NFPA 550

Guide to the Fire Safety Concepts Tree

2007 Edition

NFPA, 1 Batterymarch Park, Quincy, MA 02169-7471
An International Codes and Standards Organization

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NFPA 550

Guide to the

Fire Safety Concepts Tree

2007 Edition

This edition of NFPA 550, *Guide to the Fire Safety Concepts Tree*, was prepared by the Technical Committee on Fire Risk Assessment Methods. It was issued by the Standards Council on December 1, 2006, with an effective date of December 20, 2006, and supersedes all previous editions.

This edition of NFPA 550 was approved as an American National Standard on December 20, 2006.

Origin and Development of NFPA 550

The NFPA Committee on Systems Concepts was organized to be responsible for developing systems concepts and criteria for fire protection in structures. A primary accomplishment of this committee was the development of the Fire Safety Concepts Tree. This *Guide to the Fire Safety Concepts Tree* was developed by the Committee on Systems Concepts in 1985. Appreciation is extended to Dr. John M. Watts, Jr., of the Fire Safety Institute for his major contribution to the contents of this document.

The Committee on Systems Concepts was discharged in October 1990, at which time the Standards Council assumed responsibility for this document.

The 1995 edition represented a reconfirmation of the 1986 edition with editorial clarifications.

The 2002 edition represented the majority of the 1995 edition with changes reflecting NFPA's requirements for document uniformity as prescribed by the *Manual of Style for NFPA Technical Committee Documents*. The changes consisted of formatting, renumbering, and editorial clarifications. Minor changes were made to content and several deletions made with respect to unreferenced text.

The 2007 edition represents a reconfirmation of the 2002 edition.

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NOTE: Membership on a committee shall not in and of itself constitute an endorsement of the Association or any document developed by the committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents covering the following: (1) frameworks that identify the relationships of fire safety concepts used for fire prevention and fire control, including codes, standards and recommended practices, and (2) frameworks that describe the properties of risk assessment methods for use in regulations.

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NFPA 550

Guide to the

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2007 Edition

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NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Annex A.

Information on referenced publications can be found in Chapter 2 and Annex B.

Chapter 1 Administration

1.1 Scope. This guide describes the structure, application, and limitations of the Fire Safety Concepts Tree.

1.2 Purpose. This guide is intended to provide tools to assist the Fire Safety Practitioner (e.g., Designer, Engineer, Code Official) in communicating fire safety and protection concepts. Its use can assist with the analysis of codes or standards and facilitate the development of performance-based designs.

1.3 Application. The Fire Safety Concepts Tree provides an overall structure with which to analyze the potential impact of fire safety strategies. It can identify gaps and areas of redundancy in fire protection strategies as an aid in making fire safety decisions. The use of the Fire Safety Concepts Tree should be accompanied by the application of sound fire protection engineering principles.

Chapter 2 Referenced Publications

2.1 General. The documents or portions thereof listed in this chapter are referenced within this guide and should be considered part of the recommendations of this document.

2.2 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 13, *Standard for the Installation of Sprinkler Systems,* 2007 edition.

NFPA 70, *National Electrical Code®,* 2005 edition.

NFPA 75, *Standard for the Protection of Information Technology Equipment,* 2003 edition.

National Fire Protection Association "Fire Safety Concepts Tree," 2002 edition.

2.3 Other Publications.

2.3.1 ANSI/UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096.

ANSI/UL 913, *Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, and III, Division 1 Hazardous Locations,* 1988.

2.3.2 SFPE Publications. Society of Fire Protection Engineers, 7315 Wisconsin Avenue, Suite 1225 W, Bethesda, MD 20814.

SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings, 2000.

2.3.3 Other Publications. *Merriam-Webster's Collegiate Dictionary,* 11th edition, Merriam-Webster, Inc., Springfield, MA, 2003.

2.4 References for Extracts in Advisory Sections. (Reserved)

Chapter 3 Definitions

3.1 General. The definitions contained in this chapter apply to the terms used in this guide. Where terms are not defined in this chapter or within another chapter, they should be defined using their ordinarily accepted meanings within the context in which they are used. *Merriam-Webster's Collegiate Dictionary,* 11th edition, is the source for the ordinarily accepted meaning. Descriptions of elements or concepts in the Fire Safety Concepts Tree have been provided to help convey the intent of the Systems Concepts Committee. These descriptions are intended as a guide to the thinking that framed the tree and should not restrict alternative interpretation of the concepts if such alternative descriptions are based on appropriate fire protection engineering principles. For example, it might be appropriate to a specific application of the tree to define "Prevent Fire Ignition" in terms of a flame height or a rate of heat release. At the same time, this is the only published source of definitions of these concepts and is, therefore, a step toward better communication through common understanding. Italicized terms in the descriptions of Fire Safety Concepts Tree elements are defined in Section 3.4, Glossary Terms.

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

3.2.2* Authority Having Jurisdiction (AHJ). An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

3.2.3 Guide. A document that is advisory or informative in nature and that contains only nonmandatory provisions. A guide may contain mandatory statements such as when a guide can be used, but the document as a whole is not suitable for adoption into law.

3.2.4* Listed. Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

3.2.5 Shall. Indicates a mandatory requirement.

3.2.6 Should. Indicates a recommendation or that which is advised but not required.

3.2.7 Standard. A document, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and which is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions shall be located in an appendix or annex, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

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3.3 General Definitions.

3.3.1 Accomplish by Administrative Action. Eliminate, *limit*, *control*, or accomplish other actions referenced in the Fire Safety Concepts Tree.

3.3.2 Apply Sufficient Suppressant (*Automatically*). *Automatically* perform *suppressive* action in response to *automatic* detection.

3.3.3 Apply Sufficient Suppressant (to *Manually Suppress*). *Manually* perform *suppressive* action given response to the proper site.

3.3.4 Automatically Suppress Fire. *Automatically* perform actions on a *fire* process in order to *limit* the growth of or extinguish the *fire*.

3.3.5 Cause Movement of Exposed. Initiate movement of the *exposed* to and along a safe path.

3.3.6 Communicate Signal. Transmit knowledge of a detected *fire* via human or *automatic* or a combination of human and *automatic* means to a responsible recipient of the information.

3.3.7 Confine/Contain Fire. Provide building construction features and built-in equipment in order to *limit* the *fire* or *fire products*, or both, to within the *barriers* surrounding the area where the *fire* originated.

3.3.8 Control Chemical Composition of Environment. Limit the quantity of oxidizer available for combustion or inhibit the chemical combustion process.

3.3.9 Control Combustion Process. *Control* the inherent *fire* behavior.

3.3.10 Control Fire by Construction. *Control* the growth of the *fire* and the movement of *fire products* by performing actions involving building construction features and built-in equipment without intentionally acting upon the inherent *fire* process.

3.3.11 Control Fuel (Manage Fire). Influence the combustion process by *pre-ignition control* of the inherent or situational characteristics of the *fuel*.

3.3.12 Control Fuel (Prevent Fire Ignition). *Limit* the characteristics and uses of *fuel(s)*.

3.3.13 Control Fuel Distribution. *Control* the arrangement of the *fuel* within its environment.

3.3.14 Control Fuel Ignitibility. *Control* the ease of *ignition* of *fuels* that are present.

3.3.15 Control Fuel Properties. *Control* the inherent properties of the *fuel*.

3.3.16 Control Fuel Transport. Prevent the *fuel* from moving to a location where *ignition* can result.

3.3.17 Control Heat–Energy Sources. *Limit* the characteristics and uses of *heat–energy sources*.

3.3.18 Control Heat–Energy Source Transport. Prevent the *heat–energy source* from moving to a location where an *ignition* can result.

3.3.19 Control Heat–Energy Transfer Processes. Alter the rate(s) at which the *fuel(s)* receives heat by *control* of the *heat transfer* mechanisms, such that *ignition* cannot result.

3.3.20 Control Movement of Fire. *Control* the movement of *fire* or *fire products*, or both, by providing and (where a normal functional necessity) activating building construction features and built-in equipment.

3.3.21 Control Physical Properties of Environment. Interfere in the combustion process through a heat transfer process.

3.3.22 Control Rate of Heat–Energy Release. *Control* the rate of thermal energy release of existing *heat–energy sources*.

3.3.23 Control Source–Fuel Interactions. *Control* the relationships of *source* and *fuel* so as to *limit* the *heat* communicated from the *source* to the *fuel* in order that *fuel* temperature remains below that required for *ignition*.

3.3.24 Control the Environment. *Control* the inherent or situational characteristics of the environment.

3.3.25 Decide Action. Determine a proper reaction given the communication of the existence of a *fire*.

3.3.26 Defend Against Fire Products. *Safeguard* the *exposed* using measures that prevent the presence of, or *control* the impact of, *fire products* at the *place*.

3.3.27 Defend Exposed in Place. *Defend* the *exposed* in the *place(s)* where they were located at the time of *ignition*.

3.3.28 Defend the Place (*of the Exposed*). *Defend* the *place* occupied by the *exposed*.

3.3.29 Detect Fire (*Automatically*). Identify the presence of *fire* without reliance on human observation.

3.3.30 Detect Fire (to *Manually Suppress Fire*). Identify the presence of *fire* either by human observation or by *automatic* mechanism(s).

3.3.31 Detect Need. Recognize that the exposed are susceptible to a harm.

3.3.32 Eliminate Fuel(s). Eliminate all *fuel*.

3.3.33 Eliminate Heat–Energy Source(s). Eliminate all places, materials, or objects at which thermal energy can originate or from which thermal energy can be transferred.

3.3.34 Limit Amount Exposed. *Limit* the maximum amount of *exposed*.

3.3.35 Limit Fuel Quantity. *Limit* the amount of *fuel* that potentially can become involved in *fire*.

3.3.36 Maintain Essential Environment. Ensure the sufficient prevention, removal, dissipation, or neutralization of adverse conditions, other than *fire* or *fire products*, or both, as experienced by the *exposed* within the *place*.

3.3.37 Manage Exposed. Coordinate measures directly involving the *exposed*.

3.3.38 Manage Fire. Coordinate measures for *control* of the *fire* or *fire products*, or both.

3.3.39 Manage Fire Impact. Coordinate measures to *limit* any harm directly or indirectly resulting from *fire* or *fire products*, or both.

3.3.40 Manually Suppress Fire. *Manually* perform actions on a *fire* process in order to *limit* the growth of or extinguish the *fire*.

3.3.41 Move Exposed. Safely relocate the *exposed* to safety.

3.3.42 Prevent Fire Ignition. Prevent initiation of destructive and *uncontrolled burning*.

3.3.43 Provide Movement Means. Provide the facilities necessary for a safe path through which the *exposed* can be relocated.

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3.3.44 Provide Safe Destination (for the *Exposed*). Provide a safe location to receive the *exposed*.

3.3.45 Provide Separation (*Fuel* Transport). Provide and maintain a *separation* between the *fuel* and the *source* by measures acting only upon the *fuel*.

3.3.46 Provide Separation (*Source* Transport). Provide and maintain a *separation* between the *source* and the *fuel* by measures acting only upon the *source*.

3.3.47 Provide Structural Stability. Maintain the effectiveness of building construction features and built-in equipment.

3.3.48 Respond to Site. Respond to the proper site from which to *manually* initiate suppressive action.

3.3.49 Restrict Movement of Exposed. Prevent movement of the *exposed* beyond the boundaries of the *defended place*.

3.3.50 Safeguard Exposed. Act upon the *exposed* and the immediate surroundings of the *exposed* to *protect* the *exposed* against *fire impacts*.

3.3.51 Signal Need. Communicate the threat about the exposed.

3.3.52 Suppress Fire. Perform actions on a *fire* process in order to *limit* the growth of or extinguish the *fire*.

3.3.53 Vent Fire. Provide building construction features and built-in equipment that can *control fire* by removal of the *fire* or *fire products*, or both.

3.4 Glossary Terms. As in the case of the descriptions in Section 3.3, these definitions are subject to interpretation, but to a lesser degree.

3.4.1 Automatic (Automatically). Occurring without need of human action.

3.4.2 Barrier. A material obstacle (as opposed to *separation*).

3.4.3 Burning. Continuous combustion including smoldering.

3.4.4 Capacity (of a *Place* or Location). The maximum number or amount of *exposed* that a *place* or location can accommodate.

3.4.5 Capacity (of a Route or Path). The maximum flow rate of *exposed* that a route or path can handle.

3.4.6 Conduction. A transfer of heat from a region of higher temperature through a material by a molecular mechanism not involving bulk motion to a region of lower temperature.

3.4.7 Control. *Limit*, affect, or alter the referenced factor(s).

3.4.8 Convection. Transfer of heat by bulk motion of a fluid induced by mechanical devices or by gravitational effects due to nonuniform temperatures in the fluid.

3.4.9 Defend. As used in the Tree, *safeguard* the *exposed* using only those measures that prevent or *control fire impact* on the location of the *exposed*, without acting on the *fire* itself (see *safeguard*).

3.4.10 Exposed. Any or all of the items specified in the fire safety objectives (e.g., persons, pieces of property, activities, or other valuable considerations).

3.4.11 Fire. Any instance of destructive and *uncontrolled burning*, including explosions.

3.4.12 Fire Impact. A term used to denote the direct or indirect results of *fire*.

3.4.13 Fire Products. As used in the Tree, flame, heat, smoke, and gas.

3.4.14 Fire Safety. The measures taken to *protect* the *exposed* so as to satisfy a specified objective.

3.4.15 Fuel. A substance that yields heat through combustion.

3.4.16 Heat–Energy. A term used to indicate that only the thermal forms of energy are of concern.

3.4.17 Heat–Energy Source (*Source*). Any *place*, material, or object at which *heat–energy* can originate or from which *heat–energy* can be transferred.

3.4.18 Heat–Energy Transfer Process. The exchange of thermal energy from the *source* to the *fuel* by the mechanisms of *conduction*, *convection*, or *radiation*, or all three.

3.4.19 Ignitibility. The ease with which *fuel* undergoes *ignition*.

3.4.20 Ignition. The momentary event when *fire* first occurs.

3.4.21 Immobilize. Fix in place, so that no movement can occur.

3.4.22 Limit. Prescribe a minimum or maximum size, quantity, number, mass, extent, or other dimension.

3.4.23 Manage. Coordinate broadly-ranging available methods toward accomplishment of objectives.

3.4.24 Manual. Employing human action.

3.4.25 Place. An area within designated boundaries containing *exposed*.

3.4.26 Protect. The use of any or all available measures to *limit fire impact*.

3.4.27 Radiation. The combined process of emission, transmission, and absorption of energy traveling by electromagnetic wave propagation (e.g., infrared radiation) between a region of higher temperature and a region of lower temperature.

3.4.28 Safe Destination. A *protected place* of adequate capacity.

3.4.29 Safeguard. As used in the Tree, to *protect* the *exposed* by using only those measures directly involving the *exposed*, without acting on the *fire* itself (see *defend*).

3.4.30 Separation. An intervening space (as opposed to *barrier*).

3.4.31 Source. See 3.4.17, *Heat–Energy Source*.

3.4.32 Suppression. Extinguishment or active *limitation* of *fire* growth.

3.4.33 Thermal Energy. See 3.4.16, *Heat–Energy*.

3.4.34 Transport. The movement of either the *heat–energy source* or the *fuel*.

Chapter 4 Structure of the Fire Safety Concepts Tree

4.1 General. The Fire Safety Concepts Tree shows relationships of fire prevention and fire damage control strategies.

4.1.1 Fire safety features, such as construction type, combustibility of contents, and protection devices, and characteristics of occupants traditionally have been considered independently of one another. This can lead to unnecessary duplication of protection. On the other hand, gaps in protection or lack of desired redundancy can exist when these features are not coordinated.

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4.1.2 The distinct advantage of the Fire Safety Concepts Tree is its systems approach to fire safety. Rather than considering each feature of fire safety separately, the Fire Safety Concepts Tree examines all of them and demonstrates how they influence the achievement of fire safety goals and objectives.

4.2 Logic Gates. The Fire Safety Concepts Tree uses logic gates to show a hierarchical relationship of fire safety concepts. There are two types of logic gates in the Fire Safety Concepts Tree — "or" gates and "and" gates.

4.2.1 An "or" gate, represented by a circle with a plus sign in it, indicates that any of the concepts below it will cause or have as an outcome the concept above it. For example, in Figure 4.2.1(a), concept A is achieved if any one of the concepts B_1, B_2, or B_3 is achieved. Figure 4.2.1(b) presents a Venn diagram that illustrates the "or" gate logic, where achievement of any concept B will achieve concept A.

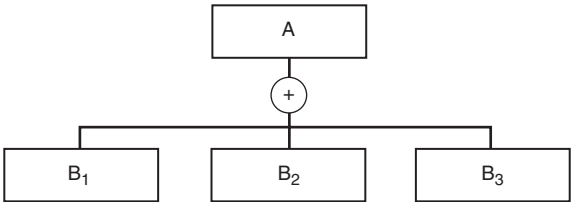


FIGURE 4.2.1(a) An Example of an "Or" Gate.

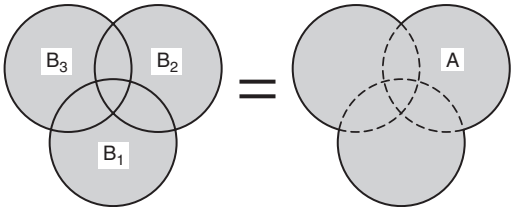


FIGURE 4.2.1(b) Venn Diagram for "Or" Gate.

4.2.2 An "and" gate is represented by a circle with a dot in the middle. This indicates that all of the concepts below the "and" gate are needed to achieve the concept above the gate. For example, in Figure 4.2.2(a), concept A can be achieved only if all three concepts B_1, B_2, and B_3 are achieved. Figure 4.2.2(b) presents a Venn diagram that illustrates the "and" gate logic, where achievement of concept A requires achievement of all three B concepts.

4.3 Fire Safety Objectives. The top box of the Fire Safety Concepts Tree is labeled "Fire Safety Objective(s)." The logic of the tree is directed toward the achievement of specified objectives. Strategies for achieving fire safety objectives are divided into two categories: "Prevent Fire Ignition" and "Manage Fire Impact." These concepts are connected through an "or" gate to the fire safety objective. *(See Figure 4.3.)* Thus, the logic of the tree is that fire safety objectives can be accomplished by preventing a fire from starting or by managing the impact of the fire. Figure 4.3 presents the top gates of the concept tree with selected lower-tiered gates. The "or" gate is the "inclusive or," which means that all the concepts below the gate can be included, but only one of them is necessary. In theory, this implies that either prevention or management alone could be followed to achieve the objective. However, theoretically, it is

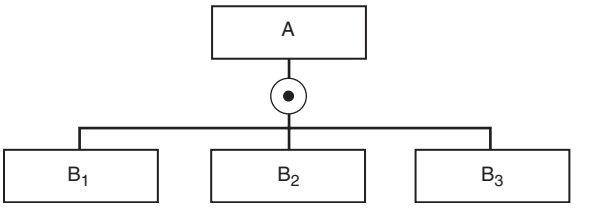


FIGURE 4.2.2(a) An Example of an "And" Gate.

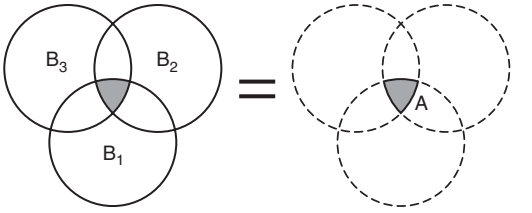


FIGURE 4.2.2(b) Venn Diagram for "And" Gate.

not possible to achieve perfect prevention or management. In practice, principles of both fire prevention and fire impact management usually are applied together. The likelihood of achieving fire safety objectives is increased by the presence of both principles. This practice is an example of reliability through redundancy (e.g., using both a belt and suspenders to hold up a pair of pants). Thus, "or" gates in the Fire Safety Concepts Tree indicate where reliability of achieving an objective is improved by implementation of more than one strategy. It is also important to note that the inputs to an "or" gate are exhaustive. This means they encompass every possible way of achieving the indicated output.

4.4 Prevent Fire Ignition. The "Prevent Fire Ignition" branch of the Fire Safety Concepts Tree includes measures representative of a fire prevention code. Fire safety measures included in this branch of the tree require continuous monitoring to ensure their effectiveness. The responsibility, therefore, is more the owner's or occupant's than the designer's.

4.4.1 Ignition results from a heat source in contact with, or sufficiently close to, a combustible substance. Thus, "Prevent Fire Ignition" branches into "Control Heat–Energy Source(s)," "Control Source–Fuel Interactions," *or* "Control Fuel" *(see Figure 4.4.1)*. Again, the "or" gate indicates that any one of these three strategies, if carried out fully, is sufficient to prevent ignition, but use of more than one will improve the chances of prevention. For example, control of heat–energy sources can be achieved by eliminating them. This also achieves the prevention of fire ignition, and no other strategy is needed. However, there is a reliability associated with the strategy of eliminating all heat–energy sources (i.e., it is possible that somehow an ignition source might find its way into the protected area). If the control fuel strategy also is applied, then the reliability that ignition will be prevented is increased.

4.4.2 "Control Source–Fuel Interactions" is the output of an "and" gate with input strategies of "Control Heat–Energy Source Transport," "Control Heat–Energy Transfer Processes," *and* "Control Fuel Transport." On the printed tree, the symbol for an "and" gate is a circle with a dot in the middle. The "and" gate is the logic operation that indicates all of the inputs must coexist simultaneously in order to produce the output. This means that the heat source should not be allowed to move too close to the fuel, excessive heat should be prevented from being transferred

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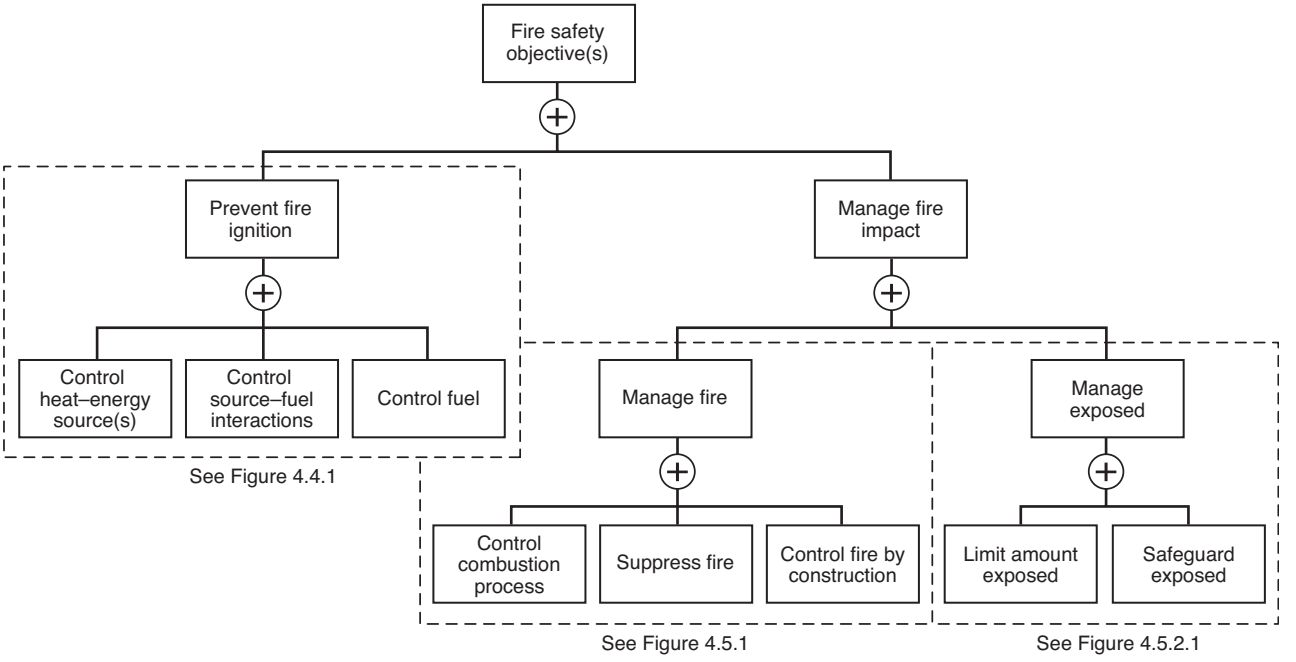


FIGURE 4.3 Top Gates of Fire Safety Concepts Tree with Selected Lower-Tiered Gates.

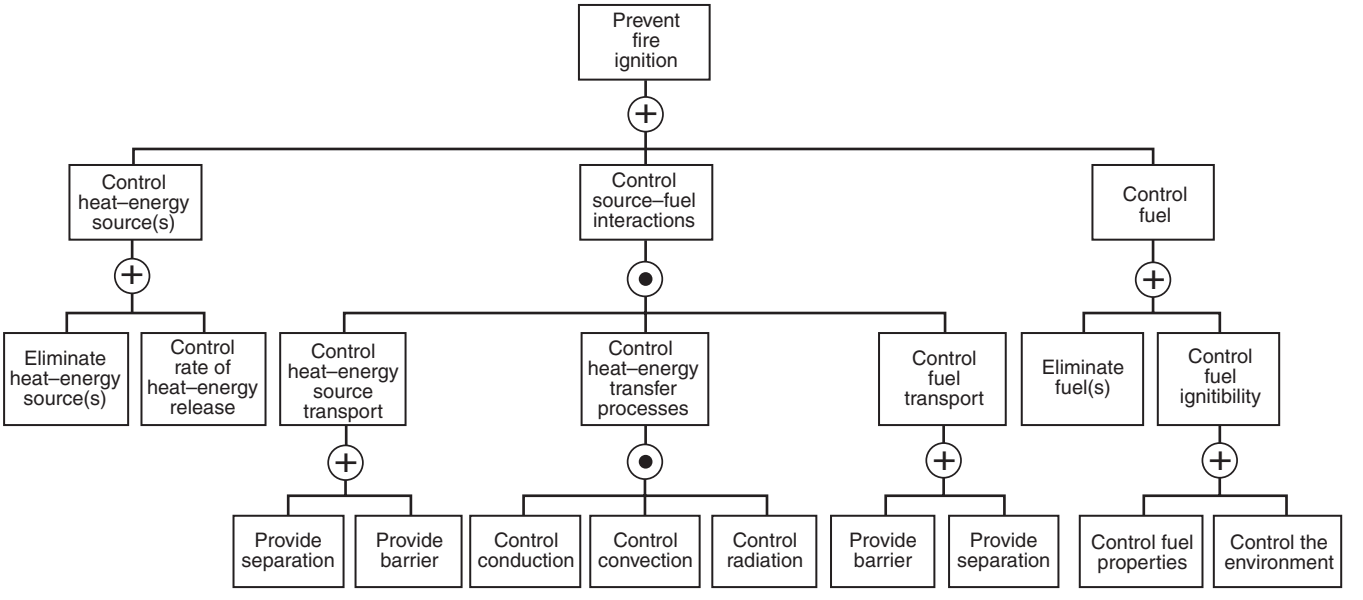


FIGURE 4.4.1 "Prevent Fire Ignition" Branch of Fire Safety Concepts Tree.

to the fuel, *and* the fuel should not be allowed to move too close to the heat source. All these concepts are necessary to achieve control of source–fuel interactions; there is no redundancy. "And" gates in the Fire Safety Concepts Tree represent checklists of items that are necessary to achieve the output objective or strategy.

4.4.3 The plus and dot symbols used for "or" gates and "and" gates *(see Figure 4.4.3)* also are used in fault trees. They are the standard symbols for these logic operations, which are used in electronic circuit diagrams and Boolean algebra. They are derived from the algebra of probabilities.

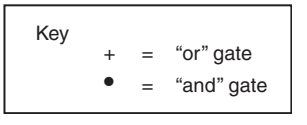


FIGURE 4.4.3 Logic Symbols Used in Fire Safety Concepts Tree.

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4.5 Manage Fire Impact. The "Manage Fire Impact" side of the tree has two major branches as inputs to an "or" gate: "Manage Fire" and "Manage Exposed" *(see Figure 4.5)*. This is the basic approach to loss control (i.e., to limit the magnitude of the hazard or to minimize the effects).

4.5.1 Manage Fire. The objectives of the "Manage Fire" strategy are to reduce hazards associated with fire growth and spread, and to thereby reduce the impact of the fire. Approaches to fire management are as follows:

(1) Control the rate of production of smoke and heat through alteration of the fuel or the environment
(2) Control the combustion process by manual or automatic suppression
(3) Control fire propagation with venting or containment, or both *(see Figure 4.5.1)*

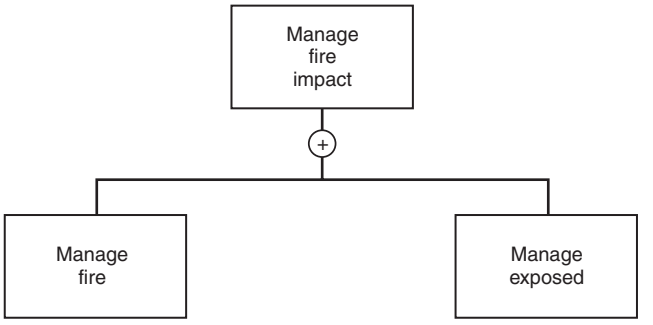


FIGURE 4.5 Major Branches of "Manage Fire Impact."

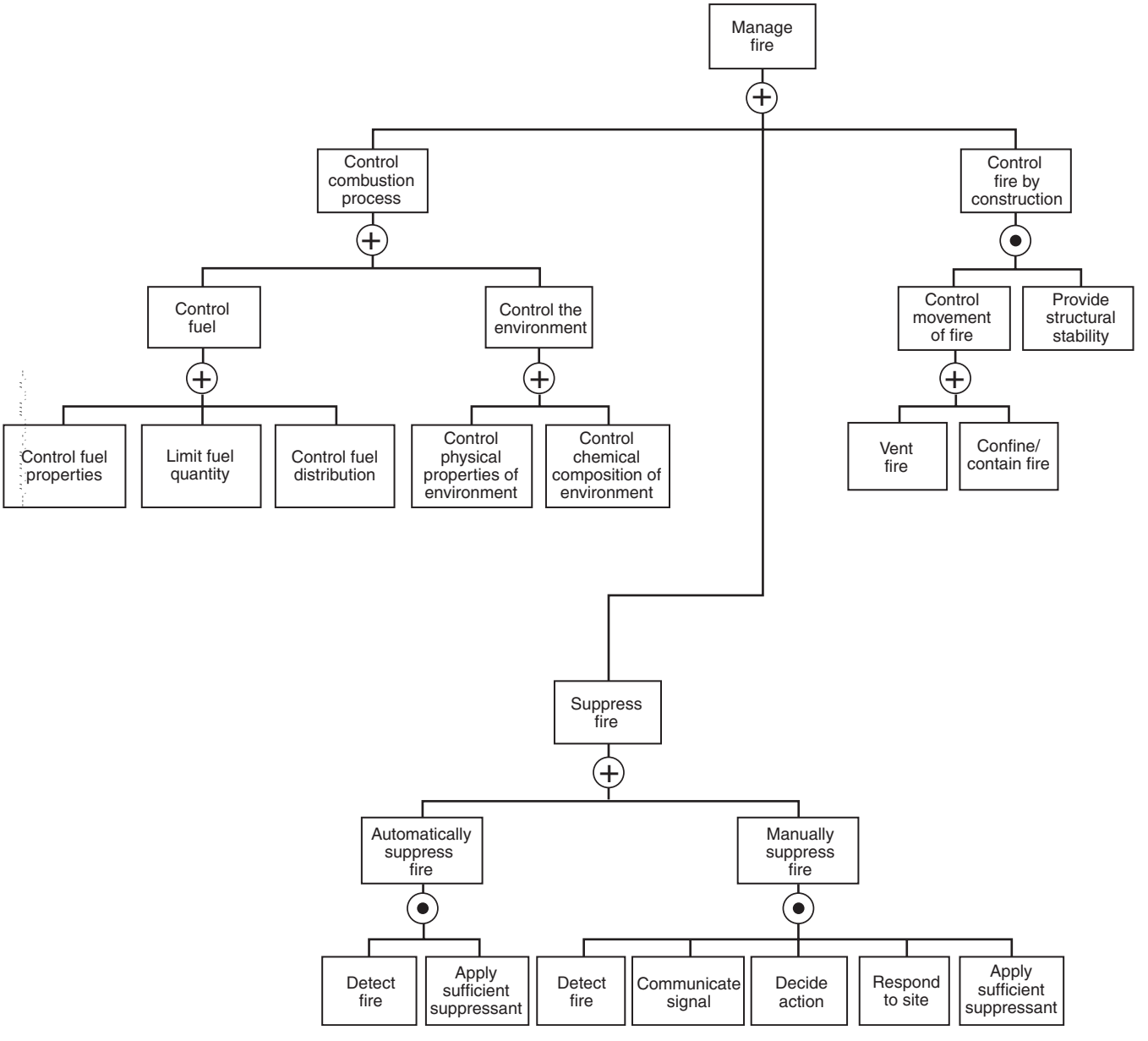


FIGURE 4.5.1 "Manage Fire" Branch of Fire Safety Concepts Tree.

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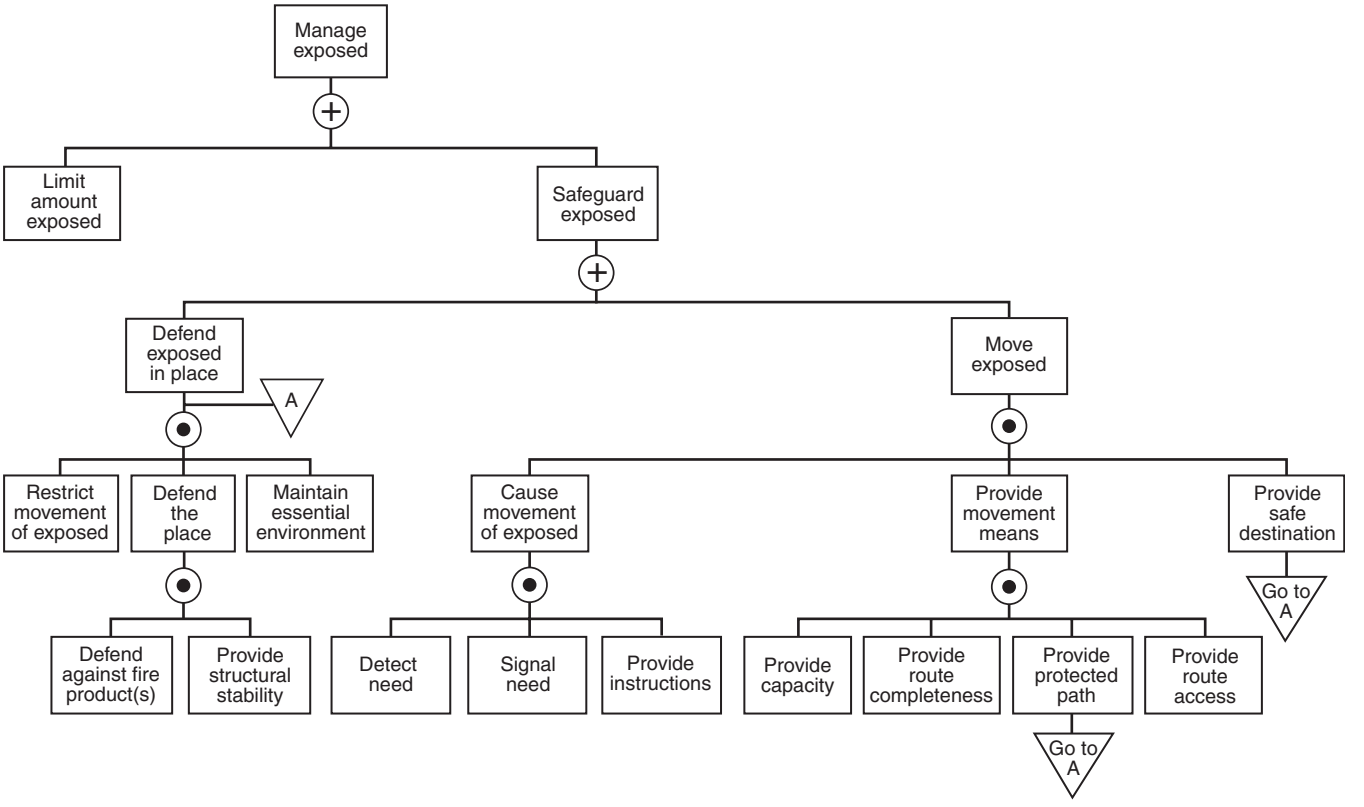


FIGURE 4.5.2.1 "Manage Exposed" Branch of Fire Safety Concepts Tree.

4.5.1.1 Again, the "or" gate indicates that these strategies can be applied simultaneously for increased reliability of managing the fire. Note that controlling fire propagation with venting or curtains includes managing fire products such as smoke.

4.5.2 Manage Exposed.

4.5.2.1 "Manage Exposed" means to coordinate measures involving any or all of the items specified in the fire safety objectives (e.g., people, property, activities, or other valuable considerations). The "Manage Exposed" branch is achieved by either limiting the number of individuals and amount of property that are exposed *or* safeguarding all persons and property subject to exposure *(see Figure 4.5.2.1)*. In the case of property or immobile persons, such as nonambulatory hospital patients, the exposed is safeguarded most often by defending the occupied space from fire exposure.

4.5.2.2 "Hardening against fire" is another term for the strategy of making the exposed resistant to the effects of fire. For more mobile occupants, the most common strategy for safeguarding the exposed is to relocate the exposed while protecting the route for the duration of transit. This includes smoke management as described by the "Vent Fire" and "Confine/Contain Fire" elements under the "Control Movement of Fire" branch of the tree.

4.5.2.3 The transfer symbol labeled "entry point" in the key to the Fire Safety Concepts Tree is shown in Figure 4.5.2.3. This transfer symbol indicates where portions of the tree are repeated. In Figure 4.5.2.1, the portion of the tree under the element "Defend Exposed in Place" is repeated under the elements "Provide Safe Destination" and "Provide Protected Path."

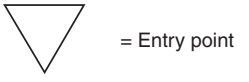


FIGURE 4.5.2.3 Transfer Symbol.

Chapter 5 Applications

5.1 General. The Fire Safety Concepts Tree is a general qualitative guide to fire safety. It is a flexible tool that can be used in a number of different ways.

5.2 Communications. Perhaps the most important use of the tree is for communication with architects and other professionals involved in building design and management. Codes and standards are not intended to be tutorial; they presume a significant level of comprehension of the principles of fire protection engineering. The Fire Safety Concepts Tree is a simple visual representation of the total concept of fire safety incorporated in codes and standards. It can be used as a means of communication between fire safety specialists and others to help identify the role of specific requirements. The tree should be considered as a first level of education in fire protection engineering (i.e., as an introduction to the full breadth of the subject).

5.3 Code Equivalency. A more specific Fire Safety Concepts Tree application is as an adjunct to building codes. An important feature in building codes is the provision for "Equivalencies." Equivalency clauses state that alternatives to specified code requirements are acceptable if they provide a degree of fire safety equivalent to that of the code. The Fire Safety Concepts Tree

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provides a guide to identifying design strategies that may provide an equivalent of safety. "Or" gates indicate where more than one means of accomplishing a strategy in the tree is possible. A decrease in the quality or quantity of one input to an "or" gate can be balanced by an increase in another input to the same gate. Determination as to whether a particular design strategy provides an equivalent level of safety would require an engineering analysis; however, the tree provides guidance on which concepts to assess. The *SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings* identifies a process for developing and evaluating trial design strategies to determine whether they provide a satisfactory level of equivalency.

5.4 Building Management. The Fire Safety Concepts Tree can be used to assess fire safety in an existing building. Inputs to "and" gates in the tree comprise a checklist of required components that should be maintained in order to accomplish their respective strategies. Thus, in a structure for which particular strategies are identified as necessary to achieve fire safety objectives, appraisal of inputs to those strategies constitutes a fire safety assessment of the structure.

5.5 Building Design. The Fire Safety Concepts Tree can be used as a design tool. Once basic fire safety objectives for a building are identified, the designer can analyze the alternative tree paths through which these objectives can be met. Examination of the "or" gates in the tree indicates where alternative strategies exist and where redundancies can be built into the design to improve reliability. The tree then can be used to communicate the fire safety concepts of the design to stakeholders. The *SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings* identifies a process for developing and evaluating trial design strategies to determine whether they provide a satisfactory level of fire safety.

5.6 Building Change Management. The Fire Safety Concepts Tree can be used to evaluate and manage changes in a building's fire safety performance that can result from changes in occupancy, use, or fire protection features. It is particularly important to have a means of evaluating the impact of changes in a building on critical fire safety features and design assumptions that could be affected during the life of the building when designed with a performance-based methodology. For example, a tree documents the required components of the original design and is a rational tool for assessing the impact of changes to these components. Alternative strategies can be examined within the context of the tree, or such alternative strategies can be further evaluated with other risk assessment or hazard assessment tools. The tree could then be revised accordingly and remain as an ongoing change management tool.

5.7 Performance-Based Evaluation. The purpose of performance-based fire safety evaluation is to ensure attainment of a set of stated goals. Fire safety is an overall outcome to be achieved with regard to fire.

5.7.1 It is not possible to directly implement fire safety goals. In order to assess the degree of achievement of a goal, intermediate measures such as performance objectives are needed. In general, objectives define a series of actions necessary to make the achievement of a goal much more likely.

5.7.2 In most cases, the performance objectives are still too indeterminate, so they must be further broken down until an acceptable degree of observable or measurable detail is achieved. This process of analyzing objectives and decomposing them is effectively represented by the Fire Safety Concepts Tree, where each of the specific fire safety concepts is explicitly linked to the higher level objective or goal.

5.8 Research. Another application of the Fire Safety Concepts Tree is as a research tool. The tree could also be used to classify fire safety strategies as a guide for research activities.

5.9 Other Applications. The applications described throughout this chapter represent only some of the more common uses of the Fire Safety Concepts Tree. In addition, the tree could be used as a guide to code organization, standards organization, information retrieval, curriculum development, marketing, indexing, and fire investigation.

Chapter 6 Limitations

6.1 General. The Fire Safety Concepts Tree has met with some success as a comprehensive qualitative guide to fire safety. It allows identification of alternatives and combinations of fire safety measures as well as the identification of redundancies and gaps. However, there are significant limitations to its application.

6.2 Interaction of Concepts. The tree structure does not adequately consider multiple interactions of fire safety concepts (i.e., concepts that are inputs to more than one strategy). This is most apparent in regard to the combined contribution of detection systems to the management of fire and to the management of the exposed. The logic tree approach does not portray lateral influences of fire safety components (i.e., concepts at the same level in the tree that affect each other).

6.3 Time Factors.

6.3.1 One of the major limitations of fire safety trees is the lack of chronological sequences. Fire safety depends on the elimination of combustion products and people coexisting in the same place at the same time. That is, avoidance of fire casualties depends on the avoidance of exposure in both space and time. One can either endure a fire or escape it. To escape a fire means to move faster than the fire and its products of combustion. The temporal aspect of fire development is not represented in the Fire Safety Concepts Tree.

6.3.2 The Fire Safety Concepts Tree does not indicate whether inputs to "and" gates need to be sequential. For example, the basic elements that are inputs to "Manually Suppress Fire" have an implied order in which they should occur. No distinction is made to identify "and" gates where this implicit order exists.

6.4 Objectives. The Fire Safety Concepts Tree is limited in its ability to deal simultaneously with multiple objectives. There can be 10 or more distinct fire safety objectives for buildings, each requiring a different course of action. Although a series of trees can be used to evaluate the success of achieving each objective individually, there is no convenient way to deal with multiple objectives collectively.

6.5 Quantification. The Fire Safety Concepts Tree is similar in appearance to a fault tree, a graphic tool used in reliability analysis. However, the boxes in a fault tree represent events with specific probabilities of occurrence while the concepts in the Fire Safety Concepts Tree are more abstract and generally do not lend themselves to quantification.

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Chapter 7 Use of the Tree

7.1 General. There are many methods for using the Fire Safety Concepts Tree. These range from cursory visual examination through systematic consideration of each concept to adaptation for quantitative analysis. This section illustrates one systematic approach to qualitative assessment of fire safety.

7.2 Procedure. The following procedure is a step-by-step approach for one way in which the Fire Safety Concepts Tree can be used to evaluate fire safety. It should not be inferred that this is the only way the tree can be used. As indicated previously, there is a wide variety of applications and methods for using the Fire Safety Concepts Tree.

7.2.1 Step One. Define the objectives. This is the most important step in making any decision. This question should be asked: "What do I want the fire safety strategies to achieve?" (e.g., provide a high level of assurance that operations will not be interrupted, meet the intention of the code, minimize the possibility of a multiple-fatality fire).

7.2.2 Step Two. Assess each of the lowest elements in the tree (i.e., all elements that do not have any inputs). For the particular structure in question, estimate the extent to which each basic element is present as a fire safety feature. For example, consider a simple scale made up of the following four categories, where "standard" indicates an appropriate level of consensus:

(1) Nonexistent
(2) Below-standard
(3) Standard
(4) Above-standard

7.2.2.1 Next, label each of the lowest elements according to its applicable category. Evaluation should include consideration of the reliability of fire safety systems to perform as designed.

7.2.3 Step Three. Where the lowest level elements are inputs to an "or" gate, the value of the output will be at least as high as the highest valued input. For example, if compliance with the strategy "Eliminate Heat–Energy Source(s)" is only partial, it might be evaluated as below-standard. Similarly, if the only heat–energy source is electricity and the installation is in accordance with NFPA 70, *National Electrical Code*, "Control Rate of Heat–Energy Release" could qualify as standard. Therefore, "Control Heat–Energy Source(s)" as the output of an "or" gate would be rated as at least standard.

7.2.4 Step Four. Where the lowest level elements are inputs to an "and" gate, the quality of the output should be limited to that of the least-valued input. For example, consider an automatic sprinkler system with appropriately temperature-rated sprinklers spaced according to NFPA 13, *Standard for the Installation of Sprinkler Systems*. The strategy "Detect Fire" then could be considered standard. If, however, the water supply to the sprinkler system is inadequate, "Apply Sufficient Suppressant" would be considered below-standard and, therefore, "Automatically Suppress Fire" as an output of an "and" gate also would be considered below-standard. Thus, the "and" gate represents a situation where the chain is only as strong as its weakest link. An "or" gate, on the other hand, is analogous to a pair of pants held up by both belt and suspenders. The pants will not fall down if either one breaks.

7.2.5 Step Five. Proceed "up" the tree in this manner, qualifying each output on the basis of the quality of the inputs and the logic gate that connects them. When each element has been evaluated, the entire tree can be examined to determine where improvements should be made to meet fire safety objectives. Alternatively, in the design stage, move down the tree, making certain that strategies are present that will yield the desired objectives. Evaluation should include reliability assessment, such as examining the effect of system failures on achievement of objectives. For example, what happens to the various outputs if the alarm system fails (i.e., "Signal Need" is rated nonexistent)?

7.3 Example. The use of the Fire Safety Concepts Tree in this manner is illustrated by examining fire prevention in a hypothetical computer facility. That is, consideration is given only to the "Prevent Fire Ignition" branch of the tree, demonstrating how a partial tree can be used for evaluation of a particular strategy.

7.3.1 Objectives. In this example, the Fire Safety Concepts Tree is used to identify a level of fire prevention for a data processing center and to identify ways to raise the level of fire prevention in the facility. Concern for the reliability of the fire prevention design also is addressed. In other words, the identified fire safety objectives are those implicit in national codes and standards, and the most effective ways to exceed this identified level of fire prevention are sought.

7.3.2 Heat–Energy Sources.

7.3.2.1 On the left side of the "Prevent Fire Ignition" branch, there are two basic strategies or lower elements dealing with ignition sources. The first strategy is "Eliminate Heat–Energy Source(s)." In a computer facility, it is standard practice to prohibit heating appliances, smoking, and any other open-flame type of ignition source. Provisions should include a security program with adequate attention to the potential for arson. If these features are satisfactorily in place, this strategy can be assessed as standard.

7.3.2.2 To improve on this level of assessment necessitates elimination of every potential ignition source including electricity. It is, of course, not feasible to eliminate completely the possibility of electrical ignition sources in a computer facility where electrically powered equipment is the nature of the occupancy. It is, however, possible to reduce the likelihood of an ignition by controlling the use of electricity. One way to do this is to conform to NFPA 70, *National Electrical Code*, Article 645, "Electronic Computer/Data Processing Equipment." If these measures are taken, the strategy "Control Rate of Heat–Energy Release" can be considered as standard. It would be technically possible, though perhaps not practical, to improve the value of this element by using an intrinsically safe electrical system such as described in ANSI/UL 913, *Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, and III, Division 1 Hazardous Locations* (an intrinsically safe electrical system is one that does not release sufficient energy to ignite the combustibles in the environment).

7.3.3 Fuel.

7.3.3.1 Consider the "Control Fuel" branch of "Prevent Fire Ignition." Common combustibles in computer facilities include paper, plastic insulation on wiring, certain components or parts of equipment, and plastic media such as tape and disks. Chapter 6 of NFPA 75, *Standard for the Protection of Information Technology Equipment*, identifies materials and equipment that might be permitted in a computer room. Compliance with NFPA 75 can be considered as a standard level for the strategy "Eliminate Fuel(s)."

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7.3.3.2 Parts of Chapter 7 of NFPA 75, *Standard for the Protection of Information Technology Equipment*, address the limits of flame spread and flash point for materials used in computer equipment. Compliance with these requirements can be construed as a standard level of the strategy "Control Fuel Properties."

7.3.3.3 Avoidance of flammable gases and oxygen-enriched atmospheres can be considered as standard for "Control the Environment," although these ordinarily are not concerns in a computer facility. An above-standard strategy is a habitable atmosphere that does not support combustion, as suggested for spacecraft and similar occupancies.

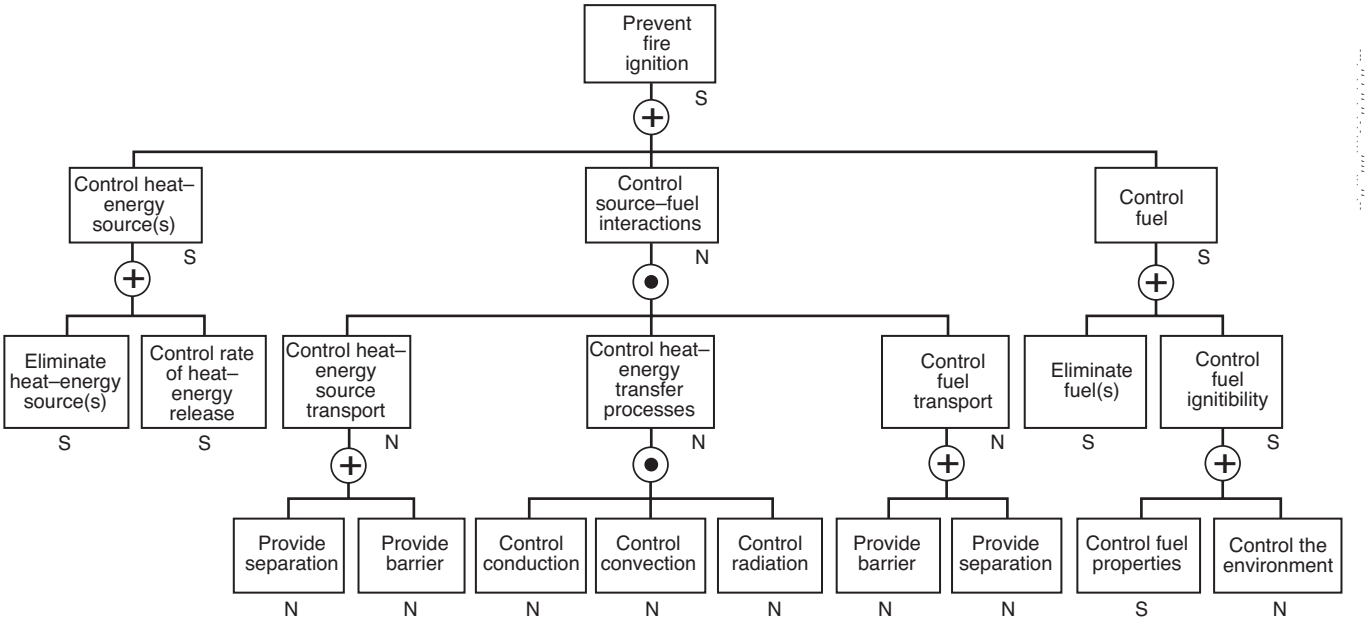
7.3.4 Source–Fuel Interactions. Control of heat transfer between ignition sources and combustibles is not a common strategy in computer facilities. It is very difficult to isolate combustible media and components from the electrical power without significant alteration of construction or procedures. For example, the electrical insulating properties of polyvinylchloride make it a most efficient material to have in contact with electrical conductors, even though it is combustible. Thus, all of the basic strategies under the "Control Source–Fuel Interactions" branch could be classified as nonexistent. Note that, even though certain valuable media are sometimes stored in a fire-resistive container, this is primarily a strategy for managing the exposed, which is not likely to contribute significantly to preventing ignition.

7.3.5 Results. The results of this process are shown in Figure 7.3.5. Now that a qualitative assessment of each lowest element in the "Prevent Fire Ignition" branch has been made, it is possible to follow the procedures of steps three and four to evaluate the results. Input of a standard element (in this case, there are two) to "Control Heat–Energy Source(s)" indicates that the output element also is standard. On the other side, standard inputs also indicate that "Control Fuel" is standard. With only nonexistent elements as inputs, "Control Source–Fuel Interactions" is nonexistent. Then, the final "or" gate leading to "Prevent Fire Ignition" has two standard inputs, so the output is standard (only one standard input is needed for the output to be considered standard, since it is an "or" gate).

7.3.5.1 The results shown on the diagram can lead to the following conclusions:

(1) Prevention of fire in the computer facility meets a level arbitrarily identified as standard, and reliability is provided by redundant (duplicate) standard inputs to the "or" gate that yield "Prevent Fire Ignition."
(2) A standard level of "Control Source–Fuel Interactions" provides a third degree of redundancy.
(3) Ways exist to improve certain elements to above-standard, but all the current standard elements need to be improved to provide consistent reliability.

7.3.5.2 This same process could be applied to other branches or to the entire Fire Safety Concepts Tree. However, it is important to keep in mind that this approach is not a general solution to any fire problem. The Fire Safety Concepts Tree provides support for a specific decision. It is a tool for examining a particular situation to discover possible alternatives, but it does not condone such alternatives automatically. Each situation is unique, and the tree can be used to provide a structure for an analysis based on accepted principles of fire protection engineering.



Key: A = Above-standard
S = Standard
B = Below-standard
N = Nonexistent

FIGURE 7.3.5 Fire Prevention in a Computer Facility.

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Chapter 8 Reserved

Chapter 9 Administrative Action

9.1 Administrative Action Guide. The Administrative Action Guide uses the logic format to show various ways to regulate or promote fire safety strategies. It is intended as a generalized guide to encourage any of the measures described in the Fire Safety Concepts Tree.

9.2 Administrative Structure.

9.2.1 The Fire Safety Concepts Tree is a branching chain of goal/means relationships. However, beyond the tree, an infrastructure exists in the form of an administrative scheme or social organization that is necessary to achieve the means deemed appropriate by the tree. Such an administrative structure is shown in Figure 9.2.1.

9.2.2 This administrative scheme could pertain to any means throughout the tree, since it represents only a generalized conceptual scheme (entirely nontechnical) for facilitating a means to achieve goals.

Annex A Explanatory Material

Annex A is not a part of the recommendations of this NFPA document but is included for informational purposes only. This annex contains explanatory material, numbered to correspond with the applicable text paragraphs.

A.3.2.1 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A.3.2.2 Authority Having Jurisdiction (AHJ). The phrase "authority having jurisdiction," or its acronym AHJ, is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A.3.2.4 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

Annex B Informational References (Reserved)

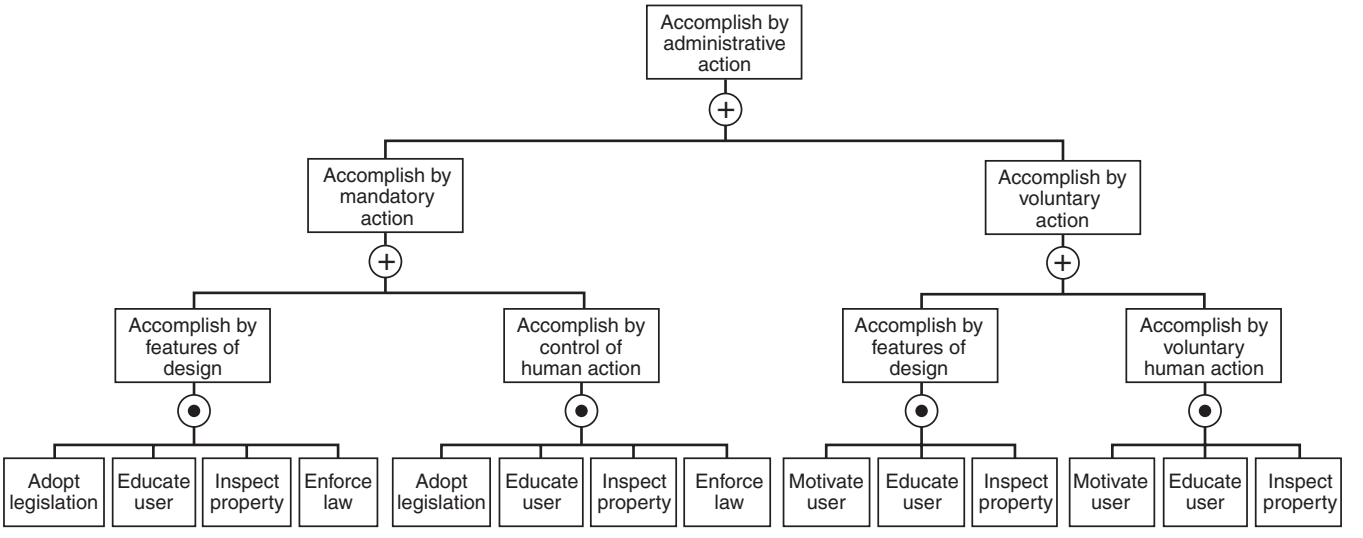


FIGURE 9.2.1 Administrative Action Guide.

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- Committee votes by written ballot on Proposals. If two-thirds approve, Report goes forward. Lacking two-thirds approval, Report returns to Committee.
- Report on Proposals (ROP) is published for public review and comment.

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3.3.78 Effective Ground-Fault Current Path. An intentionally constructed, permanent, low impedance electrically conductive path designed and intended to carry ~~underground~~ electric fault current ~~conditions~~ from the point of a ground fault on a wiring system to the electrical supply source.

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