BUILDING TECHNOLOGY
1109 SPRING STREET SILVER SPRING MD 20910
301-588-5020

BUILDING REGULATIONS
AND
EXISTING BUILDINGS

EXISTING BUILDINGS AND BUILDING REGULATIONS

Prepared by
Building Technology, Inc.

For
U. S. Department of Housing and Urban Development

Contract H-5196

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This is one of three state-of-the-art reports prepared for the U.S. Department of Housing and Urban Development, under Contract H-5196, "Building Regulations and Existing Buildings". The other two reports are entitled Evolution of Building Regulation in the United States and Problems with Existing Building Regulatory Techniques.

Table of Contents

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* See next page for expanded Table of Contents

EXPANDED TABLE OF CONTENTS

A. INTRODUCTION

This report summarizes the state-of-the-art of information on the relationship between existing buildings and building regulations. It addresses two aspects of this relationship, aspects that are almost reciprocal. First, as regulations change over time, building performance changes. Second, building performance influences regulations.

Building regulations are intended to control specific attributes, such as fire safety and accident safety. As regulations change, buildings constructed during each period should thereby display varying degrees of fire safety, accident safety, etc. The buildings reflect the effectiveness of the regulations under which they were built. In the following discussion, measures of building dysfunction such as fire incidence data and epidemiology data will be related to regulatory history.

This relationship, if established, has a corollary. If there is a pattern to the age distribution of buildings in the United States, and if building regulations in effect influence building performance, a pattern of change will emerge. For example, a steady increase in regulation of building performance, coupled with disproportionate removal of many old buildings, would yield a disproportionate increase in overall building performance. (The RFP for this project postulated such an "obsolescence model".)

In the second aspect of the relationship, building performance triggers specific code changes. A disaster attributable to the failure of a certain building element may lead to a regulation designed to prevent a recurrence. Our discussion of this relationship will be in the form of an historic narrative.

We should at the outset point out some limitations or caveats regarding these relationships. (And we hasten to add that despite these qualifications, this report is valuable for the insights it may provide and the research needs it may generate.)

The history of model building codes in the United States is documented in the accompanying report, Evaluation of Building Regulations in the U.S. How closely can this regulatory history be related to building performance throughout the U.S.? We know that in the past two decades the model codes have become widely adopted and are representative of building regulations in effect throughout the country. However, it is unclear how representative they are when viewed over a 50-80 year time period.

How many local jurisdictions actually adopted the early editions of the National and Uniform Building Codes, beginning in 1905 and 1927, respectively? How many buildings constructed early this century came under any form of regulation? Even if local regulations were in effect, to what extent were they enforced in construction?

The answers are not reported in the general literature and lie beyond the scope of this study. Therefore, even if we had valid data on the fire safety of buildings built, say, in the 1920s (see later discussion on the validity of the data), these caveats would limit the degree to which the data might indicate effectiveness of model building regulations at the time.

As to building performance triggering a regulatory response, several documented events suggest a causal relationship, and many anectodal histories allege that this or that disaster led to this or that regulation. Some of these are reported in the following discussion. Nonetheless, the very nature of the regulatory process in this country—code change procedures, voluntary consensus standards, etc.—precludes a definitive finding of rigorous causality. The code change process itself is not rigorous, nor is it fully, or in many cases even partially, documented. At best one can cite trends, and draw broad, general conclusions.

Finally, even if some meaningful observations can be made about each of these relationships, there is this general caveat: The spheres of building regulations and existing building performance are not isomorphous. By their natures, building regulations address physical attributes, such as corridor length or fire resistance. On the other hand, building performance, and especially building "misperformance" (i.e., fire deaths, accidents, collapses, incidence of disease), reflects the interaction of these physical attributes, and the behavior of human occupants. A fire death results from both the corridor length and the person's perception of the hazardous condition and his control over it. Thus, before meaningful conclusions can be drawn about how effectively building regulations (past or proposed) influence building performance, one must normalize for all aspects such as human behavior. The subsequent discussion of major building attributes will elaborate.

B. ATTRIBUTES

(1) FIRE SAFETY

(a) Introduction

Over the past 50-75 years, fire incidence data and reporting in the United States have been quite extensive. Yet they cannot support a detailed analysis of the relationship between building regulations and building performance. This is so because the building age, type of construction, and occupancy class (as used in the codes) usually is not reported in the fire incidence data, even though these categories are of utmost importance in the regulatory framework. Ordinarily, reports of fire deaths fail to indicate where the death occurred, for example, room of origin, other room, public corridor, or stairs. Such information could be a significant indicator of how effective various code-required egress elements are.

Even if fire incidence data conveyed information relevant to building regulations, it would be no simple matter to deduce relationships with building performance. Before meaningful deductions could be made, at least three variables would have to be normalized: human behavior, building content, and firefighting technology.

Human behavior is important both in creating hazardous, or potentially hazardous, conditions (including arson) and in determining the response to a fire. Human behavior, in turn, is a function of a variety of socio-economic, cultural, and psychological factors.

Building content—furniture, equipment, draperies, etc.—generally is not controlled by building regulations. (Exceptions are certain hazardous materials in certain occupancies which are controlled by fire prevention codes.) Yet content is obviously a significant factor in both the ignition and spread of fire. Building content has not remained constant over the past 75 years. And while change in content has been the subject of some anecdotal reports, it has not been subjected to rigorous research and analysis.

Finally, firefighting technology, including water supply, highways and roads, mechanized equipment and trained personnel, has not remained constant over time. Fire losses and building performance will clearly be affected by the improvements in firefighting technology.

Without models for normalizing each of these variables, the best fire incidence data could shed little light on the relationships between building regulation and performance. All that can be done is to describe the "fire problem" at a given point in time.

(b) Dollar Fire Loss

In 1900, the "Aggregate Property Loss", as reported by the National Board of Fire Underwriters (NBFU), was $160,929,805. In 1979, the last year for which data are available, the total fire loss, as reported by the National Fire Protection Association, was $5,750,000,000. The fire loss in buildings was $4,964,000,000. It is not clear whether the "aggregate property loss" included non-building losses. The first year in which building and non-building losses were explicitly distinguished was 1947. Since then, non-building fire loss has been roughly 15% of the total fire loss. (Appendix A Table Nos. 1 and 2)

Assuming the aggregate loss was in buildings only, the annual fire loss in buildings has increased slightly more than thirty-fold since 1900. If the 1900 figure is adjusted for an assumed 15% non-building loss, then the annual fire loss in buildings has increased slightly over thirty-six fold.

This increased dollar loss is not adjusted for inflation. Using 1967 as a base of 100, the Consumer Price Index (CPI) has increased from 25 in 1900 to an average of 217.7 for the year 1979—an 871% hike. (Published by the U.S. Department of Labor, the CPI is a common measure of cost-of-living changes and is used by the federal government to measure the rate of inflation.) The total dollar loss from building fires is 30-36 times greater than in 1900; but it takes almost nine 1979 dollars to equal one 1900 dollar. Therefore in constant dollars, fire loss in buildings has increased 3.5-4.1 times.

One other factor should be considered. While fire loss in buildings has increased, this increase may simply mean there has been increasingly more property to burn. A chart prepared by the United States Fire Administration (USFA) showed direct fire loss as a percentage of the Gross National Product (GNP) rose from 0.25% in 1955 to 0.3% in 1975[1]. (The GNP, one measure of the national wealth, measures the goods and services produced in a given year. Data is not available for the early years.) The loss as percentage of GNP has fluctuated, the low being 0.2% in 1965; the high, 0.3% in 1975. This relatively slow average growth indicates the percentage of national wealth lost to fire has not increased significantly in the past twenty years, although fractions of a percent represent great sums of money. Given the recent substantial increase in losses to arson, whether for profit, revenge, amusement, or gratification, it is possible that losses due to "building defects" may have remained constant or even decreased slightly as a percentage of the GNP. This cannot, however, be explicitly determined.

(c) Per Capita Loss

Another common measure of fire loss is per capita loss: the total dollar loss divided by the total number of people. This measure is intended to correct for differences in population over time. Complete per capita fire loss data is not available. Figures published by the NBFU for the years 1915 through 1939 show an increase from $1.71 to $2.29. However, per capita loss had reached a high of $4.90 in 1924, then lowered steadily over the next 15 years. (Appendix A Table No. 3) This trend followed the general total fire loss over this period, the decline being generally attributed to the depressed economy in the 1930s. Though the per capita loss increased 34% from $1.71 to $2.29, the CPI increased 37%. Therefore, adjusted for inflation, the per capita fire loss remained essentially unchanged.

For the period 1955-1975, the USFA reported that per capita fire loss increased from roughly $8.75 to $11.75 in constant 1967 dollars: an increase of 34% in 20 years.[2] During this same period, the fire dollar loss as a percent of the GNP increased only 20%, from 0.25% to 0.3%. Therefore, though the loss per person had increased, this increased loss represented a smaller portion of the national wealth. This agrees with the conclusion of the Insurance Information Institute report, Insurance Facts: "While the trend of fire losses has been generally upward over the years, the ratio of such losses to the aggregate value of property subject to such losses has been declining for many years as a result of countrywide fire prevention efforts."[3]

(d) Number of Building Fires

The number of building fires per 1,000 population shows a slight decrease over time. Again, only partial data are available. The fire rate in 1936 was 5.24 building fires per 1,000 population. That rate rose to 5.58 in 1941, but dropped to 5.08 in 1943. The next report, in 1960, revealed a rate of 4.93, which dropped to 4.74 in 1965. The rate rose slightly to 4.8 in 1970 and 1971, the last year for which national data were published. (Appendix A Table No. 4) By this measure, there was an 8% reduction in the fire frequency per 1,000 population during the 35-year period 1936-1971. (It should be noted, however, that the percentage of apartment dwellers has risen during this period, which may indicate a concommitant reduction in total number of buildings per 1,000 population.)

(e) National Loss Estimates by Occupancy

In October, 1937, the National Fire Protection Association (NFPA) noted that there were "no complete National statistics on the distribution of the fire loss in the United States, either by causes or by occupancy classes".[4] Nonetheless, the NFPA, believing that the losses reported were representative of the nationwide fire loss, prepared the first national estimates by occupancy. These were based upon 1936 fire loss data submitted by the fire marshals of 12 states.

Beginning with 1937 fire loss data, the NFPA published annual fire loss statistics in its membership publication, Fire Quarterly and the successor Fire Journal. The series, "Fires and Fire Losses Classified", ended in 1975 because of uncertainties over the accuracy of both data collection and data analysis procedures. Since then the National Fire Data Center of the United States Fire Administration (USFA) has been developing its own data collection system—the National Fire Incident Reporting System (NFIRS). Also, as required by Congress, the Center in December, 1978 published the first comprehensive analysis of the national fire problem based upon 1975 data. Culminating ongoing give and take, the USFA and NFPA recently agreed to share data sources. Hopefully, the collaboration will lead to more reliable information.

For the years 1937-1975, the NFPA reported that the annual dollar fire loss in residential occupancies increased from $96,700,000 to $1,389,000,000: 3.8 times the rise in the Consumer Price Index (CPI). For offices, the increase was from $5,700,000 to $57,800,000: 2.7 times the CPI. Mercantile losses grew from $40,330,000 to $449,200,000: 3.0 times the CPI.

For the same time period—1937-1975, the approximate annual increase in fire loss from building fires of all types was 3.5-4.2 times the CPI. The range is necessary because the loss report for 1937 fails to specify whether the figure represents the total fire loss or only fire loss in buildings, and if so, the percentage of building and non-building losses. Nonetheless, the increase in residential losses has grown at about the same rate as the total fire loss in buildings, while losses in mercantile and office occupancies grew somewhat more slowly than overall building fire losses.

As a percentage of the total dollar fire loss (building and non-building fires), the loss in office occupancies has remained almost consistently between 1-2%. Mercantile losses declined from 15% of total fire loss in 1937 to 11% in 1975, with a range between 16% (1940) and 8% (1960) for the years studied. On average, there has been a slight decline of a few percentage points since 1937.

Residential losses have been the most volatile. In 1937, the dollar fire loss in all residential occupancies represented 36% of the total dollar fire loss. This declined to a low of 22% in 1945, the end of World War II, and has since climbed steadily to 33% in 1975, with only a slight dip in the mid-1950s. (Appendix A Table No. 5)

Given the quality of the data, the reduction from 36% to 33% over the years is not significant. However, the USFA, based upon 1978 data, concluded that 46% of the total dollar loss was suffered in residential buildings. The dollar loss from all other building occupancies combined totalled only 43% of dollar fire loss.[5] The discrepancy between USFA and NFPA data arises from different data collection and analysis techniques; it is not known which estimate, if either, is correct. Regardless, residential fire loss is a significant problem.

(f) Deaths by Fire

Fire loss statistics on people are extremely poor. The primary reason is that for many years, property insurance companies were the only organizations that compiled such statistics. Since these companies were insuring against property loss they had no need to accumulate death and injury data. Around 1910, the NFPA's Fire Quarterly began publishing selected accounts of individual fires; however, there was no systematic attempt to report fire deaths. These reports and other brief articles were never sufficiently comprehensive or reliable to permit analysis.

Another problem, even today, is that public health agencies often have different definitions of "fire death". As a result, there have been accounts of improper attribution of death, particularly where death occurred sometime after the fire. For example, where pneumonia was induced by smoke inhalation, cause of death has often been reported as respiratory failure rather than fire.

The NFPA reported there were 10,000 fire deaths, in absolute numbers, in 1950. Data for earlier years were not reported, but estimates range between 10,000-15,000 deaths per year. The number of deaths rose to a high of 12,200 in the years 1967 and 1970, but has decreased since then to a low of 7,780 in 1979. (Appendix A Table No. 6)

A major reevaluation of fire death statistics was brought about by the 1977 USFA report, "Fire Deaths in the United States: Review of Data Sources and Range of Estimates".[6] The report concluded that NFPA life loss estimates, based in relevant part upon the 1951 study, "Fire Casualty Statistics"[7] had grossly overstated the number of fire deaths attributable to transportation accidents. This realization was reflected in NFPA's next loss statistics when the number of reported fire deaths was 8,800 for 1976, down from 11,800 in 1975.

Excepting the years 1975 and 1976, the USFA reports a steady decline in fire deaths from 9,000 in 1971 to an estimated 7,800 in 1979. The USFA and NFPA estimates for 1979 are nearly identical, although they vary greatly in previous years. Nonetheless both organizations agree the death rate has declined. For 1950, NFPA reported 66.4 fire deaths per million population (DPM), which rose to 69.5 DPM in 1955, but decreased steadily to 55.4 DPM in 1975. The Fire Administration reported 43.7 DPM in 1971 and 37.1 DPM in 1978. (Appendix A Table No. 6)

Information on the demographics of fire deaths is only now becoming available. Based upon 1977 data, the USFA reported the death rates for non-whites is nearly 2-1/2 times the rate for whites, and the death rate for males is nearly twice the fatality rate of females. However, the fatality rate for non-white females is higher than the rate for white males (47.3 vs. 41.0 deaths per million persons).[5]

(g) Multiple-Death Fires

Multiple-death fires are significant from two perspectives. First, they are generally better documented in the literature. As such, they are a valuable source of engineering information, particularly for earlier years where other fire loss data are not available. Second, they constitute a grossly disproportionate portion of all fire deaths.

Comprehensive data on multiple-death fires were not reported until 1959. However, at that time a multiple-death fire was defined as claiming six or more lives. This number was reduced to five in 1960, four in 1961, and finally to three in 1962.

In 1962, 263 multiple-death fires claimed 1,159 lives. In 1979, 271 multiple-death fires killed 1,084. In the intervening years, there was a gradual improvement through the late 1960's and early 1970's. The lowest number of fires was 193 in 1972; the lowest number of deaths was 911 in 1971.

In the past decade, the number of multiple-death fires has risen. However, the total loss from multiple-death fires has increased at a somewhat slower rate: the number of multiple-death fires grew 30% from 208 in 1971 to 271 in 1979, while the number of deaths increased only 19% from 911 to 1,084. This decrease is due to a reduction in the number of fires causing ten or more deaths--the figure dropped from approximately 10 to 8 per year. In addition, the average number of deaths, though fluctuating between four and five per fire, has lowered from slightly less than five to slightly more than four. (Appendix A Table No. 7)

As mentioned above, multiple-death fires constitute a grossly disproportionate portion of total fire deaths. For example, for 1978, NFPA reported 1,137,227 building fires, 3,070,597 fires of all types, 8,621 fire-related deaths, and 286 multiple-death fires causing 1,158 deaths. Assuming all multiple deaths occurred in buildings, 0.025% of the fires caused 13.4% of the deaths. For all fires, the percentage of multiple-death fires is less than 0.01% of the total.

(h) Fires Causing Ten or More Deaths

A list of major building fires since 1875 which caused ten or more deaths has been compiled from various sources as part of this study. (Appendix A Table No. 8) While systematic data collection began only recently, fires of this magnitude have generally found their way into the literature. Most early anecdotal accounts were based upon insurance company investigations. Though the completeness of these earlier accounts cannot be determined, a general pattern emerges.

Since the turn of the century, the number of fires causing ten or more deaths has increased. However, the magnitude of individual losses has lowered.

The fires at the Beverly Hills Supper Club (1977: 165 dead) and the MGM Grand Hotel (1980: 84 dead) are notable exceptions, but it is such calamitous fires that have decreased most notably. Before the Beverly Hills fire, the most recent fire that claimed over 100 lives was the Winecoff Hotel fire in 1946—119 people died. But shortly before that, 168 died in the Ringling Brothers Circus in 1944, 491 died at the Cocoanut Grove Night Club in 1942, and 207 died at the Rhythm Night Club in 1940.

Historically, of fires causing ten or more deaths, as many claimed more than 25 lives as claimed between 10 and 25 deaths. Clearly since 1950, the number of fires with more than 25 deaths has been greatly reduced.

(i) Deaths by Occupancy

Reliable data on fire deaths by occupancy could only be located for the most recent years. Based upon limited data for 1975 and 1976, the USFA reported that 67.8% of all fire deaths occurred in residential occupancies, while 21.3% were the result of transportation mishaps. The next largest category was "other", 4.0%, followed by stores and offices of 2.0%. Only 0.1% of all deaths occurred in public assembly occupancies and 1.2% in institutions. There were no fire deaths in schools.[8]

For 1978, the USFA reports 77% of all fire deaths in residential occupancies. Transportation and non-residential fires each claimed 10%, with the remainder classified as "other".[5]

Because of the more complete data on fires causing ten or more deaths, some additional observations can be made. The general pattern of increased frequency and decreased severity holds true for most occupancies. For some, however, fires have also declined in number.

While the potential for disaster remains whenever large groups of people assemble, the last theater fire to claim ten or more lives was in 1911—26 people died at the Opera House in Cannonsburg, Pennsylvania. Moreover, those deaths were due to suffocation after people panicked and rushed the exits—fire posed no danger. In schools, the last fire of this magnitude was at Our Lady of Angels in 1958, where smoke spread through open stairwells killing 93, including 90 children. The last office disaster was in 1969: 11 died in a building with a single exit. Substantial improvements are also noted in business/commercial occupancies.

Less improvement has been shown in hotel/motels and other residential occupancies, in places of assembly (other than theaters), and in institutional occupancies, particularly for the elderly.

(j) Injury by Fire

Only in recent years have data on fire-related injuries become available. Even these data are scanty and not entirely reliable. Nonetheless, for 1975, the USFA reported a "best" estimate of approximately 310,000 fire related injuries.[9] For 1978, the number was reported as 290,000.[5] The bulk of both these figures is an estimate of unreported injuries, casting doubt on the significance of the reduction. Most of the injuries occurred in residences: 68%, as opposed to 13% and 10% in non-residential and transportation fires, respectively.[5]

(k) Causes of Fires, Deaths and Dollar Loss

In 1936, the NFPA began reporting estimates of fires by cause. However, it is unclear whether these early figures include non-building as well as building losses, and comparison with losses reported by other sources only creates greater uncertainty. It was not until 1947 that the proper classifications were made.

The most dramatic increase has occured in the incendiary/suspicious category, which grew from 1.0% of building fires and 2.2% of the building dollar loss in 1950 to 11.4% of the fires and 18.4% of the dollar loss in 1975. In the same period, the number of fires caused by children and matches grew from 3.3% to 5.1%, while the dollar loss grew from 1.0% to 3.4% of total building dollar loss.

The number of electrical fires remained relatively unchanged at 12%, though the percentage of dollar losses dropped slightly from 12.0% to 10.4%. The number of heating and cooking fires, which were combined as a single category, decreased from 15.2% to 13.1% of total building fires while the percentage dollar loss was halved from 12.9% to 6.5%. (Appendix A Table No. 9)

Data on the cause of fires by occupancy type first became available in 1978 with the USFA's National Fire Estimates based upon limited 1975 and 1976 data.[10] For relevant occupancies, the major cause, or causes when no single cause dominated, are:

- Public Assembly: cooking; incendiary/suspicious
- Institutions: smoking; incendiary/suspicious
- Stores and Offices: incendiary/suspicious; electrical distribution

The USFA has not yet reported on later years.

There is considerable current information on residential fires. The first USFA estimates showed cooking (18%) as the leading cause of fire in residences, followed by smoking (13%), heating (13%), incendiary/suspicious (11%), electrical distribution (7%), appliances (7%), and children playing (5%). "Unknown" was 10%.[11] The USFA's second estimates, the most current and the most complete ever available, report a substantial rise in heating fires (19%), replacing cooking (16%) as the leading cause. This is followed by incendiary/suspicious (11%), smoking (10%), electrical distribution (8%), appliances (7%), and children playing (6%). Again, "unknown" was 10%.[12]

The USFA also reported the cause of fire by type of residential occupancy. Heating (22%) was the leading cause of fire in one- and two-family dwellings, followed by cooking (15%) and incendiary/suspicious (10%). However, in apartments cooking (24%) was the leading cause, followed by smoking (18% vs. 7% in one- and two-family dwellings), and incendiary/suspicious (15%). Heating fires in apartments were only 6% of the total. In mobile homes, heating (22%) was the leader, followed by electrical distribution (15%) and cooking (13%). By far the dominant cause in hotels/motels is smoking (36%), followed by incendiary/suspicious (16%). Far less responsible are heating (8%), cooking (7%), and electrical distribution (7%).[13]

For all residential occupancies, smoking (22%) is the leading cause of fire deaths, followed by heating (13%), incendiary/suspicious (7%), cooking (6%), children playing (6%), and electrical distribution (5%). Thirty-one percent of fire deaths are listed as unknown. The leading cause of injuries is again smoking (18%), followed closely by cooking (15%) and heating (13%), and then incendiary/suspicious (8%), children playing (8%), and electrical distribution (6%). Fifteen percent of injuries are reported as unknown. Heating (18%) is the leading cause of dollar loss, followed closely by incendiary/suspicious (15%), and then electrical distribution (10%), smoking (8%), cooking (6%), and appliances (5%) and children playing (5%). Nineteen percent of the residential dollar loss is attributed to unknown.[12]

Large life loss fires generally have one key feature in common: the cause of the fire is often less critical than fire safety deficiencies, which either allow the fire to spread or result in failure of the building's exit system. For as long as records have been kept, major contributing factors have been unprotected vertical and horizontal openings, including unenclosed stairs, improper interior finish, overcrowding, single or insufficient exits, and lack of automatic extinguishing and alarm systems, alone or in combination. Other reviewers of the literature have reached similar conclusions.[14,15]

One recent and increasingly frequent cause of large life loss fires is arson—and more often for revenge than for profit. Generally a fire set for profit is made to appear accidental; large fires set for this reason seldom begin in exits or when the building is occupied by many people. However, the central motive of the irate customer or jealous lover is not property damage but human harm; too often the person heads straight to the front door and sets the primary exit ablaze with gasoline.

(1) Conflagrations

The one clear success in fire safety has been the virtual elimination of conflagrations (extensive fires) in our cities. During the 19th and early 20th century, fires ravaged such major cities as New York, Charleston, Pittsburgh, Philadelphia, San Francisco, and Baltimore. And, of course, there is Mrs. O'Leary's cow and the Great Fire of Chicago. Jamestown, the first American colony, was the first American conflagration: the city burned to the ground in 1676. A list of the largest fires has been assembled as part of this study. (Appendix A Table No. 10)

With these staggering losses, the insurance industry became actively involved in the problem, leading to eventual publication of the first model building code in 1905. Building set-back and separation requirements arose not only from concern for light and ventilation but also for fire safety. Wood-frame construction was banned in congested areas. Fire walls and parapets were increasingly required, along with protection of openings in exterior walls by wire glass windows or fire shutters. City streets were widened, and public water supplies and fire department capabilities improved substantially.

All these measures have combined to essentially eliminate the conditions for a full-scale conflagration. The major conflagration in Chelsea, Massachusetts, which began on October 14, 1973, is a stark reminder that disaster will return given the right conditions. Improper construction, unprotected outside storage of combustibles, and sloppy housekeeping fed this fire, which destroyed 300 buildings, caused $2,000,000 in property damage, and forced some 3,500 people to evacuate their homes. Chelsea had burned before—in 1908—and the same unsafe conditions had been allowed to return. The latest fire began only 200 feet from the 1908 blaze.[16]

The few conflagrations in this century have generally enveloped a smaller area or occurred in smaller, older, or more rural communities, where new construction practices had not yet taken hold. One problem, especially from 1901-1925, was wood shingle roofs. These were cited in an NFPA analysis of conflagrations as a principal factor in 45 fires: more than twice the second cause, high winds. Flying burning brands spread fire from building to building, across streets and other fire breaks, sometimes blocks away.[17]

Since 1925, high wind has been the principal cause of conflagrations.[17] In recent years, community growth into outlying areas beyond public water supplies and fire departments has been a significant factor. In Southern California, the combination of hot, high winds, thick brush, and difficult access is particularly troublesome. The Los Angeles fire in 1961, which destroyed 505 homes, is an example. Even today, a fire watch goes out when the brush is dry and the "Devil Winds" rip out of the mountains.

All in all, the conditions which permit major conflagrations have long been understood, and the corrective measures long perfected. The solution was simply the will to solve the problem, whether through enactment of fire safety regulations, urban renewal, condemnation, or simply the good sense to do better once a major fire provided the need and opportunity to rebuild. For the most part, this has been done.

(m) Fire Losses and Code Changes

The relationship between building codes and fire losses is difficult to define because the code change process traditionally has been very poorly documented. There is no hard record as to why things were done. The most complete information—personal anecdotal accounts—is also the least rigorous form of data.

Most people mention the code changes enacted in response to large disasters. Given the unwritten history of fire protection, it is only natural that the big fires are remembered best. But the major bulk of change has come slowly—almost glacial—as the codes were "fine tuned" to address smaller, more local problems.

Fire loss data is relevant to building regulation in three ways:

- whether past code changes have produced the expected results, i.e., the "obsolescence model"
- whether code changes are needed for the future, i.e., new construction
- whether code action is needed for the present, i.e., existing buildings.

Code changes limited to new construction take years to have effect because only a small percentage of the building stock is affected at any given time. The fire losses of today, therefore, must be viewed as a measure of code changes of a generation ago.

The primary goal of the first modern building codes was to end conflagrations, and this has been realized. Fire resistive construction replaced ramshackle wood shacks as the cities grew and rebuilt over the years. The egress problems of today--buildings with a single exit and/or fire escapes--were the solutions of a generation ago. The number of buildings with automatic sprinklers is slowly increasing, following expanding code requirements.

Later code changes reflected other developments in fire protection technology and philosophy. Manual and automatic detection and alarm systems, flame spread of interior finish materials, fire-rated corridors, and two or more remote exits are examples. The most significant code changes of the 1970s involved smoke detectors in residential occupancies and a package of provisions for high-rise buildings.

Have these changes provided greater safety? There can be no definitive answer because building age is not part of the fire loss data. But other measures, such as the declining death rate and relatively stable fire loss as a function of GNP, are positive indicators.

Increased energy consumption (for heating/cooling and electrical appliances), greater use of plastics and other synthetic materials, more and different interior furnishings, lighter weight building materials, arson, and other "non-code" changes have increased the fire hazard in buildings. Neither the increased hazard nor the level of safety in the codes can be explicitly measured. But recognizing that hazards beyond the reach of the codes have also increased over time adds support to the conclusion that past code changes have improved building performance.

Finally, though the data are only very recent and incomplete at best, fire losses in rural areas and amongst minority groups are higher than the national average. While the exact reasons are not yet fully understood, the buildings (especially housing) are likely older and in poorer condition. Code enforcement in rural and economically depressed areas is also more difficult. This would also support the hypothesis that new buildings, constructed according to updated codes, provide a greater level of safety than older buildings.

The second aspect of building regulations is the relationship between fire losses and changes in new construction codes.

For the "big" fires, the system has worked reasonably well. The fire is analyzed, the problem(s) identified, and the code amended. The lessons of the Iroquois Theater Fire (1903: 602 dead) solved the problem of fires in theaters; rigorous enforcement has prevented its return. The invention of safety film ended the problem of fires in movie theaters. The Triangle Shirtwaist Fire (1911: 145 dead) highlighted the danger of locked exits. The Hartford Circus Fire (1944: 168 dead) led to the banning of untreated canvas tents.[18] These are but a few examples, but they illustrate a direct relationship between a loss and the resultant code change. (See Appendix A, Table 11 for other major fires and their associated lessons.)

But only a few of the many changes over the years can be attributed to a specific event. For example, the Uniform Building Code (UBC) underwent a major change in 1946, yet the reason is not documented. There were significant changes affecting hotels, but the most notorious hotel fires in American history did not occur until after this edition of the UBC. A fire in September, 1943 at the Gulf Hotel in Houston, Texas claimed 55 lives. Perhaps this was the impetus for the UBC code change that appeared in the next edition. It is, though, only speculation.

The smaller and more subtle issues are even more difficult to trace. There is no rigorous process in which overall fire loss data are systematically analyzed. Instead, code changes are proposed by individuals, often in response to highly specific situations in their respective communities. This has caused the codes to become overly detailed and complex.

There have been instances when a problem was comprehensively studied. The high-rise provisions adopted in the 1970s is a good example. But other issues have not received similar treatment.

The problem of smoke control has been discussed in the literature since the advent of air conditioning and mechanical ventilation systems in the 1930s. The toxicity of plastics and other synthetic materials was a major issue of the 1970s. But the MGM Grand Hotel Fire (1980: 84 dead) showed the deadly effects of smoke movement throughout a building--most fire victims were over 20 stories above the actual fire. Both smoke control and toxicity have been variously regulated by the codes, though attempts to regulate plastics have been essentially abandoned for lack of a usable test standard. Smoke control and toxicity, both long established problems, are still not yet within the grasp of the regulatory process.

Yet despite this and other failures, a lack of documentation as to why and where code changes come from, and too narrowly defined problems, the code process does seem to respond to those issues presented for consideration. The occupancies most heavily regulated have the most stable or reduced fire losses.

The greatest failure of the regulatory system has been with residential occupancies. They are the least regulated, both in terms of the stringency of the codes and the level of enforcement. Not surprisingly, residences have the greatest number of deaths, injuries, and dollar loss of all occupancy classes (including non-building fires). The fire problem has followed the people from the tenements to the suburbs (though the older city and rural residential buildings are still the most dangerous).

The fire protection features required in other buildings are absent in residential buildings. Our homes and apartments are our "castles", politically beyond the reach of meaningful regulation. But the price for this personal liberty is reflected in the exceedingly high losses.

The final aspect of building regulations and fire losses is the impact on existing buildings.

Losses can occur when built-in fire protection is not maintained: holes poked through fire walls, fire doors blocked open, sprinkler and alarm systems never tested or serviced. That is the reason there are "maintenance" codes--to maintain the level of fire safety provided at the time of original construction.

But losses can also occur because the existing level of fire protection is inadequate: single exits or unenclosed stairs, for example. If the hazard or loss is deemed too great, then the new construction code is changed. This will prevent a similar occurrence in all new buildings, but does nothing to prevent a similar loss in other existing buildings. The early building codes addressed both new and existing buildings, but this is not common practice today.

Fire losses that prompt changes for new construction are, by definition, fires in existing buildings. That is where the problem exists. And retroactive ordinances for existing buildings have been around since colonial days. So a decision to limit remedial action to new constructions is a political or economic decision that immediate action is not necessary— that resolution can wait until the next generation of buildings. Rarely, though, is this decision consciously made.

The regulation of existing buildings is effectively beyond the scope of the model building code change process. What little has been done has occurred at the local level. But largely, fire loss data is never rigorously analyzed at any level to identify those risks in existing buildings that demand immediate correction.

(2) ACCIDENT SAFETY, HEALTH AND SANITATION*

(a) A General Note on the Documentation of Health and Safety Hazards

Most of the detailed specifications in the model building and housing codes were introduced prior to the development of systematic laboratory or survey research in the areas covered. Rarely can it be shown that a specific code provision was originally triggered by thorough documentation of a hazard pattern or of a single hazardous incident. The only clear instance appears to have occurred in the plumbing codes of 1938: as a result of an outbreak of amoebic dysentery at the 1933 Chicago World's Fair, below-the-rim supply connections were prohibited. In most other cases, it appears that specifications related to health and safety were based on the conventional wisdom then prevailing in the public health and building communities.

Many of the early provisions for reduction of health and safety hazards, while inspired by the good intentions and strong commitments of the social reformers of the late 19th century, appear to have been rooted both in the self-serving agendas of the model tenement movement and the technical innovations of private industry. While there seems to have been a sense that such innovations would make things better, there is little evidence that actual conditions (how good or bad) were clearly understood.

Subsequent adjustment of the detailed specifications based on laboratory or field research has presented two major problems. First, in areas such as heating and ventilation, the criteria have often shifted from health to comfort. Thus, some specifications originally proposed to curtail diseases like tuberculosis (window areas equal to 10% of the gross floor area, for example) are now based on comfort criteria such as the perception of body odor. Remarkably, despite such radical shifts in performance criterion, many of these specifications remain essentially unchanged in any quantitative or qualitative sense!

Second, some model code provisions have been adjusted for health purposes while actual hazardous conditions have never been determined. An example is the amount of square footage required per person. Often the original figures have been tacitly accepted as a baseline, then increased or decreased in accordance with prevailing opinions, data, or external conditions. Good examples are decreases in required square footage during the Depression, and temperature requirements following the Arab oil embargo. In neither case was there a body of evidence indicating a space or temperature threshold that would be hazardous to health or safety, although there may have been rigorous individual studies demonstrating beneficial health effects. In fact, there appears to have been no body of prior evidence to justify most model code provisions for health or safety, with the possible exception of data on thermal comfort and acceptable odor levels.

* All biblographic references for this section of the report may be found in Appendix B.

Part of this problem stems from the way most evidence has been gathered on the health and safety aspects of housing. Historically, the evidence has correlated very precise indicators of health with very general indicators of housing quality. Very tangible figures for death, accident, or infection rates have often been used to characterize very ambiguously defined "poor housing". Unless the precise elements or attributes are defined, the concept of poor housing is meaningless for purposes of the model building or housing codes.

In 1834, Gerritt Forbes tabulated death statistics against population statistics for the tenement districts of New York. In 1865, the number of tuberculosis cases in the Gotham Court apartments was well publicized. In his Tenement House Exhibition of 1900, Lawrence Veiller plotted the number of tuberculosis cases and the income levels for every building in lower Manhattan. All these studies showed there were problems of disease and accidents in the more crowded tenement districts of the city, but none directly linked these problems to the building subsystems addressed in the model laws and codes. Nonetheless, most health and safety specifications in the current editions of the model codes had already been quantified by the turn of the century!

As late as 1945, the American Public Health Association (APHA) was still trying to perfect a single, overall measure of housing quality, despite the fact that its own model housing code addressed health and safety hazards on an item-by-item basis. In sum, there continues to be a misfit between how hazards are understood and how they are regulated in the model codes.

Next, there is the question of whether more recent health and safety data support any of the earlier provisions in the model codes. The answer is yes, particularly in the areas of plumbing, safety glazing, and some of the regulations for stairs (such as the 3/16" maximum variation in riser and tread dimensions). However, the question is also much more complicated. Since most of the model code provisions were first introduced, there have been a number of changes in the way health and safety problems are conceptualized. Prior to the 1880s, vague notions relating disease to things like the miasma accompanying sewer gases gave rise to phenomenological interpretations of disease, such as those governing the early requirements for daylighting in habitable rooms. The acceptance of germ theory in the late 1880s gave rise to a far more deterministic approach, in which each illness or disorder was thought to follow from a single etiology. This approach was exemplified by Veiller's work in which the primary objective of building regulations was the elimination of the single direct cause of the illness or disease. Thus, to remove and dilute airborne sources of tuberculosis and other diseases, Veiller vigorously pursued ventilation and square footage requirements. He did so even though he had no data actually tying tuberculosis infection rates to measures of ventilation or room size.

Because it was in this context that most of the current model code provisions for heating, ventilating, and sanitary facilities were introduced, it is particularly noteworthy that in the 1950s, there was yet another conceptual shift in the relation between housing and health or safety. Instead of a single etiology linking each disease to a single source, most health and safety matters began to be considered in terms of multiple etiologies. Environmental and non-environmental causes were seen to interact to produce different incidence rates in different socio-environmental contexts. Within this more ecological framework, the issue of justifying current model code provisions based on direct causal evidence becomes moot unless the socio-economic and life-cycle circumstances of the occupants are also specified.

The state of knowledge in epidemiology and public health makes it extremely difficult to completely separate the health or safety effects of a building element or attribute from the many non-environmental factors at work in relation to a hazard. Moreover, improved medical care in this century, such as the removal of tuberculosis victims to sanitariums and the introduction of antibiotics has tended to separate disease victims from potentially hazardous environments, minimizing the apparent direct connection between built environments and many diseases. Therefore it is now extremely difficult to think about the direct health or safety benefits of most model code provisions.

This is not to say building attributes or subsystems have no affect on health and safety. Rather, researchers now attempt to identify the degree to which each problem can be attributed to building elements under different combinations of circumstances. In many cases, it is thought that factors such as stress, exposure levels, fatigue, adaptation, and familiarity interact with environmental conditions to increase the probability of certain problems among certain groups or individuals. Thus, the emphasis has shifted from direct effects to multiple causation and indirect effects. Since many of these indirect effects are counterintuitive, they are seldom anticipated by the model building or housing codes, and many remain undocumented.

Nevertheless, much of the recent research in consumer product safety and epidemiology rests on the premise that illnesses and accidents may have multiple causes, including aspects of building design and construction. Studies of stair, window, and bathtub or shower accidents and of the toxic or carcinogenic effects of lead paint, asbestos, and formaldehyde insulation have pointed to a number of building elements and attributes that are hazardous under certain circumstances. Yet most of these indirect hazards are ignored in the model building and housing codes, even though many are much more serious and more fully documented than most of the health and safety issues that are regulated.

Overall, though recent documentation of building hazards has stressed multiple causation and probabilistic effects, the model codes remain predicated on singular causation and direct benefits for health and safety. Thus, not only is it difficult to demonstrate the benefits of the code provisions, it is also difficult to incorporate into the codes provisions for indirect health and safety, citing conditions, for example, that cause prolonged or extreme discomfort.

The tradition of basing very precise code specifications on rather loosely defined measures of building conditions is inconsistent with the current understanding of health and safety hazards. As a result, many known serious hazards are ignored by the model codes, while several less critical or even questionable hazards remain very tightly regulated.

(b) Light and Ventilation

Light and ventilation within the dwelling were originally regulated to assure enough fresh air to remove the sources of airborne diseases, such as tuberculosis and respiratory infections. This continual supply of healthy fresh air could be provided in two ways: through the operation of windows and transoms, and through natural light, which was thought to destroy impurities in the air. Both approaches have gradually given way to mechanical and artificial techniques. A third approach to controlling disease-producing impurities--minimum dimensions, areas, or volumes for rooms--will be discussed more fully in the next section.

(i) The replacement of air through and around operable windows and transoms was first regulated by the New York Tenement Law of 1867. The law required that windows equal 10% of the floor area in the room, with the top half operable. It is not clear where this rather precise ratio came from. As early as 1824, an English engineer named Tredgold had recommended air changes of four cubic feet per minute (cfm) per person as an acceptable level of ventilation in occupied rooms, a figure apparently based on some unspecified studies he had done. In 1835, a Dr. Reid, who was involved with the ventilation of the House of Commons, recommended 10 cfm/person. By 1857, the Barracks Commissioners of England called for 20 cfm/person. Despite this steady increase, it is not clear how these air changes were measured or how they might have related to the 10% requirement of the New York Tenement Law.

But other contemporary developments may have had an even greater influence on the 1867 law than recommendations for specific air change rates. By 1857 in Massachusetts, death rates from tuberculosis were on the order of 450/100,000. In New York in 1863, there were anti-housing riots by the immigrant poor. And in 1865, the Gotham Court tenement in lower Manhattan was identified as a breeding ground for tuberculosis. The 10% ratio of window to floor area may simply have been a conventional figure, agreed to in order to provide a certain unspecified amount of ventilation in habitable rooms.

It was not until 1875 that a specific health-related criterion was used to justify a recommended level of ventilation in occupied spaces. In that year, De Chaumont recommended 50 cfm/person as the minimum needed to maintain levels of carbon dioxide at six parts per 10,000. This was two parts of carbon dioxide per 10,000 above normal. The level appears to be based on the assumption that the unhealthy qualities of indoor air result in part from exhalation by a room's occupants. In 1881, Pettenkofer and Flugge recommended between .07% and .10% as permissable indoor levels of carbon dioxide.

However, in 1882, a discovery by Robert Koch gave rise to germ theoretic interpretations of disease. Koch isolated the tubercle bacillus, identifying it as the causative agent of tuberculosis. This and many similar discoveries produced the theory that tuberculosis and other communicable diseases are transmitted via airborne microorganisms, carried on water droplets and dust particles.

Thus, not until 15 years after the New York Tenement Law and its minimum ventilation requirements were the airborne causes of tuberculosis and other diseases confirmed! This is noteworthy because to this day, the 10% ratio of window to floor area, with 1/2 openable, specified in 1867, has survived with only minor variations in most model codes. (Exceptions are certain occupancies or where mechanical ventilation is permitted.)

Between 1894 and 1900 a number of physicians, including Dr. John Pryor, Health Commissioner of Buffalo, testified before the New York Tenement House Commission that the poor quality of light and air in the tenements was directly responsible for the rapid spread of pulmonary tuberculosis. Armed with this unanimous testimony and the prevailing interpretations of germ theory, Lawrence Veiller in 1900 assembled an elaborate exhibition. Using maps, he intended to demonstrate that reported rates of tuberculosis (and other maladies) were directly correlated with crowding and poor housing conditions in New York's tenement districts. This exhibit was widely credited with assuring the passage in 1901 of the New York Tenement Code and Law.

However, the New York law, despite significant advances in the understanding of disease during the intervening third of a century, retained the same window area and operability requirements as the 1867 law. Moreover, by 1901, despite Veiller's demonstration that tuberculosis was more prevalent in poor housing, together with the widely held belief that inadequate light and ventilation were at fault, neither Veiller nor anyone else produced any evidence of a direct causal link between tuberculosis (or any other disease) and poor ventilation!

In 1904, the State of New York required 30 cfm for each pupil in a classroom. The following year, Flugge, et al conducted one of the first known laboratory studies of indoor air quality. Using comfort as the performance criterion, they found that increased heat and moisture, rather than increased levels of carbon dioxide or other chemical constituents, were the primary sources of unpleasantness. These results were confirmed in 1913 by Hill and his colleagues and in the following two years by studies conducted by the New York Commission on Ventilation.

Although in 1914 the American Society of Heating and Ventilating Engineers recommended 30 cfm/person in public and semi-public buildings, the objective of such recommendations seems to have shifted from controlling disease to improving comfort. In 1923, the New York Commission on Ventilation reconfirmed the earlier findings that temperature and humidity had more effect on comfort than did ventilation. The commission then proceeded to reduce the requirement from 30 cfm/person to 10 cfm/person, citing an annual savings in operating expenses of $3,000,000 nationwide. Apparently, it was not until 1935 that this lower rate of ventilation was found to be acceptable based on the subjective perception of human body odor; the tests were conducted by Lehmberg, Brandt & Morse. Note that in this century, most research on indoor heating, ventilation, and air conditioning has used comfort rather than health criteria as the primary indicator of acceptability (Winslow & Herrington, 1949).

Meanwhile, in 1933, New York City's Slum Clearance Committee undertook a study of tuberculosis rates in the Lower East Side of Manhattan. The study included many of the tenement blocks that Veiller, more than 30 years earlier, had cited as breeding grounds for the disease. While nationwide tuberculosis rates had dropped from 188/100,000 at the turn of the century to 71/100,000 by 1930, rates as low as 50/100,000 were found in some of the same blocks that Veiller had mapped for his 1900 exhibit! In fact, some tenements that had had the city's highest rates when Veiller studied them had the lowest rates when studied by the Slum Clearance Committee.

While this dramatic improvement could be attributed in part to improved health care which removed many of the infected residents to sanitariums, the reduction now appears to have been more closely associated with changes in the residents' socio-economic characteristics and living conditions. Later analyses by Dubos (1968), Kasl (1977), Cassel (1977), and many others have shown that high incidence rates of tuberculosis (and many other diseases) are more closely related to major disruptions in the living patterns of individuals and families than to deficient air quality. These researchers further point out that when Veiller was plotting his maps in the 1890s, there was considerable European immigration and major population shifts from the farms to the cities. Thus, large numbers of uprooted families settled in highly crowded urban tenements, which also happened to provide very little natural light or ventilation.

Many subsequent epidemiological studies support this contention that the high rates of tuberculosis and other diseases in New York tenements around the turn of the century should be attributed to the susceptibility of the recently dislocated immigrants rather than to any specific housing characteristic (De Groot & Mason, 1969; Cassel, 1977).

Although initially, most model building and housing codes regulated natural ventilation in order to reduce airborne disease, there is virtually no evidence directly linking ventilation and disease. Even if the "dislocation" hypothesis could be discounted (which it cannot), strong correlations between incidence rates and amounts of ventilation do not demonstrate a causal link between tuberculosis and room air quality unless the air's microbial constituents are also known. De Groot & Mason point out that not until 1967 was a sampling device available which was large enough to handle room-sized volumes of air. By that time most of the ventilation requirements in model building and housing codes had already been specified in considerable detail.

As already noted, most of the research supporting the ventilation requirements in the model codes has used indicators of comfort, rather than health, as performance criteria. The most commonly used comfort indicator has been the perception of body odor. This shift in emphasis from tuberculosis to body odor was underscored in 1936. Yaglou, et al reconfirmed Flugge's finding that carbon dioxide, originally proposed as an indicator of hazardous airborne substances, is not a very reliable indicator of odor concentration. From the standpoint of olfactory comfort, a number of studies have confirmed that tolerable levels of perceived body odor can be attained with air changes in the currently specified range of 10 cfm/person.

However, in 1955, a finding by Yaglou raised some questions about the adequacy of current ventilation requirements. He reported that 25 cfm/person is required to reduce the odors (not health hazards) from cigarette smoking to acceptable levels (De Groot & Mason, 1969). Other questions are raised by Tromp's finding in 1963 that, even under optimal wind and pressure conditions, each hour, little more than 40% of a room's air can be replaced through cracks around windows and doors. Even without considering recent efforts to seal air leaks to conserve energy, it is not clear whether current minimum ventilation requirements are sufficient for subjective comfort.

Yet it recently has become apparent that some modern mechanical ventilation system—presumably designed to meet comfort criteria—may have created some new health hazards. The classic example is Legionnaire's Disease, which now appears to be directly related to the dispersion of vaporized water droplets from cooling towers (Cordes & Fraser, 1980; Science, 1981). It is worth noting that the quality of the evidence linking Legionnaire's Disease to mechanical ventilation systems is far superior to most of the evidence originally linking tuberculosis to inadequate light and ventilation.

Finally, it also appears that in some large office buildings dependent solely upon mechanical ventilation, indoor air quality may be contributing to certain allergic-type reactions among occupants. Current studies at the Center for Disease Control (Kelter, 1981) have shown this problem may be partly related to the inability of the mechanical filters to remove cigarette smoke and office machine fumes from the recirculating air supply.

In retrospect, available evidence partially supports expected relationships between the 10% ratio of window to floor area, air changes of 10 cfm/person, and perceived comfort (in terms of body odor). By contrast, assumed relationships between window areas, air changes, and the incidence of airborne disease have not been documented and appear to have been misdirected. Ironically, most of the ventilation provisions in the current editions of the model codes can be traced directly to the questionable notion that tuberculosis is the product of stale air.

(ii) The purification of air using the germicidal properties of sunlight seems to have been implicitly tied to most ventilation requirements since 1667, when in England, building heights were first related to street widths. These requirements initially may have stemmed from a more immediate concern for limiting the spread of conflagrations. However, subsequent modifications, such as the Building Act of 1844, appear to have been directly concerned with bringing natural light into the interior of dwelling spaces (Sprunt, 1975).

In this country, the early New York Tenement Laws specified a maximum of 65% to 75% coverage on interior lots. The open space created as a result of this requirement, and by the courts in the "dumb-bell" plan of 1879, were considered adequate sources of natural light and fresh air.

The healthful effects of sunlight (and fresh air) have apparently been recognized for some time. As early as 1855, sunlight was used to treat various ailments in Switzerland (Giedion, 1948). In 1877, Downes and Blunt established that sunlight has certain bactericidal (germ killing) properties (Mumford, 1938). No doubt, this knowledge played some role in the testimony of many physicians and health officials before the New York Tenement House Commission from 1894 to 1900. As noted above, it was unanimously charged that the high rates of tuberculosis in lower Manhattan tenements could be attributed directly to the poor quality of light and ventilation.

Given the known germicidal effects of sunlight, the testimony before the commission, and the overwhelming evidence assembled in Veiller's Tenement House Exhibition of 1900, it is not surprising to see the changes made in the 1901 New York Tenement Code and Law. The law's requirements relating the widths of courts and yards to building height were increased, and requirements for windows in bathrooms and water closets were added. The requirements for courts and yards were increased again in the Model Tenement House Law of 1910. In 1915, the National Building Code (NBC) acquired a provision to improve interior lighting and ventilation; it required intervening courts for rooms deeper than 18 feet. Requirements for windows in kitchens were added in 1931.

In general, there has been an increase over the years in requirements for court and yard, and site coverage in all the Model Codes. In most cases, simple geometric calculations of sun angles appear to have influenced requirements relating court widths to building heights, and relating allowable window credits to the distance from the nearest obstruction. By 1939, the APHA's Practical Standards for Modern Housing related window areas to latitude and to the heights of adjacent buildings or the widths of adjacent streets. By this time it seems clear that the minimum dimensions for windows and courts were based as much on the need for adequate daylighting as on ventilation.

However, as early as 1926, Luckeish reported that ordinary window glass blocks out the types of ultraviolet light that may be useful as germ killing agents. Furthermore, in their review of the germ killing properties of ultraviolet radiation, De Groot and Mason (1969) show that the wave lengths that are most effective in killing bacteria and viruses (2600-2700 Angstroms) are shorter than the lower limit of ultraviolet solar radiation reaching the earth (2920 A). They also show that these germicidal wave lengths, which do not penetrate the earth's atmosphere, are very close to the wave lengths that can cause serious cell damage in humans (2600 A). De Groot and Mason thereby concluded that natural light has virtually no direct health effects within the home. They do note that effective germ control may be attainable in closed ventilation systems if ultraviolet lamps are placed in the air conditioning ducts (see Rentschler, 1940). Unfortunately, this is not relevant to the issue of natural lighting addressed by model codes.

Although the health benefits of natural light within buildings have not been demonstrated, many psychological benefits have recently been considered. An elaborate study of windowless classrooms that began in 1959 revealed negligible effects on pupil learning and attitude, slight increases in absenteeism, and a few strong preferences on the part of task-conscious teachers (Larson, 1965). More thorough reviews of the psychological effects of windows and daylighting have been compiled by Manning (1965), Markus (1967), and Collins (1975). The current consensus appears to be that, while natural light within buildings probably has no direct effect on health, it may have a direct effect on satisfaction, which could affect health indirectly.

In sum, it has not been shown that current model code provisions for light and ventilation have any direct effect on health by either removing or destroying the airborne sources of disease. However, they do appear to have other beneficial effects on occupant comfort and satisfaction. These secondary effects, in turn, may have indirect effects on the occupants' health. To date, such indirect effects have not been fully documented.

(c) Space and Dimensions

The original purpose of the regulation of room size and total dwelling space was to assure that enough air was available and to physically separate each occupant from the airborne sources of disease. These requirements were generally closely tied to those for ventilation. The required separation can be accomplished in two ways: (1) by specifying minimum room size to dilute the concentration of any hazardous substances and (2) by specifying the number of occupants in each room. In most cases, the spatial requirements in the model codes address the size of rooms (because this is an easily verifiable and enforceable measure), while research dealing with physical or mental health effects of crowding focus on the number of occupants. The relationships between the two are seldom elaborated.

(i) The dilution of air in dwelling spaces was first addressed by the provisions for ventilation (see above) and minimum room heights and volumes in the early New York Tenement Laws (1869-1900). By 1901, the New York Tenement Code and Law began specifying minimum room dimensions, in addition to ceiling heights, for habitable rooms. In subsequent editions of the New York laws and in the model codes, these requirements tend to have increased, except for some reductions in the 1930s, apparently in response to the economic reversals of the Depression.

Most of the evidence bearing on these developments has been reviewed in the preceding discussion of ventilation through and around windows. In general, the number of cubic feet of air required per minute per person is first treated as a function of the rate of replacement through the cracks around operable windows and doors, and then as a function of the amount of dilution provided by the air in the room.

The only other evidence relating room size to disease is Miller's (1963) finding that no further reduction in infection rates will occur when sleeping spaces increase beyond 50 square feet per person. This indicates that increases in infections from other persons can only be expected with very close proximity—well below the minimum spatial or volumetric requirements in most model codes. Unfortunately, Miller's findings are based on studies of military personnel and their applicability to the civilian home environment is not clear.

Interestingly, while 500,000 people died in 1918 from an influenza epidemic in the U.S., no adjustments in room sizes appeared in the model codes at that time. Other data relating respiratory and communicable diseases to the number of occupants per room are discussed below. From an overall health standpoint, however, the data supporting minimum room size on the basis of air volume seem to bear little relation to the provisions of the model codes.

(ii) Consideration of crowding within rooms shifts attention from the amount of space provided to the number of people served. As early as 1834, Gerritt Forbes, the City Inspector of the New York City Board of Health, noted that deaths were increasing much faster than the population in the tenement districts. In his annual report, he attributed some of the excessive deaths to the "crowded and filthy" state of the dwellings which, he said, resulted from the landlords' urge to "stow the greatest number of human beings in the smallest space". No doubt, such concerns led to a requirement in the New York Tenement Law of 1867 that there be 400 cubic feet of air for each adult and 200 cubic feet for each child under 12.

Apparently the enforcement of these requirements was relaxed somewhat after 1879; in that year, the Tenement Law was amended in accord with Ware's prize winning design for the "dumb-bell" tenement (Lubove, 1962). Also by this time, the model tenement house movement was in full gear. The movement consisted of several private associations formed to show that sanitary tenement housing could be provided by the private sector at a profit; this thereby eliminated the need for restrictive public laws, in the movement's view. Among these private groups were the Octavia Hill Association in Philadelphia, the Boston Cooperative Building Company, and Alfred T. White's Home Building Association in New York.

Nevertheless, by 1895, the New York Legislature condemned 87 tenements. It also recommended mandatory enforcement of the 1867 requirements for minimum air volumes for adults and children (Lubove, 1962). In 1901, the New York Tenement Code and Law added minimum square footage requirements for habitable rooms, while retaining the older volume requirements. Over the next three decades the emphasis of the spatial requirements gradually shifted from volume of air per occupant to square feet per room, thus deemphasizing crowding in favor of the more easily quantifiable floor area.

In the late 1920s, the "Chicago School" of sociologists began publishing studies of mental disorders and other forms of social disorganization. They saw these problems as functions of certain "natural areas" within urban communities. Among the areas with the highest concentrations of poverty and pathology were the inner city tenement and rooming house districts; they were characterized as being overcrowded and having a highly transient population.

The Chicago School's research was very influential during the 1930s. Culminating the research was the publication of Faris and Dunham's Mental Disorders in Urban Areas in 1939. The book never deals directly with crowding, but it does link mental illness with "poor housing" and often defines such housing in terms of crowding.

During this same period, the results of a massive National Health Survey began to be published by Britten and Altman. The nationwide survey, conducted in 1935 and 1936, covered 700,000 households. The findings showed direct relationships between the incidence of pneumonia, influenza, and rheumatism, and the degree of crowding--measured in terms of the number of persons per room. This relationship was found to be particularly strong among lower income groups, for whom tuberculosis rates were also correlated with crowding. Of particular interest was the finding that crowding had a strong effect on the rates of measles, whooping cough, chicken pox, scarlet fever, and other communicable childhood diseases (except diptheria and mumps) among children under the age of 5. Yet it seemed to have a negative effect on these disease rates for children over the age of 5! These findings were interpreted as an indication that increased crowding lowers the age at which children contract these diseases, thereby increasing immunization among older children (Britten & Altman, 1941).

With the possible exception of these findings on childhood diseases, most of the Chicago and National Health Survey data linking mental and physical illness to crowding are open to the same criticism as Veiller's link between tuberculosis and poor light and ventilation, noted above. During the Depression there was substantial rural-to-urban migration. Thus a lot of lower-income people from the farms relocated in crowded inner city housing. Any illness among this population was probably as much a function of recently disrupted living patterns as housing conditions. Nonetheless, this type of research appears to have influenced model codes of that period.

In 1931, the NBC set new requirements for all living and sleeping rooms. It began requiring 480 cubic feet for adults and 300 cubic feet for children. The rationale behind the numbers is not clear, but it appears that the general intent is consistent with the aforementioned widely publicized sociological research. Changes in the APHA Practical Standards for Modern Housing of 1939 also appear to be linked to the research. The APHA document began to specify room dimensions in terms of the number of occupants, requiring at least two rooms for sleeping and 500 cubic feet per occupant in all habitable rooms.

Subsequent studies on the effects of crowding revealed strong relationships with occupant satisfaction (Reimer, 1945); additional relationships to mental illness rates (Roberts & Myers, 1959); and additional relationships with respiratory and childhood diseases (Wilner, et al., 1962). Some reviewers have seen much of this evidence as supporting the notion that overcrowding and similar housing factors affect illness and disease (Schorr, 1966; Novick, 1970). Others, however, have argued that most of the reported effects are intercorrelated with other factors, such as the situation of the individual or family (Kasl, 1977; Cassel, 1977). Clinard (1970) reported a .85 $\pm$ .04 correlation between juvenile delinquency rates and crowding; yet he also noted that such data are insufficient to prove the link because too many other socio-economic factors enter in.

Much of the environmental determinism that guided research on the health effects of housing through the 1940s has given way to a much more ecological interpretation. Housing is now viewed as one of many aspects of a complex socio-economic system. This is particularly true in the area of crowding, where extensive research since 1960 has raised many more questions than it has answered (Stokols, 1978). Despite reconceptualizations of crowding that may have preoccupied the research community, model housing codes in the past several years have incorporated several increases in the amount of space required per person.

In sum, except for a direct effect on certain childhood diseases, and a possible effect on the incidence of influenza and other respiratory illnesses, crowding's link to physical or mental illness is problematic at best. As De Groot and Mason (1969) have pointed out, any illnesses that can be related to overcrowded housing can probably be more effectively controlled through immunization and direct medical care programs than through more costly regulation of the amount of space in dwellings. Although they appear quite plausible, most of the occupant-based area and volume requirements in the current model building and housing codes, viewed as health precautions, lack very strong support by the available evidence. However, these requirements are closely tied to those for ventilation and, as such, may have indirect health benefits as they increase occupant satisfaction and comfort. These spatial requirements are also indirectly related to furnishability and maintainability of dwellings, which in turn are probably related to satisfaction and comfort.

(d) Sanitary Facilities

The provision of adequate toilet, washing, and bathing facilities in dwellings is regulated to minimize the likelihood of direct contact with the waterborne sources of several diseases, such as cholera, dysentery, and typhoid, that can and have reached epidemic proportions. There are two distinct ways to approach the control of waterborne disease: (1) by assuring that water arriving from public sources is uncontaminated and (2) by providing enough plumbing fixtures to minimize the possibility of contacting human wastes or other contaminated human residue left by other persons. A third approach, the separation of waste water from water supplies within a building's own plumbing system, will be discussed in the later section on Plumbing.

(i) The supply of potable water from sources outside the building is generally not addressed by the model building or housing codes. This may be because unclean water was recognized as a health hazard as early as the 17th century, when van Leeuwenhoek first observed the organisms we now know as bacteria. Since that time, the hazard has been addressed by public health mechanisms other than building regulations. By the time Snow identified contaminated water as the source of cholera in 1850, many attempts at filtration and chlorination had been initiated. That same year, efforts to purify water supplies were speeded up by cholera epidemics throughout Europe. Nonetheless, typhoid fever death rates in Boston climbed from between 40 and 50/100,000 in the late 1850s to 86/100,000 in 1872. By the 1870s, cities across the U.S. began taking over the operation of their water systems from private companies and installing filtration plants (Mumford, 1938). The waterborne organisms causing typhoid were identified by Eberth in 1880 and those for cholera and dysentery in 1883 and 1898, respectively.

The only time the codes of the day mention the need to protect the domestic water supply from contamination is a brief note in a New York plumbing code of 1882, which was later rescinded. Apparently the concern for clean water was considered to be adequately covered by public health mechanisms other than the model codes. Aside from an occasional outbreak, like the typhoid epidemic that struck Massachusetts' Merrimac Valley in 1893, most subsequent concern focused on improved technologies rather than on purification itself.

Soon slow sand filters and chlorination became the primary methods of purifying the water supply. By 1911, over 800,000,000 gallons of water serving 20% of the U.S. population were being treated daily. By that time, most U.S. cities provided clean drinking water from public mains. So great was the confidence in the water supply that it was not until 1960 that any model code specified that each dwelling's water supply must be connected to a potable water source.

In this context, a recent report by Maugh (1981) linking the chlorination of surface water to cancer should be of some concern. Unfortunately, it is too early to assess the significance of such findings in the areas covered by model building and housing codes.

(ii) The number of required fixtures has been addressed by every model code since 1867, when the New York Tenement Law required a water tap for every building and a water closet for every 20 occupants. In 1884, the maximum number of people served by each water closet was reduced to 15. As was the case for light and ventilation, these specifications appeared before germ theory (which became widely accepted in the late 1880s) provided a scientific basis for relating such code provisions to their target diseases. Apparently in or near the early tenements, the filth around the toilet and washing facilities was so great as to make the need for such requirements self-evident.

This problem was underscored again in 1894 by the testimony of Dr. Pryor and others before the New York Tenement House Committee, and in 1900 by some of the photographs displayed at Veiller's Tenement House Exhibition. In an apparent response to this "evidence", a water closet in a separate compartment was required in each apartment by the New York Tenement Code and Law of 1901 and in subsequent revisions through 1910 (also see "Privacy", below).

Interestingly, there was no direct evidence at the time linking the number of fixtures to health criteria! Perhaps the need was so great that it did not appear to require documentation. It is also interesting to note that bathing facilities were not yet required, although the problem of poor personal hygiene had long been recognized.

At the Berlin Hygiene Exhibition in 1887, Dr. Lassar, among others, began advocating and demonstrating public bathing houses containing ten shower cubicles. In 1895, Gerhard strongly recommended shower baths rather than tubs for the tenements because they occupied less space and there was some suspicion that the residents might not accept the concept of tub bathing (Giedion, 1948). However, no bathing facilities were required until the (1939) APHA standard specified a private water closet, lavatory, and bath in every dwelling (also see "Privacy", below). It was not until 1976 that the NBC required bathing facilities in dwellings!

In general, most of the requirements for bathing facilities in dwellings seem to have been in the form of a delayed response to technological innovations and product developments. At the turn of the century, hygiene became a major inspiration for styles and fashions in housing. Bell (1980) reports that the color white became associated with clean kitchens and bathrooms and that washable tiles and linoleum were in great demand. Hotels first began connecting the toilet and bathing facilities to individual guest rooms and suites in the late 1870s. In 1908, the Statler Hotel in Buffalo became the first to provide a full bathroom (as we now know it) for every guest room, thereby setting a major housing trend for the following decades (Giedion, 1948). Yet it was not until much later that most of these developments affected the model codes. The one exception was the water closet, which underwent major technological developments from 1905 onward, many of which were reflected in the increasingly stringent code requirements of that era.

So seemingly widespread was the use of the fixtures specified in the model codes in the first half of this century that it was not until 1960 that substantial data were assembled linking any illnesses to inadequate toilet or washing facilities! In that year Wilner, et al reported that increased rates of acute respiratory infections, certain childhood diseases, and minor digestive diseases were all associated with inadequate toilet and washing facilities, as well as with several other factors. The lack of specificity in this classic study confounds the evidence provided on the numbers of fixtures needed to produce desirable health effects.

Novick (1970) mentions a study of 16,000 children in England in which it was found that seven-year-olds from overcrowded homes without hot water or toilets were retarded by nine months in their reading and mathematical abilities. Unfortunately, Novick fails to cite his source or to specify the precise housing conditions that could be related to the model codes. In fact, it was not until 1974 that any data on the number of fixtures needed per occupant were published. In that year, Henning began to study the relationships between use patterns and the number of water closets and other fixtures in public restrooms. Again, it is unfortunate that Henning's data did not relate to any clearly stated health objectives, only to the demand and duration of use per fixture during peak periods.

The outcome of several recent court cases has hinged on the lack of any systematic evidence on the relationships between the number of fixtures required and health criteria. In Givner vs. Commissioner of Health in Baltimore in 1955, the court held that the requirement for a toilet in each apartment was excessive and that a toilet shared between two apartments would be more likely to be kept clean by the involved parties. In Safer vs. City of Jacksonville in 1973, the court held that "...research fails to reveal any substantial number of instances in which living [without potable hot water, lavatory, etc.] adversely effected the health, safety, or morals of our forebears...".

In effect, while common sense seems to have governed most model code requirements for the provision of sanitary fixtures within dwellings, there appears to be no adequate documentation demonstrating any of the alleged health benefits. In fact, based on the evidence available, one would have to conclude that current requirement follow more from prevailing fashions than from a demonstration of the number of fixtures or users required to minimize direct contact with the hygienic residue left by other people.

(e) Privacy

Mumford (1938) has shown that spatial arrangements intended to assure more personal privacy can be traced back to the middle ages. The same author demonstrated that the grouping of rooms along corridors, instead of opening into each other, began in the 18th century. Attempts to regulate privacy in dwellings can be traced back to the early New York Tenement Laws which specifically prohibited access to living rooms, other bedrooms, and water closets via a bedroom.

Case (1981) has indicated that the requirement for a water closet within each apartment was initially motivated by a concern that women and children might be exposed to immoral activities and people in the hallways. This was a particular concern where saloons were located on the first floors of the tenements and drunks would come upstairs to use the hallway water closets. The avoidance of requirements for public baths in the tenements (see "Sanitary Facilities", above) apparently also was a deliberate attempt to protect women and children from improprieties. Case also notes that in the New York Tenement Laws between 1901 and 1910, the rationale for increasing the dimensions of interior courts and yards was to make it more difficult to see or hear activities in neighboring apartments. Although such spatial and sensory privacy is commonly understood and often discussed, it has seldom been the subject of systematic research.

One study found that due to a lack of beds, blacks living in poor housing in Chicago averaged less than five hours of sleep per night. The study went on to suggest this had obvious detrimental effects on mental and physical health (Davis, 1946).

In an extensive review of the relationships between privacy and circulation routes through dwellings, Chapin (1951) introduced the notion of "use crowding". He used the term to characterize the effect on mental health of uncontrolled and unexpected encounters with other family members pursuing their separate routines throughout the home. While Chapin presented no actual data on the subject, he did present a cogent argument for the need for extensive research on the consequences of housing layout on mental health. Few such studies have been reported, but one review of those studies concluded that too many people sharing too few separate spaces and pieces of furniture or fixtures will become so irritated and fatigued that it will have an adverse affect on their health (Schorr, 1966). As mentioned earlier, Novick (1970) alluded to a British study in which seven-year-old children from homes without direct access to private toilet and washing facilities were found to be retarded by nine months in their school work. Unfortunately, Novick gave no further explanation and failed to include a reference.

Privacy, in the form of limited access through certain rooms and controlled views into neighboring apartments, has been addressed by some codes for over a century, yet it appears that applicable research was not done until the mid-1940s. This suggests that privacy has been treated as a matter of common sense, requiring no documentation. The NBC still regulates access through rooms, but there is virtually no evidence that circulation patterns within dwellings affect mental or physical health. Furthermore, none of the current research on privacy even considers the issue in terms of circulation patterns within dwellings (see Margulis, 1977).

(f) Heating

Except for provisions for fireplaces and stoves in the early New York Tenement Laws, heating was not addressed by the model codes until 1939. In that year, the APHA Standard required heating to a minimum of 65 degrees, with an optimum of 70 degrees and a maximum of 75 degrees.

It is not clear why such requirements did not appear sooner. As early as 1905, Flugge had shown that temperature and humidity are more critical comfort issues than concentrations of carbon dioxide or other airborne substances. These findings were reconfirmed by Hill in 1913 and by the New York Commission on Ventilation in 1914-15. The Commission went on to state that temperatures above 75 degrees produce discomfort and fatigue. In 1923, the New York Commission elaborated its conclusions on the harmful effects of temperatures over 75 degrees; these were said to include: increased heart rate, body temperature, and respiration; decreased ability to do physical work; and a general susceptibility to disease.

In 1925, Yaglou and Miller established the comfort zone for clothed persons as being between 63 and 71 degrees, with optimums between 64-1/2 and 66 degrees. In 1937, Yaglou published an extensive review of the health effects of temperature on industrial workers. Among workers exposed to temperatures below 40 degrees or to major temperature changes, he found increased incidences of a number of respiratory diseases and other illnesses. Yaglou also cited the New York Commission on Ventilation's data on the effects of temperatures above 75 degrees (see above). In 1939, Winslow reported that the optimum comfort zone for reclining subjects was between 77 and 86 degrees! The wide variation in these studies is attributable to the different clothing (nude to fully clothed) and task conditions (reclining to hard labor) studied, and to the use of different temperature measures. In a review of the previously published research, Keeton, et al (1940) found the comfort range for different types of clothing at different times of the year to lie between 63 and 82 degrees, with the optimum between 66 and 75 degrees. This comfort range corresponds closely to the APHA requirement of 1939.

Prior to 1939, the reluctance to regulate indoor temperature may have stemmed from the prevailing concern for health, as opposed to the issue of comfort addressed in most of the early thermal research. It may also be partially attributable to the fact that the negative health effects reported for high temperatures could not be addressed by the technology available through the 1930s. (An exception was the cooling effects of ventilation, which had been demonstrated by Flugge in 1905.)

Most research published since 1941 has addressed either subjectively rated comfort or the adverse health effects of prolonged exposure to high temperatures. One exception is a 1949 report in Heating and Ventilating which showed that at 72 degrees Fahrenheit, 50% relative humidity is fatal to most of the bacteria causing respiratory diseases. Other research on temperature and comfort is reviewed in each edition of the ASHRAE Guide. In 1960, the Guide recommended optimum indoor temperatures between 66 and 77 degrees on the basis of comfort. Since 1939, most model code requirements for minimum temperatures have been within this range. Occasional variations in these minimum requirements, such as the lowering of the minimum to 68 degrees in the APHA Recommended Housing Maintenance and Occupancy Ordinance of 1975, appear to have been responses to external factors like the energy crisis.

Extensive research on the negative health effects of indoor temperatures above 86 degrees Fahrenheit has revealed a number of mental (Wing, 1965), physical, and metabolic decrements that could have lasting effects or even trigger the onset of heatstroke (De Groot & Mason, 1969; Goromosov, 1963). Certain detrimental effects of high temperature on the action of medication are also known (Sollman, 1957). However, to date, no model code has established minimum cooling requirements, except those which are implicit in provisions for ventilation (see Ventilation, above). De Groot & Mason also point out that no model code specifies a temperature range. By only requiring a minimum temperature, a code ignores the special needs of newborn infants, the elderly, and those recovering from illnesses (De Groot & Mason, 1969). The model codes also fail to address the issue of humidity, which is well understood to combine with temperature and air movement to create the thermal conditions actually experienced by building occupants.

Overall, the model code requirements for minimum temperatures appear to be well supported by the evidence available on thermal comfort (Goromosov, 1963; Keeton, 1941). Except for the negative effects of very high temperatures (heatstroke) and very low temperatures (frostbite), few health effects of indoor temperatures have been documented (De Groot & Mason, 1969). In most cases, the temperature extremes for which definite health effects are known lie beyond the range of temperatures addressed in the model building and housing codes.

(g) Basements and Cellars

Since the New York Tenement Code and Law first prohibited the use of cellars for habitation in 1901, there have been a number of model code provisions directed toward interior spaces below ground level. These have addressed the depth below grade, ventilation, waterproofing, and ultimate habitability. One of the major concerns appears to have centered on the attractiveness of below grade spaces to rats and other rodents that host disease-bearing fleas, lice, and mites. In addition to the problem of rat bites—there were 14,000 per year in the U.S. in 1969 (Clinton, 1969)—rat fleas and lice have been identified as the primary carriers of the bubonic plague and typhus.

In 1945, a large outbreak of typhus was reported in Atlanta after a slum clearance project displaced a large number of flea-bearing brown rats into new neighborhoods (Clinton, 1969). It has also been found that the mite known to carry a type of rickettsia (a form of typhus) is most attracted to a host mouse under the temperature and humidity conditions found around incinerators (Horsfall & Tamm, 1965). While these data indicate the possibility of substantial health problems when attractive places for rats and mice are provided within dwellings, they bear little relation to the provisions for basements and cellars found in several of the model codes.

(h) Glazing

Large glass sliding doors were first introduced in expensive homes built in Florida and California during the 1940s. By 1965, over 2,000,000 glass door panels were being sold in the U.S. each year. However, by 1961, reports of serious accidents involving sliding glass doors and storm doors had become so prevalent that the city of Seattle passed an ordinance requiring safety glazing in residential construction. The State of Washington passed a similar law in 1963. In that same year, a study commissioned by the Public Health Service (Holland & Johnson, 1963) estimated that each year, 100,000 people in the U.S. were being injured by large glass doors. In response to these data, the American National Standards Institute (ANSI) issued a voluntary safety glazing standard in 1966. This is apparently the standard now referenced in most model codes.

In 1969, a study of accidents related to household fixtures and appliances was conducted by the Teledyne-Brown Engineering Company for HUD. It revealed that of the products studied, glass doors ranked third in the number of home injuries caused. In fact, the doors accounted for almost 13% of the injuries studied. Of these injuries, over 60% involved doors in which improper glass had been installed. Over 40% involved clear glass panels that were inadequately marked. (Many of the accidents were attributed to multiple causes.)

As a result of this HUD study, the glass industry in 1969 formed the Consumer Safety Glazing Committee. In 1973, the newly formed Consumer Products Safety Commission (CPSC) ranked glass door injuries within the 10th most hazardous product category. That same year, the Consumer Safety Glazing Committee petitioned CPSC to issue a mandatory product safety rule related to architectural glass. To provide the technical basis for such a rule, CPSC funded a research effort at the National Bureau of Standards in 1975. This research led to the issuance of a new standard in 1977.

(i) Acoustics

The evidence on the health effects of acoustics within and between dwellings was not reviewed.

(j) Plumbing

From a health and sanitation point of view, model code regulation of plumbing is mainly concerned with the removal of contaminated wastes from the dwelling and with the separation of waste water from potable water within buildings (see Sanitary Facilities, above). Apparently, many such code requirements have evolved from trial and error, with the exception of the following few cases.

In the mid-1800s, crude plumbing and waste handling systems could not prevent accumulated sewer gases from flowing back into the habitable rooms through the drain pipes. This miasma was regarded as one of the primary causes of disease until bacterial sources of disease were discovered in the 1880s. Neilsen (1963) reports that in 1874, the wealthy owner of a new private dwelling in New York City complained of this problem to his plumbing contracter. The contractor, after discussing this problem with his colleagues, devised a vent, which could be combined with the liquid trap seal to prevent the back siphonage of effluents and the back pressure of sewer gases. The contractor installed such a vent in his client's home and found that it relieved the problem. By 1876, the local plumbing code required vents for all drains.

A somewhat more systematic approach was introduced in 1923 when the National Bureau of Standards (NBS) published an extensive set of plumbing requirements for buildings. The requirements were based upon the bureau's research on the mechanics of plumbing systems. The research was exhaustive, but little attention was given to the health aspects of the provisions. Instead, the work focused on the more general issue of efficiently moving water in and out of buildings, on the assumption that this would benefit health.

An instance in which the documentation of a specific health hazard was directly responsible for a change in the building codes occurred following the 1933 outbreak of amoebic dysentery at the Chicago World's Fair. The problem was ultimately traced to fixtures with water supplies connected below rim level--a practice that had been prohibited by the New York Board of Health in 1883! A similar outbreak of brucellosis at Michigan State University, involving 80 students, was ultimately traced to a below-the-rim supply connection in a biology laboratory sink. The two events are generally credited with triggering new code provisions in 1938. Fixtures with below-rim supply were prohibited. Later, vacuum breaker installations were required where such fixtures could not be avoided.

Similar case-by-case discoveries have led to many subsequent refinements in the provisions for plumbing systems in the model codes. For example, in 1969, a hepatitus outbreak among 75 members of the Holy Cross University football team was eventually traced to negative pressure in the lawn sprinkling system which had contaminated the drinking water (Bechtel, 1973). In reviewing this and similar cross-connection problems, Bechtel recommended that model codes take a more proactive stance to prevent such hazards. To rephrase his comment slightly, current plumbing codes, in response to individual cases, have eliminated the known sources of illnesses. However, the provisions do not follow from an internally consistent model of health that anticipates such problems before they arise (De Groot & Mason, 1969).

(k) Stairs

The first systematic observations on stair design were published in 1672 by Francois Blondel. He concluded that to accommodate the normal gait of 24 inches, two inches should be subtracted from the depth of the tread for every inch in the height of the riser. He then devised a formula in which twice the riser height plus the tread depth should equal 24 inches ($2r + t = 24''$).

Two centuries later, when stair design was first regulated by the New York Tenement Law of 1867, the only requirements were the provision of banisters and railings and the continued good repair of the stairs. Riser and tread dimensions were first addressed by the New York Tenement Code and Law of 1901. Specifications called for an eight inch maximum riser height and a 10 inch minimum tread depth, but no required relationship between the two. The same dimensions were specified in the 1905 edition of the NBC, which also required that risers and treads be uniform throughout a flight, but without stipulating a maximum tolerance.

The first modern study of riser and tread dimensions was published by Frederick Law Olmstead in 1911. Olmstead plotted two empirically based curves relating riser and tread dimensions based on subjectively rated user satisfaction. According to Mowery (1930), the first standard relating riser height to tread depth appeared three years later with a formula approved by the National Workmen's Compensation Service Bureau. Under the formula, riser height plus tread depth was to equal 17-1/2 inches ($r + t = 17\text{-}1/2''$). One year later, in 1915, the NBC reduced the maximum riser height to 7-3/4 inches and the minimum tread depth to 9-1/2 inches. The rationale behind this change is not known, but the revised dimensions come much closer to fitting both the Blondel and the Workmen's Compensation formulas than the dimensions originally adopted in 1905.

The criteria for regulating stair design prior to 1915 are not known, but there appears to have been at least some concern for accident prevention. Even the concern for user satisfaction expressed by both Olmstead and Blondel can be interpreted as an effort to avoid an awkward gait which could lead to an accident. There were no data indicating a serious stair accident problem at that time. The closest such data was a 1913 Census Bureau report showing that falls of all types were the leading cause of accidental death in the U.S..

With such catastrophes as a major fire in 1911 at the Triangle Shirtwaist Factory, the focus of stair design regulation shifted from accident prevention to emergency evacuation.

Beginning with the New York Factory Laws of 1914, the primary interest in stair design centers on the relationship between stair width and the number of people who can be evacuated in a given period of time (Stahl & Archea, 1977). The notion that the capacity of a stair should be specified in 22-inch increments was standardized during this period. In 1915, the NBC increased the minimum width required for stairs in multi-family dwellings from 42" to 44". In 1917 and 1918, the National Fire Protection Association (NFPA) Committee on Safety to Life determined evacuation times on the basis of 22-inch units of width. The first edition of the Uniform Building Code (UBC) in 1927 required stairs in multi-family dwellings to be at least 44" wide.

To a large extent, since 1915, most model code provisions for stair design appear to have been directed toward the issue of emergency evacuation rather than accident prevention. A thorough review of the research on the use of stairs for building evacuations has been prepared by Stahl and Archea (1977).

With the emphasis shifted away from accidents, subsequent research on the relationship between stair design and emergency egress appears to accept the Blondel and Olmstead formulas without question. In an extensive study of exit design conducted by the National Bureau of Standards in 1935, it is noted "that the 2 or 3 rules customarily used for proportioning risers and treads are adhered to very closely" in the design of the stairs studied. The report goes on to recommend that stairs be proportioned according to the 2r + t = 24"-25" formula originally proposed by Blondel. However, it never compares the exit performance of stairs designed according to this formula with those that meet alternative specifications (NBS, 1935).

This oversight is interesting since as Templer (1974) has noted, Blondel's formula is based on the length of the human stride (as observed for Frenchmen), which has probably changed substantially since the 17th century. Moreover, the inch used in Blondel's original formula does not correspond to the English inch used in the U.S. at this time! Templer goes on to suggest that if the proper adjustments were made, the Blondel formula should read 2r + t = 28.2", a figure that corresponds more closely to the provisions of the 1901 New York Tenement Code and Law than to most subsequent specifications in the model code.

Meanwhile, the architectural and safety press reported several aspects of stair design that were shown to relate to accidents reported to insurance companies. These included two perceptual characteristics of tread surfaces that the courts found to be grounds for negligence rulings in the cases of Keiser vs. Milwaukee Boston Store (Mowery, 1930) and Twohy vs. Owl Drugs (Howell, 1942). Howell also cited a number of accidents on stairs whose riser and tread dimensions conformed to Blondel's formula. He went on to suggest that in place of any formula, the specific dimensions of a 6-3/4" riser and a 10-1/2" tread be required, since such dimensions "practically never appear in an accident".

The National Health Survey, published in the early 1940s, revealed high rates of accidental falls in poor quality housing, especially among people 65 years of age and older (Britten & Altman, 1941). However, it was not until the early 1950s that data on the relative frequency and severity of stair accidents per se were available. And not until the late 1960s did the etiology of stair accidents become the object of systematic research. However, by that time, model codes contained numerous stair requirements. In most of them, stair widths and riser/tread dimensions were precisely specified, intermediate landings were required on long flights, and winders and open risers were prohibited.

The first systematic study of stairway accidents was published by Velz and Hemphill in 1953. They found that stairs on which accidents occurred had the following common characteristics: missing handrails, excessive steepness (not defined), improperly located light switches, and non-uniform risers and treads. In the following seven years several field studies were published which revealed that: (a) stairs accounted for 4.7% of all home accidents, the overwhelming majority being through slipping or tripping (Merrill, et al, 1957); (b) stairs accounted for 9.7% of all home accidents (Lossing & Goyette, 1957); (c) 75% of the stairs on which accidents occured had riser or tread non-uniformity of 1/2" or more, 72% of the stair accidents began at a point where handrails were missing, slipping was involved in 38% of the accidents, and winders did not appear to contribute to stair accidents (Miller & Esmay, 1958; Esmay, 1961); (d) missing handrails and irregularities in riser and tread dimensions of 1/4" or more were found on 94% and 59%, respectively, of interior stair flights on which accidents occurred (Gowings, 1960); and (e) one-third of all accidental falls among the elderly occurred on stairs (Sheldon, 1960).

Although issues like handrails and riser/tread uniformity were addressed in the model codes by the mid-1960s, few of the requirements appear to have had any direct relationship to the research cited above. For example, provisions for handrails focused on projections into the path of travel, the size of objects that could pass through the supports, and the height above surrounding surfaces. There were no requirements that handrails be continuous throughout the flight. The emphasis appears to have been on preventing people from falling off the stairway during a mass evacuation, rather than on preventing falls on the stairs by solitary users.

In the case of riser/tread uniformity, the situation is similar. The Uniform Building Code (UBC) had stipulated a maximum 3/16" variation in riser and tread dimensions since its first edition in 1927. However, it was not until 1967 that Harper, Warlow, and Clarke actually measured the extent to which the descending user's heel strikes the nosing or riser. Six years later, Nelson (1973) revealed that the user's toe often cleared the nosing by as little as 1/4" in ascent, thus providing some support for the figures included in the UBC over 40 years earlier. On the other hand, the Basic Building Code (BBC) made no mention of riser/tread uniformity until 1975. And it was not until 1978 that it specified the 3/16" maximum variation for risers and treads in the same flight!

It is also interesting that Harper, et al (1967) found that, based on precise biomechanical measurements, slipping is not a likely cause of stair accidents (under dry and clean conditions). This conclusion was reached despite requirements for slip-resistant stair treads in the BBC and the NBC, and the listing of "slipping" as a major cause of stair accidents in two of the six major studies cited above. Perhaps some of these discrepancies between the model code provisions and research arise from the fact that the seriousness of the stair accident problem was first recognized fairly recently.

The magnitude of the stair accident problem nationally was first documented in 1969 when the Teledyne-Brown Engineering Co. conducted the survey of home accidents for HUD. That survey reported that stairs account for 17.9% of all home injuries; it ranked stairs as the most hazardous item in the home! Teledyne-Brown attributed 29.6% of the 1,800,000 stair injuries per year to slippery treads; 22.4% to missing handrails; and 16.3% to articles left on the stairs.

In 1971, the National Injury Surveillance System (NISS) reported that 12% of all product-related accidents occurred on stairs and that 72.7% of these occurred in the home. In that same year, the Buffalo Organization for Social and Technological Innovation (BOSTI) analyzing much of the published data on home accidents, found that stair accidents accounted for over 8% of the accidental deaths. It also found that 85% of all stair-related injuries occur in the home. Moreover, BOSTI discovered that when a single index combining frequency and severity is used, stairs rank fifth among the top 40 accident-related consumer product categories (Brill & See, 1971).

In 1973, the National Electronic Injury Surveillance System (NEISS) reported that stair accidents in the U.S. were responsible each year for 356,000 injuries serious enough to require hospital treatment. By 1976, improved reporting methods apparently raised that number to 540,000 hospital-treated stair injuries per year. Overall, these data and others reveal that stairs are the most hazardous item encountered in the everyday environment, producing almost as many deaths per year as building fires and over four times as many reported fire injuries.

An extensive study was begun at the National Bureau of Standards (NBS) in 1973 in order to determine ways to reduce the frequency and severity of household stair accidents. The major finding was that visual deceptions built into the stair treads or other materials, and visual distractions created by a stairway's relation to the surrounding environment, may play a major role in stair accidents (Archea, Collins, & Stahl, 1979). This supports some of the earlier claims by Mowery (1930) and Howell (1942). A field study of residential stair quality conducted by the NBS in Milwaukee (Carson, et al, 1978) also concluded that slipping was not a major cause of accidents on dry and clean stairs, supporting the earlier findings of Harper, et al (1967). Surprisingly, the NBS studies also found no clear evidence linking riser and tread dimensions to stair accidents (Templer, et al, 1978; Carson, et al, 1978).

In many respects the NBS research raised more questions than it answered. Perhaps its greatest impact has been to shift a portion of the explanation of stair accidents away from the purely physical issues of slip-resistance and riser/tread dimensions, and towards the more perceptual attributes of the tread surfaces and the spaces surrounding the user.

Extensive laboratory and field research over the past 30 years has identified a number of design factors involved in stair accidents. Yet very few of these findings are reflected in the model building and housing codes. The addition of a maximum 3/16" variation in riser and tread dimensions by the BBC in 1978 may be one of the few cases in which a model code provision accurately reflected the current state of knowledge about stair accidents.

Another example might be a change in the 1981 edition of the BBC requiring risers between 4" and 7" high and treads at least 11" deep in certain occupancies. This was apparently in response to Templer's findings reported in 1974. Although the NBS studies found no relationships between riser or tread dimensions and accidents, earlier studies by Ward (1967) and Templer (1974) found that increasing tread depths to a minimum of 10-1/2" or 11" and decreasing riser heights to between 4" and 7" can reduce energy expended and improve gait. Although neither researcher studied accidents directly, both suggested that the longer treads and lower risers should contribute to the reduction of such accidents.

Based on his findings, Templer also questioned the advisability of using Blondel's linear equation to determine riser and tread dimensions. However, except for the recent change in the BBC, most model code requirements for riser and tread dimensions remain virtually unchanged since their first editions in 1905, 1927, and 1946, respectively. In fact the Standard Building Code (SBC) still requires risers and treads to be proportioned according to Blondel's 2r + t = 24"-25" formula. The NBC has required that stairs conform to the r x t = 70-75 formula in use since 1931. The origin of the r x t = 70-75 has not been documented.

Overall, the correspondence between the requirements in current model building and housing codes and the published evidence on stair accidents is somewhat mixed. Certain riser and tread dimensions and uniformity requirements can clearly be supported on the basis of the available evidence. However, many model codes still prohibit winders and open risers which have not been found to be hazardous in any studies published to date. (Once again, the concern for winders may be attributed to a concern for emergency evacuation of the building, rather than accidents on the stairs.)

The requirements for projected nosings found in most model codes are not supported by the published research findings. Requirements on slip-resistance, although mentioned in the BBC and the NBC, are not specifically found in any of the model codes. Yet slipping has been identified as a major cause of stair accidents in almost all studies except those by Harper, et al (1967) and the NBS research (Archea, et al, 1979). This omission underscores the contention that accident prevention has not been a major concern of the model codes. It also points up that the primary concern in stair safety continues to be emergency exits, despite substantial evidence that accidents constitute a greater risk to building occupants.

(1) Unregulated Health Hazards

Ironically, although the primary focus of model code provisions since their inception has been the removal of disease-bearing organisms or substances, it has recently become apparent that several modern technological advances in building design and construction may be introducing a whole range of new health hazards. Among these hazards are the toxic properties of lead-based paint, the carcinogenic properties of asbestos materials and insulation containing formaldehyde, and the characteristics of airborne water droplets originating in large cooling towers that have been shown to play a major role in the spread of Legionnaire's Disease (see Ventilation, above).

Lead-based paint has long been recognized as a hazard. Its effects on children were identified as early as 1914 (Blackfan) and the City of Baltimore has had an ordinance since 1941 requiring the removal of such paint from surfaces exposed to children. In 1971, the federal government launched a major program to remove lead-based paint from all federally owned or subsidized dwellings. However, recent reports from the Center for Disease Control indicate that toxic effects of the paint remain a major health problem in 1980. Lead-based paint is not addressed in the model building codes. However, at least one model housing code (Basic Property Maintenance Code) has addressed the problem since 1978.

The data on the carcinogenic effects of asbestos and formaldehyde are more equivocal. However, given the course of recent research, it appears certain that a major health hazard exists whenever the asbestos used in fireproofing or soundproofing begins flaking into the supply of indoor air available to building occupants. In some buildings the levels of airborne asbestos particles have been found to be 30 times the levels currently considered safe (Science, 1979). Yet, for some reason, the use of asbestos material in buildings is ignored by all the model codes!

The treatment of such health hazards as lead paint and asbestos by the model building codes brings up an interesting point. Despite many unanswered questions, the quality of the evidence linking these materials and building subsystems to specific disease patterns, like cancer, is already much greater than the quality of the data initially used to link characteristics of dwellings to tuberculosis and other types of disease. Yet ironically, where enthusiasm once led logical speculation to the point of developing building regulations to eradicate epidemics, there is now an apparent reluctance to accommodate a much more substantial body of evidence.

(m) Unregulated Safety Hazards

The first direct attempt to address the problem of building-related accidents occurred in the late 1960s. This was when most model codes began to regulate the design of glass doors by reference to a voluntary ANSI safety glazing standard that had been adopted in 1966 (see Glazing, above). This is noteworthy because, while glass doors ranked third among the most hazardous home fixtures studied by Teledyne-Brown in 1969, and in the tenth most hazardous consumer product category listed by CPSC in 1973, in one or both of these studies, several other building elements were found to have contributed to comparable or greater numbers of injuries. Except for stairs—ranked as the most hazardous building item in both studies--none of these other high risk building elements have been addressed in the model codes. Even the design of stairs, which has long been addressed by the model codes, has been more commonly considered with reference to stairs' occasional use as emergency exits than as a potential factor in injury-producing accidents (see Stairs, above). The other unregulated building elements that have been shown to contribute to large numbers of accidental injuries each year are: bathtubs and showers, non-glass doors, windows, slippery floors, and floor furnaces.

In 1969, the Teledyne-Brown survey found that 250,000 injuries per year occurred in and around bathtubs and showers, making them the second most hazardous home fixture studied. The largest number of injuries were attributed to slippery surfaces and the lack of handholds. This rate of bathtub and shower injuries is quite high when compared with the 100,000 injuries per year that have been attributed to glass doors. Teledyne-Brown also reported an additional 25,000 burns and scalds per year that were caused by excessively hot water in bathrooms!

Based on its Accident Frequency and Severity Index (AFSI), the Consumer Product Safety Commission (CPSC) in 1973 ranked bathtubs and showers 14th on its list of hazardous products. However, among adult women, bathtub and shower injuries were ranked seventh in terms of frequency and severity. CPSC attributed most of the more than 150,000 bathtub and shower injuries per year to slippery surfaces. A detailed study of bathtub and shower accidents was published by Abt Associates in 1974.

In the Teledyne-Brown survey, non-glass doors were found to contribute to 150,000 injuries per year, ranking fifth among the home items investigated. Striking the exposed edge of open doors, being struck when others opened or closed a door, and faulty closing mechanisms were listed as the most common causes of door accidents. In 1973, the CPSC ranked non-glass doors as the third most hazardous consumer product according to the AFSI. The major causes of injuries were opening or closing a door into the traffic flow and catching fingers between the door and the jamb.

Teledyne-Brown ranked windows as the fourth most hazardous building item in the home, accounting for 100,000 injuries per year. The leading cause of these injuries was found to be the excessive force required to open windows that were stuck or did not move freely. Other significant causes included having to assume an unstable position to clean a window and open windows that suddenly slammed shut. The CPSC included windows in the tenth most hazardous consumer product category. It also found that the excessive force required to open or close stuck windows was a leading cause of injuries. In 1977, BOSTI completed a performance analysis of windows which assessed a number of design strategies for reducing the frequency and severity of window accidents.

Floor accidents were ranked ninth and 26th, respectively, in the Teledyne-Brown and CPSC surveys. While the overall hazardousness of floors cannot be equated with the other items just mentioned, these rankings do draw attention to the more general issue of slip-resistance which was also found to be the leading factor in bathtub and shower accidents. Several of the model building and housing codes mention slip-resistance in very general terms in conjunction with their requirements for stair treads (see Stairs, above). However, none address the precise surface characteristics needed to provide adequate slip-resistance on level wet or dry surfaces. Despite intense research on the matter since the 1940s, no national standards for slip-resistance have yet been adopted (Brungraber, 1976).

However, recent research has clarified that most serious slipping problems occur on or near wet surfaces—particularly where sudden changes from dry to wet walking surfaces are unexpectedly encountered (Safety Sciences, 1977). Controversies remain over the measurement and definition of adequate slip-resistance. Yet the role of moisture in the likelihood of slipping on a level walking surface is at least as well understood as many of the other items in the model codes.

Finally, in testimony before the House Subcommittee on Commerce and Finance in 1972, Julian Waller noted that floor furnace burns were the second most common causes of burns among children, and the most common cause for children under the age of five. Waller then cited estimates that as many as 65,000 such injuries per year occur among children under the age of five. He attributed these injuries to grille temperatures ranging between 300 and 350 degrees (normally used for cooking ham or veal) which the children encountered while crawling on their hands and knees!

In 1973, the CPSC ranked floor furnaces in the 38th most hazardous product category, with an estimated 67,000 injuries per year, primarily involving children. Such hazards have not yet been addressed in the model codes.

Overall, with the recent exception of glass doors, the prevention of accidents does not appear to have been a major concern in the model building and housing codes, despite documentation that certain safety hazards are greater than or equal to many of the health hazards the codes have addressed. For example, injury rates in the early 1970s of 240/100,000 for stairs, 122/100,000 for bathtubs and showers, and 118/100,000 for windows are comparable to the infection rate of 188/100,000 for tuberculosis at the turn of the century.

In addition, recent advances in the state of knowledge on occupant safety suggest that many of these hazards can be controlled through the model code process. A catalog of design strategies intended to reduce the frequency and severity of most types of accidents described above was prepared for the National Bureau of Standards by the BOSTI group in 1978.

In addition to the causes of accidents discussed above, there may be other critical safety aspects of building design that have not been anticipated in the model codes. Note the deaths of 66 soccer fans during a non-emergency egress on a crowded stairway at the Ibrox Stadium in Glasgow in 1971, and the deaths of 11 teenagers during the ingress to a rock concert at the Riverfront Coliseum in Cincinnati in 1979.

(3) STRUCTURAL SAFETY

Since the turn of the century, structural safety failures have usually been categorized as either material failures or major natural disasters, such as earthquakes. Most material failures occur during construction rather than when a building is operational. This discussion includes both material failure experience and a discussion of earthquake and wind damage experience.

(a) Pre 1900 Experience

The structural requirements in early tenement laws and building codes related to conventional building construction materials: brick masonry walls with wood joists, beams, and posts. Cast iron was used for both beams and columns in the early 19th century, but after about 1860 was used mainly for columns.

Building regulations were developed in response to the continuing efforts of contractors (developers) of tenements and other buildings to cut costs by reducing wall thickness and column and beam sizes. In 1825, a New York newspaper reported: "It is astonishing how carelessly buildings are erected in the city ... Six houses which were nearly finished in Reed Street, fell to the ground, and broke three ribs of one of the workmen—this is the second time these houses have fallen ... we understand that the thickness of the walls was that of only one brick!"[19] Such experiences led to required masonry wall thicknesses for structural stability.

Structural collapse has often been responsible for the adoption, modernization, or change of building code requirements. On April 13, 1905, Engineering News reported that across the country, 20 buildings had collapsed in the past three weeks. The article ("An Expert's Report in the Collapse of Buildings in New York City") noted that in New York City alone, eight building collapses occurred. They were all in Manhattan, typically in "flat" type buildings or tenement houses, five to six stories in height. The article reported on the shoddy construction, especially the foundation walls that were full of voids, and improperly bonded and bedded. Numerous building code violations were reported.

The article described these other collapses: March 9, 1905 -- 3 story Factory Building, Reading, Pennsylvania — Foundation yielded, walls bulged; March 10, 1905 -- Store Building, Dickson, Tennessee -- crushed its foundation and collapsed. Charges made that building had excessive weight on floors; March 19, 1905 -- 5 story Factory, Morris, Ill. — Lower floor failed.

While this series of failures arose from a variety of causes, such as overloading of floors, faulty foundations or materials, and shoddy workmanship, codes or design standards were generally not blamed. Instead, the problems were attributed to inadequate inspection by city inspectors, architects, or engineers. A review of the early literature shows that adherence to contemporary criteria for brick wall thickness and for iron, steel, and timber, would have produced stable, safe buildings.

(b) Vertical Loads

As discussed above, most structural failures occurred during construction, and code design criteria were not identified as problems. The design live loads specified in building codes are generally lower today than at the turn of the century. This resulted in large part from the National Bureau of Standards research which in 1925 led to publication BH-7, Minimum Live Load Allowed for Use in Design of Buildings.

Vertical load design has been influenced by experience with several materials:

Wood has traditionally been used in bending (joists and beams), compression (columns), and in tension (lower chords of trusses). "Bow-string" type trusses were commonly used for commercial and industrial buildings from the 1920s through the mid 1950s. After 25 or 30 years, the lower chord often failed at the highly stressed ends, leading to roof and sometimes wall collapse. These failures occurred suddenly; in some cases the first warning was the sound of the trusses breaking. Many building departments and most experienced engineers now require an inspection of truss roofs either at specific intervals or when a permit is issued for any work in the building. The allowable tensile stress for Douglas Fir in the 1961 Uniform Building Code was 1500 psi, the same as the bending stress. In 1964, in response to building failures, this was reduced to 1200 psi. In 1971, allowable stress was further reduced to 1000 psi, based on new research.

Brick masonry construction was based on empirical methods until the mid 1960s. In the early 1960s, design methods similar to those used for concrete were introduced for masonry design. Much of this work arose from seismic design needs, together with an intuitive feeling that the behavior of reinforced brick is similar to that of concrete. Design methods for masonry have continued to be validated and improved by research. Now, in early 1981, ultimate strength design methods are being developed.

The principal new technology that emerged at the beginning of the 20th century was reinforced concrete. Although there were no design standards for concrete at the turn of the century, a body of professional research was in evidence. The ASCE Transaction of March 1898 included a paper on tests and design methods for "Steel Concrete Construction". Many other articles and discussions appeared in trade magazines of the time.

Between 1900 and 1920, many concrete structures failed. Engineering News of November 29, 1906, reported on the collapse of the Bixby Hotel, a six story concrete structure under construction in Long Beach, California. No cause was given. In Engineering News, July 18, 1907, the failure of a reinforced concrete building in Philadelphia was reported. This time early removal of shoring was reported to be the cause.

Among additional reports at the time of the failure of buildings nearing completion: a reinforced concrete building for Eastman Kodak in Rochester, New York—Engineering News, January 3, 1907; the Henke Building, a four-story Cleveland building almost completed—Engineering News, December 8, 1910; a failure of the roof of a reinforced concrete building in Winnipeg, Massachusetts—Engineering News, October 5, 1911; and collapse of the Chamber of Commerce Building in Cincinnati, Ohio—Engineering News, February 2, 1911.

Most of the reported failures stemmed from construction operations rather than design methods. Typical problems arose from premature removal of forms and shoring, and the application of dead loads (upper stories) on the "green" concrete of the lower stories.

As noted earlier, the opinion of engineers is that the wide variation in allowable stresses in concrete in various building codes reflected concern for the safety of reinforced concrete buildings. By 1910, the basic design approach, formulas, etc., were evident and reasonably consistent in most codes.

The concrete industry research and marketing organization, the Portland Cement Association, was formed in 1906. Along with other organizations, it developed the design criteria that became the basis of building regulations. In 1909, Trautwine published Design of Reinforced Construction.[22]

Concrete buildings failed in succeeding decades as well. Virtually all failures occurred during construction. Typically, structural failure, cracking, etc. would result in an unconventional structure in which the stresses were not understood by the engineer or architect.

(c) Seismic Loads

One other major structural code development is the design of earthquake resistant buildings. Early designers assumed that wind force design was adequate to provide for earthquake safety. But seismic forces are not really comparable to wind; they are inertial rather than a uniform load over the building surface. Thus there were innumerable early building failures from earthquakes. Most frequently, brick buildings failed, but other types of construction suffered damage as well.

Initially, there was little regulatory response to quake damage. One exception was in San Francisco. Due to labor pressure at the time, the city had prohibited the use of reinforced concrete, that is, did not include it in the city building code. However, following the massive failure of brick buildings in the 1906 earthquake, the code was amended to permit the use of reinforced concrete.

Earthquake damage to brick buildings follows a typical pattern. During the quake, a wall pulls away from the roof or floor and collapses from lack of lateral support. At the same time, the roof and floors, lacking vertical support, collapse--pancake style. To overcome this condition, engineers developed a method whereby walls are constructed using reinforcing steel in the grout space between wythes of brick, and the floor and roof system is physically anchored to the walls. This construction method was not specifically required until after 1933.

The 1927 Uniform Building Code (lst edition) contained, as an appendix, design provisions for seismic zones. These criteria considered seismic forces as inertial in nature.

The 1933 Long Beach earthquake generated major legislative response. The California legislature adopted statewide seismic design requirements for all buildings except dwellings and agricultural buildings. It also required state review and approval for school buildings.

Each significant earthquake since Long Beach in 1933 has produced changes in earthquake codes. Design criteria in 1933 California statewide regulations specified 2% of the total vertical design load. The 1933 Los Angeles code specified a coefficient of 8% of the dead load plus one-half of the live load. This was also the value in the 1935 Uniform Building Code. These design criteria were to be doubled for poor soils (less than 2000 psf).

In response to the 1926 Santa Barbara earthquake, strong motion seismic recording devices were developed by the U.S. Geological Survey (U.S.G.S.), leading to future design criteria.

The 1940 El Centro earthquake was the first to be monitored by strong motion seismographs. The measured accelerations became the basis for codes through 1973. World War II limited progress, but near the end of the war some changes were made for multi-story buildings.

The greatest advances in earthquake design have occurred since World War II (see accompanying report, Evolution of Building Regulations in the United States for discussion). The 1964 Alaska earthquake increased understanding of high-rise building design and the potential for soil liquefaction. The 1967 Caracas, Venezuela earthquake developed an understanding of the role of soil type in increasing or damping bedrock ground motions. The 1972 Nicaragua and the 1971 San Fernando earthquakes generated requirements for higher design standards for certain buildings that must remain operational following a quake. Another problem identified at that time was that of the "soft story", a result of prevalent architectural style. Also added after 1971 were code requirements for non-structural building elements, such as ceilings and storage racks, and criteria for life-line engineering for utilities.

Recent earthquakes have generally repeating experiences with the older buildings. Thus the 1980 El Centro quake again had damage to unreinforced masonry buildings. Earthquakes in other countries have repeated the illustration of masonry construction performance—how masonry can collapse, causing deaths and injuries.

In the opinion of most engineers the current overall force criteria are adequate and provide safety for each structural element. Code changes are now being considered for non-structural building elements including ceilings, curtain walls, and electrical and mechanical systems.

Some retroactive or hazard abatement ordinances have been adopted, although many city councils have rejected such ordinances. Los Angeles recently adopted such an ordinance, affecting as many as 10,000 buildings. This may initiate a trend in strengthening the type of older buildings known to collapse catastrophically in an earthquake.

(d) Wind Load

General codes have always required buildings to be designed for wind forces. By 1910, this was explicit for higher structures, and implicit for lower buildings, based on a height to width ratio that assured stability. Most wind related failures occurred during construction, before bracing was installed, and to non-structural building elements such as curtain walls.

Areas of the country subject to extreme winds such as hurricanes have adopted requirements for hurricane anchors. These tie the roof members to the walls with straps. Such a requirement was added to codes in the southeast in the mid 1960s. It is included in the Standard Building Code (SBCI) as an appendix for local adoption.

(4) ELECTRICAL SAFETY*

The National Electrical Code (NEC) initially was directed toward eliminating faulty electrical installations that were thought to have contributed to substantial fire losses. (For a discussion of electrical fire hazard see section on Fire Safety, above.) In 1937, NEC's scope was expanded to encompass other safety issues related to electrocution and shock. For example, to reduce several hazards associated with extension cords, more electrical outlets were required for each room.

Although data for the earliest decades of this century were not reviewed, in 1943 in the U.S., there were 802 deaths involving electric current, according to the National Safety Council (1945). The figure is relatively low when compared with 24,179 deaths from falls, 5,591 from burns, and 2,775 from conflagration that same year. In fact, deaths involving electrical installations or appliances have tended to be lumped into the "other" category in listings of the principal causes of accidental deaths. It was not until the mid-1960s that the National Safety Council even listed electric current as an important cause of the accidents in its "other" category.

In his review of worldwide domestic accident statistics and patterns, Backett (1963) classified electrocution in the "other" category along with snake and insect bites, among others. However, he did note that electrocution was a major problem in newly electrified rural districts where people were unfamiliar with the hazards. He also cited data from a study (Lossing & Goyette, 1957) which revealed a substantial reduction in the number of electrocutions in homes where the current was reduced from 440 volts to 110 volts A.C..

In 1969, the Teledyne-Brown survey of home accidents conducted for HUD revealed that electrical fixtures and appliances accounted for approximately 7% of all accidental injuries. Only about one-third of these appeared to be related to the installation of electrical circuits and materials within the building itself. The report then suggested that such accidents could substantially be reduced or made less severe by installing ground fault circuit interruptors (GFCIs) and more effectively locating receptacles and fixtures.

In 1971, a study of newspaper clippings indicated that 45.5% of all reported electric shock fatalities in or around the home occurred either outdoors or in bathrooms (Smoot, 1971). In 1973, the National Electronic Injury Surveillance System (NEISS) ranked electric fixtures (outlets, circuit breakers, etc.) as the 79th most hazardous consumer product category according to the Accident Frequency and Severity Index (AFSI). Appliance and extension cords ranked 85th.

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From these data it is difficult to determine how serious electrical safety hazards in buildings were or are in the U.S. (Note that electrical fire hazards are not included in this discussion.) In 1970, the National Center for Health Statistics reported 1,140 deaths in the U.S. as a result of electric shock (Underwriters Laboratories, n.d.). Of these, 270 occurred in or around the home (McConnaughey, 1978). From 1963 through 1974, electric shock caused an average of 290 home deaths each year, most of which were attributed to wiring and appliances.

Electrical hazards tend to cause fewer accidents and injuries than a number of other safety hazards that are not now addressed in the model codes. Using an 80:1 ratio of injuries to fatalities (Arthur Young & Co., 1976), it appears that each year in the U.S. there are about 23,200 electricity-related home injuries. This is in contrast to over 100,000 household injuries per year related to bathtubs and showers, non-glass doors, and windows (Teledyne-Brown, 1969).

In the mid-1970s the Underwriters Laboratories published a pamphlet showing that the annual death rate from electrical sources had dropped from 6.3 per million in 1950 to 5.6 per million in 1970. This was despite a 633% increase during the decade in home electrical consumption. The pamphlet also noted that 39.6% of all electrical fatalities occurred in the home, and that two-thirds of these involved electrical appliances. The rest resulted when TV antennas came into contact with overhead utility lines.

A recent study by McConnaughey (1978) assessed the cost-effectiveness of using ground fault circuit interrupters to reduce electricity-related fatalities in and around the home. He found that only 1.2 lives per year would be saved, over and above those which would be saved through effective grounding alone. Furthermore, he estimated that the cost of installing GFCIs in all new residential bathroom and outdoor circuits would be approximately $92,000,000 per year in 1975 dollars. In effect, for each life saved, the cost for 20 years of service for each GFCI would be somewhere between $2,500,000 and $7,000,000. Thus, the cost of further reducing electrical fatalities in the home appears to be quite high.

Electrical installations appear to have a relatively low rate of death or injury compared to other home hazards, and in other building types generally. Electrical installations in buildings have been continuously regulated by the NEC since the beginning of this century. However, from the data reviewed, it cannot be determined to what extent this safety record can be attributed to the effectiveness of the provisions of the NEC or other regulations.

C. EVOLUTION OF THE BUILDING INVENTORY IN THE U.S. AND BUILDING PERFORMANCE

An original thesis in the RFP for this report is that the overall quality and safety of the total building stock increases each year, since buildings which are demolished are older and of poorer quality than those left standing or newly constructed. The assumption is that older codes were less stringent or safety oriented than more recent, "updated" codes.

On the surface, the thesis is logical. However, in at least three situations demolition may occur for reasons other than obsolescences: natural disasters; local, regional or national programs such as highway construction where perfectly good buildings are demolished along with bad ones; and social distress cases such as Pruitt-Igoe and the current Oriental Gardens in New Haven, Connecticut.

Furthermore, the thesis cannot be substantiated by published census data. Census data on the inventory and the condition of non-housing structures have never been compiled. Housing census data have been collected since 1850; but not until the mid 1900s did these begin to indicate amenities and the year of construction*, both for structures added to and removed from the inventory, and for structures which are the "same" in a subsequent census. Such data (adequacy of kitchen, bathroom, bedroom facilities, and plumbing and heating equipment) perhaps could be used to determine if there is a correlation between updated building code compliance and the condition of the housing inventory, but only for a relatively short time span.

Only since 1973 have annual housing surveys been made. Data pertinent to this study are not published, but are on Bureau of Census longitudinally linked tapes dating from 1974. For instance, the number of housing units removed from the inventory in a given year, as typically published, combine permanent with retrievable losses. In the 1978 Annual Housing Survey, just being published in 1981, a table is included which separates total U.S. permanent from retrievable losses.[23] However, such category breakdowns as region and age of structure are not published.

Published data which can be compared show regional breakdowns for age of the housing inventory, and age of the units being removed by demolition.[24] In the 1950s, the trend to demolish older buildings was closely proportionate to each region's age distribution of the total housing stock. The exception was the South where percent of older units demolished was considerably higher than the percent of housing built prior to 1939. Conversely, the percent of newer units demolished was conversely considerably lower than the respective proportion of recently built housing (see Table 2, below).

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* See Table 1 for a chronology of housing census methodology.

TABLE 1

HOUSING CENSUS STATISTICS COLLECTION: CHRONOLOGY

1850	Census counted number of dwellings.
1890	Census also counted home owners separately.
1930	Census included non-farm housing, rent paid, value of owner-occupied property.
1940	First full-fledged housing census: number, type, amenities; also year built.
1950	First "modern" housing census, including number of units built 1939 and earlier, etc.
1960	Census included components of inventory change since the previous census: same units; units changed by conversion or merger; units added through new construction or other means; units lost through demolition or other means.
1970	Census established an Annual Housing Survey, first published with 1973 as the base year. The AHSs include 1973 characteristics of housing units removed from the inventory in subsequent years, accumulated. Data combines permanent and retrievable losses.
	Beginning in 1978, a table is published in Part A of AHS reports listing total number of units lost annually through demolition or disaster; permanent and retrievable losses are separated.

Table 2: 1950 Age Breakdowns, by Region of Housing Units and Demolitions

REGION	BUILT 1939 AND EARLIER Total Housing	BUILT 1939 AND EARLIER Total Demolitions	BUILT 1940-49 Total Housing	BUILT 1940-49 Total Demolitions
NORTHEAST	88%	88%	12%	12%
NORTH CENTRAL	84%	85%	16%	15%
SOUTH	72%	88%	28%	12%
WEST	67%	68%	33%	32%

Source: United States Census of Housing, 1960, Tables 1 and 3

In the 1960s, the rate of demolition of pre-1939 housing was considerably higher than any region's proportion of this older housing stock, although least disproportionate in the West. In the Northeast and North Central regions a relatively small percentage of housing built after 1940 was being demolished; in the South, a somewhat higher percentage was being demolished. The largest percentage of post-1940 buildings demolished in the 1960s was in the West (which actually had a slightly higher percent of housing demolished compared to the percent of housing stock in the West built between 1940-49 category). See Table 3 to compare the regional age breakdowns of housing units and demolitions in 1950 and in 1960.

Clearly, the preceding data are too general, and cover too short a time span in relation to the decades into which the data are aggregated, to suggest any simple conclusions on the relation of age distribution of buildings demolished to the building regulations under which these buildings were constructed.

Furthermore, the utility of aggregated census data on buildings as in any way directly reflecting building performance (building quality, dysfunction, etc.), must be questioned in light of the following observations (see Figures 1 and 2). Nine of the 11 states with highest fire death rates (as reported for 1974-75 by the U.S. Fire Administration) are in the South, and of the 15 states included in this region, as designated by the census, 14 are in the highest two categoriess (of four) in terms of fire death rates. However, the South is a region which is lower than both the Northeast and North Central in proportion of housing built prior to 1939 (as reported in the 1970 census).

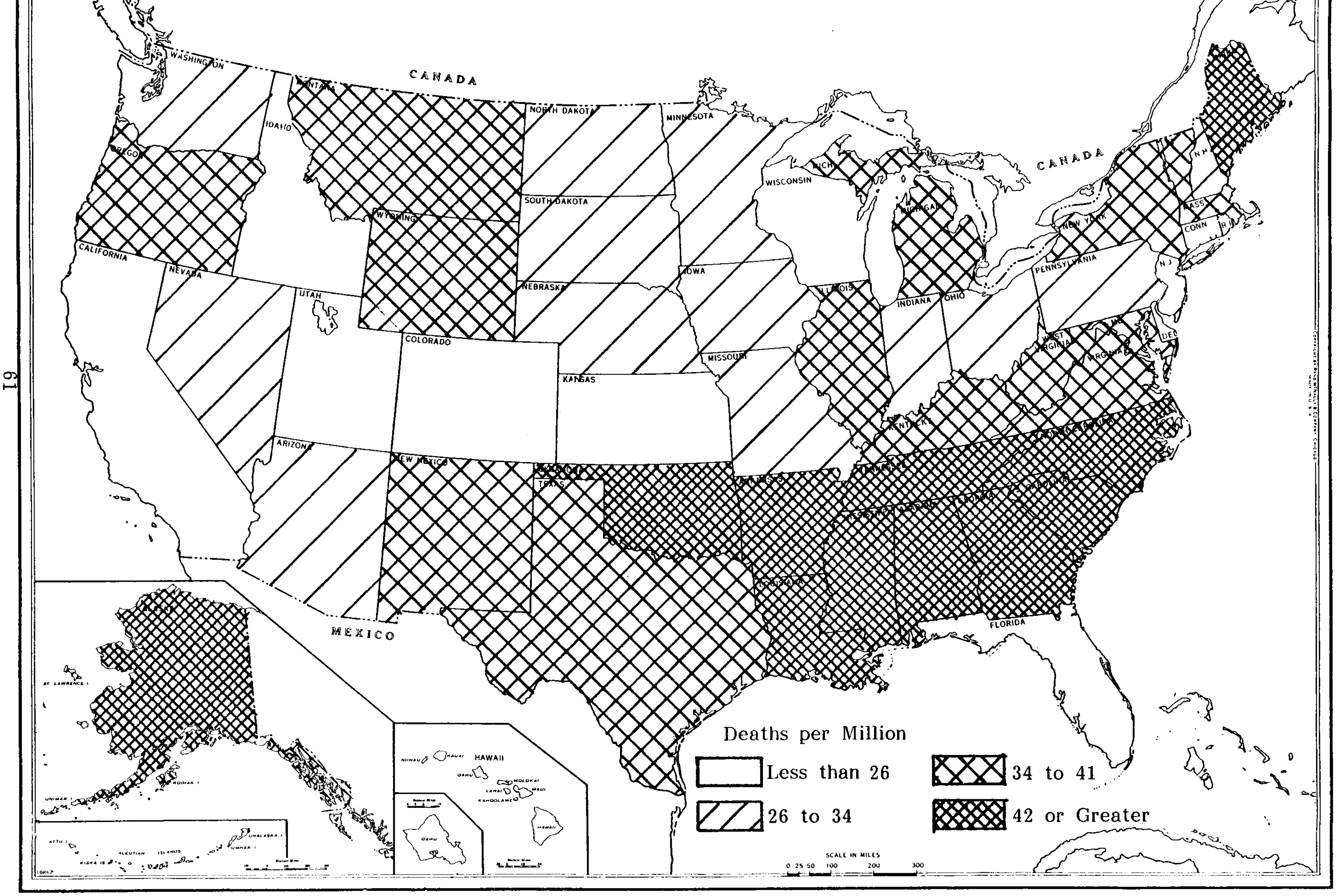
Considering that residential fire deaths account for about two-thirds of all fire deaths, this simple comparison suggests that age of buildings may not be a good measure of fire-related building performance.

Table 3: 1950 and 1960 Regional Age Breakdowns of Housing Units and Demolitions

REGION		% TOTAL HOUSING	% TOTAL DEMOLITION
NORTH EAST		1950	Between 1950-1960
	Total	26	16
	Built 40-49	12	12
	Built 1939-	88	88
		100	100
		1960	Between 1960-1970
	Total	25	18
	Built 50-59	22	4
	Built 40-49	10	4
	Built 1939-	68	92
		100	100
NORTH CENTRAL		1950	Between 1950-1960
	Total	30	24
	Built 40-49	16	15
	Built 1939-	84	85
		100	100
		1960	Between 1960-1970
	Total	29	26
	Built 50-59	24	7
	Built 40-49	11	7
	Built 1939-	65	86
		100	100
SOUTH		1950	Between 1950-1960
	Total	30	45
	Built 40-49	28	12
	Built 1939-	72	88
		100	100
		1960	Between 1960-1970
	Total	29	36
	Built 50-59	25	11
	Built 40-49	20	17
	Built 1939-	45	72
		100	100
WEST		1950	Between 1950-1960
	Total	14	15
	Built 40-49	33	32
	Built 1939-	67	68
		100	100
		1960	Between 1960-1970
	Total	16	20
	Built 50-59	38	19
	Built 40-49	17	21
	Built 1939-	45	59
		100	100

Source: United States Census of Housing, 1960 (for 1950 data), 1970 (for 1960 data), Tables 1 and 3

FIGURE 1 STATE FIRE DEATH RATES--DEATHS PER MILLION POPULATION (AVERAGE
(AVERAGE 1974-75)



UNITED STATES

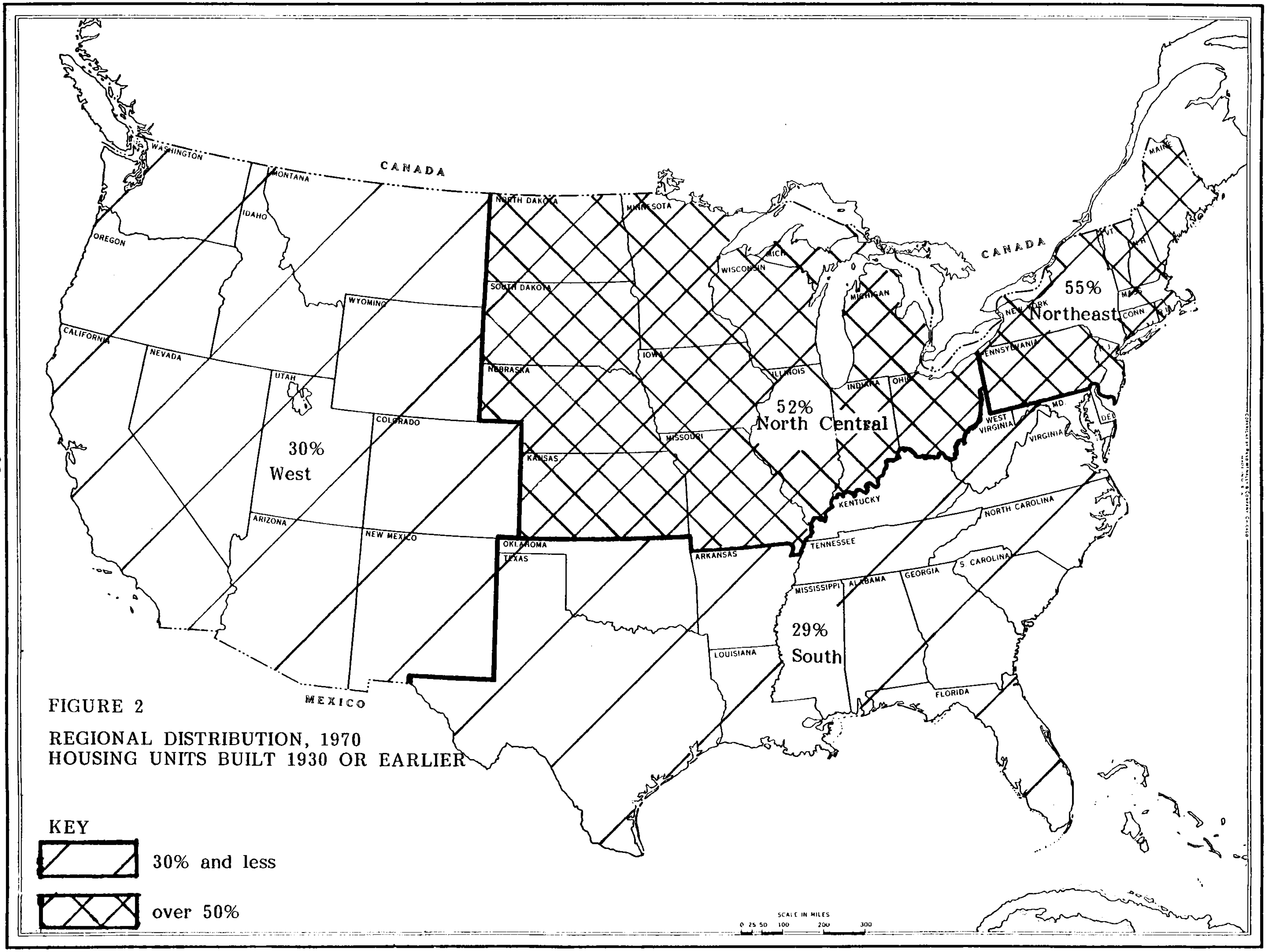


FIGURE 2

REGIONAL DISTRIBUTION, 1970
HOUSING UNITS BUILT 1930 OR EARLIER

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APPENDIX A

ANNUAL DOLLAR FIRE LOSS

Year	Aggregate Property Loss $	Year	Aggregate Property Loss $
1900	160,929,805	1924	549,062,124
1901	165,817,810	1925	559,418,184
1902	161,078,040	1926	561,980,751
1903	145,302,155	1927	472,933,969
1904	229,198,050	1928	464,607,102
1905	165,221,650	1929	459,445,778
1906	518,611,800	1930	501,980,624
1907	215,084,709	1931	451,643,866
1908	217,885,850	1932	400,859,554
1909	188,705,150	1933	271,453,189
1910	214,003,300	1934	271,197,296
1911	217,004,575	1935	235,263,401
1912	206,438,900	1936	266,659,449
1913	203,763,550	1937	254,959,423
1914	221,439,350	1938	258,477,944
1915	172,033,200	1939	275,102,119
1916	258,377,952	1940	285,878,697
1917	289,535,050	1941	303,895,000
1918	353,878,876	1942	314,295,000
1919	320,540,399	1943	373,000,000
1920	447,886,677	1944	437,273,000
1921	495,406,012	1945	455,329,000
1922	506,541,001	1946	580,000,000
1923	535,372,782		

Source: National Board of Fire Underwriters, as published in NFPA Fire Quarterly

TABLE NO. 1

APPENDIX A

BUILDING LOSS

Year	$ Building Loss	# Building Fires	# Non-Bldg. Fires	$ Non-Bldg. Loss	TOTAL $ Total Loss	TOTAL # Fires
1947	703,000,000	538,000	1,104,000	72,700,000	775,700,000	1,642,000
1948	714,800,000	570,000	1,147,000	61,462,000	776,000,000	1,717,000
1949	672,500,000	580,000	1,172,500	70,334,000	742,834,000	1,752,500
1950	699,600,000	600,000	1,200,700	76,840,000	776,400,000	1,800,700
1951	739,550,000	625,000	1,164,000	97,050,000	836,600,000	1,789,000
1952	793,500,000	703,000	1,311,600	149,150,000	942,650,000	2,014,600
1953	889,120,000	727,000	1,172,400	132,600,000	1,021,720,000	1,899,400
1954	875,450,000	774,000	1,218,700	141,465,000	1,017,000,000	1,993,000
1955	943,551,000	811,800	1,166,150	197,217,000	1,140,768,000	1,977,950
1956	1,016,000,000	824,400	1,115,750	215,576,000	1,231,576,000	1,940,150
1957	1,068,115,000	843,900	1,181,600	211,811,000	1,279,926,000	2,025,500
1958	1,056,308,000	866,700	1,126,875	222,500,000	1,278,808,000	1,993,575
1959	1,083,210,000	883,300	1,231,060	356,430,000	1,439,640,000	2,114,360
1960	1,139,700,000	890,200	1,233,660	404,500,000	1,544,200,000	2,123,860
1961	1,232,400,000	857,400	1,332,640	293,900,000	1,526,300,000	2,190,040
1962	1,283,000,000	886,600	1,389,190	307,600,000	1,590,600,000	2,275,790
1963	1,408,500,000	918,600	1,549,900	379,600,000	1,788,100,000	2,468,500
1964	1,361,500,000	912,600	1,454,725	291,200,000	1,652,700,000	2,367,325
1965	1,455,900,000	921,700	1,425,425	285,400,000	1,741,300,000	2,347,125
1966	1,528,000,000	970,800	1,425,750	332,500,000	1,860,500,000	2,396,550
1967	1,623,000,000	960,900	1,432,100	493,200,000	2,116,200,000	2,393,000
1968	1,786,900,000	974,400	1,389,300	468,100,000	2,255,000,000	2,363,700
1969	1,933,800,000	973,000	1,452,350	513,800,000	2,447,600,000	2,425,350
1970	2,209,200,000	992,000	1,557,550	421,200,000	2,630,400,000	2,549,550
1971	2,266,000,000	996,600	1,731,600	477,260,000	2,743,260,000	2,728,200
1972	2,416,300,000	1,050,200	1,707,400	511,500,000	2,927,800,000	2,757,000
1973	2,537,200,000	1,085,900	1,608,200	483,600,000	3,020,800,000	2,694,100
1974	3,260,000,000	1,270,000	1,712,000	558,800,000	3,818,800,000	2,982,000
1975	3,436,600,000	1,264,400	1,840,800	734,000,000	4,170,600,000	3,105,200
1976	2,656,400,000	964,200	1,974,900	703,600,000	3,360,000,000	2,939,100
1977	5,227,000,000	1,179,000	2,334,000	837,000,000	6,064,000,000	3,513,000
1978	4,015,337,827	1,137,227	1,933,370	463,591,356	4,478,929,183	3,070,597
1979	4,964,000,000	1,036,500	1,809,000	786,000,000	5,750,000,000	2,845,500

Source: National Fire Protection Association, "Fires and Fire Losses Classified" from years shown.

TABLE NO. 2

APPENDIX A

PER CAPITA DOLLAR FIRE LOSS

Year	Per Capita Fire Loss
1915	1.71
1916	2.10
1917	2.42
1918	2.76
1919	2.99
1920	4.23
1921	4.56
1922	4.62
1923	4.84
1924	4.90
1925	4.85
1926	4.80
1927	3.96
1928	3.87
1929	3.81
1930	4.09
1931	3.64
1932	3.21
1933	2.16
1934	2.08
1935	1.85
1936	2.08
1937	1.96
1938	2.05
1939	2.29

Source: National Board of Fire Underwriters, as published in NFPA <u>Fire Quarterly</u>

TABLE NO. 3

APPENDIX A

BUILDING FIRES PER 1,000 POPULATION

Year	Fires/1,000 Population
1936	5.24
1937	4.82
1938	5.14
1939	5.24
1940	5.50
1941	5.58
1942	5.05
1943	5.08
1960	4.93
1965	4.74
1970	4.8
1971	4.8

Source: National Fire Protection Association, "Fires and Fire Losses Classified" from years shown.

TABLE NO. 4

APPENDIX A

SELECTED FIRE DOLLAR LOSSES BY OCCUPANCY

	Residential (All Types)		Office		Mercantile	
	$	%*	$	%*	$	%*
1937	96,700,000	(36%)	5,700,000	(2%)	40,330,000	(15%)
1940	90,700,000	(31%)	7,500,000	(3%)	46,000,000	(16%)
1945	108,000,000	(22%)	9,100,000	(2%)	57,800,000	(12%)
1950	218,100,000	(28%)	18,000,000	(2%)	87,000,000	(11%)
1955	283,135,500	(25%)	10,064,000	(1%)	142,650,000	(13%)
1960	415,800,000	(27%)	12,700,000	(1%)	130,400,000	(8%)
1965	488,000,000	(28%)	17,800,000	(1%)	232,200,000	(13%)
1970	841,700,000	(32%)	43,000,000	(2%)	351,600,000	(13%)
1975	1,389,000,000	(33%)	57,800,000	(1%)	449,200,000	(11%)

* Percentage of total dollar loss from fires of all types

Source: National Fire Protection Association, "Fires and Fire Losses Classified" from years shown.

TABLE NO. 5

APPENDIX A

FIRE DEATH STATISTICS

	National Fire Protection Association		United States Fire Administration	
Year	Total Deaths	Deaths/Million Population	Total Deaths	Deaths/Million Population
1950	10,000	66.4	*	*
1955	11,475	69.5	*	*
1959	11,300	*	*	*
1960	11,350	63.0	*	*
1967	12,200	61.8	*	*
1968	12,100	60.7	*	*
1969	12,100	60.1	*	*
1970	12,200	59.9	*	*
1971	11,850	57.2	9,000	43.7
1972	11,900	57.1	8,900	42.7
1973	11,700	55.7	8,700	41.2
1974	11,600	55.4	8,400	39.4
1975	11,800	55.4	8,100	37.9
1976	8,800	*	8,400	39.3
1977	9,950	*	8,500	39.4
1978	8,621	*	8,100	37.1
1979	7,780	*	7,800 (est)	*

* No data reported.

Source: National Fire Protection Association, "Fires and Fire Losses Classified, 1971" September 1972 and other years shown; United States Fire Administration, "Highlights of Fire in the United States", 2nd Edition, November 1980.

TABLE NO. 6

APPENDIX A

MULTIPLE-DEATH FIRES
(3 or More Deaths)

Year	Number of Fires	Number of Deaths	Average Number Deaths/Fire	Number of Fires With 10 or More Deaths
1962	263	1159	4.4	—
1963	286	1485	5.2	—
1964	283	1224	—	7
1965	272	1325	—	12
1966	340	1442	—	10
1967	205	918	4.8	6
1968	248	1227	4.9	11
1969	227	1001	4.4	10
1970	209	988	4.7	7
1971	208	911	4.4	10
1972	193	992	5.1	10
1973	205	1008	4.9	12
1974	224	916	4.1	4
1975	250	1091	4.4	7
1976	293	1261	4.3	9
1977	272	1342	4.9	8
1978	286	1158	4.0	7
1979	271	1084	4.0	8

Source: Reported annually in "Multiple Death Fires", Fire Journal, NFPA

TABLE 7

APPENDIX A

MAJOR LOSS OF LIFE FIRES

Date	Occupancy	Location	Deaths	Notes	Ref.
12/5/1876	Brooklyn Theatre	Brooklyn, NY	295	*	1
1/31/1882	New York World Newspaper	New York, NY	12	*	1
1/10/1883	Newhall Hotel	Milwaukee, WI	71	Victims trapped on upper floors	1
12/12/1895	Front Street Playhouse	Baltimore, MD	24	*	1
3/17/1899	Windsor Hotel	New York, NY	92	Damage - millions; 14 jumped to death	1
9/20/1902	Church	Birmingham, AL	115	*	1
1/13/1903	Rhoades Opera House	Boyertown, PA	170	*	1, 2
12/30/1903	Iroquois Theatre	Chicago, IL	602	*	1
3/4/1908	Lake View Elementary Sch.	Collinwood, OH	176	*	1
10/1/1910	Los Angeles Times Bldg.	Los Angeles, CA	21	Explosion	1
3/25/1911	Triangle Shirtwaist Factory	New York, NY	145	Fire on 8th, 9th & 10th floors; exits locked	1
8/27/1911	Opera House	Cannonsburg, PA	26	Deaths from suffocation after panic in exits; fire posed no danger	12
7/21/1913	Oakley Prison Farm	Jackson, MI	35	Prisoners locked in cells	1
7/22/1913	Binghamton Clothing Co.	Binghamton, NY	50	*	1
12/2/1913	Arcadia Hotel	Boston, MA	28	*	2
3/9/1914	Missouri Athletic Club	St. Louis, MO	37	*	1
10/28/1915	St. John's Parochial School	Peabody, MA	22	*	2

TABLE 8

Date	Occupancy	Location	Deaths	Notes	Ref.
4/13/1918	Oklahoma State Hospital for the Insane	Norman, OK	38	Few survived	1
9/17/1918	American Button Company	Newark, NJ	11	Overcrowded, poor exits	13
11/22/1919	Dance Hall	Ville Platte, LA	25	*	2
4/8/1920	Rooming House	Ponca City, OK	32	Explosion	2
11/14/1921	Apartment	New York, NY	11	Fire in hallway blocked single stair; tenants foreigners, failed to use rear fire escape	14
2/7/1922	Lexington Hotel	Richmond, VA	12	Inadequate elevator shaft	15
10/22/1922	Apartment House	New York, NY	15	Fire in baby carriage in rear hallway blocked exit; combustible stairs	25
2/18/1923	Manhattan State Hospital for the Insane	Ward's Island, NY	27	*	1
4/27/1923	Tenement	New York, NY	12	Improper stair doors; air shaft in stairwell	16
5/17/1923	Cleveland Rural Grade Sch.	Camden, SC	77	Graduation exercises; single exit from 2nd floor auditorium; stair decreased in width	1, 16
6/21/1923	Tenement	Chicago, IL	10	Improper gas installation ignited combustible stairway enclosure	16
12/26/1923	Illinois State Hospital for the Insane	Dunning, IL	18	*	16
2/15/1924	Apartments over Mercantile	Montpelier, VT	11	Fire started in store; victims trapped in apt. over store	16

Date	Occupancy	Location	Deaths	Notes	Ref.
2/19/1924	Tenement	New York, NY	14	5-story ordinary construction; combustible stairs and enclosure	16
12/24/1924	Babb's Switch School	Hobart, OK	36	Christmas tree started blaze	1
1/23/1926	Lafayette Hotel	Allentown, PA	13	Built 1809; defective flue ignited combustible wall and floor; open stair; victims from upper floors	17
7/14/1926	Twilight Inn	Haines Falls, NY	14	Resort hotel, 3-story wood frame; 1st floor fire blocked exits	18
4/13/1928	Bond Dance Hall	West Plains, MO	38	*	2
5/15/1929	Cleveland Clinic Hospital	Cleveland, OH	121	Poison gas from burning X-ray film	1
9/20/1929	Detroit Study Club	Detroit, MI	22	Night club on second floor, single exit; combustible interior finish and decorations	2, 20
12/10/1929	Pathe Sound Studio	New York, NY	10	Flammable decorations	21
4/21/1930	Ohio State Penetentiary	Columbus, OH	322	Victims in hospital or locked cells	1
7/24/1931	Little Sisters of the Poor Home	Pittsburgh, PA	48	Home for the aged	1
3/24/1934	Federal Transient Relief	Lynchburg, VA	22	Lodgings	1, 2
12/11/1934	Hotel Kerns	Lansing, MI	32	Open stairways	2, 27

Date	Occupancy	Location	Deaths	Notes	Ref.
2/12/1936	Victoria Mansions Hotel	Lakewood, NJ	16	*	2
3/6/1936	Hardware Store & Supply Co.	Gainesville, GA	57	*	1
5/16/1938	Terminal Hotel	Atlanta, GA	38	Unprotected stairs and elevator shafts	1, 29
1/3/1940	Marlborough Hotel	Minneapolis, MN	19	Apartments	2
4/23/1940	Rhythm Night Club	Natchez, MI	207	Flammable decorations overcrowding, exits blocked	1,2,31
11/18/1941	Brunswick Home	Amityville, NY	7	4-story wood frame, open wooden stairs	34
12/16/1941	Riverview Convalescent Home	Rotterdem, NY	8	Wood frame construction; careless use of smoking materials	34
1/20/1942	Melvin Hall Apartments	Lynn, MA	13	5-story ordinary; open stair	35
11/28/1942	Cocoanut Grove Night Club	Boston, MA	491	Exits locked, flammable decorations, door swung against direction of travel	1
1/31/1943	Forest Park Sanitarium	Seattle, WA	32	*	2
9/7/1943	The Gulf Hotel	Houston, TX	55	*	1
7/6/1944	Ringling Bros. Circus	Hartford, CN	168	Tent fire	1
1/31/1945	Day Nursery	Auburn, ME	17	16 children	1
7/28/1945	Empire State Building	New York, NY	14	Fire after bldg. struck by aircraft	2
12/24/45	Niles Street Hospital	Hartford, CN	17	*	1

Date	Occupancy	Location	Deaths	Notes	Ref.
2/2/1946	Catholic Home for Aged	Garfield Heights, OH	14	*	2
6/5/1946	LaSalle Hotel	Chicago, IL	61	200 hurt	1
6/9/1946	Canfield Hotel	Dubuque, IA	19	*	2
12/7/1946	Winecoff Hotel	Atlanta, GA	119	*	1
12/12/1946	Tenement House	New York, NY	37	Knickerbocker Ice Co. fire; bldg. collapsed on tenement	1, 2
12/25/1947	Gambling Shack	Dressleville, NY	14	*	2
4/5/1949	St. Anthony's Hospital	Effingham, IL	77	20 newborn babies killed	1
1/7/1950	Mercy Hospital	Davenport, IA	40	Mental hospital	1
12/22/1950	Walker Convalescent Home	Amarillo, TX	10	Fire through heat ducts blocked exit passageway	6
1/30/1951	Rest Home	Hoquiam, WA	20	*	1
10/31/1952	Cedar Grove Nursing Home	Hillsboro, MO	18	Combustible fiberboard ceiling	2
11/26/1952	West Virginia State Hosp.	Huntingdon, WVA	17	*	2
3/29/1953	Littlefield's Nursing Home	Littlefield, FL	33	*	1
4/16/1953	Haber Corp.	Chicago, IL	35	Mfg. facility; inadequate exits	1, 7
9/7/1953	Spector Realty Co.	Chicago, IL	18	Tenement	2

Date	Occupancy	Location	Deaths	Notes	Ref.
3/31/1954	Cleveland Hill School	Cheektowaga, NY	15	Elementary School	2
12/24/1954	Sharecropper Dwelling	Parkin, AR	13	*	2
2/4/1955	Tenement	Amsterdam, NY	12	*	2
2/12/1955	Barton Hotel	Chicago, IL	29	Dormitory type, skid row hotel	1
8/10/1955	Restaurant	Andover, OH	22	Lightning fire	1
1/29/1956	Arundel Park (Social Hall)	Brooklyn, MD	11	Delayed alarm and evacuation; combustible concealed attic	8
3/8/1956	Dwelling	Oxford, PA	12	*	2
2/13/1957	Council Bluffs Convalescent Home	Council Bluffs, IA	15	*	2
2/17/1957	Katie Jane Memorial Home	Warrenton, MO	72	*	1
11/16/1957	Tenement	Niagara Falls, NY	18	*	2
2/17/1958	Duplex	Atlanta, GA	12	*	2
3/19/1958	Monarch Underwear Co.	New York, NY	24	Loft building fire	1
12/1/1958	Our Lady of Angels	Chicago, IL	93	School, 90 children died	1
1/8/1959	Dwelling	Boswell, OK	16	*	2
3/5/1959	Arkansas Negro Boys Industrial Reformatory	Little Rock, AR	21	*	1

Date	Occupancy	Location	Deaths	Notes	Ref.
1/7/1961	Thomas Hotel	San Francisco, CA	20	*	1
3/28/1961	Dwelling	Dotsonville, TN	12	*	2
12/8/1961	Hartford Hospital	Hartford, CN	16	*	2
10/3/1962	N.Y. Telephone Co.	New York, NY	23	Office building; boiler explosion; 94 injured	1
11/18/1963	Surfside Hotel	Atlantic City, NJ	26	21 injured	1
11/23/1963	Golden Age Nursing Home	Fitchville, OH	63	*	1
12/25/1963	Dwelling	Charleston, SC	12	*	2
12/29/1963	Roosevelt Hotel	Jacksonville, FL	21	*	1
5/23/1964	All Hallows Church Parrish Hall	San Francisco, CA	17	*	2
12/18/1964	Maples Convalescent Home	Fountaintown, IN	20	*	1, 2
11/24/1965	Iowa National Guard Armory	Keokuk, IA	12	*	2
12/11/1965	Tavern	Chicago, IL	13	Customer ignited gasoline at front exit; combustible finish & materials; 2nd exit, 30", opened in	9
12/20/1965	Jewish Community Center	New York, NY	12	28 injured	2
1966	Rooming House	Miami, FL	10	*	35
1/6/1966	Carleton Hotel	St. Paul, MN	12	Open stairwell; combustible interior finish; insufficient exits	10
9/12/1966	Lane Hotel	Anchorage, AK	14	*	2
2/7/1967	Dale's Penthouse Restaurant	Montgomery, AL	25	Top 10-story apt. house	1

Date	Occupancy	Location	Deaths	Notes	Ref.
7/26/1967	State Prison Road Camp	Jay, FL	37	Locked barracks	1, 2
1/19/1968	Apartments	Brooklyn, NY	13	Apartments located over paper box plant	2
2/25/1969	Office Building	New York, NY	11	Single exit	28
6/3/1969	Apartment House	Kansas City, MO	12	Fire spread through dumbwaiter	28
6/8/1969	Dwelling	Parkersburg, WV	12	Arson (gasoline)	28
1/9/70	Nursing Home	Marietta, OH	27	*	1
3/20/1970	Hotel	Seattle, WA	19	16 injured	1
8/5/1970	Apartment	Minneapolis, MN	12	Open stairways; doors blocked open	28
9/13/1979	Ponet Square Apartment Hotel	Los Angeles, CA	19	Spread by stairways; suspicious origin	28
12/20/1970	Pioneer International Hotel	Tucson, AZ	28	8 of 11 stories burned; 28 injured	1
1/14/1971	Nursing Home	Buechel, KY	10	No automatic protection	28
4/25/1971	Apartment	Seattle, WA	12	Careless smoking; open stairways	28
10/19/1971	Geiger Nursing Home	Honesdale, PA	15	No automatic protection	28
1/16/72	Pennsylvania House Hotel	Tyrone, PA	12	*	3
1/26/1972	Home for the Aged	Lincoln Heights, OH	10	*	3
4/4/1972	Home for the Aged	Rosecrans, WI	10	*	3

Date	Occupancy	Location	Deaths	Notes	Ref.
5/5/1972	Carver Convalescent Home	Springfield, IL	10	*	3
11/29/1972	Rault Center	New Orleans, LA	6	16-story office/apts; opened in 1968	3
11/30/1972	Baptist Towers Home	Atlanta, GA	10	11-story apts; opened April 1972	3
1/29/1973	Street's Rest Home	Pleasantville, NJ	10	2-story wood frame; fire set by resident	4
2/7/1973	Apartment House	Alameda, CA	11	*	4
6/24/1973	Cocktail Lounge	New Orleans, LA	32	2nd floor lounge; fire set in main exit route with poor 2nd exit and barred windows	4
7/11/1973	Apartment House	Worcester, MA	10	5-story ordinary construction	4
9/13/1973	Washington Hill Nursing Home	Wayne, PA	11	*	4
9/29/1973	Apartment	Hoboken, NJ	11	Open stairwell; 5-story ordinary construction; arson suspected	4
11/16/1973	Apartment	Los Angeles, CA	25	Open stairwell; 3-story wood frame	4
12/4/1973	Caley Nursing Home	Wayne, PA	10	*	4
1/24/1974	Apartment	Liberty, NY	10	3-story wood frame; apt. top floor only with single exit; 14 injured	5
6/30/1974	Discotheque	Port Chester, NY	24	Arson	5

Date	Occupancy	Location	Deaths	Notes	Ref.
8/25/1974	Hotel	Berkeley Springs, WV	12	1880 4-story ordinary; open stairs and no firestopping	5
6/9/1975	Jail	Sanford, FL	11	Intentionally set; blocked exit and locked doors	6
7/7/1975	Hotel	Portland, OR	12	26 injured, incendiary	6
12/12/1975	Apartment	San Francisco, CA	14	Open stairs, incendiary origin	6
1/30/1976	Nursing Home	Chicago, IL	24	Smoke spread throughout fire-resistive building	7
2/4/1976	Apartment	Manhattan, NY	10	Cigarette ignited couch; smoke spread through pipe chases	7
4/1976	Avondale Hotel	Miami, FL	10	Building occupied as apartments; open door	35
10/24/76	Puerto Rican Social Club	Bronx, NY	25	Single enclosed exit to 2nd story club ignited by gasoline; window to fire escape blocked	7
12/20/1976	Apartment	Los Angeles, CA	10	Couch in open stairway set on fire	7
12/22/1976	Department store	Brooklyn, NY	12	*	7
12/23/1976	Apartment	Chicago, IL	12	Charcoal grill used inside building; lighter fluid ignited	7
1/28/1977	Hotel	Breckenridge, MN	17	3-story wood frame; open wooden stairways	8

Date	Occupancy	Location	Deaths	Notes	Ref.
5/28/1977	Beverly Hills Supper Club	Southgate, KY	165	Overcrowding; inadequate exit capacity	8
6/26/1977	County Jail	Columbia, IN	42	Material in padded cell ignited by 16-yr. old inmate	8
12/10/1977	Hotel	Bay City, MI	10	Plywood paneling in corridor; open stairways	8
12/13/1977	Dormitory	Providence, RI	10	Flammable decorations in hallways; dead-end corridors	8
1/28/1978	Hotel	Kansas City, MO	20	Poor exits and unprotected vertical openings	9
11/5/1978	Hotel	Honesdale, PA	12	Incendiary origin; fire safety violations had been under correction	9
11/5/1978	Department Store	Des Moines, IA	10	*	9
11/26/1978	Hotel	Greece, NY	10	Combustible interior finish in exits; unprotected openings in stairway	9
12/7/78	Tenement	Newark, NJ	12	Open stairway; 100 yr 3-story wood frame bldg.	9
12/29/78	Institute for the Mentally Retarded	Ellisville, MI	15	Fire-resistive bldg; smoke spread on floor	9
1/20/1979	Apartment	Hoboken, N.J.	21	Fire set by children; open stairwell	10
4/1/1979	Boarding facility	Connellsville, PA	10	Improper interior finish	10
4/2/1979	Boarding facility	Farmington, MO	25	*	10

Date	Occupancy	Location	Deaths	Notes	Ref.
4/11/1979	Boarding facility	Washington, DC	10	Open stairways; single exit	10
7/31/1979	Hotel	Cambridge, OH	10	Improper interior finish; open stairs	10
11/11/1979	Boarding facility	Pioneer, OH	14	Child playing with lighter; open stairs; no compartmentation; improper interior finish	10
12/27/1979	Jail	Lancaster, SC	11	*	10
7/26/1980	Brinley Inn	Bradley Beach, NJ	24	Institutional occupants; unprotected openings; no 2nd exit	30
11/21/80	MGM Grand Hotel	Las Vegas, NV	84	Smoke spread through vertical shafts; improper interior finish	11
12/4/80	Stouffer's Inn	Harrison, NY	26	Hotel meeting room; no automatic protection	3

APPENDIX A

CAUSES OF FIRES AND DOLLAR LOSS

Year	Heating & Cooling		Electrical		Smoking & Matches		Children & Matches		Incendiary/Suspicious		Total Building Loss	
	#	$	#	$	#	$	#	$	#	$	#	$
1950	91,300	90,300,000	73,800	84,500,000	93,000	55,000,000	20,200	6,900,000	5,600	15,100,000	600,000	699,600,000
	(15.2%)	(12.9%)	(12.3%)	(12.0%)	(15.5%)	(7.9%)	(3.3%)	(1.0%)	(1.0%)	(2.2%)		
1955	171,900	148,250,000	99,900	100,900,000	122,000	66,700,000	29,900	13,120,000	9,600	27,100,000	811,800	943,551,000
	(21.1%)	(15.7%)	(12.3%)	(10.7%)	(15.0%)	(7.1%)	(3.7%)	(1.4%)	(1.2%)	(2.9%)		
1960	209,300	163,600,000	129,900	187,000,000	141,100	69,500,000	38,600	26,800,000	23,900	30,900,000	890,200	1,139,700,000
	(23.5%)	(14.4%)	(14.6%)	(16.4%)	(15.9%)	(6.1%)	(4.3%)	(2.4%)	(2.7%)	(2.7%)		
1965	153,600	126,000,000	149,000	214,200,000	163,900	80,400,000	58,400	38,600,000	33,900	74,000,000	921,700	1,455,900,000
	(16.7%)	(8.7%)	(16.2%)	(14.7%)	(17.8%)	(5.5%)	(6.3%)	(2.7%)	(3.7%)	(5.1%)		
1970	142,900	168,000,000	145,700	264,400,000	107,200	95,900,000	63,800	70,400,000	65,300	206,400,000	992,000	2,209,200,000
	(14.4%)	(7.6%)	(14.7%)	(12.0%)	(10.9%)	(4.3%)	(6.4%)	(3.2%)	(6.6%)	(9.3%)		
1975	165,600	222,800,000	150,500	358,100,000	137,800	166,800,000	64,200	116,900,000	144,100	633,900,000	1,264,400	3,436,600,000
	(13.1%	(6.5%)	(11.9%)	(10.4%)	(10.9%)	(4.9%)	(5.1%)	(3.4%)	(11.4%)	(18.4%)		

Note: Number in parenthesis is percentage of total.

Source: National Fire Protection Association, "Fires and Fire Losses Classified" from years shown.

TABLE 9

APPENDIX A

MAJOR CONFLAGRATIONS

Date	Location	Buildings Involved	Area Involved	$ Loss	Deaths	Notes	Ref.
1676	Jamestown, VA	*	City Burned to Ground	*	*	*	1
3/21/1788	New Orleans, LA	856	*	3,000,000	Scores	*	1
12/16/1835	New York, NY	654	13 Acres	20,000,000	*	*	1
4/27/1838	Charleston, S.C.	*	City Gutted	millions	4	*	1
10/4/1839	Philadelphia, PA	52	*	*	*	*	1
4/10/1845	Pittsburgh, PA	1100	*	10,000,000	2	*	1
6/20/1845	New York, NY	1300	*	6,000,000	6	*	1
12/16/1845	New York, NY	*	Same District as 1835	*	*	*	1
7/13/1846	Nantucket, MA	300	*	*	*	*	1
8/17/1848	Albany, NY	300	*	3,000,000	*	25 Steamboats also destroyed	1
9/9/1848	Brooklyn, NY	300	*	*	*	*	1
5/17/1849	St. Louis, MO	425	15 City Blocks	4,000,000	*	25 Steamboats also Destroyed	1, 2
2/9/1850	Philadelphia, PA	400	*	Over 1,000,000	39	Slum District	1
9/15/1850	San Francisco, CA	1500	*	4,000,000	*	3rd and Most Destructive Fire in 3 Yrs.	1
3/12/1851	Nevada, CA	200	*	1,500,000	*	*	1

TABLE 10

Date	Location	Buildings Involved	Area Involved	$ Loss	Deaths	Notes	Ref.
5/31/1851	San Francisco, CA	2500	70% of City	3,500,000	30	*	1
5/14/1851	Stockton, CA	*	*	1,500,000	*	*	1
8/24/1851	Concord, NH	*	Downtown Business District Destroyed	*	*	*	1
7/30/1854	Jersey City, NJ	30	Homes and Factories	*	*	*	1
8/25/1854	Milwaukee, WI	*	Most of City Destroyed	*	*	*	1
8/25/1854	Troy, NY	100	Houses and Factories	*	*	*	1
11/8/1856	Syracuse, NY	100	*	Over 1,000,000	*	*	1
1861	Charleston, SC	*	*	10,000,000	*	*	2
2/8/1865	Philadelphia, PA	50	3 Sq. Blocks	Over 500,000	20	*	1
7/4/1866	Portland, ME	1500	200 Acres	10,000,000	*	*	1, 2
10/8/1871	Chicago, IL	18,000	*	200,000,000	250-300	"Great Fire" Set by Mrs. O'Leary's Cow; 90,000 Left Homeless	1
11/9/1872	Boston, MA	930	*	75,000,000	12	*	1
1874	Chicago, IL	*	*	5,000,000	*	*	1

Date	Location	Buildings Involved	Area Involved	$ Loss	Deaths	Notes	Ref.
6/6/1889	Seattle, WA	*	64 Acres	15,000,000	*	*	1
8/4/1889	Spokane, WA	*	Entire Business District	10,000,000	2	*	1
1889	Boston, MA	52	*	3,600,000	4	*	2
1889	Lynn, MA	*	*	5,000,000	*	*	2
6/4/1892	Oil City, PA	*	*	*	130	Fire & Floods Created "Human Hell"	1
1892	Milwaukee, WI	*	*	6,000,000	*	*	2
1900	Hoboken, NJ	*	*	4,600,000	326	Piers and Steamships	2
5/3/1901	Jacksonville, FL	1700	*	10,000,000	*	Fire at City	1, 2
1902	Paterson, NJ	525	*	5,500,000	*	*	2
10/16/1903	Aberdeen, WA	140	*	millions	4	*	1
2/7/1904	Baltimore, MD	*	75 City Blocks	85,000,000	1	*	1
4/18/1906	San Francisco, CA	28,000	75% of City,	350,000,000	700	*	1, 2
4/12/1908	Chelsea, MA	3500	City Destroyed	12,000,000	12	*	1, 2
1911	Bangor, ME	267	*	3,200,000	2	*	2
6/25/1914	Salem, MA	*	Fire Destroyed City	12,000,000	*	*	1
3/21/1916	Paris, TX	1500	*	14,000,000	*	*	1
6/15/1922	Arverne, NY	141	*	2,000,000	*	*	24
9/17/1923	Berkeley, CA	600	*	10,000,000	24	Wood Shingle Roofs	1

Date	Location	Involved	Involved	$ Loss	Deaths	Notes	Ref.
6/24/1927	Montgomery, AL	22	2 city blocks	1,500,000	*	*	19
7/21/1929	Mill Valley, CA	130 homes	*	over 1,000,000	*	Forest & Brush Fire	26
6/7/1931	Norfolk, VA	60	*	1,250,000	*	5 Piers and Wholesale Business District	22
7/13/1932	Coney Island, NY	*	3-4 Blocks	3-5 million	*	*	23
5/7/1933	Ellsworth, ME	127	1/4 sq. mile	1,350,000	0	Wood Shingle Roofs	26
5/15/1933	Auburn, ME	250	1/2 mile X 600 ft	1-1/2 - 2 million	0	*	26
9/26/1936	Bandor, OR	*	Town Destroyed	1,250,000	11	Controlled burning spread 7 miles to town; wood roofs; 1800 homeless	2, 28
7/30/1940	Camden, NJ	*	*	2,000,000	10	Fire after explosion at mfg plant	32
4/21/1941	Marshfield, MA	450	6000 ft X 1000 ft	1,000,000	0	Marsh grass fire ignited wooden roofs	33
11/6/1971	Los Angeles, CA	505	*	30,000,000	*	Wood shingle roofs, hot dry winds	2
10/14/73	Chelsea, MA	300	Many Blocks	2,000,000	0	Same conditions as before 1908 fire	4

APPENDIX A

SELECTED MAJOR FIRES AND CODE CHANGES

Date	Occupancy	Resultant Code Change or Lesson
12/30/1903	Iroquois Theater Chicago, IL	Roof vents and automatic sprinklers over theatrical stages
11/28/1942	Cocoanut Grove Night Club Boston, MA	Panic hardware, interior finish
7/6/1944	Ringling Brothers Circus Hartford, CN	Fire retardant canvas circus tents
12/24/1945	Niles Street Hospital Hartford, CN	Linoleum tile on walls
3/31/1954	Cleveland Hill School Cheektowaga, NY	Combustible fiberboard tile
1/29/1956	Arundel Park (Social Hall) Brooklyn, MD	Combustible fiberboard tile
12/1/1958	Our Lady of Angels School Chicago, IL	Transoms
12/29/1963	Roosevelt Hotel Jacksonville, FL	Fire through pipe vent shafts
1970	919 3rd Avenue 1 New York Plaza	General Services Administration High-rise Conference; high-rise code package

Source: Personal conversation with John G. Degenkolb, March 1981

TABLE 11

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