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NFPA 550 Firesafety Concepts Tree 1986

National Fire Protection Association Batterymarch Park, Quincy, MA 02269

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The Board of Directors reaffirms that the National Fire Protection Association recognizes that the toxicity of the products of combustion is an important factor in the loss of life from fire. NFPA has dealt with that subject in its technical committee documents for many years.

There is a concern that the growing use of synthetic materials may produce more or additional toxic products of combustion in a fire environment. The Board has, therefore, asked all NFPA technical committees to review the documents for which they are responsible to be sure that the documents respond to this current concern. To assist the committees in meeting this request, the Board has appointed an advisory committee to provide specific guidance to the technical committees on questions relating to assessing the hazards of the products of combustion.

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MGR FM 85

NFPA 550

Guide to the

Firesafety Concepts Tree

1986 Edition

This edition of NFPA 550, *Guide to the Firesafety Concepts Tree*, was prepared by the Technical Committee on Systems Concepts for Fire Protection in Structures, and acted on by the National Fire Protection Association, Inc. at its Fall Meeting held November 18-20, 1985 in Baltimore, Maryland. It was issued by the Standards Council on December 10, 1985, with an effective date of December 30, 1985.

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 NFPA Firesafety Concepts Tree. This guide to that Firesafety Concepts Tree was developed by the Committee on Systems Concepts in 1985. Appreciation must be extended to Dr. John M. Watts, Jr. of the Fire Safety Institute for his major contribution to the contents of this document.

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Contents

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Chapter 1 Introduction

1-1 General. Intense need for reliability in the U.S. space program generated a new discipline known as System Safety Analysis. Many analytical approaches to safety evolved in this new field. One of the more powerful tools is Fault Tree Analysis. Fault Tree Analysis uses a tree-like diagram to describe relationships of events that can lead to a system failure (see Appendix B). The NFPA Firesafety Concepts Tree uses a similar diagram to show relationships of fire prevention and fire damage control strategies.

Firesafety aspects such as construction features, combustibility of contents, protection devices, and characteristics of occupants have traditionally been considered independently of each other. This can lead to unnecessary duplication of protection. On the other hand, there may be gaps in protection when these pieces do not adequately come together as evidenced by large losses that continue to occur.

The distinct advantage of the Firesafety Concepts Tree is its "systems approach" to firesafety. Rather than considering aspects of firesafety separately, the Firesafety Concepts Tree looks at all of them and shows how they influence achievement of firesafety goals and objectives.

1-2 Scope and Application. The Firesafety Concepts Tree is useful in providing an overall structure with which to analyze the potential impact of various codes and standards on a particular firesafety problem. It can identify gaps and areas of redundancy in alternative fire protection strategies as an aid to firesafety decisions. Use of the Firesafety Concepts Tree should be accompanied by application of sound fire protection engineering principles.

1-3 Purpose. This guide is intended to answer questions that have been directed to the Systems Concepts Committee over the past ten years and to stimulate new questions. Firesafety is not a static concept but grows with the expansion of our knowledge about the nature of fire and with the imagination of the firesafety practitioner.

Chapter 2 Background

2-1 General. In the 1960s there was growing awareness that modern high-rise buildings designed in accordance with building codes and standards were deficient in firesafety. In response, a special workshop and follow-up conference of selected experts was convened to consider systematic ways of developing new or revised approaches to firesafety. These conferences, held in 1971, were brain-storming sessions with the objective of producing a logical framework for providing adequate firesafety in high-rise structures. They were the stimulus for organization of a special NFPA committee with the scope of being "responsible for developing systems concepts and criteria for fire protection in structures." A primary accomplishment of the Committee on Systems Concepts was development of the NFPA Firesafety Concepts Tree.

2-2 Current Application. The original committee document, published in 1974, was a logic diagram referred to as the "Decision Tree." This term was used to identify the tree as an aid to firesafety decision making. While incorporating the logic and structure of a fault tree, this tree described paths leading to success rather than failure. Another important distinction from a fault tree is that components of firesafety are not always well-defined events to which a probability of occurrence can be assigned . In order to emphasize that the tree components are concepts rather than events, the name was changed to the Firesafety Concepts Tree when it was revised and updated in 1980.

Physically, the NFPA Firesafety Concepts Tree is printed on a single large sheet of paper and folded into approximately letter size. Unfolding and spreading out the tree permits viewing the entire firesafety process in one place at one time.

Chapter 3 Structure of the Firesafety Concepts Tree

3-1 Firesafety Objectives. At the top of the NFPA Firesafety Concepts Tree is a box labeled "FIRESAFETY OBJECTIVE(S)." The logic of the tree is directed toward the achievement of specified objectives, as in the recognized approach of "Management by Objectives" (MB0). In this case concern is for managing the fire risk. The concept is that the clearer idea one has of what one is trying to accomplish, the greater the chance of accomplishing it. Three basic firesafety objectives are: life safety, property protection, and operational continuity. More specific operating objectives might include averting a catastrophic loss, avoiding public anxiety, and preservation for posterity.

Strategies for achieving firesafety objectives are divided into two categories: PREVENT FIRE IGNITION and MANAGE FIRE IMPACT. These concepts are connected through an "OR gate" to the firesafety objectives. On the printed tree this is shown by the lines coming out of the top of the boxes labeled PREVENT FIRE IGNITION and MANAGE FIRE IMPACT, joining together and leading upward through a circle with a plus sign in it to the box labeled FIRESAFETY OBJECTIVE(S) (Figure 3-1). The circle with the plus in it is the symbol used to designate an OR gate. An OR gate is a logic operation whereby any of several possible inputs will produce the indicated output. Thus, the logic of the tree says that firesafety objectives may be accomplished by preventing a fire from starting OR by managing the impact of the fire. Note that although we tend to read the tree downward, the logic flow is upward, i.e., the inputs are below the outputs.

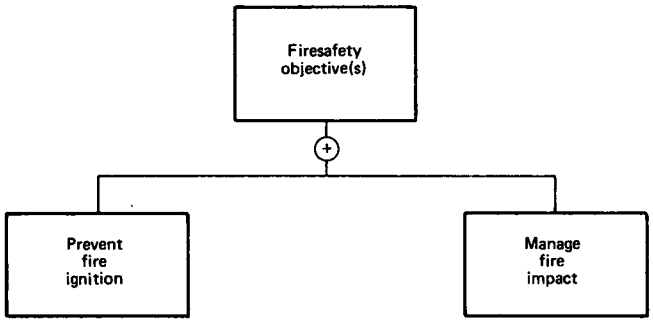


Figure 3-1

The OR gate is the "inclusive or" which means that all the concepts below the gate may 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, we can never achieve theoretically perfect prevention or management. In practice, principles of both fire prevention and fire impact management are usually applied together. The likelihood of achieving firesafety objectives is increased by the presence of both inputs. This is an example of reliability through redundancy i.e. using both a belt and suspenders to hold up a pair of pants. Thus, OR gates in the Firesafety 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. That means they encompass every possible way of achieving the respective output.

3-2 Prevent Fire Ignition. The PREVENT FIRE IGNITION branch of the Firesafety Concepts Tree includes measures representative of a fire prevention code. Firesafety measures included in this branch of the tree require continuous monitoring to assure their effectiveness. Responsibility is therefore more with the owner or occupant than the designer.

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 (Figure 3-2). Again, the OR Gate indicates that any one of these three strategies, if carried out fully, is sufficient to prevent ignition, but using more than one will improve the chances of that happening.

For example, controlling heat-energy sources can be achieved by eliminating them. This would also achieve the prevention of fire ignition and no other strategy would be required. 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 may find its way into the protected area. If the control fuel strategy is also applied, then we increase the reliability that ignition will be prevented.

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 which says that all of the inputs must coexist simultaneously in order to produce the output. This means that we must not allow the heat source to move too close to the fuel, we must also prevent excessive heat being transferred to the fuel, "and," we must not allow the fuel 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 Firesafety Concepts Tree represent checklists of items which are required to achieve the output objective or strategy.

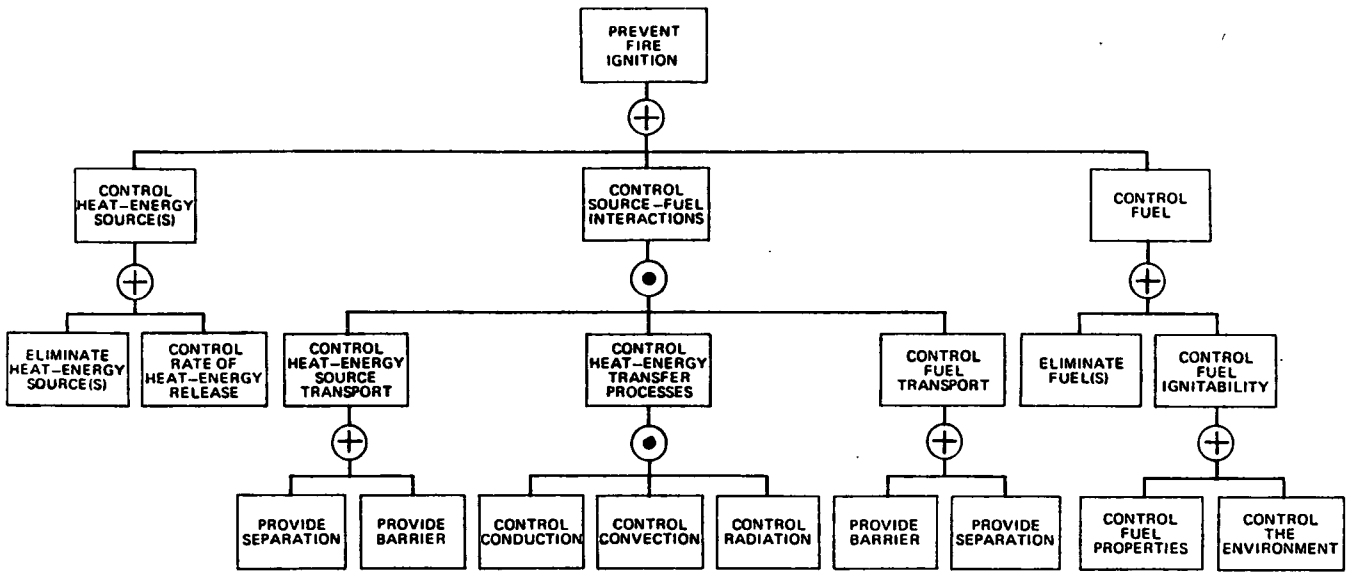


Figure 3-2

The plus and dot symbols used for OR gates and AND gates [(Figure 3-1.(a)] are also used in fault trees. They are standard symbols for these logic operations used in electronic circuit diagrams and Boolean algebra. They are derived from the algebra of probabilities (*see Appendix C*).

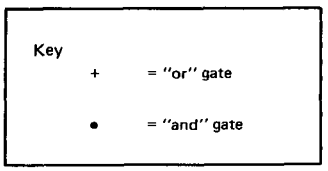


Figure 3-2(a)

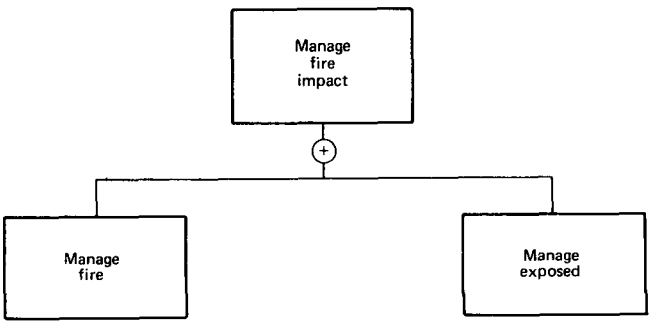


Figure 3-3

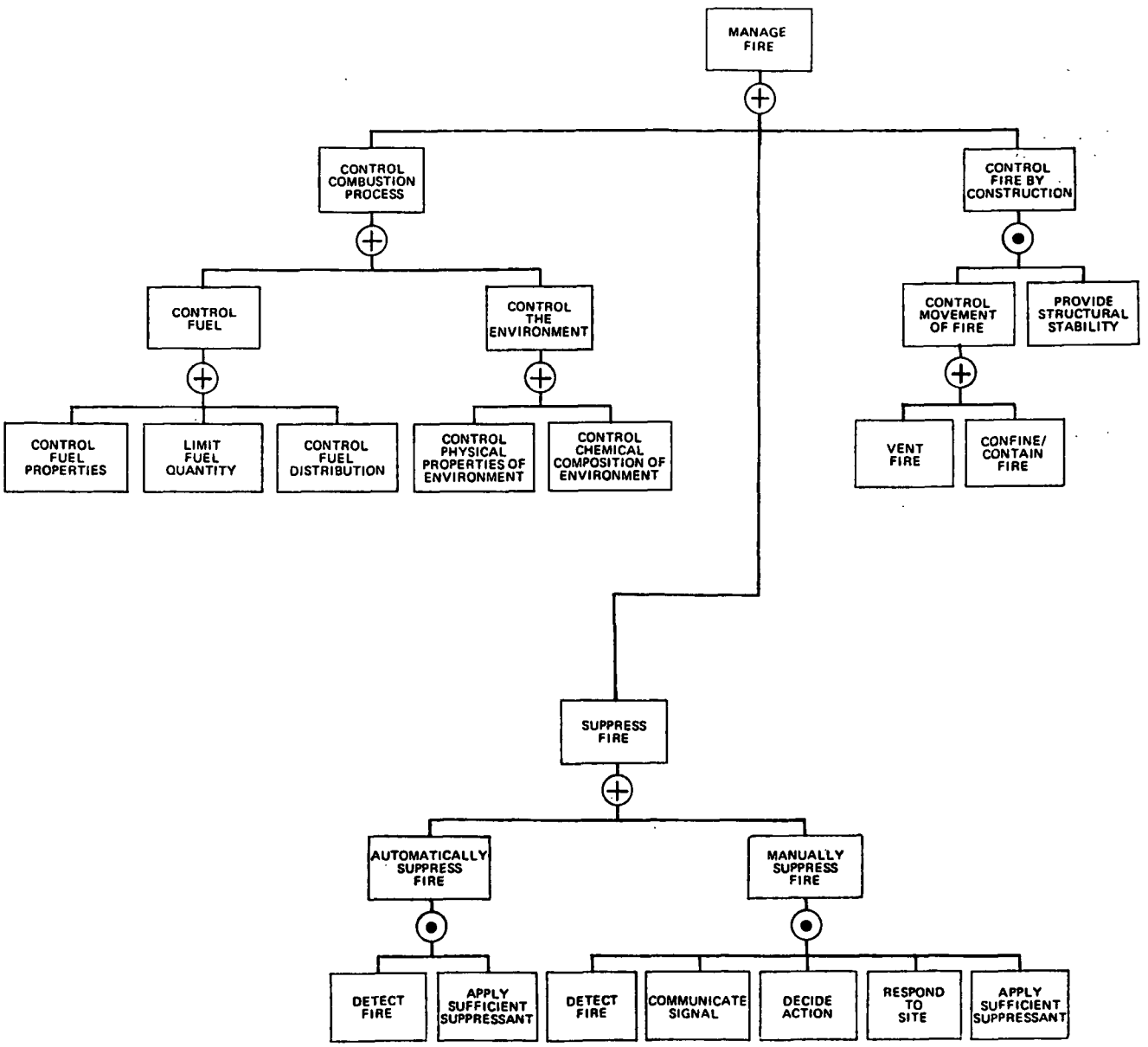


Figure 3-3.1

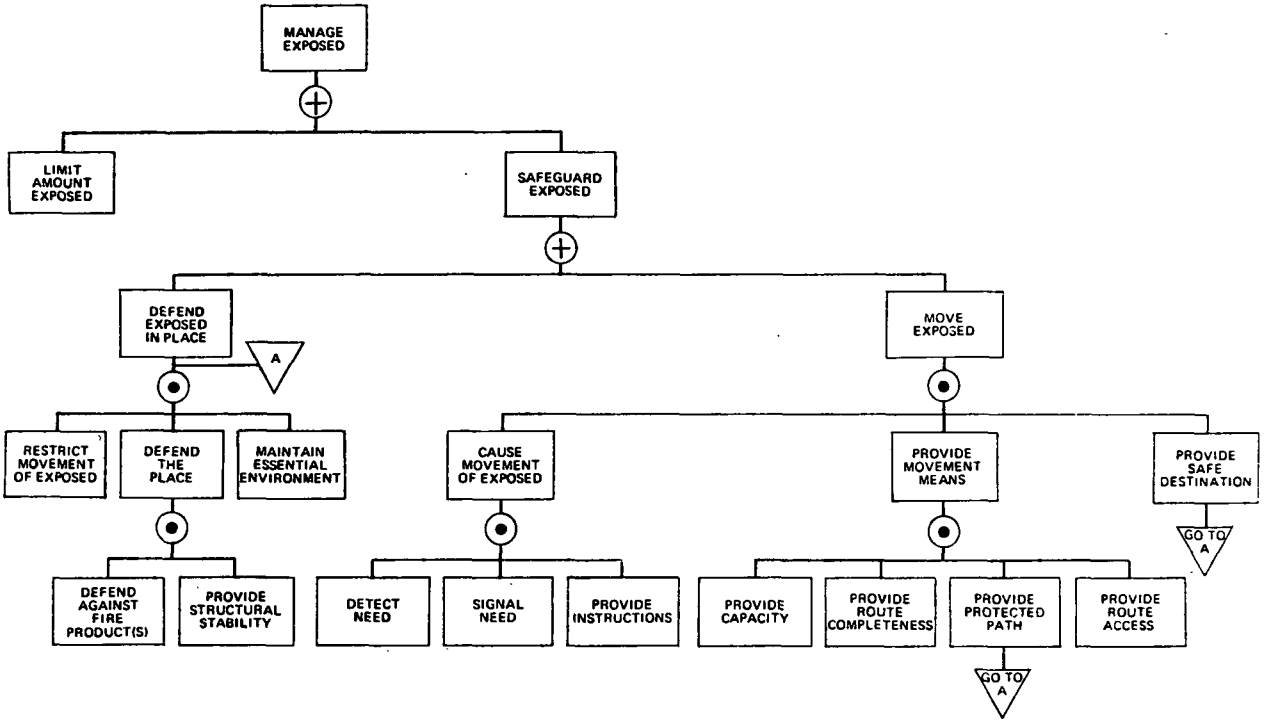


Figure 3-3.2

3-3 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 (Figure 3-3). This is the basic approach to loss control, i.e., to limit the magnitude of the hazard or to minimize the effects.

3-3.1 Manage Fire. 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: (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, and (3) control fire propagation with venting and/or containment (Figure 3-3.1). Again, the OR gate indicates that these strategies may be applied simultaneously for increased reliability of managing the fire.

3-3.2 Manage Exposed. MANAGE EXPOSED means to coordinate measures involving any or all of the items specified in the firesafety objectives, e.g., people, property, activities, or other valuable considerations. The MANAGE EXPOSED branch is achieved by either limiting the amount which is exposed "or" safeguarding whatever may be subject to exposure (Figure 3-3.2). In the case of property or immobile persons, such as bed confined hospital patients, the exposed is safeguarded most often by defending the occupied space from fire exposure. Hardening against fire is another term for the strategy of making the exposed resistant to 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 their transit.

The transfer symbol labeled as "entry point" in the key to the Firesafety Concepts Tree is shown in Figure 3-3.2.(a).

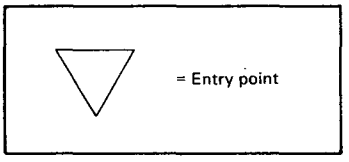


Figure 3-3.2(a)

This symbol indicates where portions of the tree are repeated. In Figure 3-3.2, the portion of the tree under the element DEFEND IN PLACE is repeated under the elements PROVIDE SAFE DESTINATION and PROVIDE PROTECTED PATH.

Chapter 4 Applications

4-1 General. The Firesafety Concepts Tree is a general qualitative guide to firesafety. It is a flexible tool which can be used in a number of different ways.

4-2 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 comprehen-

sion of the principles of fire protection engineering. The Firesafety Concepts Tree is a simple pictorial description of the total concept of firesafety incorporated in codes and standards. It may be used as a means of communication between firesafety specialists and others to help identify the role that specific requirements play. The tree may be thought of as a first level of education in fire protection engineering, i.e., as an introduction to the subject.

4-3 Code Equivalency. A more specific application of the Firesafety Concepts Tree is as an adjunct to building codes. An important feature in most, if not all, building codes is the provision for "equivalencies." Equivalency clauses state that alternatives to specified code requirements are acceptable if they provide a degree of firesafety equivalent to that of the code. The Firesafety Concepts Tree provides a guide to the determination of what is equivalent. OR gates indicate where more than one means of accomplishing a strategy in the tree is possible. A decrease in quality or quantity of one input to an OR gate may be balanced by an increase in another input to the same gate. However, it must be emphasized that this application is subjective. Comparative values of tradeoffs are usually determined by experienced judgment. The importance of the tree is in suggesting which concepts to assess.

4-4 Building Management. The Firesafety Concepts Tree may be used to assess firesafety in an existing building. Inputs to AND gates in the tree comprise a checklist of required components which must be maintained in order to accomplish their respective strategies. Thus, in a structure for which particular strategies are identified as necessary to achieve firesafety objectives, appraisal of inputs to those strategies constitutes a firesafety assessment of the structure.

4-5 Building Design. Ideally, the Firesafety Concepts Tree is a design tool. Once basic firesafety objectives for a building are identified, the designer can analyze the alternative paths through the tree by which these objectives can be met. Examination of the OR gates in the tree indicates where there are alternative strategies and where redundancies can be built into the design to improve reliability. The tree can then be used to communicate the firesafety concepts of the design to management and code officials.

4-6 Research. Another application of the Firesafety Concepts Tree is as a research tool. The tree can be used to classify firesafety strategies by which research activities can be guided. In one case, an investigation to determine alternatives to federal firesafety requirements for housing projects began with an analysis of residential firesafety using the Firesafety Concepts Tree. In another research project, qualitative techniques of fault tree analysis were applied to the Firesafety Concepts Tree to produce an exhaustive set of firesafety strategies with which the effectiveness of specific firesafety variables were compared. A similar approach was used to link firesafety objectives with specific features in a study of hospital firesafety in the UK.

4-7 Other Applications. The above represent only some of the more common applications of the Firesafety Concepts Tree. In addition, the tree has been used or proposed for use as a guide to code organization, standards organization, information retrieval, curriculum development, marketing, indexing, and fire investigation. Bell Telephone adapted the Firesafety Concepts Tree as a table of contents to their "Bell System Firesafety Practices" and the U. S. Department of State uses an approach based on the Firesafety Concepts Tree to evaluate their foreign property. Among the more than 10,000 trees that have been "planted" (i.e. distributed) by NFPA there are likely hundreds of different applications, limited in scope only by the imagination of the user.

Chapter 5 Limitations

5-1 General. The NFPA Firesafety Concepts Tree has met with some success as a comprehensive qualitative guide to firesafety. It allows one to identify alternatives and combinations of firesafety and to highlight redundancies and gaps. However, there are significant limitations to its application.

5-2 Interaction of Concepts.

The tree structure does not adequately consider multiple interactions of firesafety concepts, i.e., concepts which are inputs to more than one strategy. The area in which this is most apparent is with respect 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 firesafety components, i.e., concepts at the same level in the tree which affect each other.

5-3 Time Factors. One of the major limitations of firesafety trees is in the lack of chronological sequences. Firesafety denotes the exclusion of combustion products and people occupying the same place at the same time. That is, avoidance of fire casualties depends on the avoidance of exposure in space or time. One can either endure a fire or outrun it. To outrun it, means moving faster than the fire and its products of combustion. The temporal aspect of fire development is not represented in the Firesafety Concepts Tree.

The Firesafety Concepts Tree does not indicate where inputs to AND gates must 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.

5-4 Objectives. The NFPA Firesafety Concepts Tree is limited in its ability to deal simultaneously with multiple objectives. There may be ten or more distinct firesafety objectives for buildings, each requiring a different course of action. Although a series of trees could be used to evaluate the success of achieving each objective individually, there is no convenient way to deal with multiple objectives collectively.

5-5 Quantification. Ideally, the Firesafety Concepts Tree could be quantified like a fault tree. However, assigning probabilities or other numerical measures to firesafety tree "concepts" is much more difficult than identifying probabilities for fault tree "events." It is unlikely that the NFPA tree in its present form will be satisfactorily quantified in the near future.

Chapter 6 Use of the Tree

6-1 General. There are many methods for using the Firesafety Concepts Tree. These range from cursory visual examination, through systematic consideration of each concept, to adaption for quantitative analysis. This section illustrates one systematic approach to qualitative assessment of firesafety. References listed in Appendix A describe other approaches to using the tree.

6-2 A Procedure. The following procedure is a step-by-step approach to one way in which the Firesafety Concepts Tree can be used to evaluate firesafety. 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 Firesafety Concepts Trees.

6-2.1 Step One. Define Objectives. This is the most important step of any decision. It is difficult to come up with the best answer if you have the wrong problem. Ask the question: "What do I want the firesafety system to do?," 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; etc.

6-2.2 Step Two. Assess each of the lowest elements in the tree, i.e., all elements which do not have any inputs. For the particular structure in question, estimate the extent to which each basic element is present as a firesafety feature. For example, consider a simple scale made up of four categories: nonexistent, below standard, standard, and above standard; where "standard" indicates an appropriate level of consensus. Then label each lowest element according to its applicable category. Evaluation should include consideration of the reliability of firesafety systems to perform as designed.

6-2.3 Step Three. Where these lowest level items 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 the strategy ELIMINATE HEAT-ENERGY SOURCE(S) is only partially complied with, it might be evaluated as "below standard." Similarly, if the only heat energy source is electricity and the installation meets the *National Electrical Code®*, CONTROL RATE OF HEAT-ENERGY RELEASE could be qualified as "standard." Then, CONTROL HEAT-ENERGY SOURCE(S) as the output of an OR gate would be rated at least as "standard."

6-2.4 Step Four. When the lowest level items are inputs to an AND gate, the quality of the output is limited to that of the least valued input. As an example of this situation, consider an automatic sprinkler system with appropriately temperature rated sprinklers spaced according to NFPA 13. The strategy DETECT FIRE could then be considered "standard." If, however, the water supply to the sprinkler system is inadequate, APPLY SUFFICIENT SUPPRESSANT would be "below standard" and, therefore, AUTOMATICALLY SUPPRESS FIRE as an output of an AND gate would also be "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.

6-2.5 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 which connects them. When each element has been evaluated, the entire tree can be examined to determine where improvements should be made to meet firesafety objectives. Alternatively, in the design stage, move down the tree being sure that strategies are present which will yield the desired objectives.

Evaluation should include reliability assessments 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?'

6-3 An Example. Use of the Firesafety Concepts Tree in the manner just described is illustrated by examining fire prevention in a hypothetical computer facility. That is, consideration will be only with the PREVENT FIRE IGNITION branch of the tree, showing how a partial tree can be used for evaluation of a particular strategy.

6-3.1 Objectives. The first step is to identify objectives. The general goal is to provide life safety, property protection, and operational continuity through prevention of the occurrence of fire. More specifically, in this example the Firesafety Concepts Tree will be used to identify a "standard" level of fire prevention for a data processing center and to identify ways to raise the level of fire prevention in the facility to "above standard." There is also concern for the reliability of the fire prevention design. Another way to express this is to say the firesafety objectives are those implicit in national codes and standards, and the most effective ways to exceed this level of fire prevention are sought.

6-3.2 Heat-Energy Sources. On the left hand side of the PREVENT FIRE IGNITION branch, there are two basic strategies or lower elements dealing with ignition sources. The first strategy is to 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. This should include a security program with adequate attention to the potential for arson. If these actions are accomplished satisfactorily, this strategy may be assessed as "standard."

To improve on this level of assessment would require elimination of every potential ignition source including electricity. It is, of course, not feasible to completely eliminate 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 would be to conform to the *National Electrical Code*, Article 645 - Data Processing Systems. If these measures are taken, the strategy CONTROL RATE OF HEAT-ENERGY RELEASE could 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 NFPA 493 (an intrinsically safe electrical system is one which does not release sufficient energy to ignite the combustibles in the environment.)

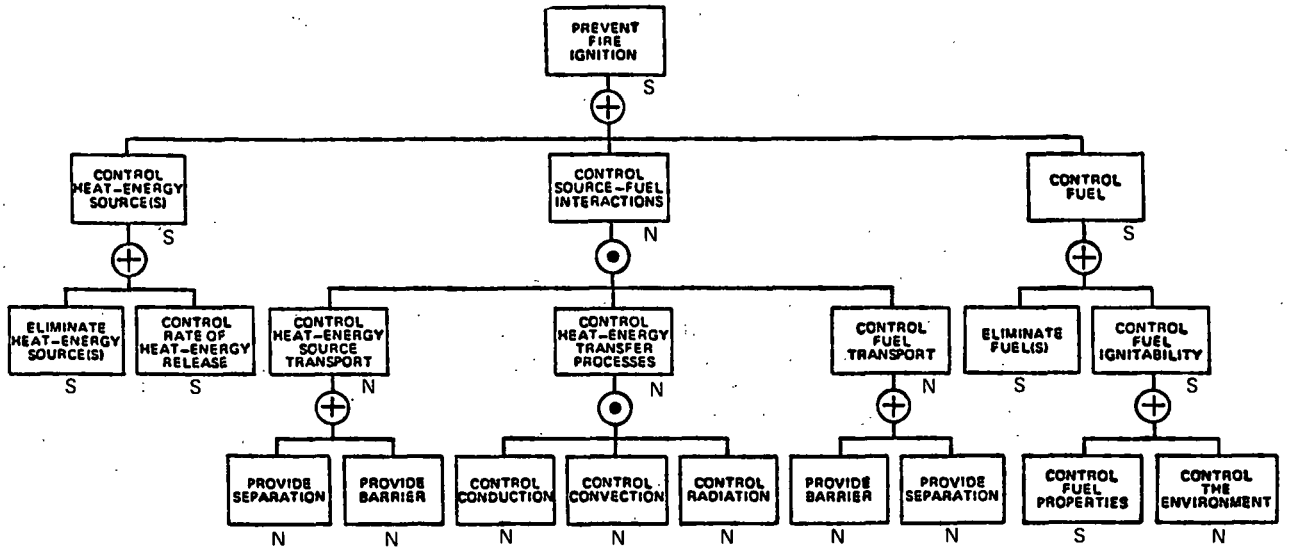
6-3.3 Fuel. Now consider the CONTROL FUEL branch of PREVENT FIRE IGNITION. Common combustibles in computer facilities include paper, plastic insulation on wiring, certain components or parts of equipment, and plastic media such as tape and disks. Section 3-1 of NFPA 75 on Electronic Computer Equipment identifies materials and equipment which may be permitted in a computer room. This could be taken as a "standard" level for the strategy ELIMINATE FUEL(S).

Parts of Chapter 4 of NFPA 75 deal with limits of flame spread and flash point for materials used in computer equipment. Compliance with these recommendations might be construed as a "standard" level of the strategy CONTROL FUEL PROPERTIES.

Avoidance of flammable gases and oxygen enriched atmospheres might constitute "standard" for CONTROL THE ENVIRONMENT, although these are not ordinarily concerns in a computer facility. An "above standard" strategy would be a habitable atmosphere which does not support combustion, as suggested for spacecraft and similar occupancies.

6-3.4 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.

6-3.5 Results. Results of this process are shown in Figure 6-3.5. Now that a qualitative assessment of each lowest element in the PREVENT FIRE IGNITION branch has been made, one can follow the procedure of steps 3 and 4 to evaluate the results. Input of a "standard" element (in this case there are two) to CONTROL HEAT-ENERGY SOURCE(S) indicates that this output element is also "standard." On the other side, "standard" inputs also indicate that CONTROL FUEL is



Key
A = Above Standard
S = Standard
B = Below Standard
N = Nonexistent

Figure 6-3.5 Fire Prevention in a Computer Facility

"standard." With nothing but "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" (it only needed one "standard" input to be considered "standard" since it is an OR gate).

The results shown on the diagram can lead us to several observations:

(1) Preventing fire in our computer facility meets a level that we have arbitrarily identified as "standard" and reliability is provided by redundant (duplicate) "standard" inputs to the OR gate which yields PREVENT FIRE IGNITION.

(2) A "standard" level of CONTROL SOURCE-FUEL INTERACTIONS would provide a third degree of redundancy.

(3) There exist ways to improve certain elements to "above standard" but all the present "standard" elements must be improved, to provide consistant reliability.

This same process could be applied to other branches or to the entire Firesafety Concepts Tree. However, it is important to keep in mind that such a result is not a generalized answer to any fire problem. The Firesafety Concepts Tree provides support for a specific decision. It is a tool for examining a situation to discover possible alternatives but it does not automatically condone such alternatives. 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.

Chapter 7 Additional Information

7-1 General. In order to assist an understanding of each concept in the tree, additional information was appended to the Firesafety Concepts Tree published in 1980. This information appears in three parts: descriptions of elements in the tree, a glossary of terms, and an administrative action guide.

7-2 Description of Elements in the Firesafety Tree (Figure 7-2). Descriptions of tree elements or concepts were provided to help convey the intent of the Systems Concepts Committee. These descriptions are intended as a guide to the thinking which 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 may 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 definition of these concepts and is therefore a step toward better communication through common understanding.

7-3 Glossary (Figure 7-3). Italicized terms in the descriptions of Firesafety Concepts Tree elements are defined in the glossary. As with the descriptions, these definitions are subject to interpretation but to a lesser degree.

THE FIRESAFETY CONCEPTS TREE
(A Qualitative Guide to Firesafety Strategies)

The following set of descriptions is presented to offer the Systems Concepts Committee's best guidance on the application of the Firesafety Concepts Tree. It is not intended to force a narrow or singular interpretation by those who find sound value in a broader or otherwise more relevant application of the expressions in the Tree. This system of definitions is consistent with the thinking which the committee applied in naming the expressions and terms used.

It will be noted that some of the lower level Tree expressions are not defined here, but that the essential terms used therein are defined in the Glossary.

DESCRIPTION OF ELEMENTS IN THE FIRESAFETY CONCEPTS TREE

Accomplish by Administrative Action means to eliminate, *limit, control,* or accomplish other actions referenced in the Firesafety Concepts Tree.

Apply Sufficient Suppressant (*automatically*) means to *automatically* perform *suppressive* action in response to *automatic* detection.

Apply Sufficient Suppressant (*to manually suppress*) means to *manually* perform *suppressive* action given response to the proper site.

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

Cause Movement of Exposed means to initiate movement of the *exposed* to and along a safe path.

Communicate Signal means to 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.

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

Control Combustion Process means to *control* the inherent *fire* behavior.

Control Fire by Construction means to *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.

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

Control Fuel (Prevent Fire Ignition) means to *limit* the characteristics and uses of *fuel(s).*

Control Fuel Distribution means to *control* the arrangement of the *fuel* within its environment.

Control Fuel Ignitibility means to *control* the ease of *ignition* of *fuels* that are present.

Control Fuel Properties means to *control* the inherent properties of the *fuel.*

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

Control Heat-Energy Sources means to *limit* the characteristics and uses of *heat-energy sources.*

Control Heat-Energy Source Transport means to prevent the *heat-energy source* from moving to a location where an *ignition* can result.

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

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

Control Rate of Heat-Energy Release means to *control* the rate of thermal energy release of existing *heat-energy sources.*

Control Source-Fuel Interactions means to *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.*

Control the Environment means *control* of the inherent or situational characteristics of the environment.

Decide Action means to determine a proper reaction given the communication of the existence of a *fire.*

Defend Against Fire Products means to *safeguard* the *exposed* using measures which prevent the presence of, or *control* the impact of, *fire products* at the *place.*

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

Defend the Place (*of the exposed*) means to *defend* the *place* occupied by the *exposed.*

Detect Fire (to *manually suppress fire*) means to identify the presence of *fire* either by human observation or by *automatic* mechanism(s).

Detect Fire (*automatically*) means to identify the presence of *fire* without reliance on human observation.

Eliminate Fuel(s) means to eliminate all *fuel.*

Eliminate Heat-Energy Source(s) means to eliminate all places, materials, or objects at which thermal energy can originate or from which thermal energy can be transferred.

Limit Amount Exposed means to *limit* the maximum amount of *exposed.*

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

Maintain Essential Environment means to assure the sufficient prevention, removal, dissipation, or neutralization of adverse conditions, other than *fire* and/or *fire products,* as experienced by the *exposed* within the *place.*

Manage Exposed means to coordinate measures directly involving the *exposed.*

Manage Fire means to coordinate measures for *control* of the *fire* and/or *fire products.*

Manage Fire Impact means to coordinate measures to *limit* any harm directly or indirectly resulting from *fire* and/or *fire products.*

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

Move Exposed means to safely relocate the *exposed* to safety.

Prevent Fire Ignition means to prevent initiation of destructive and *uncontrolled burning.*

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

Provide Safe Destination (for the *exposed*) means to provide a safe location to receive the *exposed.*

Provide Separation (*fuel* transport) means to provide and maintain a *separation* between the *fuel* and the *source* by measures acting only upon the *fuel.*

Provide Separation (*source* transport) means to provide and maintain a *separation* between the *source* and the *fuel* by measures acting only upon the *source.*

Provide Structural Stability means to maintain the effectiveness of building construction features and built-in equipment.

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

Restrict Movement of Exposed means to prevent movement of the *exposed* beyond the boundaries of the *defended place.*

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

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

Vent Fire means to provide building construction features and built-in equipment that can *control fire* by removal of the *fire* and/or *fire products.*

Figure 7-2 The Firesafety Concepts Tree — A Qualitative Guide to Firesafety Strategies

Automatic (automatically) means occurring without need of human action.
Barrier means a material obstacle (as opposed to *separation*).
Burning means continuous combustion including smoldering.
Capacity (of a *place* or location) means the maximum number or amount of *exposed* which a *place* or location can accommodate.
Capacity (of a route or path) means the maximum flow rate of *exposed* which a route or path can handle.
Conduction means 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.
Control means to *limit*, affect or alter the referenced factor(s).
Convection means transfer of heat by bulk motion of a fluid induced by mechanical devices or by gravitational effects due to non-uniform temperatures in the fluid.
Defend, as used in the Tree, means to *safeguard* the *exposed* using only those measures which prevent or *control fire impact* on the location of the *exposed*, without acting on the *fire* itself (see *safeguard*).
Exposed means any or all of the items specified in the firesafety objectives (e.g., persons, pieces of property, activities, or other valuable considerations).
Fire means any instance of destructive and uncontrolled *burning*, including explosions.
Fire Impact is a term used to denote the direct or indirect results of *fire*.
Fire Products, as used in the Tree, means flame, heat, smoke and gas.
Fire Safety means the measures taken to *protect* the *exposed* so as to satisfy a specified objective.
Fuel means a substance that yields heat through combustion.
Heat-Energy is a term used to indicate that only the thermal forms of energy are of concern.
Heat-Energy Source (*source*) means any *place*, material or object at which *heat-energy* can originate or from which *heat-energy* can be transferred.
Heat-Energy Transfer Process means the exchange of thermal energy from the *source* to the *fuel* by the mechanisms of *conduction, convection*, and/or *radiation*.
Ignitibility means the ease with which *fuel* undergoes *ignition*.
Ignition means the momentary event when *fire* first occurs.
Immobilize means to fix in place, so that no movement can occur.
Limit means to prescribe a minimum or maximum size, quantity, number, mass, extent or other dimension.
Manage means to coordinate broadly-ranging available methods toward accomplishment of objectives.
Manual means employing human action.
Place means an area within designated boundaries containing *exposed*.
Protect means the use of any or all available measures to *limit fire impact*.
Radiation means the combined process of emission, transmission, and absorption of energy traveling by electromagnetic wave propagation (for example, infrared radiation) between a region of higher temperature and a region of lower temperature.
Safe Destination means a *protected place* of adequate capacity.
Safeguard as used in the Tree, means to *protect* the *exposed* by using only those measures directly involving the *exposed*, without acting on the *fire* itself (see *defend*).
Separation means an intervening space (as opposed to *barrier*).
Source — See *Heat-Energy Source*.
Suppression means extinguishment or active *limit*ation of *fire* growth.
Thermal Energy — See *Heat-Energy*.
Transport means the movement of either the *heat-energy source* or the *fuel*.

Figure 7-3 Glossary

ADMINISTRATION ACTION GUIDE

The NFPA Firesafety Concepts Tree is a branching chain of goal-means relationships. There is, however, a dimension beyond the Tree, an infra-structure in the form of an administrative scheme or social organization which is always necessary to bring about the means called for by the Tree. Such an administrative structure has been included here.

This branch could well be visualized as pertaining to any means throughout the Tree, since it represents only a generalized conceptual scheme (entirely nontechnical) for facilitating employment of means to achieve goals.

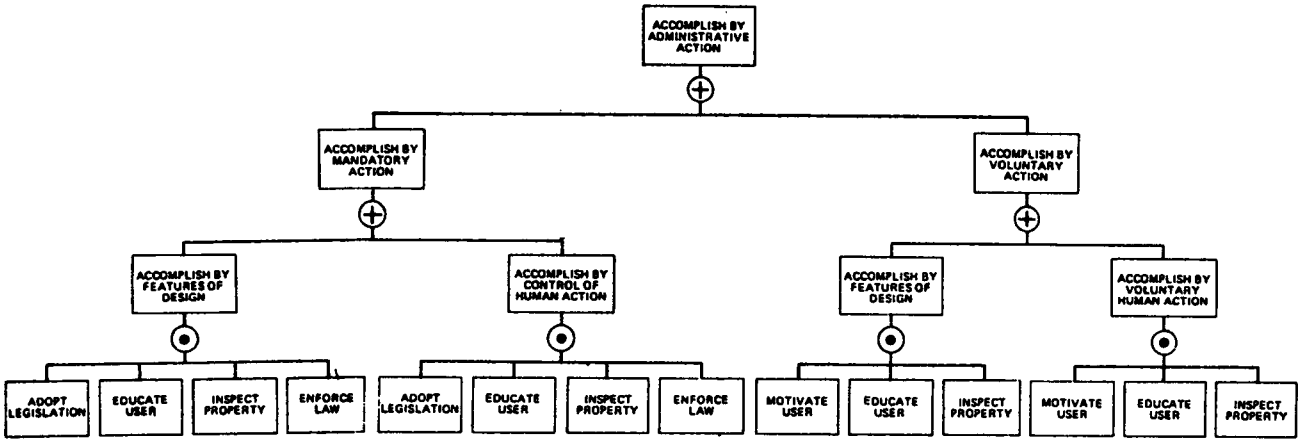


Figure 7-4 Administration Action Guide

7-4 Administrative Action Guide (Figure 7-4). The Administrative Action Guide uses the logic tree format to show various ways to regulate or promote firesafety strategies. This is intended as a generalized guide to the encouragement of any of the measures described in the Firesafety Concepts Tree.

Appendix A Bibliography

This appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

This bibliography on the Firesafety Concepts Tree is a collection of references to background documents from which the tree was developed and examples of uses and applications of the tree.

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Appendix B Fault Tree Analysis

This appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

According to Recht (1), fault tree analysis was developed in 1962 by H. A. Watson of Bell Telephone Laboratories. The technique was subsequently made famous by the Boeing Company in its application to the Minuteman Ballistic Missile Program (2).

Fault tree analysis uses a tree-like diagram to describe and analyze the undesired or "top" event, so called because it is at the top of the diagram, with "branches" of the tree extending downward from it. These branches connect the events or conditions which cause the top event to happen. Relationships of these causative events are shown by the connecting lines going through one of two basic "logic gates" — the AND gate and the OR gate. The AND gate indicates that a "fault" will occur when all the causative events happen simultaneously. If any single one of a group of events can produce the fault, then they are inputs to an OR gate.

Fault trees are based upon setting down a specific failure and examining the system in a logical, well organized way to determine what can go wrong to produce the failure. Alternatively, one can consider a desirable top event. A "success tree" is based upon analysis of requirements and alternatives to achieve a specified goal or objective. The NFPA Firesafety Concepts Tree is a success type tree.

Use of fault tree analysis requires close knowledge of the system being analyzed. It is often time consuming, but if thorough, will be revealing. It often leads to discovery of combinations of factors which otherwise might not have been recognized as causative of the event being analyzed. The tree becomes a record of the thought process of the analyst and serves as an excellent visual aid for communication with designers and management. More detailed descriptions of fault trees and fault tree analysis will be found in references (3-5 below).

References

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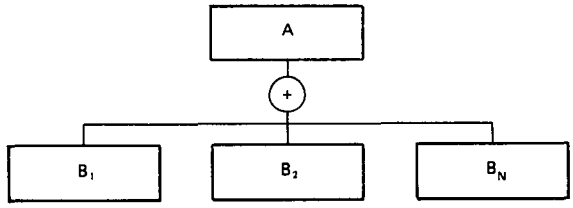
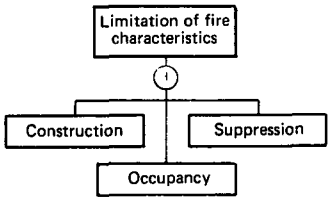
Appendix C Logic Gates

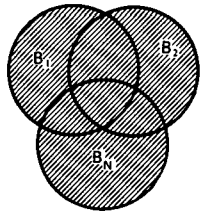
This appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

The plus and dot symbols used for OR gates and AND gates in fault trees and the Firesafety Concepts Tree are standard symbols for these logic operations used in electronic circuit diagrams and Boolean algebra. They are derived from the algebra of probabilities. For example, consider the flip of a coin. If we want to calculate the probability of a head OR a tail we add the probability of a head (.5) to the probability of a tail (.5), i.e., .5 + .5 = 1. Thus the symbol for an OR operation is a plus sign. Now suppose we flip the coin twice and want to calculate the probability of getting first a head AND then a tail. This is found by multiplying probabilities, i.e., (.5) . (.5) = .25, thus the symbol for an AND gate is a dot signifying multiplication. Some additional examples of these logic gates are illustrated below.

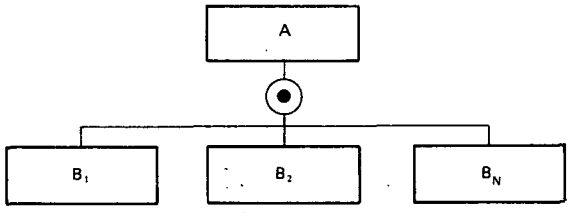
Or gate

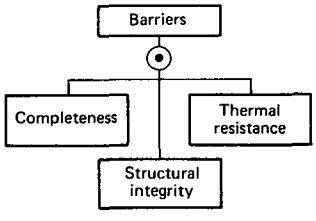


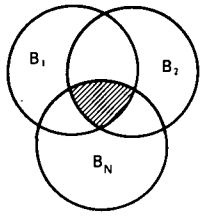




And gate







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Contact NFPA Standards Administration for final date for receipt of proposals on a specific document.

INSTRUCTIONS

Please use the forms which follow for submitting proposed amendments. Use a separate form for each proposal.

1. For each document on which you are proposing amendment indicate:
   (a) The number and title of the document
   (b) The specific section or paragraph.

2. Check the box indicating whether or not this proposal recommends new text, revised text, or to delete text.

3. In the space identified as "Proposal" include the wording you propose as new or revised text, or indicate if you wish to delete text.

4. In the space titled "Statement of Problem and Substantiation for Proposal" state the problem which will be resolved by your recommendation and give the specific reason for your proposal including copies of tests, research papers, fire experience, etc. If a statement is more than 200 words in length, the technical committee is authorized to abstract it for the Technical Committee Report.

5. Check the box indicating whether or not this proposal is original material, and if it is not, indicate source.

6. If supplementary material (photographs, diagrams, reports, etc.) is included, you may be required to submit sufficient copies for all members and alternates of the technical committee.

NOTE: The NFPA Regulations Governing Committee Projects in Paragraph 10-10 state: Each proposal shall be submitted to the Council Secretary and shall include:

(a) identification of the submitter and his affiliation (Committee, organization, company) where appropriate, and

(b) identification of the document, paragraph of the document to which the proposal is directed, and

(c) a statement of the problem and substantiation for the proposal, and

(d) proposed text of proposal, including the wording to be added, revised (and how revised), or deleted.