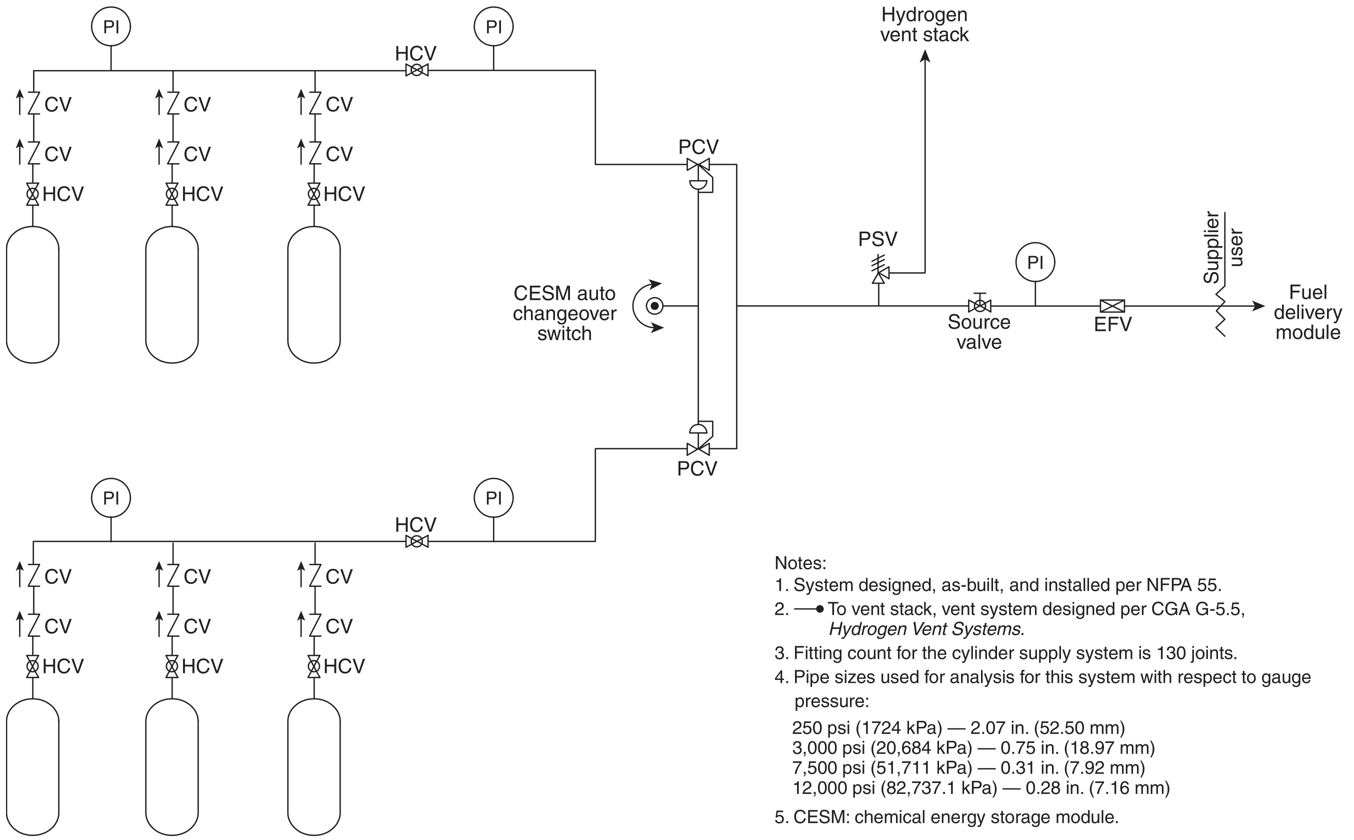



**Δ FIGURE A.3.3.232.2(e) Typical Chemical Energy Storage Module (CESM). [55:Figure A.3.3.95.9.1(e)]**

**A.3.3.247.3 Source Valve.** The source valve is located at a point downstream of a bulk gas supply system and used as the defined point of termination of the bulk supply. It is a point that differentiates between the "supplier" side of the system and what is commonly referred to as the "user" or "customer" side of the system. [**55,** 2020]

**A.3.3.248 Vaporizer.** The outside source of heat can include, but is not limited to, ambient air, steam, thermal fluids (such as water or oil), or other sources that are capable of adding heat to the system.

**A.3.4.7 Exposure Fire.** An exposure fire usually refers to a fire that starts outside a building, such as a wildlands fire or vehicle fire, and that, consequently, exposes the building to a fire. [***101*,** 2018]

**A.3.4.8 Fire Model.** Due to the complex nature of the principles involved, models are often packaged as computer software. Any relevant input data, assumptions, and limitations needed to properly implement the model will be attached to the fire models. [***101*,** 2018]

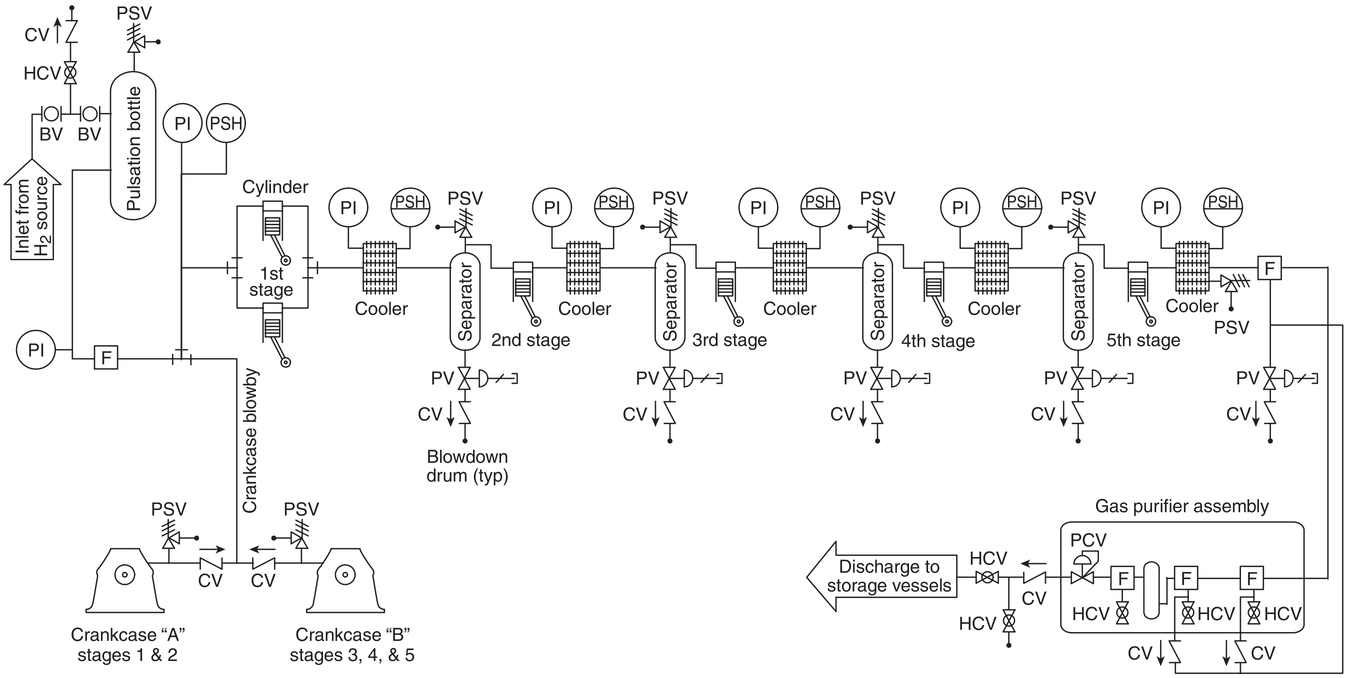
**A.3.4.9 Fire Scenario.** A fire scenario defines the conditions under which a proposed design is expected to meet the fire safety goals. Factors typically include fuel characteristics, ignition sources, ventilation, building characteristics, and occupant locations and characteristics. The term *fire scenario* includes more than the characteristics of the fire itself but excludes design specifications and any characteristics that do not vary from one fire to another; the latter are called assumptions. The term *fire scenario* is used here to mean only those specifications required to calculate the fire's development and effects, but, in other contexts, the term might be used to mean both the initial specifications and the subsequent development and effects (i.e., a complete description of fire from conditions prior to ignition to conditions following extinguishment). [***101*,** 2018]

**A.3.4.14 Performance Criteria.** Performance criteria are stated in engineering terms. Engineering terms include temperatures, radiant heat flux, and levels of exposure to fire products. Performance criteria provide threshold values used to evaluate a proposed design. [***101*,** 2018]

**A.3.4.15 Proposed Design.** The design team might develop a number of trial designs that will be evaluated to determine whether they meet the performance criteria. One of the trial designs will be selected from those that meet the performance criteria for submission to the authority having jurisdiction as the proposed design. [***101*,** 2018]

The proposed design is not necessarily limited to fire protection systems and building features. It also includes any component of the proposed design that is installed, established, or maintained for the purpose of life safety, without which the proposed design could fail to achieve specified performance criteria. Therefore, the proposed design often includes emergency procedures and organizational structures that are needed to meet the performance criteria specified for the proposed design. [***101*,** 2018]

**A.3.4.20.1 Design Specification.** Design specifications include both hardware and human factors, such as the conditions produced by maintenance and training. For purposes of




Notes:
1. System designed, as-built, and installed per NFPA 55.
2. —• To vent stack, vent system designed per CGA G-5.5, *Hydrogen Vent Systems.*
3. Fitting count for the compression system is 225 joints.
4. Pipe sizes used for analysis for this system with respect to gauge pressure:
   250 psi (1724 kPa) — 2.07 in. (52.50 mm)
   3,000 psi (20,684 kPa) — 0.75 in. (18.97 mm)
   7,500 psi (51,711 kPa) — 0.31 in. (7.92 mm)
   12,000 psi (82,737.1 kPa) — 0.28 in. (7.16 mm)

**Δ FIGURE A.3.3.232.2(f) Typical Compressor Module. [55:Figure A.3.3.95.9.1(f)]**

performance-based design, the design specifications of interest are those that affect the ability of the building to meet the stated goals and objectives. [**5000,** 2018]

**A.4.1.2** Zoning codes in some jurisdictions will determine whether a proposed use is permitted. In some jurisdictions, the installation of bulk hydrogen systems might not be permitted in densely populated areas or in other than industrial zones. Local zoning regulations will dictate requirements, and users are responsible for determining the limitations of zoning regulations on a case-by-case basis.

**A.4.1.3** Permits for construction of facilities, whether indoors or outdoors, will vary based on jurisdictional requirements. Not all jurisdictions require permits. Some jurisdictions might require permits for hydrogen, others might require permits for the operation of certain equipment. The local fire prevention code or adopted building code might require permits, depending on the operation or the facility to be constructed. Users are responsible for determining whether permits are required and for meeting the requirements on a case-by-case basis.

**A.4.2** The overall goals of this code are presented in 4.2.1. These overall goals are treated in greater depth in 4.2.3 through 4.2.5. In each of these subsections, an overall goal for the subsection is defined, specific goals relating to the overall goal are presented next, and the objectives that relate to the specific goal follow. This format is intended to enhance the usability of the code.

**A.4.2.1** These highest level goals are intentionally general in nature. Each includes a broad spectrum of topics as shown in 4.2.3. The property protection goal is not just a goal unto itself, as it is also achieved in part as a result of designing to achieve the other stated goals. A reasonable level of safety is further defined by subsequent language in the Code. The facility/property owner or an insurance representative might also have other goals, which might necessitate more stringent objectives as well as more demanding criteria. [**1:**A.4.1.1]

**A.4.2.2** The objectives apply regardless of which option a user of the Code selects for a design — the performance-based option or the prescriptive-based option. The objectives are stated in more specific terms than the goals and tend to be more quantitative. The goals and objectives, taken together, form the broad, general targets at which a performance-based design can take aim. Specific criteria for design follow in Chapter 5. [**1:**A.4.1.2]

**A.4.2.3** The concept of providing for safety applies not only to safety during a fire, explosion, or hazardous materials incident, but also during the normal use of a building or facility. A reasonable level of safety should be provided for occupants in and individuals near the facility or building in question. The resultant design in addition to providing for occupant's safety also promotes the public welfare. Public welfare is also provided as a result of the mission continuity provisions of this Code. [**1:**A.4.1.3]

**A.4.2.3.1.1** The phrase *reasonably safe* from fire is defined by subsequent language in this Code, primarily in the objectives. [**1:**A.4.1.3.1.1]

**A.4.2.3.1.2.2** In many cases, the provisions of the Code to provide safety for occupants satisfies this goal for protection of emergency responders. [**1:**A.4.1.3.1.2.2]

**A.4.2.3.1.2.5** This provision addresses the fire safety objectives of operations addressed elsewhere in the Code, such as hot work, tar kettle operation, and so forth, that are not directly related to building construction and use. [**1:**A.4.1.3.1.2.5]

**A.4.2.3.2.1** The phrase *reasonably safe during normal use* is defined by subsequent language in this Code, primarily in the objectives. Certain requirements, such as heights of guards and stair dimensions, are provided to ensure that the occupants are safe during nonemergency use of the buildings. Failure to address these features could result in falls or other injuries to occupants in their normal day-to-day activities in the building. [**1:**A.4.1.3.2.1]

**A.4.2.3.3** The focus of NFPA 2 is on hydrogen. However, this should not detract from the overall safety goal of reducing the hazards from exposure to or mishap with other hazardous materials. For example, hydrogen can be generated from natural gas or ammonia. One cannot disregard the hazards of these materials and focus solely on the hazards of hydrogen. It is not intended that NFPA 2 be used as the sole means to regulate the broad category of hazardous materials. For additional information on hazardous materials refer to the adopted fire prevention code or other referenced codes and standards. See Section 2.2 and Annex N for additional information.

**A.4.2.3.3.2.2** For item 3, the phrase *external force* refers to the application of factors such as heat, water, shock, or other phenomenon onto hazardous materials that are sensitive to such factors and could react vigorously to produce unsafe conditions. [**1:**A.4.1.3.3.2.2]

**A.4.2.4.2.1** Ignition occurs when combustible materials come into contact with a source of heat of sufficient temperature and power for a requisite time in an atmosphere where oxygen is present. Combustible material does not necessarily ignite immediately upon contact with a source of heat. [**1:**A.4.1.4.2.1]

**A.4.2.4.2.2** Examples of specific conditions to avoid include, but are not limited to, flashover, fire spread beyond the item or room of fire origin, overheating of equipment, and overpressure of exterior walls. [**1:**A.4.1.4.2.2]

**A.4.2.5.1** This goal is applicable to certain buildings and facilities that have been deemed to be necessary to the continued welfare of a community. Depending on the nature of the critical mission provided by the building, various stakeholders, including community leaders, AHJs, and owners will identify the mission critical buildings. Mission critical areas should be identified and appropriately protected. The objectives for property protection and mission continuity are sometimes difficult to differentiate. Achieving the objectives for property protection could, to a certain extent, accomplish the objectives for mission continuity. [**1:**A.4.1.5.1]

**A.4.2.5.2** Examples of buildings and facilities that provide a public welfare role for a community could include hospitals, police and fire stations, evacuation centers, schools, water and sewerage facilities, and electrical generating plants. Also included are buildings and facilities with significant impact on the economic viability of the community. This objective is intended to ensure that such buildings and facilities are capable of providing essential services following a disaster since the community's well-being depends on such service being available. [**1:**A.4.1.5.2]

**A.4.3.1** Additional assumptions that need to be identified for a performance-based design are addressed in Chapter 5. [**1:**A.4.2.1]

**A.4.3.2** It is not assumed that a design scenario will be considered that simulates the hazards produced when unauthorized releases of hazardous materials occur simultaneously at different locations within a facility, unless it is reasonable to expect that a single incident, such as a fork lift accident or pipe failure, could be expected to create such a condition. However, when hazardous materials are in close proximity to one another, such as on a shelf or in adjacent storage cabinets, it could be reasonable to apply a design scenario where multiple releases of the hazardous materials occur simultaneously from these close proximity areas. In this case, it is not unreasonable to expect the shelf to collapse or a forklift to damage adjacent hazardous materials containers. [**1:**A.4.2.2]

**A.4.3.3** It is not assumed that a design scenario will be considered that simulates the hazards produced when a fire, explosion, or external force that creates a dangerous condition occurs at the same time that hazardous materials have been subject to an unauthorized release. This does not preclude considering a scenario where a fire or explosion occurs and impinges on hazardous materials that are in their normal storage, use, or handling conditions. [**1:**A.4.2.3]

The phrase *external force that creates a dangerous condition* refers to the application of factors such as heat, water, shock, or other phenomenon onto hazardous materials that are sensitive to such factors and could react vigorously to produce unsafe conditions. [**1:**A.4.2.3]

**A.4.8** Out-of-service systems should not be abandoned in place. Systems that remain out of service should be maintained in a usable condition to ensure that the appropriate safeguards are in place. Permits should be maintained in a current state so that the AHJ remains aware of the installation until such time that the system is removed. [**55:**A.4.4]

***N*** **A.4.9.2** See Section C.2 of NFPA 400 for a model hazardous materials inventory statement (HMIS).

**A.4.10.1** $GH_2$ and $LH_2$ releases do not currently require the issuance of environmental permits. The release of $GH_2$ and $LH_2$ creates potential safety concerns that are addressed by this code but are not likely to negatively impact the environment.

**A.4.10.3** The discharges recorded as unauthorized are those that are prohibited by 4.10.1 or that are catastrophic or that occur beyond the design of the system. This is not intended to include releases that are part of the design of the system, such as normal venting and operations.



Shaded text = Revisions. Δ = Text deletions and figure/table revisions. • = Section deletions. *N* = New material.

**A.4.11** The hazard potential of a facility is not dependent on any single factor. Physical size, number of employees, and the quantity and the nature of the hazardous materials are important considerations. The level of training can vary with the complexity of the facility under consideration. [**400:**A.6.1.4]

**A.4.11.4** Emergency responders can include on-site personnel that have been designated and trained to respond to emergencies, persons from the public sector such as fire department personnel, or persons from the private sector that can be contracted or otherwise engaged to perform emergency response duties. *(See Annex I in NFPA 400 for additional information.)* [**400:**A.6.1.4.4]

**A.4.11.4.1** OSHA describes an Incident Command System as a standardized on-scene incident management concept designed specifically to allow responders to adopt an integrated organizational structure equal to the complexity and demands of any single incident or multiple incidents without being hindered by jurisdictional boundaries. [**400:**A.6.1.4.4.1]

**A.4.11.4.2** Responses to releases of hazardous materials where there is no potential safety or health hazard such as fire, explosion, or chemical exposure are not considered emergency responses as defined within the context of this code. [**400:**A.6.1.4.4.2]

**A.4.11.4.3** Emergency response training will vary depending on the level of emergency response required and by the requirements of the governmental agency. [**400:**A.6.1.4.4.3]

*N* **A.4.13.1.1** An example of a nationally recognized standard for signage is the ANSI Z535 series for safety signs, colors, and symbols. This series includes ANSI Z535.1, *Safety Colors*; ANSI Z535.2, *Environmental Facility and Safety Signs*; ANSI Z535.3, *Criteria for Safety Symbols*; ANSI Z535.4, *Product Safety Signs and Labels*; ANSI Z535.5, *Safety Tags and Barricade Tapes (for Temporary Hazards)*; and ANSI Z535.6, *Product Safety Information in Product Manuals, Instructions, and Other Collateral Materials.*

**A.4.13.2.1(4)** Such locations could include vaults and other systems located underground.

**A.4.14.1.1(1)** The term *tank* is used in a generic way. All pressure vessels should be included in this requirement.

**A.4.15** The term *materials* used throughout this section applies to building construction materials and not to hazardous materials, compressed gases, or cryogenic fluids. [**55:**A.4.12]

**A.4.15.1** The provisions of 4.15.1 do not require inherently noncombustible materials to be tested in order to be classified as noncombustible materials. [***101*:**A.4.6.13]

**A.4.15.1(1)** Examples of such materials include steel, concrete, masonry, and glass. [***101*:**A.4.6.13.1(1)]

**A.4.15.2** Materials subject to increase in combustibility or flame spread index beyond the limits herein established through the effects of age, moisture, or other atmospheric condition are considered combustible. (See NFPA 259 and NFPA 220). [***101*:**A.4.6.14]

**A.5.1** The performance option of this code establishes acceptable levels of risk for facilities (i.e., buildings and other structures and the operations therewith associated) as addressed in Section 1.3. (Note that "facility" and "building" can be used interchangeably with facility being the more general term.) While the performance option of this code does contain goals, objectives, and performance criteria necessary to provide for an acceptable level of risk, it does not describe how to meet these goals, objectives, and performance criteria. Design and engineering are needed to meet the provisions of Chapter 5. For fire protection designs, the *SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings* provides a framework for these assessments. [**1:**A.5.1]

Pre-construction design requirements address those issues, which have to be considered before the certificate of occupancy is issued for a facility. [**1:**A.5.1]

**A.5.1.3** Qualifications should include experience, education, and credentials that demonstrate knowledgeable and responsible use of applicable models and methods. [**1:**A.5.1.3]

Δ **A.5.1.4** The *SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings* outlines a process for using a performance-based approach in the design and assessment of building fire safety design and identifies parameters that should be considered in the analysis of a performance-based design. As can be seen this process requires the involvement of all stakeholders who have a share or interest in the successful completion of the project. The steps that are recommended by the *SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings* for this process are shown in Figure A.5.1.4. [**1:**A.5.1.4]

The guide specifically addresses building fire safety performance-based design. It might not be directly applicable to performance-based designs involving other systems and operations covered within this code, such as hot work operations or hazardous materials storage. However, the various steps for defining, developing, evaluating, and documenting the performance-based design should still provide a useful framework for the overall design process. [**1:**A.5.1.4]

The steps in the performance-based design process are as follows: [**1:**A.5.1.4]

(1) *Step 1: Defining Project Scope.* The first step in a performance-based design is to define the scope of the project. Defining the scope consists of identifying and documenting the following:
    (a) Constraints on the design and project schedule
    (b) The stakeholders associated with project
    (c) The proposed building construction and features desired by the owner or tenant
    (d) Occupant and building characteristics
    (e) The intended use and occupancy of the building
    (f) Applicable codes and regulations
    An understanding of these items is needed to ensure that a performance-based design meets the stakeholders' needs.
(2) *Step 2: Identifying Goals.* Once the scope of the project is defined, the next step in the performance-based design process is to identify and document the fire safety goals of various stakeholders. Fire safety goals could include levels of protection for people and property, or they could provide for continuity of operations, historical preservation, and environmental protection. Goals could be unique for different projects, based on the stakeholders needs and desires. The stakeholders should discuss which goals are the most important for the project. In order to avoid problems later in the design process, all stakeholders should be aware of and agree to the goals

prior to proceeding with the performance-based design process (*see Step 7*).

(3) *Step 3: Defining Stakeholder and Design Objectives.* The third step in the design process is to develop objectives. The objectives are essentially the design goals that are further refined into tangible values that can be quantified in engineering terms. Objectives could include mitigating the consequences of a fire expressed in terms of dollar values, loss of life, or other impact on property operations, or maximum allowable conditions, such as extent of fire spread, temperature, spread of combustion products, and so forth.

(4) *Step 4: Developing Performance Criteria.* The fourth step in the design process is the development of performance criteria to be met by the design. These criteria are a further refinement of the design objectives and are numerical values to which the expected performance of the trial designs can be compared. Performance criteria could include threshold values for temperatures of materials, gas temperatures, carboxyhemoglobin (COHb) levels, smoke obscuration, and thermal exposure levels.

(5) *Step 5: Developing Design Scenarios.* Once the performance criteria have been established, the engineer will develop and analyze design alternatives to meet performance criteria. The first part of this process is the identification of possible scenarios and design scenarios. Fire scenarios are descriptions of possible fire events, and consist of fire characteristics, building characteristics (including facility operations), and occupant characteristics. The fire scenarios identified will subsequently be filtered (i.e., combined or eliminated) into a subset of design fire scenarios against which trial designs will be evaluated. Hazardous materials scenarios can be treated similarly.

(6) *Step 6: Developing Trial Design(s).* Once the project scope, performance criteria, and design scenarios are established, the engineer develops preliminary designs, referred to as trial designs, intended to meet the project requirements. The trial design(s) include proposed fire protection systems, construction features, and operation that are provided in order for a design to meet the performance criteria when evaluated using the design fire scenarios. The evaluation method should also be determined at this point. The evaluation methods used should be appropriate for the situation and agreeable to the stakeholders.

(7) *Step 7: Developing a Fire Protection Engineering Design Brief.* At this point in the process a fire protection engineering design brief should be prepared and provided to all stakeholders for their review and concurrence. This brief should document the project scope, goals, objectives, trial designs, performance criteria, design fire scenarios, and analysis methods. Documenting and agreeing upon these factors at this point in the design process will help avoid possible misunderstandings later.

(8) *Step 8: Evaluating Trial Designs.* Each trial design is then evaluated using each design scenario. The evaluation results will indicate whether the trial design will meet the performance criteria. Only trial design(s) that meet the performance criteria can be considered as final design proposals. Yet, the performance criteria can be revised with the stakeholders' approval. The criteria cannot be arbitrarily changed to ensure that a trial design meets a criterion, but can be changed based on additional analysis and the consideration of additional data.

(9) *Step 9: Modifying Designs or Objectives.* If none of the trial designs evaluated comply with the previously agreed upon performance criteria, it could be necessary to either develop and evaluate new trial designs, or revisit the objectives and performance criteria previously agreed upon by the stakeholders to determine if stakeholder objectives and performance criteria should be modified.

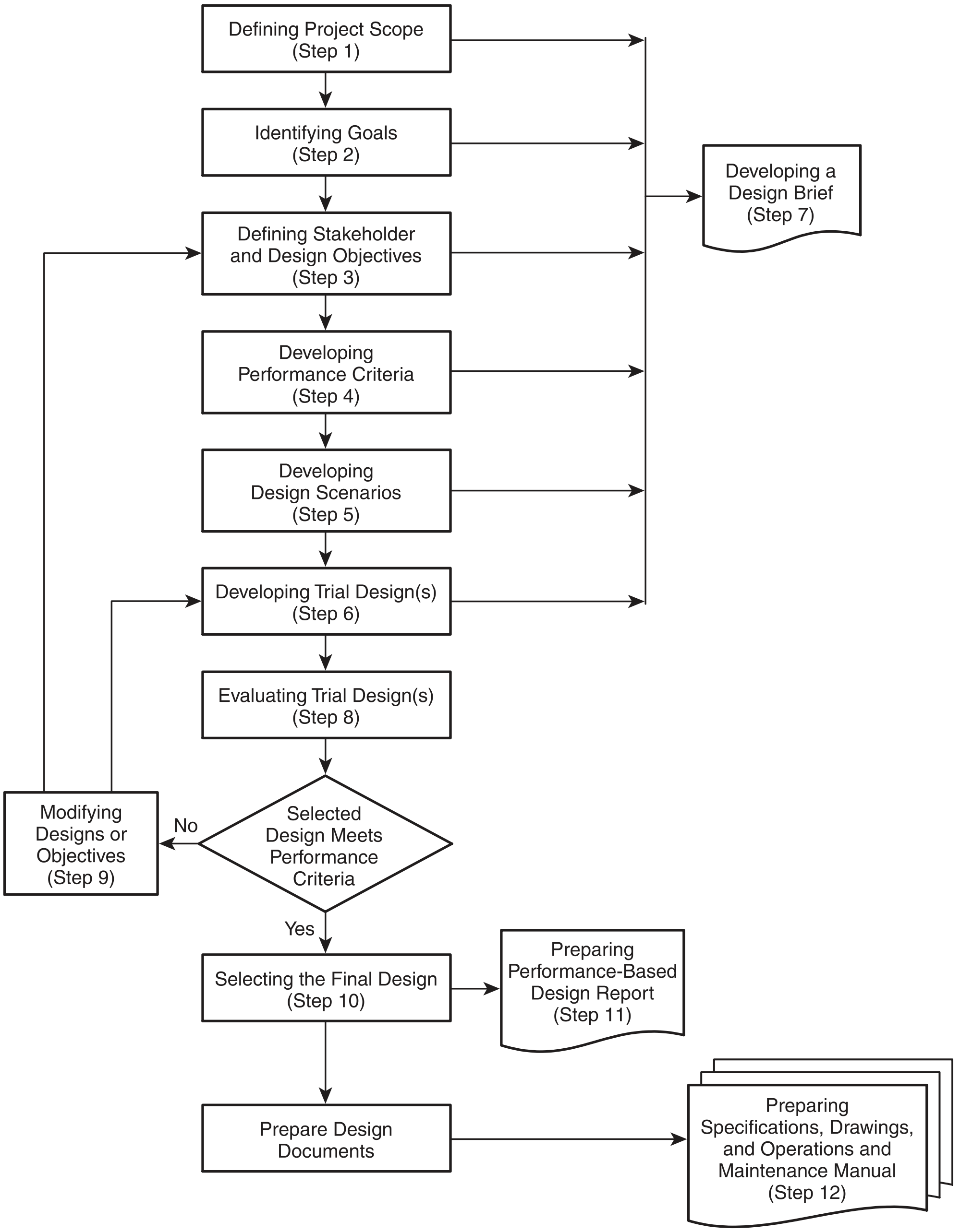
(10) *Step 10: Selecting the Final Design.* Once an acceptable trial design is identified using the evaluation, it can be considered for the final project design. If multiple trial designs are evaluated, further analysis will be needed to select a final design. The selection of an acceptable trial design for the final design could be based on a variety of factors, such as financial considerations, timeliness of installation, system and material availability, ease of installation, maintenance and use, and other factors.

(11) *Step 11: Preparing Performance-Based Design Report.* Once the final design is identified, design documents need to be prepared. Proper documentation will ensure that all stakeholders understand what is necessary for the design implementation, maintenance, and continuity of the fire protection design. The documentation should include the fire protection engineering design brief, a performance design report, detailed specifications and drawings, and a facility operations and maintenance manual.

(12) *Step 12: Preparing Specifications, Drawings, and Operations and Maintenance Manual.* The specifications and drawings portion of the performance-based design report convey to building and system designers and installing contractors how to implement the performance design. Specifications and drawings could include required sprinkler densities, hydraulic characteristics and spacing requirements, the fire detection and alarm system components and programming, special construction requirements including means of egress and location of fire-resistive walls, compartmentation, and the coordination of interactive systems. The detailed specifications are the implementation document of the performance-based design report. The detailed drawings will graphically represent the results of the performance design. The Operations and Maintenance (O&M) Manual clearly states the requirement of the facility operator to ensure that the components of the performance design are in place and operating properly. The O&M Manual describes the commissioning requirements and the interaction of the different systems' interfaces. All subsystems are identified, and inspection and testing regimes and schedules are created.

[**1:**A.5.1.4]

The O&M Manual also gives instruction to the facility operator on restrictions placed on facility operations. These limitations are based on the engineering assumptions made during the design and analysis. These limiting factors could include critical fire load, sprinkler design requirements, building use and occupancy, and reliability and maintenance of systems. The O&M Manual can be used to communicate to tenants and occupants these limits and their responsibilities as a tenant. It could also be used as a guide for renovations and changes. It also can be used to document agreements between stakeholders. [**1:**A.5.1.4]




Δ **FIGURE A.5.1.4 Steps in the Performance-Based Analysis and the Conceptual Design Procedure for Fire Protection Design. [1:Figure A.5.1.4]**

**A.5.1.5** A third-party reviewer is a person or group of persons chosen by the AHJ to review proposed performance-based designs. Qualifications of the third-party reviewer should include experience, education, and credentials that demonstrate knowledgeable and responsible use of applicable models and methods. [**1:**A.5.1.5]

**A.5.1.8** See Step 12 of A.5.1.4 for a description of these documents. [**1:**A.5.1.8]

Δ **A.5.1.9** Information that could be needed by the fire service arriving at the scene of a fire in a performance-based designed facility includes, but is not limited to, the following:

(1) Safe shutdown procedures of equipment and processes
(2) Facility personnel responsible for assisting the fire service
(3) Operating procedures required to maintain the effectiveness of the performance-based designed fire protection system: when it is and is not appropriate to alter, shut down, or turn off a design feature; assumptions that have to be maintained if a fire occurs; suggested fire-fighting tactics that relate to the specific nature of the performance-based design.

[**1:**A.5.1.9]

The design specifications and O&M Manual documentation described in 5.1.8 should provide a guide for the facility owner and tenants to follow in order to maintain the required level of safety anticipated by the original design. It should also provide a guide for the AHJ to use in conducting ongoing inspections of the facility. [**1:**A.5.1.9]

Δ **A.5.1.10** Continued compliance with the goals and objectives of the code involves many factors. The building construction, including openings, interior finish, and fire- and smoke-resistive construction, and the building and fire protection systems need to retain at least the same level of performance as is provided for by the original design parameters. The use and occupancy should not change to the degree that assumptions made about the occupant characteristics, combustibility of furnishings, and existence of trained personnel are no longer valid. In addition, actions provided by other personnel, such as emergency responders, should not be diminished below the documented assumed levels. Also, actions needed to maintain reliability of systems at the anticipated level need to meet the initial design criteria. [**1:**A.5.1.10]

Subsection 5.1.10 deals with issues that arise after the facility has been constructed and a certificate of occupancy has been issued. Therefore, any changes to the facility or the operations conducted therein, up to and including the demolition of the facility that affect the assumptions of the original design are considered as part of the management of change. [**1:**A.5.1.10]

The following is a process for evaluating performance-based facilities:

(1) Review of original design analysis and documentation as follows:
    (a) Assumptions
    (b) Input parameter values
    (c) Predictions and/or results of other calculations
(2) Review of design analysis and documentation for any subsequent renovations, additions, modifications, and so forth, as in Step 1 of A.5.1.4
(3) Review of the facility's operations and maintenance manual, including any and all revisions to it
(4) On-site inspection, involving the following:
    (a) Consideration of "prescriptive" issues (e.g., blocked egress paths, poor maintenance of systems)
    (b) Comparison of assumptions to specific, pertinent on-site conditions
    (c) Comparison of input parameter values to pertinent on-site conditions
    (d) Review of maintenance and testing documentation to ensure adherence to the schedules detailed in the facility's O&M Manual
(5) Reconciliation of discrepancies as follows:
    (a) Develop a list of discrepancies
    (b) Consultation with the facility owner and/or their representative
    (c) Preparation of a schedule that reconciles the discrepancies

[**1:**A.5.1.10]

**A.5.1.11** Private fire inspection services can be used to meet this provision provided that they are qualified to assess the impact of changes on the performance-based design and assumptions. [**1:**A.5.1.11]

**A.5.2.2** The performance criteria in 5.2.2 define an acceptable level of performance that should be agreed upon by the stakeholders, including the owner and the AHJ. The acceptable level of performance can vary widely between different facilities based on a number of factors, including the existence of potential ignition sources, potential fuel loads present, reactivity and quantity of hazardous materials present, the nature of the operations conducted at the facility, and the characteristics and number of personnel likely to be present at the facility. [**1:**A.5.2.2]

**A.5.2.2.1** Many of the performance criteria related to safety from fire can also be found in the annex of NFPA *101*. [**1:**A.5.2.2.1]

**A.5.2.2.2** It is anticipated that the design provides protection for occupants who are not intimate with the initial unintentional detonation or deflagration of explosive materials, and individuals immediately adjacent to the property. It is recognized that employees should be trained and knowledgeable in the hazards of the materials present in the workplace. It is recognized that some of these individuals could experience psychological and physical injuries, such as hearing problems, on either a short- or long-term basis. However, the intent is that they do not experience thermal burns or loss of life or limb as a direct result of the explosion. [**1:**A.5.2.2.2]

It is not the intent of the code to provide protection against explosions caused by acts of terrorism. This would involve the introduction of an unknown quantity of explosives in an unknown location within or adjacent to a building. Where protection is needed against such acts of terrorism, the appropriate military and law enforcement agencies should be consulted. [**1:**A.5.2.2.2]

**A.5.2.2.3** Given the nature and variety of hazardous materials, more than one performance criterion for a specific facility could need to be developed. Criteria have to be developed for each hazardous material and possibly for different personnel; for example, higher levels of exposure can be tolerated by personnel that are in some way protected than those personnel having no protection. Development of performance criteria for hazardous materials should be developed by the facility owner and the facility's safety personnel in conjunction with the AHJ and the emergency response personnel expected to respond to an incident. [**1:**A.5.2.2.3]

It is anticipated that the design provides protection for occupants inside or immediately adjacent to the facility who are not intimate with the initial unauthorized release of hazardous materials, or the initial unintentional reaction of hazardous materials. However, it is assumed that these individuals depart from the area of the incident in a time frame reasonable for their circumstances, based on their observation of the event, or some other form of notification. [**1:**A.5.2.2.3]

It is also anticipated that employees and emergency response personnel are trained and aware of the hazardous materials present in the facility, and the potential consequences of their involvement in the incident, and take appropriate measures to ensure their own safety during search and rescue operations. [**1:**A.5.2.2.3]

It is not the intent of the code to provide protection against acts of terrorism involving the introduction of hazardous materials into a facility. This involves the introduction of an unknown quantity of materials in an unknown location within or adjacent to a building. Where protection is needed against such acts of terrorism, the appropriate military and law enforcement agencies should be consulted. [**1:**A.5.2.2.3]

**A.5.2.2.4** Each facility designed using a performance-based approach most likely has different levels of acceptable and unacceptable property damage. This reflects the unique aspects of the performance-based designed facility and the reasons for pursuing a performance-based design. Therefore, the definition of an acceptable and an unacceptable level of property damage results from discussions between the facility's owner, manager and engineer, the designer, (possibly) the insurance underwriter and field engineer, and the AHJ. There could be cases where a property damage criterion is not needed. [**1:**A.5.2.2.4]

Note that the structural integrity performance criteria for property damage most likely differs from the structural integrity performance criteria for life safety. This reflects the difference in the associated objectives: a life safety criterion probably is more restrictive than one for property damage. [**1:**A.5.2.2.4]

**A.5.2.2.5** Each facility designed using a performance-based approach most likely has a different level of acceptable and unacceptable interruption of the facility's mission. This reflects the unique aspects of the performance-based designed facility and the reasons for pursuing a performance-based design. Therefore, the definition of an acceptable and an unacceptable interruption of the facility's mission results from discussions between the facility's owner, manager and engineer, the designer, (possibly) the insurance underwriter and field engineer, and the AHJ. There could be cases where a mission continuity criterion is not needed. [**1:**A.5.2.2.5]

**A.5.4** Many events can occur during the life of a facility; some have a higher probability of occurrence than others. Some events, though not typical, could have a devastating effect on the facility. A reasonable design should be able to achieve the goals, objectives, and performance criteria of this Code for any typical or common design scenario and for some of the non-typical, potentially devastating scenarios, up to some level commensurate with society's expectations as reflected in this Code. [**1:**A.5.4]

The challenge in selecting design scenarios is finding a manageable number that are sufficiently diverse and representative so that, if the design is reasonably safe for those scenarios, it should then be reasonably safe for all scenarios, except for those specifically excluded as being unrealistically severe or sufficiently infrequent to be fair tests of the design. [**1:**A.5.4]

**A.5.4.1.2** The *SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings* identifies methods for evaluating fire scenarios. [**1:**A.5.4.1.2]

**A.5.4.1.3** It is desirable to consider a wide variety of different design scenarios to evaluate the complete capabilities of the building or structure. Design scenarios should not be limited to a single or a couple of worst-case events. [**1:**A.5.4.1.3]

Δ **A.5.4.2** Building construction including requirements for life safety affecting the egress system should be in accordance with the adopted building code. In the absence of requirements established by the adopted building code, considerations regarding design scenarios affecting matters of construction and/or egress related to fire can include the following:

*Fire Design Scenario 1.* Fire Design Scenario 1 involves an occupancy-specific design scenario representative of a typical fire for the occupancy.

This design scenario should explicitly account for the following:

(1) Occupant activities
(2) Number and location of occupants
(3) Room size
(4) Furnishings and contents
(5) Fuel properties and ignition sources
(6) Ventilation conditions

[**1:**5.4.2.1.1]

The first item ignited and its location should be explicitly defined.

An example of such a scenario for a health care occupancy involves a patient room with two occupied beds with a fire initially involving one bed and the room door open. This is a cursory example in that much of the explicitly required information indicated in A.5.4.2 can be determined from the information provided in the example. Note that it is usually necessary to consider more than one scenario to capture the features and conditions typical of an occupancy.

*Fire Design Scenario 2.* Fire Design Scenario 2 involves an ultrafast-developing fire in the primary means of egress with interior doors open at the start of the fire. This design scenario should address the concern regarding a reduction in the number of available means of egress.

Examples of such scenarios are a fire involving ignition of gasoline as an accelerant in a means of egress, clothing racks in corridors, renovation materials, or other fuel configurations that can cause an ultrafast fire. The means of egress chosen is the doorway with the largest egress capacity among doorways normally used in the ordinary operation of the building. The baseline occupant characteristics for the property are assumed. At ignition, doors are assumed to be open throughout the building.

*Fire Design Scenario 3.* Fire Design Scenario 3 involves a fire that starts in a normally unoccupied room that can potentially endanger a large number of occupants in a large room or other area. This design scenario should address the concern regarding a fire starting in a normally unoccupied room and migrating into the space that can, potentially, hold the greatest number of occupants in the building.

An example of such a scenario is a fire in a storage room adjacent to the largest occupiable room in the building. The contents of the room of fire origin are specified to provide the largest fuel load and the most rapid growth in fire severity consistent with the normal use of the room. The adjacent occupiable room is assumed to be filled to capacity with occupants. Occupants are assumed to be somewhat impaired in whatever form is most consistent with the intended use of the building. At ignition, doors from both rooms are assumed to be open. Depending on the design, doorways connect the two rooms or they connect via a common hallway or corridor. [**1:**A.5.4.2.3]

For purposes of this scenario, an occupiable room is a room that could contain people (i.e., a location within a building where people are typically found). [**1:**A.5.4.2.3]

*Fire Design Scenario 4.* Fire Design Scenario 4 involves a fire that originates in a concealed wall or ceiling space adjacent to a large occupied room. This design scenario should address the concern regarding a fire originating in a concealed space that does not have either a detection system or suppression system and then spreading into the room within the building that can, potentially, hold the greatest number of occupants.

An example of such a scenario is a fire originating in a concealed wall or ceiling space adjacent to a large, occupied function room. Ignition involves concealed combustibles, including wire or cable insulation and thermal or acoustical insulation. The adjacent function room is assumed to be occupied to capacity. The baseline occupant characteristics for the property are assumed. At ignition, doors are assumed to be open throughout the building. [**1:**A.5.4.2.4]

*Fire Design Scenario 5.* Fire Design Scenario 5 involves a slow-developing fire, shielded from fire protection systems, in close proximity to a high occupancy area. This design scenario should address the concern regarding a relatively small ignition source causing a significant fire.

An example of such a scenario is a cigarette fire in a trash can. The trash can is close enough to room contents to ignite more substantial fuel sources but is not close enough to any occupant to create an intimate-with-ignition situation. If the intended use of the property involves the potential for some occupants to be incapable of movement at any time, then the room of origin is chosen as the type of room likely to have such occupants, filled to capacity with occupants in that condition. If the intended use of the property does not involve the potential for some occupants to be incapable of movement, then the room of origin is chosen to be an assembly or function area characteristic of the use of the property, and the trash can is placed so that it is shielded by furniture from suppression systems. At ignition, doors are assumed to be open throughout the building. [**1:**A.5.4.2.5]

*Fire Design Scenario 6.* Fire Design Scenario 6 involves the most severe fire resulting from the largest possible fuel load characteristic of the normal operation of the building. This design scenario should address the concern regarding a rapidly developing fire with occupants present.

An example of such a scenario is a fire originating in the largest fuel load of combustibles possible in normal operation in a function or assembly room or in a process/manufacturing area, characteristic of the normal operation of the property. The configuration, type, and geometry of the combustibles are chosen so as to produce the most rapid and severe fire growth or smoke generation consistent with the normal operation of the property. The baseline occupant characteristics for the property are assumed. At ignition, doors are assumed to be closed throughout the building. [**1:**A.5.4.2.6]

This scenario includes everything from a big couch fire in a small dwelling to a rack storage fire in combustible liquids stock in a big box retail store. [**1:**A.5.4.2.6]

*Fire Design Scenario 7.* Fire Design Scenario 7 involves an outside exposure fire. This design scenario should address the concern regarding a fire starting at a location remote from the area of concern and either spreading into the area, blocking escape from the area, or developing untenable conditions within the area.

An example of such a scenario is an exposure fire. The initiating fire is the closest and most severe fire possible consistent with the placement and type of adjacent properties and the placement of plants and combustible adornments on the property. The baseline occupant characteristics of the property are assumed. [**1:**A.5.4.2.7]

This category includes wildland/urban interface fires and exterior wood shingle problems, where applicable. [**1:**A.5.4.2.7]

*Fire Design Scenario 8.* Fire Design Scenario 8 involves a fire originating in ordinary combustibles in a room or area with each passive or active fire protection system or feature independently rendered ineffective. This set of design scenarios should address concerns regarding each fire protection system or fire protection feature, considered individually, being unreliable or becoming unavailable. This scenario should not be required to be applied to fire protection systems or features for which both the level of reliability and the design performance in the absence of the system are acceptable to the AHJ.

This scenario addresses a set of conditions with a typical fire originating in the building with any one passive or active fire protection system or feature being ineffective. Examples include unprotected openings between floors or between fire walls or fire barrier walls, rated fire doors that fail to close automatically or are blocked open, sprinkler system water supply that is shut off, fire alarm system that's nonoperative, smoke management system that is not operational, or automatic smoke dampers that are blocked open. This scenario should represent a reasonable challenge to the other building features provided by the design and presumed to be available. [**1:**A.5.4.2.8]

The exemption from Fire Design Scenario 8 is applied to each active or passive fire protection system individually and requires two different types of information to be developed by analysis and approved by the AHJ. System reliability is to be analyzed and accepted. Design performance in the absence of the system is also to be analyzed and accepted, but acceptable performance does not require fully meeting the stated goals and objectives. It might not be possible to meet fully the goals and objectives if a key system is unavailable, and yet no system is totally reliable. The AHJ determines which level of performance, possibly short of the stated goals and objectives, is acceptable, given the very low probability (that is, the system's unreliability probability) that the system will not be available. [**1:**A.5.4.2.8]

Δ **A.5.4.4** Design hazardous materials scenarios should explicitly account for the following:

(1) Occupant activities, training, and knowledge
(2) Number and location of occupants
(3) Discharge location and surroundings
(4) Hazardous materials' properties
(5) Ventilation, inerting, and dilution systems and conditions
(6) Normal and emergency operating procedures
(7) Safe shutdown and other hazard mitigating systems and procedures
(8) Weather conditions affecting the hazard
(9) Potential exposure to off-site personnel

[**1:**A.5.4.4]

Design hazardous materials scenarios should be evaluated as many times as necessary by varying the factors previously indicated. Design hazardous materials scenarios could need to be established for each different type of hazardous material stored or used at the facility. [**1:**A.5.4.4]

**A.5.4.4.4.2** This provision should be applied to each protection system individually and requires two different types of information to be developed by analysis and approved by the AHJ. System reliability is to be analyzed and accepted. Design performance in the absence of the system is also to be analyzed and accepted, but acceptable performance does not require fully meeting the stated goals and objectives. It might not be possible to meet fully the goals and objectives if a key system is unavailable, and yet no system is totally reliable. The AHJ determines which level of performance, possibly short of stated goals and objectives, is acceptable, given the very low probability (that is, the systems' unreliability probability) that the system will be unavailable. [**1:**A.5.4.4.4.2]

**A.5.4.5.1** An example of such a scenario would involve a fire or earthquake effectively blocking the principal entrance/exit but not immediately endangering the occupants. The full occupant load of the assembly space has to exit using secondary means. [**1:**A.5.4.5.1]

**A.5.6** The assessment of precision required in 5.7.2 requires a sensitivity and uncertainty analysis, which can be translated into safety factors. [**1:**A.5.6]

*Sensitivity Analysis.* The first run a model user makes should be labeled as the base case, using the nominal values of the various input parameters. However, the model user should not rely on a single run as the basis for any performance-based fire safety system design. Ideally, each variable or parameter that the model user made to develop the nominal input data should have multiple runs associated with it, as should combinations of key variables and parameters. Thus, a sensitivity analysis should be conducted that provides the model user with data that indicates how the effects of a real fire could vary and how the response of the proposed fire safety design could also vary. [**1:**A.5.6]

The interpretation of a model's predictions can be a difficult exercise if the model user does not have knowledge of fire dynamics or human behavior. [**1:**A.5.6]

*Reasonableness Check.* The model user should first try to determine whether the predictions actually make sense, that is, they don't upset intuition or preconceived expectations. Most likely, if the results don't pass this test, an input error has been committed. [**1:**A.5.6]

Sometimes the predictions appear to be reasonable but are, in fact, incorrect. For example, a model can predict higher temperatures farther from the fire than close to it. The values themselves could be reasonable, for example, they are not hotter than the fire, but they don't "flow" down the energy as expected. [**1:**A.5.6]

A margin of safety can be developed using the results of the sensitivity analysis in conjunction with the performance criteria to provide the possible range of time during which a condition is estimated to occur. [**1:**A.5.6]

Safety factors and margin of safety are two concepts used to quantify the amount of uncertainty in engineering analyses. Safety factors are used to provide a margin of safety and represent, or address, the gap in knowledge between the theoretically perfect model, that is, reality and the engineering models that can only partially represent reality. [**1:**A.5.6]

Safety factors can be applied to either the predicted level of a physical condition or to the time at which the condition is predicted to occur. Thus, a physical or a temporal safety factor, or both, can be applied to any predicted condition. A predicted condition (that is, a parameter's value) and the time at which it occurs are best represented as distributions. Ideally, a computer fire model predicts the expected or nominal value of the distribution. Safety factors are intended to represent the spread of these distributions. [**1:**A.5.6]

Given the uncertainty associated with data acquisition and reduction, and the limitations of computer modeling, any condition predicted by a computer model can be thought of as an expected or nominal value within a broader range. For example, an upper layer temperature of 1110°F (600°C) is predicted at a given time. If the modeled scenario is then tested (that is, full-scale experiment based on the computer model's input data), the actual temperature at that given time could be 1185°F or 1085°F (640°C or 585°C). Therefore, the temperature should be reported as 1110°F + 75°F, –25°F (600°C + 40°C, –15°C) or as a range of 1085°F to 1184°F (585°C to 640°C). [**1:**A.5.6]

Ideally, predictions are reported as a nominal value, a percentage, or an absolute value. As an example, an upper layer temperature prediction could be reported as 1112°F (600°C), 86°F (30°C) or 1112°F (600°C), 5 percent. In this case, the physical safety factor is 0.05 (that is, the amount by which the nominal value should be degraded and enhanced). Given the state-of-the-art of computer fire modeling, this is a very low safety factor. Physical safety factors tend to be on the order of tens of percent. A safety factor of 50 percent is not unheard of. [**1:**A.5.6]

Part of the problem in establishing safety factors is that it is difficult to state the percentage or range that is appropriate. These values can be obtained when the computer model predictions are compared to test data. However, using computer fire models in a design mode does not facilitate this since (1) the room being analyzed has not been built yet and (2) test scenarios do not necessarily depict the intended design. [**1:**A.5.6]

A sensitivity analysis should be performed based on the assumptions that affect the condition of interest. A base case that uses all nominal values for input parameters should be developed. The input parameters should be varied over reasonable ranges, and the variation in predicted output should be noted. This output variation can then become the basis for physical safety factors. [**1:**A.5.6]

The temporal safety factor addresses the issue of when a condition is predicted and is a function of the rate at which processes are expected to occur. If a condition is predicted to occur 2 minutes after the start of the fire, then this can be used as a nominal value. A process similar to that described for physical safety factors can also be employed to develop temporal safety factors. In this case, however, the rates (for example, of heat release and toxic product generation) will be varied instead of absolute values (for example, material properties). [**1:**A.5.6]

The margin of safety can be thought of as a reflection of societal values and can be imposed by the AHJ for that purpose. Since the time for which a condition is predicted is most likely the focus of the AHJ (for example, the model predicts occupants have 5 minutes to safely evacuate), the margin of safety is characterized by temporal aspects and tacitly applied to the physical margin of safety. [**1:**A.5.6]

Escaping the harmful effects of fire (or mitigating them) is, effectively, a race against time. When assessing fire safety system designs based on computer model predictions, the choice of an acceptable time is important. When an AHJ is faced with the predicted time of untenability, a decision needs to be made regarding whether sufficient time is available to ensure the safety of facility occupants. The AHJ is assessing the margin of safety. Is there sufficient time to get everyone out safely? If the AHJ feels that the predicted egress time is too close to the time of untenability, then the AHJ can impose an additional time that the designer has to incorporate into the system design. In other words, the AHJ can impose a greater margin of safety than that originally proposed by the designer. [**1:**A.5.6]

**A.5.7.1** The *SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings* describes the documentation that should be provided for a performance-based design. [**1:**A.5.7.1]

Proper documentation of a performance design is critical to the design acceptance and construction. Proper documentation also ensures that all parties involved understand what is necessary for the design implementation, maintenance, and continuity of the fire protection design. If attention to details is maintained in the documentation, then there should be little dispute during approval, construction, start-up, and use. [**1:**A.5.7.1]

Poor documentation could result in rejection of an otherwise good design, poor implementation of the design, inadequate system maintenance and reliability, and an incomplete record for future changes or for testing the design forensically. [**1:**A.5.7.1]

Δ **A.5.7.2** The sources, methodologies, and data used in performance-based designs should be based on technical references that are widely accepted and used by the appropriate professions and professional groups. This acceptance is often based on documents that are developed, reviewed, and validated under one of the following processes:

(1) Standards developed under an open consensus process conducted by recognized professional societies, codes or standards organizations, or governmental bodies
(2) Technical references that are subject to a peer review process and published in widely recognized peer-reviewed journals, conference reports, or other publications
(3) Resource publications such as the *SFPE Handbook of Fire Protection Engineering,* which are widely recognized technical sources of information

[**1:**A.5.7.2]

The following factors are helpful in determining the acceptability of the individual method or source:

(1) Extent of general acceptance in the relevant professional community. Indications of this acceptance include peer-reviewed publication, widespread citation in the technical literature, and adoption by or within a consensus document.
(2) Extent of documentation of the method, including the analytical method itself, assumptions, scope, limitations, data sources, and data reduction methods.
(3) Extent of validation and analysis of uncertainties. This includes comparison of the overall method with experimental data to estimate error rates as well as analysis of the uncertainties of input data, uncertainties and limitations in the analytical method, and uncertainties in the associated performance criteria.
(4) Extent to which the method is based on sound scientific principles.
(5) Extent to which the proposed application is within the stated scope and limitations of the supporting information, including the range of applicability for which there is documented validation. Factors such as spatial dimensions, occupant characteristics, and ambient conditions can limit valid applications.

[**1:**A.5.7.2]

In many cases, a method is built from and includes numerous component analyses. These component analyses should be evaluated using the same factors that are applied to the overall method as outlined in items (1) through (5). [**1:**A.5.7.2]

A method to address a specific fire safety issue, within documented limitations or validation regimes, might not exist. In such a case, sources and calculation methods can be used outside of their limitations, provided that the design team recognizes the limitations and addresses the resulting implications. [**1:**A.5.7.2]

The technical references and methodologies to be used in a performance-based design should be closely evaluated by the design team and the AHJ, and possibly by a third-party reviewer. The strength of the technical justification should be judged using criteria in items (1) through (5). This justification can be strengthened by the presence of data obtained from fire testing. [**1:**A.5.7.2]

**A.5.7.11** Documentation for modeling should conform to ASTM E1472*, Standard Guide for Documenting Computer Software for Fire Models*, although most, if not all, models were originally developed before this standard was promulgated. [**1:**A.5.7.11]

Δ **A.6.4.1.5.1** Occupancies, including industrial and storage occupancies, are defined by the building code adopted by the jurisdiction. *Occupancy* is a term used to define the activity or purpose of a building or space within a building where activity occurs. In general, occupancies are separated into various categories depending on the use. Some of the categories, depending on the adopted building code, can include, but are not limited to, the following: assembly, business, educational, factory (or industrial), hazardous, institutional, mercantile, residential, storage, and so on.

Construction features as well as engineering controls are influenced by the occupancy. The greater the hazard, the more restrictive the controls to be applied within the context of construction features and engineering controls integral to the use of the building. Limitations are placed on building heights, areas, construction types, and construction features, including building or area exits and the egress system in general, depending on the risk based on a predefined set of conditions imposed by the occupancy category. Industrial occupancies are typically involved with manufacturing of a product and involve factories and workshops used to manufacture or process a wide array of materials. A storage occupancy is one in which manufactured goods are stored. Activity in these areas is limited to the storage of goods or materials. The quantity of hazardous materials in occupancies other than those classified as hazardous is limited. When the need for quantity of various hazardous materials, including hydrogen, increases, the occupancy of the area can revert to that of a “hazardous occupancy,” or the excess quantities might have to be isolated from the factory floor by either placing them into a room that is isolated by fire-resistive construction, or by transferring the materials outside of the building or to a separate building where they can be piped to a point of use.