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CITY OF DALLAS

A STUDY EVALUATING THE CITY OF DALLAS CODES TO IDENTIFY CODE MODIFICATIONS COROLLARY TO THE PROPOSED EXPANSION OF AUTOMATIC SPRINKLER REQUIREMENTS

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PREFACE

This report summarizes a comprehensive study of the City of Dallas codes and related ordinances as a result of a contract with the City of Dallas. This study was funded, in part, by a grant from the Federal Emergency Management Agency (FEMA). Documents examined in this study included the current editions of the City of Dallas Building Code, Fire Prevention Code, Mechanical Code, Plumbing Code, Development Code and Waterworks ordinances.

The purpose of this study is to identify those requirements of the current city codes and ordinances which could be amended in order to provide an improved level of fire safety for the citizens of Dallas, and their property, without imposing an economic hardship. Specifically, the City of Dallas codes have been analyzed to identify provisions which could be amended, given the more stringent requirements for the installation of automatic sprinklers which were proposed by the City of Dallas in 1981.

Major changes proposed to the Dallas Building Code in 1981 included:

- Modification to Section 1807(a) to require buildings with more than 1,000 people above or below grade level to comply with the "high-rise" requirements. Presently, this section applies only to Group B, Division 2 office buildings and Group R, Division 1 residential buildings more than 75 feet above grade.

- Modification to Section 1807(a) to eliminate the compartmentation option thereby requiring all high-rise buildings to be sprinklered.

- Modification to Section 1807(g) to require smoke control systems for buildings with more than 1,000 people above or below grade level. Presently, this section applies only to Group B, Division 2 office buildings more than 75 feet above grade.

- Modification to Section 3802(b) to require the entire building to be sprinklered when the building area exceeds 7,500 square feet. This represents a significant expansion of the current sprinkler requirements. Presently, only specific occupancies exceeding specified minimum floor areas are required to be sprinklered.

Prior to incorporating the above modifications into the Dallas Building Code, the City of Dallas contracted Schirmer Engineering Corporation to conduct an intensive study of all applicable city codes and ordinances culminating in a report which:

- Analyzes the current building code and identifies building features that are required because of an anticipation that the building will not be equipped with an automatic fire extinguishing system.

- Evaluates the total building fire resistance and life safety requirements that could be diminished, or eliminated, if an automatic fire extinguishing system was installed.

- Includes adequate wording for each affected section of the building code to maintain the intent and integrity of the code while providing a high level of fire safety through the installation of an automatic fire extinguishing system.

- Evaluates the impact and estimated costs for the installation of an automatic fire extinguishing system in four example buildings, and

- Evaluates the potential conflict between automatic fire extinguishing systems and smoke removal or control equipment.

This report is a result of an analysis of pertinent records of the Dallas Building Inspection Division, the Dallas Fire Department, the Dallas Department of Planning and Development; a review of related literature; and, an evaluation of the impact and cost for four typical buildings.

Schirmer Engineering Corporation retained the services of RTKL Associates, Inc., Architects, Dallas, Texas, to assist in the identification of architectural features required by the current city code which should be amended, and to develop the building examples and associated construction costs for the cost impact portion of this report.

An introductory section of the report briefly describes the evolution of typical building code regulations upon which the nation's model building codes were based. The Dallas Building Code in effect at the time this analysis began is based upon one such model code -- the 1979 edition of the Uniform Building Code, published by the International Conference of Building Officials, Whittier, California. (The City of Dallas recently adopted the 1982 edition of the Uniform Building Code, with local amendments, which will be effective January 1, 1983.) The current editions of several model codes were included in the literature search and, along with experience and engineering judgment, form the bases for the code change proposals included in this report. The introductory section of the report also includes a discussion of the systems concept of fire protection engineering which was utilized, in part, as the basis of comparing "equivalency" in the analysis of both current and proposed features of the codes.

Following the introductory section of this report is a summary of the data acquired in our review of Dallas Building Inspection Division and Fire Department records which are indicative of certain trends when compared to other large municipalities and the nation as a whole. A chapter-by-chapter summary of the code changes and supporting rationale is presented in the report followed by a chapter describing the functional and cost impact of the proposals upon four typical buildings. The actual proposed code change language is included in the appendix of this report.

This report is not intended to represent a comprehensive study of the operations, staffing or equipment allocation of the Dallas Fire Department or Building Inspection Division.

The cooperation and valuable assistance of the City of Dallas Fire Department and the City of Dallas Building Inspection Division in conducting this study is greatly appreciated.

EXECUTIVE SUMMARY

An analysis was made of the current City of Dallas codes and related ordinances to identify those requirements which could be amended to provide an improved level of fire safety for the citizens of Dallas, without imposing an economic hardship. These amendments are based upon a proposed requirement for automatic sprinkler protection in all new buildings which have an area greater than 7,500 square feet.

The requirement for automatic sprinkler protection for buildings greater than 7,500 square feet is based upon an analysis which demonstrates that manual fire extinguishment of fires of this magnitude cannot reasonably be accomplished.

An analysis methodology known as the systems concept was utilized in this project. This methodology identifies the relationship at a relative importance of various fire protection features to achieving a fire safety objective. This methodology also identifies those redundent features necessary for a high probability of achieving the fire safety objective.

The reliability of automatic sprinkler systems was examined. To the extent practicable, mechanisms for automatic sprinkler system failure have been "designed out" of the proposed Dallas Code. Fire experience shows that automatic sprinkler protection designed and installed in accordance with similar provisions recommended for the City of Dallas have a level of satisfactory performance exceeding 99.5 percent. In addition, there has been no reported loss of life due to fire in a fully sprinklered building other than those persons who were intimately involved with the fire ignition. Nevertheless, a sufficient degree of redundancy has been incorporated into the building code to asure that a high level of fire safety will result.

Growth trends in terms of population and building construction for the City of Dallas were analyzed. Results of the 1980 census for the City of Dallas show a population increase of 7.1 percent over that of 1970. Population projections indicate that the city will have a population of 1 million persons prior to 1990. By the year 2000, the City of Dallas is also expected to have a substantial growth in the number of jobs -- 48 percent greater than the 1978 level. These projections indicate continuing growth both in the commercial and residential segments of the construction industry.

Recent fire experience in the City of Dallas was analyzed to determine the relative magnitude of the fire problem when related to that of other similar sized cities and fire experience on a state and national level. Fire loss data for the period 1970 through September, 1982 was analyzed. The annual number of fires increased substantially during the first seven years of the period, but has shown an overall decline in recent years. In the period reviewed, the number of fire fatalities in the City of Dallas averaged 33 deaths per year with a high of 45 deaths in 1976 and a low of 24 deaths in fiscal year 1979-80. In the last five years, the average number of fire fatalities is slightly less than that of the entire period, indicative of a downward trend.

More than 35,000 fires were reported to the Dallas Fire Department during the analyzed period, averaging 2,725 fires per year. The overall pattern is indicative of an increasing number of fires in the period through 1977 followed by a decline in the most recent five years. Similarly, the population-based rate of fires per 1,000 persons indicates an upward trend until 1977, followed by a steady downward trend in the last five years.

Direct property losses for the period 1970 through September, 1982 show a steady increase. However, this increase is partially offset by inflation. Yet, a slightly increasing trend in property loss is evident.

Residential fire losses in the City of Dallas account for a substantial number of total fires and fire fatalities, similar to the rest of the nation.

The operating expenditures of the Dallas Fire Department for fiscal years 1969-70 through 1980-81 show an upward trend. However, when adjusted for inflation, fire department operating expenditures have been relatively constant since fiscal year 1974-75. Similarly, adjusted per capita operating expenditures for the fire department have remained relatively constant since fiscal year 1974-75.

The number of uniformed personnel has increased in recent years, but when expressed in terms of fire fighters per square mile of the city, a downward trend is evident since 1972. The number of fire fighters per 1,000 population has remained relatively constant since 1972. It is apparent that substantial additional costs would be required for the fire department operating budget to materially affect the level of fire protection in the City of Dallas. The proposed code changes are intended to provide a higher level of fire protection while stabilizing or ultimately reducing fire department costs for suppression services.

Major changes have been proposed to Subchapter 5 of the Dallas Building Code which addresses general requirements for limitations on the allowable height and floor size of a building, the degree of fire resistance required for structural members of a building and requirements for buildings that house more than one occupancy. Since automatic sprinkler systems have proven to be a much more effective method of suppression than manual means, increases in the allowable heights and areas over present code requirements have been proposed without sacrificing the high level of safety intended by the code. The changes for Subchapter 5 represent a significant potential reduction in costs of construction which will partially or fully offset the cost of the required sprinkler protection.

A comprehensive proposal for covered mall shopping center buildings is included in this report. Although the proposal parallels requirements contained in the 1982 Uniform Building Code, certain overly redundant features have been deleted. However, the proposal does not allow the construction of an unlimited area building of Type III (masonry/wood joist) or Type V (frame) construction.

A revision has been proposed to Table 9-A of the Dallas Building Code which specifies maximum quantities of hazardous materials which may be allowed in a building. The proposed modification allows the quantities of materials specified in this table to be utilized on the basis of multiples of building area rather than being totally independent of building area.

An amendment has been proposed to Section 1705(b)5 of the Dallas Building Code to allow the use of nonrated construction for corridors serving an occupant load of 30 or more persons in a fully sprinklered building.

Comprehensive requirements for atrium buildings have also been proposed in this report. These provisions, again, parallel the requirements contained in the 1982 Uniform Building Code. However, certain overly redundant requirements have been proposed to be deleted from the Dallas Building Code; much broader, performance-type requirements are included.

Modifications have been proposed to Subchapter 18 concerning high-rise residential and business buildings. A careful analysis was made to determine which of the currently required fire protection features could be reduced or eliminated in these buildings when they are fully sprinklered, even though the current Dallas Building Code provides for certain reductions in fire protection elements for a sprinklered building. Additional reductions have been proposed.

Current requirements for the provision of smoke and heat venting in unlimited area buildings are proposed to be deleted on the basis of their unquantifiable benefits and possible detrimental effects on the control of a fire.

Modifications have been proposed to Chapter 33 of the Dallas Building Code concerning the calculation procedure for exit facilities in sprinklered buildings. Essentially, these changes do not require cumulative loading from floors above and below the floor under consideration for purposes of determining the number exits and exit width. A modification is also proposed concerning the arrangement of exits to allow a reduction in the required separation between exits in sprinklered buildings by one-half.

As a means of assuring a high level of reliability of the sprinkler system, additional requirements for electrical supervision of sprinkler systems have been proposed. Section 3802(c) will require that automatic sprinkler systems be supervised for waterflow, valve position and other conditions which may impair the operation of the system by an approved agency, or by a local alarm which will provide an audible signal at a constantly attended location. This arrangement of the sprinkler system is similar to that which has proven to provide a very high level of reliability.

Modifications have been proposed to the section of the Dallas Building Code dealing with standpipes which will only require Class I (fire department use only) standpipes in those buildings where standpipes are presently required. In addition, standpipes will only need to be located in exit enclosures; the criteria requiring all areas of the building to be covered by a 130-foot hose and stream will not be applicable in sprinklered buildings.

Modifications are proposed to the code which allow increased use of plastic roof panels and plastic skylights in buildings which are completely equipped with an automatic sprinkler system. This change is made consistent with currently proposed national code language.

Modifications have been proposed to the Fire Code which formally recognized the fire flow requirements of a sprinklered building as being less than an unsprinklered building.

Modifications have been proposed to the Water Works Ordinance clarifying that an elaborate check valve and meter is not required for closed fire protection systems which have an automatic waterflow alarm system. In addition, the monthly charges associated with water connections for automatic sprinkler systems has been proposed to be deleted. Both of the changes to the Water Works Ordinances are intended to remove the disincentives which currently exists for the installation of automatic sprinkler systems.

An estimate of the cost impact of the proposed changes was demonstrated with four example building types: high-rise office, high-rise residential, low-rise office and low-rise residential. In the case of a high-rise office building, the proposed code changes show a net cost reduction of $0.49 per square foot for the proposed sprinklered building over the current sprinklered building. This is in addition to the cost advantage which currently exists for the sprinklered building over the unsprinklered building. In the case of a high-rise residential building, the proposed modifications to the Dallas Building Code will provide an additional cost differential $0.45 per square foot over the current code requirements.

The case for a two-story office building demonstrated a significant reduction in construction cost due to a reduction in the building construction type. This resulted in an additional cost savings of $1.02 per square foot.

No significant cost reduction was readily apparent for the case of a low-rise residential building. Additional incentives are recommended to be explored to help set the cost of sprinkler installations in this type of occupancy.

Other benefits resulting from the proposed automatic sprinkler requirement include a reduction in the number of fire-related fatalities and injuries, a property damage reduction and a reduction in indirect fire losses.

Ultimately, a reduction in the cost of providing public fire suppression services will result. Evidence of such a reduction exists in another municipality which has adopted extensive automatic sprinkler requirements.

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INTRODUCTION

In recent years, the subject of fire safety has received increased attention, both from within and without the fire protection community. The impact of building codes on the fire problem has also been the subject of increased study. At the same time, interest has been directed toward the costs and associated benefits of building regulations, including building codes and retrospective requirements of fire prevention codes.

This report represents a comprehensive analysis of the City of Dallas codes and ordinances for the purpose of identifying specific provisions which can be reduced or eliminated, without materially affecting the level of safety, if automatic sprinklers are mandated for a larger number of buildings.

In order to identify such provisions, fire loss records of the City of Dallas for the recent period, national fire loss data, related literature, code provisions of other jurisdictions, fire department staffing and budget data were reviewed.

The Systems Concept

There is presently no generally accepted methodology for the evaluation, analysis or design of fire protection. In contrast with other engineering disciplines, fire protection engineering, as related to building design, relies to a greate extent upon tradition, experience and empirical methods. It is not possible, for example, to quantify the level of fire safety of a building to a point where one can measure the safety of additional fire protection measures, or, to say that the fire protection design of a building has a specific factor of safety. Recent analysis techniques are striving toward such quantification, but there is no widespread agreement in the building community with respect to this approach.

The prevailing method of fire safety evaluation in the United States is by code compliance. Building codes are legal documents which set forth minimum requirements to protect public health, safety and welfare in structures. The code categorizes structures by occupancy, construction and the presence or absence of sprinkler protection, and then applies specific provisions to each resulting class. Buildings, however, are becoming more complex both in terms of occupancy and with respect to their subsystems. Frequently, a large building will contain significant areas of multiple occupancy which seemingly defies traditional occupancy classification.

The development of code provisions has largely been a response to specific fires and the desire to prevent the recurrence of undesirable events. For example, many of the present requirements for life safety were implemented as a result of the Cocoanut Grove night club fire, the Chicago school fire and, more recently, the MGM Hotel fire in Las Vegas. The outcome of this process is that new provisions are typically added to existing ones without evaluation of the net resultant impact on efficiency of fire safety. This provides the potential for expensive redundancy in building design.

Thus, the justification for code requirements is more sociological than scientific. Many of the provisions are based on historical procedures without technical merit. Many provisions derived in this manner assume a greater degree of stature over the course of time. There is simply inadequate technical input to consider code requirements as a valid measure of fire safety.

A fundamental deficiency in the traditional building code approach to fire safety is the lack of a specified level of performance. Even within a single code there are various (unspecified) levels of safety. Although building codes are trending toward performance rather than specification criteria, there is little variation permitted within code requirements.

Unlike the vast majority of structures in the U.S., the property of the federal government does not fall under the jurisdiction of commonly used building codes. In this light, the U.S. General Services Administration (GSA) was able to deviate from the accepted practice of code compliance and formulate the Goal Oriented Systems Approach, first presented at the Airlie House Conference in 1971.[1]

This method has since evolved and has become known as the "Systems Approach" to fire safety analysis. The National Fire Protection Association "Committee on Systems Concepts" has developed a similar version of the GSA systems approach, the NFPA "Decision Tree" (Figure 1). The systems approach provides an organized approach to a building's fire safety with respect to established goals for the life safety, property protection and/or business continuity which may not be related to the unspecified goals contained in a building code. Similarly, the use of the Decision Tree allows the evaluation of a particular building component, a public address system for example, with respect to the established goals.

There are two approaches or uses possible with regard to the Decision Tree. One is the objective approach. This approach develops mathematical probability goals. For example, it could be decided that the goal was 99.7 percent probability of success in having not more than one fire death per 100,000,000 man hours of exposure and 99.6 percent probability of success in preventing any fire from exceeding $100,000 in property damage or $250,000 in business interruption loss.

The General Services Administration used this approach in several of their building designs. They establish parameters such as 99.999 percent probability of success in confining a fire to a work station, a room, a floor, or a building.

The objective use of the systems approach requires development of success probabilities related to all components of a building's fire safety system. In some cases, statistical data is available to develop these probabilities with a good degree of confidence. In other cases, fire test data makes it possible to accept basic assumptions. Unfortunately, this is not true with regard to all aspects of the Decision Tree and, as a result, many assumptions are purely judgmental. Other than the natural reluctance of the code community in accepting the systems approach, the lack of a data base is the primary weakness of this methodology at the present time. As statistical bases expand and as fire test data becomes more and more available, the objective use of the tree can become extremely advantageous.

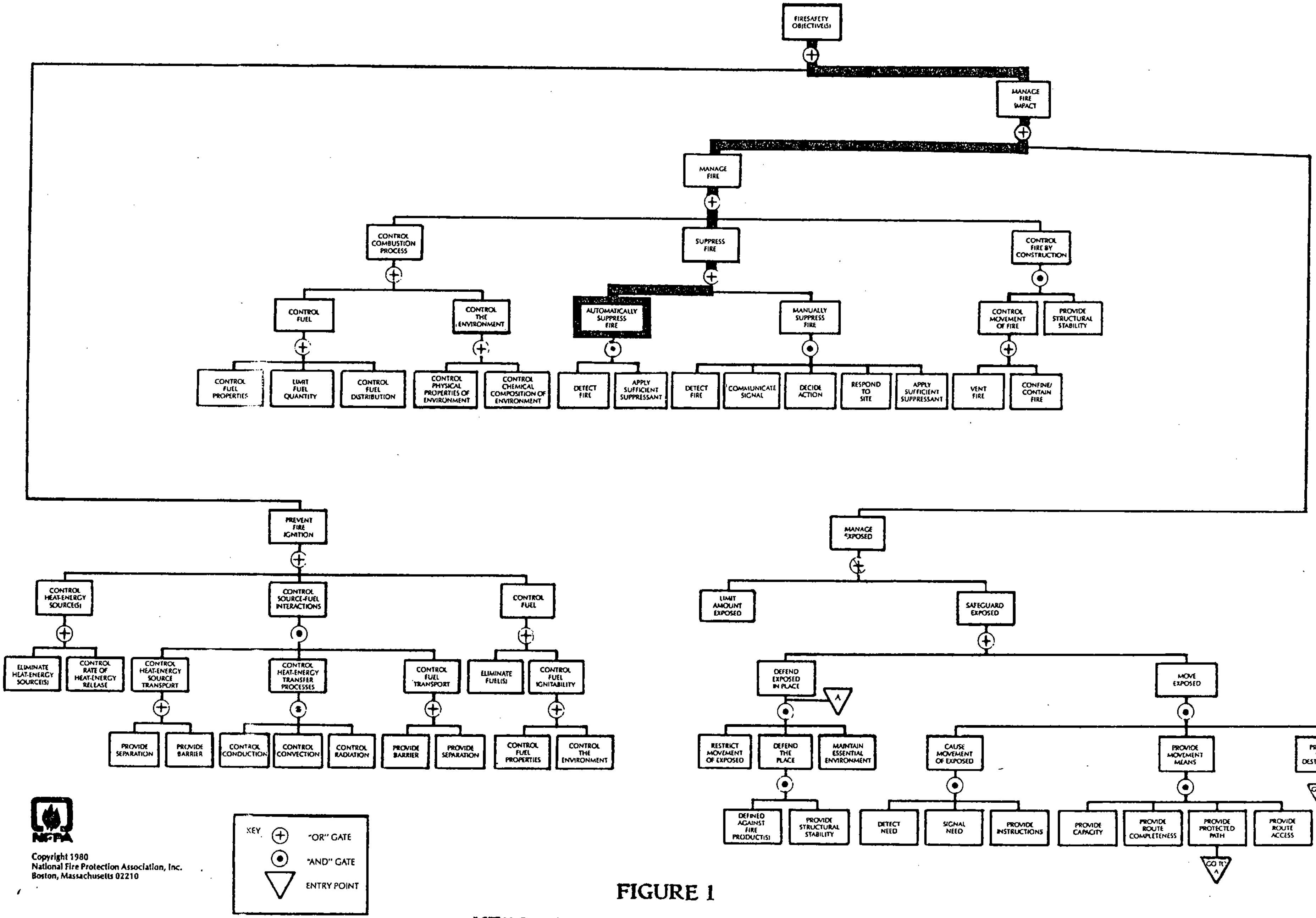

FIGURE 1

NFPA FIRE SAFETY CONCEPTS TREE

Source: Building Standards, January/February, 1982.

The second approach to the use of the Decision Tree is subjective. In this case the Decision Tree is used as a method of organizing thoughts regarding the design for fire safety. It disciplines the design team and the regulatory authorities in investigating alternate approaches. Further, it facilitates recognition of alternate solutions or equivalencies. The subjective use of the tree provides an excellent communication tool between the fire protection engineer, the owner, the architect and the local authorities.

In both the objective and subjective approaches to the tree, it is first necessary to establish goals. These will relate to the ability to limit loss of life or the size of a fire. One may think in terms of a fire not spreading beyond the place of origin, the room of origin, the floor of origin, the building of origin, etc. Each of these relates to an exposure in terms of a number of people and/or dollars. A decision is necessary as to the acceptable level of loss with a full recognition that "100 percent safe" is not possible.

In reviewing the Decision Tree, it should be noted that two types of "gates" are provided below the various levels of decision. These include "or" gates (+) which indicate that either solution below a particular gate will satisfy the objective above it if they are totally successful or that proportions of each combined will totally satisfy the objective. The "and" gates (.) indicate that in order to satisfy the goal immediately above the "and" gate, all items in the level immediately below it must be satisfied.

An overall view of the Decision Tree would indicate that the left side, "Prevent Fire Ignition," refers primarily to those items which would be normally contained within a fire prevention code. The right side of the tree under "Manage Fire Impact" deals primarily with those items which would be included within a building code. The Decision Tree indicates that it is possible to achieve a fire safety objective by either preventing fire ignition or by managing the fire impact.

In reviewing the "Prevent Fire Ignition" items, it can be seen that only in extremely rare instances would it be possible to achieve a high degree of success in these items and, therefore, make it necessary to consider items relating to managing the fire impact. As an example, consider the item referring to the control of heat-energy sources which would be one method of preventing fire ignition. In order to accomplish this, it it possible to either limit the rate of heat-energy release or limit the presence of a heat-energy source. In the case of a flammable liquids operation, this would most likely be accomplished by complete elimination of smoking and smoking materials, strict control over electrical installations (including explosion-proof equipment), preventative measures regarding static electricity discharge, etc.

A lack of maintenance, however, could still result in overheated bearings which could provide an ignition source, and, a severe fire. A simple human error should not be allowed to result in a catastrophic failure in the achievement of the fire safety objective. It is quite obvious that control of fire ignition cannot be 100 percent successful as the sole means of providing for life safety. Therefore, we must consider "Managing Fire Impact."

When we consider "Managing Fire Impact," we can decide either to "Manage the Fire" or "Manage the Exposed."

It is possible, in part, to manage the fire by construction. This requires controlling the movement of the fire and the provision of structural integrity. Within building codes, this would relate to the fire resistance requirements of the structural elements plus compartmentation or area limitations which might be introduced. Considering the fact that the model building codes will allow unlimited building area when fire resistive construction is used in many occupancy classes, it becomes questionable whether any defined fire safety objectives were involved in the original promulgation of area limitations within these codes. This may account for some of the severe life loss and property loss fires which have occurred within "fire resistive" buildings.

The compartmentation option suggested by building codes is not always usable as it may well defeat an open office landscaping scheme originally decided upon by the owner or developer. In addition, the integrity of rated barriers is often violated by penetrations after construction, leaving the owner and occupants with a false sense of security.

However, the use of building integrity as a basic part of our fire safety system should not be discarded. The protection of vertical openings, for example, is a fundamental principle of fire protection which is not minimized by the systems approach. Nevertheless, total success in controlling the fire by construction alone is difficult or impossible and would make it necessary that the fire be suppressed.

Within the Decision Tree, fire suppression may be either manual or automatic. In the case of manual extinguishment, the human element must be considered. Numerous opportunities for failure to meet the fire safety goal exist in each of the following steps for manual suppression, <u>all</u> of which must be successful:

- o The detection of the fire.
- o The communication of a fire signal to responsible persons.
- o The decision to act.
- o The response to the affected area.
- o The initiation of the suppressant.
- o The achievement of fire control.

A great length of time can elapse between the time of origin of a fire and its detection. Additional time can also be expended between the detection of a fire and the communication to responsible persons.

In considering detection, it is apparent that those areas of the building that are normally unoccupied or normally not visible to occupants present the possibility of a delay in detection which could be significant in the fire safety of the building, particularly if the areas contain a large amount of combustibles. Numerous large-loss fires have occurred due to "delay in detection" and/or "delay in alarm." Even with automatic fire detection systems, the elapsed time between fire detection and the initiation of suppressant can be of a magnitude to jeopardize the overall fire safety of the building.

It is apparent that the immediate application of suppressant by automatic means during the early stages of a fire, without human intervention, offers a much higher degree of reliability in controlling or extinguishing fires as demonstrated by the record of performance of systems that are properly installed and maintained. The most widely used method of automatic suppression is the automatic sprinkler system. In recent years, most major building codes have required the installation of sprinkler protection in an ever increasing number of occupancies. The installation cost in new construction is usually partially or fully offset by a reduction in a building's structural fire resistance, increased travel distance, etc. According to the National Fire Protection Association's Fire Protection Handbook,

> Automatic sprinklers, properly installed and maintained, provide effective safeguards against loss of life by fire. Their value is psychological as well as physical; they give a sense of security to the occupants of buildings, and minimize the possibility of panic.

If we choose to control the fire by automatic suppression, it becomes apparent (refering to the Tree) that lesser degrees of attention could be given to other methods of reaching our fire safety objective. Referring to Figure 1, it is clear that several methods, or combinations of methods, may be used to meet the fire safety objective. For example, it becomes questionable as to whether the same degree of fire resistance is necessary as if no suppression system was installed. The degree of reduction which might be allowed would depend to an extent upon the nature of the occupancy and the reliability of the suppression system. In the case of automatic sprinklers, this would require that a close review be made of sprinkler performance history for the particular occupancy and that the various modes of failure be "designed out" of the system to the greatest extent possible.

In considering "Manage Fire Impact," it is possible to choose to "Manage the Exposed" rather than to "Manage the Fire." This refers to protection of people or possibly, to protection of valuable records, computer tapes, or another object being considered. Again, a number of choices are involved including the limiting of the amount exposed (e.g., control of occupant loads) or safeguarding the exposed.

The "Safeguard Exposed" concept allows an individual to be either defended in place or moved. The "Defend in Place" concept relates to areas of refuge and compartmentation presently included within many of our codes. It is interesting to note, however, that if we have successfully managed the fire via an automatic suppression system, an area of refuge is redundant and unnecessary.

A movement means is called for within the Decision Tree which relates to the exiting system normally called for within building codes. The traditional consideration of building life safety in the event of a fire is based upon rapid removal of the building occupants from the affected area. The movement means must have adequate exit facilities for each floor of the building. The number and size of exits is based upon two basic principles: travel distance and exit capacity. Travel distance is the maximum allowed distance to reach an exit from any point (on any floor) in the building. Exit capacity relates to the width of doors and stairways and is dependent upon the occupant load and use of the building.

Depending upon the occupant load and use, the code may require a minimum number of exits for each space or on each floor. Aside from providing adequate capacity and meeting travel distance requirements, multiple exits also provide an additional factor of safety should one of the exits become unusable.

It is not the intent of this discussion to delve into a detailed analysis of systems application to code or design methodology. It is, however, intended to identify an analysis method which can provide a reasonable design for fire and life safety. The method provides an outline for the thought process which should be involved in the design. It encourages definition of goals for the level of protection desired. It also provides a basis for evaluation of the contribution of individual code provisions, and, thus, was utilized in this project.

The method is applicable to a universe of structures, ranging from the one and two family dwelling -- our nation's most challenging fire problem -- to the major structure or multi-use complex. The method provides a means of analyzing present code approaches and guiding future code developments.

In summary, the elements employed in fire protection for buildings can be generally categorized. Aside from preventing fire ignitions and controlling the fuel environment within a building, fire protection goals for most structures may be accomplished by managing the fire impact either by:

- Construction (compartmentation),
- Suppression, or,
- Managing the exposed (i.e., people) by moving them out of the affected area via an exiting system.

These three methods are considered to represent the basic components of a building's fire protection strategy. It is important to note that good fire protection practice dictates that reliance for safety to life not depend solely upon a single feature. The NFPA Life Safety Code states:

> The design of exits and other safetguards shall be such that reliance for safety to life in case of fire or other emergency will not depend solely on any single safeguard; additional safeguards shall be provided for life safety in case any single safeguard is ineffective due to some human or mechanical failure.

Therefore, in most cases, two of the above three methods for providing fire safety should be incorporated into a building. This principle is utilized in the application of the Fire Safety Evaluation System (FSES) developed by the National Bureau of Standards and included in Appendix C of the NFPA Life Safety Code. Essentially, the FSES is a systems application used to measure an equivalent level of safety intended by the Life Safety Code. Successful use of the FSES in measuring equivalency requires that a minimum standard be met in each of three areas: containment safety (construction), extinguishment safety (suppression) and people movement safety (exits).

Reliance upon building construction as the sole means for preventing fire spread has, in recent years, received serious reconsideration. Even in relatively well-compartmented buildings, smoke from an uncontrolled fire can spread to other portions of the building by way of stairways, elevator shafts and ventilating systems. In addition, there is an uncertainty regarding the integrity of fire resistant barriers over a period of time. Frequently, repairs, extension of utilities and general use can render these barriers and opening protective devices (e.g., fire doors) vulnerable to fire. For these reasons, many communities have included mandatory sprinkler provisions into their codes.

Similarly, the reliability of automatic sprinkler systems is routinely questioned when reductions in building construction requirements are discussed. Various statistics are available concerning sprinkler reliability.[2,3] Results of these studies are summarized in Table 1. It is important to note that the successful performance ratio of studies included in Table 1 has a relationship to the thoroughness of the reporting system. In Australia and New Zealand, all sprinkler actuations are reported by law.

TABLE 1
AUTOMATIC SPRINKLER PERFORMANCE SUMMARY

Study	Number of Incidents	Statisfactory Performance (%)
Australia and New Zealand (1886-1968)	5,734	99.8
Australia and New Zealand (1968-1976)	1,945	99.5
New York City High-Rise (1969-1978)	1,648	98.4
U.S. Dept. of Energy (1952-1980)	115	98.3
National Fire Protection Association (1925-1969)	81,425	96.2
New York City Low-Rise (1969-1978)	4,061	95.8
U.S. Navy (Shore Facilities, 1964-1977)	724	95.7
Factory Mutual (1970-1977)	3,292	86.1
Oregon State Fire Marshal (1970-1978)	1,648	85.8

The NFPA has stopped reporting sprinkler performance data after 1970 since:

> ...it became apparent that the data being used were biased by collection criteria which concentrated on fires causing large dollar loss. This bias led to an apparent and misleading decline in sprinkler effectiveness. Informationof sprinkler effectiveness from insurers is also biased toward the larger property loss and the possible failure because of the widespread use of deductibles. Many fires which are extinguished by a small number of sprinklers and result in small property loss are never reported to the insurer.[4]

More important than the reasons for successful performance are the reasons for unsuccessful performance. Such an identification allows one to take the necessary steps to "design out" all the failure mechanisms reasonably possible. For example, the NFPA statistics show that more than 25 percent of the failures are due to inadequate water for the sprinklers as a result of closed valves or empty storage tanks.[5] These potential failure points can be electrically monitored (supervised) to provide an alarm at a constantly attended location which would indicate a sprinkler impairment.

A reason for the very high successful performance of sprinkler systems in Australia and New Zealand is that essentially all systems are electrically supervised for impairments and for sprinkler waterflow. A sprinkler waterflow alarm, monitored at a constantly attended location, results from the operation of a sprinkler system and is indicative of a fire. Responsible persons receiving either a sprinkler waterflow alarm or a sprinkler supervisory alarm can then contact appropriate parties, such as the fire department or building personnel, for corrective action. With electrical supervision of those components which can cause sprinkler impairment -- control valves, fire pump power, water storage tank level, tank temperature, etc. -- and monitoring of sprinkler waterflow signals, the reliability of the sprinker systems proposed for the City of Dallas will approach a level as high as practicable.

Records of the NFPA and in Australia and New Zealand attest to the superior life safety protection of sprinklered buildings: there has been no reported multiple life loss (3 or more fatalities) due to fire in fully sprinklered buildings. Fatalities have occurred in sprinklered buildings as the result of explosions or where the individual has had intimate involvement with the fire origin.