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

BUILDING REGULATIONS
AND
EXISTING BUILDINGS

EVOLUTION OF BUILDING REGULATIONS IN THE UNITED STATES

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 Existing Buildings and Building Regulations and Problems with Existing Building Regulatory Techniques.

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A. TYPES OF BUILDING REGULATIONS - GENERAL DISCUSSION

(1) PLANNING

City planning regulations, which control aspects of environmental design at the city and neighborhood scales, are not usually thought of as building regulations. Normally they would be excluded from a discussion of how building regulations have evolved.

However, in three distinct areas, planning regulations directly interface with building regulations. The two types of regulations address either the same aspects of building or aspects of city infrastructure which may influence building regulation.

In the former category are zoning ordinances. In general, they have been used to regulate two aspects of city planning:

- land use (including the designation of "fire limits", and more recently, historic districts).
- building density, including building height; area; and yard, alley and street dimensions.

Both aspects are also addressed in building codes. Regarding land use, "fire limits" have been used in building codes to limit certain types of construction and, indirectly, building height and area as a function of building density, age, and materials. Building height and area, as they relate to fire safety, are also regulated. Yard, alley and street dimensions are addressed in terms of the natural light and ventilation they allow through windows. In regard to yards and courts, building codes, and especially model building codes, often permit the zoning ordinance to potentially override the building code requirements.

The first comprehensive zoning ordinance in the United States was adopted in New York in 1916. It included specifications for building density, found previously in the tenement laws.

Certain design standards for public works may also relate to the regulation of buildings. Examples are standards governing the location and details of fire hydrants and their supply network, and those governing the steepness of roads. Each of these standards is often considered by building regulators in determining fire safety, when the building code allows for subjective judgment. (In response to firefighting needs, New York City in 1842 installed a pressurized water distribution system. The provision of a safe and sanitary water supply for buildings followed).[1]

Both zoning ordinances and public works design practices are adopted and implemented by local governments.

(2) BUILDING CONSTRUCTION

Tenement laws were used from the 1860s by states or local governments. They regulated both new construction and the use of existing residential buildings. The laws as originally developed in New York State covered only sanitation (ventilation, light, drainage, plumbing), but eventually were expanded to include fire safety. By the late 1920s, multiple dwelling laws were introduced to replace tenement laws.

Construction codes are generally called "building codes", although the building code (regulating structural, fire, accident, and health safety), is merely one component. A construction code also includes an electrical code, plumbing code, mechanical code, and a variety of specialty codes controlling such elements as boilers and elevators. To accomplish their objectives of safety, health, welfare, and property protection, the codes regulate design, construction, repairs, use, maintenance, moving, and demolition of buildings or portions thereof.

In general, these codes contain three types of technical requirements:

- design requirements and criteria for building elements and systems for various occupancies,
- specifications for construction materials, and
- construction details.

The codes make frequent reference to separately published standards. These standards may cover materials, assemblies, design methods, and test methods. The codes, and their referenced standards, often require products to be labeled by certified laboratories. Some codes, especially "specialty" codes (e.g., boiler, elevator), are in fact specific standards that have been adopted by statute.

The codes also contain administrative provisions for code enforcement, as well as licensing requirements for contractors and construction trades. Construction codes may be adopted at the state or local level, depending upon state law. The various codes (building, electrical, plumbing, etc.) may be enforced by one agency or several. These varying arrangements may significantly affect building regulation. The enforcement of construction codes is usually triggered by an application for a permit (e.g., building, electrical, plumbing) to construct.

Construction codes are updated periodically. The model codes, which are adopted by many jurisdictions, are updated and republished every few years, with amendments published periodically between each new edition. The updating of codes involves five types of code modifications:

- elimination of references to materials and methods of construction no longer used in modern construction (i.e., "archaic" materials and methods);
- addition of references to new materials and methods of construction;
- change in criteria for meeting existing requirements;
- addition of new requirements; and
- modification of administrative provisions.

The adoption of construction codes is most common in larger towns and cities. A 1968 survey[2] revealed that of the almost 18,000 local governments sampled, only 46.6% had building codes. However, among the approximately 4,000 cities or towns with a population of over 5,000, this figure rose to over 80%.

(3) BUILDING MAINTENANCE AND USE

As discussed earlier, the tenement laws regulated both building construction and building maintenance. Later, a variety of other codes regulated the maintenance and use of existing buildings.

Housing codes traditionally have been used to establish minimum levels of safety, health, and sanitation in existing residential buildings, and to provide a means for eliminating substandard housing. More recently, property maintenance codes have expanded the coverage of housing codes to other types of buildings, but these codes are not in common use.

Fire prevention codes also are a form of building maintenance code. They are intended to control fire hazards in buildings of various occupancies through proper operation and maintenance procedures, and to assure the proper functioning of a building's fire safety features such as exits, standpipes, fire alarms, and automatic sprinklers.

Various health codes control cleanliness and sanitation in food handling and preparation areas in hotels, restaurants, and places of public assembly.

Housing, fire prevention, and health codes are adopted by either the state or local government. They are often administered and enforced by an agency other than that charged with enforcing the building code. Code enforcement is usually triggered by citizen complaints and by routine inspections (the latter often concentrating on selected occupancies or selected neighborhoods). In some communities, code enforcement may be triggered by periodic license or permit requirements such as a business license or fire marshal's permit. In many communities, a significant number of buildings probably do not comply with housing and/or fire prevention codes because limited resources make routine inspection of all buildings impossible.

The widespread adoption of housing codes is relatively recent. A 1956 study revealed that fewer than 100 large cities had housing codes, while a 1968 survey of nearly 18,000 local governments of all sizes showed that only 4,904 had a housing code.[3]

Hazard abatement codes provide another basis for measuring or evaluating the condition of an existing building. These codes carefully provide for due process of law to ensure that an enforcing body acts legally when it deems a building to be dangerous and requires its repair, evacuation, or demolition.

Hazard abatement codes include easily implemented provisions for structural analysis and set specific limits for material stresses. On the other hand, the fire, accident, and health requirements generally refer back to the code under which the building was built, and, in general performance language, state how the required building safety elements are to be operated and maintained.

Hazard abatement codes traditionally have been used to secure the demolition of buildings. Their enforcement usually results from complaints, inspections, or other actions that bring the potential hazard to the attention of the authorities.

Finally, many specialty construction codes, such as those for boilers and elevators, include provisions for the maintenance and routine inspection of the items they cover.

(4) RETROACTIVE REGULATIONS

In some cases, states or local governments have declared certain building features to be unsafe or otherwise undesirable, such as unenclosed stairs or unreinforced masonry walls, and have required that all buildings of a certain occupancy or class be altered to remove the unsafe or undesirable condition. In other cases, governments have required the installation of a specific feature that contributes to a building's safety, such as smoke detectors. All existing buildings covered by such retroactive regulations are required to be modified to conform.

Retroactive regulations generally contain enforcement provisions, often carried out through special inspections to insure compliance. However, enforcement often is constrained by lack of available resources, in which case the community may establish an enforcement schedule based on neighborhood location, type of building, or other factors.

B. ORGANIZATIONS DEVELOPING OR PROMULGATING CODES—HISTORIC DEVELOPMENT

(1) ORGANIZATIONS RELATED TO FIRE SAFETY

The early settlers brought with them the fire problems of the Old World, such as thatched roofs and wooden chimneys, and the Old World laws prohibiting their use. Regulation, though, lagged behind growth. Fire losses mounted as cities became congested and their industrial base grew in scale and sophistication. By 1860, there had been major fires in large cities from coast to coast.

Without a national government, fire safety regulation was of necessity a local responsibility in Colonial America. Though the nation matured politically, fire safety regulation did not. In 1860, almost 250 years after Pilgrim leaders had banned thatched roofs, the states still had no meaningful role in fire safety. As civil war loomed, the attention of the Federal government was on the future of the Union. Fire safety regulation remained the responsibility of local government.

A power vacuum existed because fire, a national problem, received only local attention. This vacuum was filled in 1866 by the stock insurance industry with the creation of the National Board of Fire Underwriters, beginning our present system of fire safety regulation. The National Board, as it became known, provided the stock insurance industry with engineering and underwriting expertise. Soon, fire safety became a factor in the availability and cost of insurance.[4]

Ironically, a refusal by the stock insurance companies to give insurance premium discounts for superior fire protection led to the formation in 1835 of the Manufacturers Mutual Fire Insurance Company. A mutual insurance company is owned by its policyholders, who share in profits but also must share the burden of any net losses. The founders of Manufacturers Mutual, New England textile mill owners, admitted into their mutual insurance society only those who would meet rigorous fire safety standards and submit to periodic inspection. Over time, the company grew into the Factory Mutual System (FM), and their concept of protection became known as HPR—Highly Protected Risk.[5] The Factory Insurance Association, organized in 1890 and now known as Industrial Risk Insurers (IRI), is another follower of HPR fire protection.[6]

The insurance carrier thus became the primary fire safety regulator. As their names imply, "factory" and "industrial", this class of companies insures mostly large commercial, manufacturing, and heavy industrial properties. They are a dominant force in the properties they insure, and their influence is widespread. Today, FM and IRI have insurance in force in excess of one trillion dollars.

The strength of the mutual insurance companies went beyond promoting the fire safety practices of the day. Their engineering staffs also undertook basic and applied research, product evaluation, and standards development. This technical support permitted fire protection to keep pace with changing industrial processes and products.

Meanwhile, the attention of the National Board focused on the cities and the smaller, less industrialized businesses. In 1872, after major fires in Chicago and Boston, a special committee was formed by the National Board to study conflagrations and existing fire safety laws and regulations. This work resulted in the publication in 1905 of the National Building Code, the first "model" building code. The final push toward its publication came after the Baltimore fire of 1904.[4] Unlike building codes of today, the National Code regulated existing structures as well as all new construction.

The National Fire Protection Association (NFPA) was founded in 1896 by the same stock insurance interests. Standards development was then and still is NFPA's primary function, though now it is also involved in other fire safety areas such as public education and data collection. The fundamental difference between a code and a standard is that a code dictates what must be done while a standard spells out how to do it. For example, the building code may require automatic sprinklers installed in accordance with a "nationally recognized standard". Most often, this "nationally recognized standard" is NFPA 13, "Standard for the Installation of Sprinkler Systems". NFPA currently publishes over 200 standards, addressing varied topics from fire engines to fire protection for nuclear reactors.

NFPA 101, the Life Safety Code, warrants special attention. Work began on it in 1913 with the formation of the Committee on Safety to Life. The impetus for this Committee likely may have been the Triangle Shirtwaist Factory fire in March, 1911, where locked exits trapped 145 people, mostly young women, after fire involved the 8th, 9th, and 10th floors of a New York City factory building. Originally, standards or pamphlets were adopted for particular exit components or particular occupancies, such as, "Outside Stairs for Fire Exits" (1916) and "Safeguarding Factory Workers from Fire" (1918). The Committee eventually adopted a broader view of exiting problems from all occupancies, and in 1927 published the more comprehensive Building Exits Code. The Safety to Life Committee was restructured in 1963, and in 1966, the name of the code was changed to the "Code for Life Safety from Fire in Buildings and Structures".

The Life Safety Code is really part standard and part building code. This has led to conflicts in some jurisdictions because construction requirements in the Life Safety Code are not always consistent with local building code requirements. The Life Safety Code is important because its requirements for means of egress have traditionally been adopted by the other model code organizations. The Federal government also enhanced the status of this document when in the 1970s Congress mandated that nursing homes and hospitals had to comply with the Life Safety Code as a condition for reimbursement under the Medicare/Medicaid program. With literally billions of dollars of Federal money at stake, the health care sections of the Life Safety Code are often among the most widely debated.

The National Board of Fire Underwriters had two other primary accomplishments: sponsorship of the Underwriters Laboratories and the development of the Municipal Grading Schedule.

The Underwriters Laboratories is known by the famous "UL" label on everything from clock radios to fire pumps. UL began in 1893 when the Chicago Board of Fire Underwriters summoned an electrical investigator named William Henry Merrill from Boston to end a troublesome rash of electrical fires that plagued the nation's first grand display of electrical power, the Palace of Electricity at the Chicago Columbian Exposition of 1893. From his work at the Exposition, Merrill recognized the need for stringent product standards to deal with the fire and shock hazards from unsafe and untested electrical products.

Merrill developed standards and tested various products, "approving" those that complied. But a problem soon surfaced that began an entirely new element of fire safety regulation: quality control. Products being sold on the open market were not meeting the quality of samples tested in the laboratory. Continued product quality was essential if the original "approval" was to have any credibility. The solution adopted was unannounced in-factory inspections. A manufacturer who did not agree to inspection could not promote a product as having been approved. This practice continues today and has been adopted by other organizations providing a similar service.

With his aproval procedure refined, Merrill and two helpers formed the Underwriters' Electrical Bureau. Originally, the Bureau planned to serve only member insurance companies of the Western Union, a midwestern fire underwriters' association. But word of the Bureau soon reached the National Board and a long-time sponsorship began. The name was changed at that time to the Electrical Bureau of the National Board of Fire Underwriters. In 1901, the company was incorporated as Underwriters Laboratories, Inc.

UL moved very quickly into more traditional fire safety products. By 1903, a furnace had been constructed to test fire doors and windows, and another device was created to test the performance of various roofing materials exposed to fire. In later years, with the adoption of other fire test methods, UL expanded its role in the fire rating of building materials and assemblies.[7]

The final role of the National Board involved the evaluation and grading of municipal fire defenses. Work first began in 1889 and the first edition of the Municipal Grading Schedule was published in 1916. National Board inspectors surveyed all towns with a population over 25,000. (Smaller communities were inspected by individual State insurance rating bureaus.) Included in the survey were water supply; fire department apparatus, manpower, and procedures; fire alarm systems; and building regulation and the physical built environment. Greatest attention, and the most stringent requirements, were focused on the major commercial areas—known as CBDs (central business districts) or HVDs (high value districts)—areas most prone to conflagration.

Intended or not, the Municipal Grading Schedule became the design guide for municipal fire protection in the 1900s. Fire departments and water systems were designed with an eye toward the community's "grade": an improved score meant lower insurance premiums. The Grading Schedule was used to justify budgets and support requests for new equipment, though no attempt was made to determine whether these increased outlays could ever be recovered through decreased fire losses or reduced insurance premiums.

This local abuse of grading surveys and a realization that insurance industry goals and community goals are not necessarily the same, has led to a decrease in the importance of the Grading Schedule in recent years. This trend, supported by the insurance industry, will likely continue as new and better planning techniques are developed. But the primary goal of the Grading Schedule was realized: a general upgrading of municipal fire suppression capabilities and the elimination of major conflagrations in cities.

This lessened presence of the insurance industry is part of a general trend. The industry intervened when a needed service was lacking. Once that need was satisfied or no longer needed, the service ended.

The National Building Code was developed when there was not any recognized model building code. With the three model code groups long established, the American Insurance Association (the National Board of Fire Underwriters merged with the American Insurance Association in 1965) discontinued servicing of the National Building Code, and in 1980 transferred all rights to it to the National Conference of States on Building Codes and Standards.

The NFPA was created when there was a need for fire safety standards. The National Board used to distribute NFPA standards free of charge. But with the NFPA firmly established and able to promote its own standards, the practice was ended in 1964 as the National Board prepared to merge with the American Insurance Association (AIA).

The Underwriters Laboratories was formed when there was no organization to undertake product testing.

As the importance of municipal surveys decreased, responsibility for municipal surveys of cities over 25,000 population, retained by the AIA in the 1965 merger with the National Board, was transferred in 1970 to the Insurance Services Office (ISO). De-emphasis of the Grading Schedule by ISO continues today.

The only area where major insurance industry involvement has remained, and in fact grown, has been in the area of highly protected risks (HPR). No other system or organization has evolved that can economically provide the intensive engineering support necessary to protect these risks. It would be wasteful for individual local governments to attempt to do so. This system has proven effective and responsive since Zachariah Allen began the Factory Mutual System in 1835. A recent but increasingly popular refinement of this approach is captive insurance companies, which are formed by industries or companies with similar and highly specialized problems. These "captives" provide cheaper insurance and the highly specialized engineering expertise necessary to minimize losses.

The last major organization in the present fire safety regulatory system is the American Society for Testing and Materials (ASTM). Though founded in 1898, ASTM has only recently established its position, and its E-5 Committee on Fire Standards is now regarded as the final authority on fire standards used in the testing and evaluation of materials, products, and building assemblies. Two standards, processed though not developed by ASTM, have especially changed fire safety regulation.

ASTM E-119, first adopted in 1918, provided a standard test for fire endurance. It allowed code writers to specify a level of performance, such as a 3-hour fire wall, without specifying the exact materials or method that had to be used. Any product tested according to the standard test method that satisfied code requirements could be used. The benefit to designers and material producers was that a code change was no longer necessary before a new product could be used.

The second standard, ASTM E-84, provided a method for regulating the surface flame spread properties of interior finish materials. Early codes recognized the problem of hazardous interior finish materials, but could only proceed on a material by material basis. With the first adoption of the E-84 test method in 1950, code writers quickly enacted interior finish requirements. The impetus for the control of combustible interior finish was the Cocoanut Grove Night Club fire in 1942 which claimed 491 lives.

Conclusion

Fire safety regulation began as and largely remains a function of local government. But to a large extent, the development of the codes, standards, and test methods and the evaluation of materials and products has been shifted to national or regional organizations. There is a fine balance of power and a carefully guarded division of responsibility between the various organizations. The process is as much political as technical. Perhaps reflective of our American system of government, the entire process is known as "voluntary consensus".

Overall, the original goals of the National Board have been met. Conflagrations no longer plague our cities and industry is generally well served. There are many organizations besides those mentioned: UL is not the only product certifier; FM and IRI are not the only HPR insurers. This report presented only a brief history of the process through which codes set requirements, standards specify details of construction, test methods provide methods to measure performance, and materials and products are tested to insure compliance.

(2) ORGANIZATIONS INVOLVED IN THE NATIONAL ELECTRICAL CODE

The need for a national code for electric wiring in buildings became apparent to the electrical industry shortly before the turn of the nineteenth century because numerous insurance companies had developed their own rules, and installers were plagued by their many differences. It was thus agreed to develop a national code through a conference which would provide participation from the various segments of the electrical industry. This decision appears to have been based on the belief that a higher degree of voluntary acceptance could be achieved through a national code developed through those involved in its use. This appeared to be in the best interest of all participating groups and was preferable to having the insurance companies adjust their rates individually to compensate for noncompliance.

Thus, the National Electrical Code (NEC) was originated in 1897 by the National Conference on Standards Electrical Rules, and this group was responsible for and continued to revise the Code until 1911. The group consisted of representatives from the following organizations:

- American Institute of Architects
- American Institute of Electrical Engineers
- American Society of Mechanical Engineers
- American Society of Mining Engineers
- American Street Railway Association
- Associated Factory Mutual Fire Insurance Companies
- National Association of Fire Engineers
- National Board of Fire Underwriters
- National Electric Light Association
- National Electrical Contractors Association
- Underwriters National Electric Association

Seven additional organizations participated during the next five editions of the Code, but in 1910, the National Conference was dissolved and the National Fire Protection Association became sponsor. The participating organizations were reduced to the following:

- American Electric Railway Association
- American Institute of Electrical Engineers
- Associated Factory Mutual Fire Insurance Company
- National Board of Fire Underwriters
- National Electric Light Association
- National Electrical Contractors Association
- National Electrical Inspectors Association

Over the next few years, though, additional organizations were added until the 1925 edition of the Code, which was produced under the procedure of the American Standards Association, had 33 organizations participating. This and subsequent editions of the NEC were recognized as American Standards.

With the 1947 edition of the Code, the Sectional Committee producing Code changes consisted of 50 voting members, but a number of organizations had seven voting representatives and the processing of Code changes had become somewhat political with behind-the-scenes vote trading to accomplish individual objectives.

To change this situation, the Chairman of the Sectional Committee (at that time Alvah Small, President of Underwriters Laboratories, Inc.) proposed assigning separate Code-Making Panels, assisted by technical subcommittees, to review technical material and to determine whether a consensus existed in the Panel on proposals to revise the Code. This procedure was used to process the 1951 NEC and subsequent editions until 1978, which edition had 23 Code-Making Panels and 51 participating organizations.

The front part of the National Electrical Code contains a listing of the various Panels, their assigned Articles, and their membership. Each member is classified as to the type of organization represented, and no classification can have representation exceeding one-third of the total number of members on that Panel. The intent is that member organizations be national in scope and that the Panel size be limited to a workable level.

The electric utility companies are represented through the Electric Light and Power Group; inspectors through the International Association of Electrical Inspectors; contractors through the National Electrical Contractors Association; manufacturers through the National Electrical Manufacturers Association; electricians through the International Brotherhood of Electrical Workers; Federal Government through the National Bureau of Standards, the Rural Electrification Administration, and the Veterans Administration; telephone companies through the Telephone Group, etc., with representation consisting of over 50 organizations including the Institute of Electrical and Electronics Engineers. Each Panel has specific responsibility for a portion or Article of the NEC and all revisions thereto. For the code to be changed, there must be sufficient agreement among the Panel members so that a consensus is established.

Subsequent to the 1978 edition, the procedure for processing national standards was changed when the American Standards Association became the American National Standards Institute. The procedures of the National Electrical Code had to be revised accordingly. In the process, the Board of Directors of the National Fire Protection Association decided that all their sponsored standards should use the same procedure, and a new one was developed.

The general structure of existing NEC committees was not changed. But additional procedural safeguards were added to insure that all proposals would be processed in a manner whereby the public would be advised of each step taken, to allow reconsideration of actions in a public meeting, and to provide for appeal where those affected by the NEC could further argue their case.

Under the present procedure, anyone can make a proposal to revise the NEC, and each such proposal is published in a document that also indicates the preliminary action taken by the Panel. After this document is reviewed by the public, including those who submitted proposals to revise the NEC, the appropriate Panel reviews all public comments and takes action, which is again reported in a public document. Because of the large number of proposals submitted on the NEC and the need for correlation between related requirements, the complete proposed revised text of the NEC is also made available to the public prior to its presentation for adoption at an annual meeting of the National Fire Protection Association.

Proposals referred back to the Committee by an action taken at the annual meeting are not included in the adopted text, but remain on the docket of the assigned Panel. Proposals modified on the floor of the meeting are subject to ratification by the Panel and the Correlating Committee, and are subject to review by the Standards Council and the Board of Directors of the NFPA.

(3) ORGANIZATIONS ACTIVE IN THE HOUSING AREA

(a) The National Housing Association

During the 1890s Lawrence Veiller surveyed the largest American cities to stimulate interest in their housing conditions. In 1890, only New York City, Buffalo, Boston, Philadelphia, and Washington were conscious of bad housing conditions; by 1900, about 20 cities had initiated movements for improving them.

The National Housing Association (NHA) was formed in 1900 as a private citizens' organization to press the need for housing reform. As such, and not operating within the local governing structure, the NHA was concerned mainly with urging the establishment and enforcement of housing codes and with making improvements in the existing housing supply under private ownership.[8] The NHA sought:

- to improve housing conditions, both urban and suburban, in every practicable way;
- to encourage the formation of Improved Housing Associations in cities where they did not exist; and
- to aid in the enactment and enforcement of laws that would (a) prevent the erection of unfit types of dwellings, (b) encourage the erection of proper ones, (c) secure their proper maintenance and management, (d) bring about a reasonable and practicable improvement of buildings, (e) secure reasonable, scientific, and economic building laws.

Nineteen cities were represented on the initial board of directors of the NHA. It is interesting to note the local organizations and individuals in these cities that gave impetus to housing reform:

Baltimore	Housing Committee of the Baltimore Associated Charities
Boston	Improved Dwellings Association of Boston
Buffalo	Buffalo Charity Organization Society
Chicago	City Homes Association
Cincinnati	Associated Charities
Cleveland	Chamber of Commerce housing committee
Elizabeth (N.J.)	State Tenement House Board
Evansville (Ind.)	Individual efforts
Hartford	Charity Organization Society
Los Angeles	An official housing commission (1896)
Louisville	Women's clubs
New Orleans	Kingsley House
New Haven	Individual initiative
New York	Tenement House Committee of the Charity Organization Society; Improved Dwelling Association of Brooklyn

Philadelphia	Octavia Hill Association
Pittsburgh	Women's clubs; Chamber of Commerce; Civic Commission
Providence	General
St. Louis	Civic League
Washington, D.C.	Washington Sanitary Improvement Company

The NHA held an annual national Housing Conference, the proceedings of which were published as "Housing Problems in America" and summarized then current thought on the subject. NHA also published monographs and a quarterly journal, Housing, edited by Lawrence Veiller, which reported on housing movements around the world.

Many of the leading social reformers of the day were on the NHA Board of Directors or were otherwise contributing to its goals and efforts. Perhaps best remembered are Jane Addams from Chicago and Jacob A. Riis from New York City. The real backbone of the organization, however, was its founding secretary, Lawrence Veiller, a New Yorker who prepared extensive, detailed, statistical and often illustrated studies on housing conditions and housing regulations from the 1850s to the early 1900s. He wrote and published many treatises on the evils of tenement housing as well as "A Model Tenement House Law" (1910), "A Model House Law" (1914) and a 1920 revision. As late as 1930, one of Veiller's monographs was titled "The Housing Problem in the United States", which covered inadequacies, chief defects, and high financing costs of housing.

(b) American Public Health Association

The American Public Health Association (APHA) is usually credited with development of the prototype for modern housing codes.

In 1939 the Committee on Physical Standards and Construction of the National Association of Housing Officials (NAHO) in collaboration with the Commitee on the Hygiene of Housing of the APHA published Practical Standards for Modern Housing, standards for the design and construction of low-rent housing intended for lay members of local housing authorities.

NAHO approached the housing problem by outlining physical means of obtaining "healthful living" conditions, leaving exact methods to local bodies and agencies to develop. Included were site selection and development, dwelling plan and equipment, and design of structure. APHA was concerned specifically with basic human needs within shelters, and its detailed report was directed to physiological and psychological needs, protection against disease and accidents in housing.

APHA's report was attached to NAHO's Standards as an appendix and was referenced often for details.

During the 1940s the Committee on the Hygiene of Housing further developed standards for healthful housing, and in 1952 the Committee published A Proposed Housing Ordinance, a prototypical guide upon which to base a formal code having the force of law. The intent was to eliminate serious health hazards associated with substandard dwellings.[9]

Two important points were stressed in A Proposed Housing Ordinance: (1) the ordinance was meant to be modified to suit local conditions, and (2) enforcement of the ordinance would be the responsibility of local health officers, but would not infringe on any powers and duties of building or fire departments.

Revisions of the A Proposed Housing Ordinance in 1969 and 1971 were released under the joint sponsorhship of the APHA and the United States Public Health Service (PHS), titled The APHA-PHS Recommended Housing Maintenance and Occupancy Ordinance.

The latest revision of this recommended ordinance was published in 1975, a collaborative effort of the Center for Disease Control of HEW (now Health and Human Services) and APHA, under the title APHA-CDC Recommended Housing Maintenance and Occupancy Ordinance.

> "Many of the modifications and additions found in the present version of the APHA-CDC Recommended Housing Maintenance and Occupancy Ordinance are, in reality, more stringent requirements for housing than those in the previous editions. However, they are not as restrictive as renewal standards and should not be confused with such standards. The provisions of this recommended legislation are intended to establish safeguards for the health, safety, and well-being of the occupants of the dwelling and persons residing in the vicinity of the dwelling. No attempt has been made to include requirements that are solely for the benefit of upgrading the economic value or improving the aesthetic quality of housing. These advantages may be attained coincidentally with the raising of the quality of dwelling as pertains to health, safety, and decency."[10]

APHA was also a participant in the development of model plumbing codes, as discussed later in this report.

(4) MODEL CODE ORGANIZATIONS

Almost as soon as there were building code enforcement officials, they established professional organizations to provide bases for communication throughout the various cities, to help solve mutual problems, and to provide educational opportunities for building department staffs. The International Society of State and Municipal Building Commissioners and Inspectors was the first such organization, established at the turn of the century. Later organizations included the Building Officials Conference of America (BOCA, 1915), the Pacific Coast Conference of Building Officials (1922), the New England Conference of Building Officials (1937), and the Southern Building Code Congress (1940).

In 1913, F. W. Fitzpatrick, executive officer of the International Society of State and Municipal Building Commissioners and Inspectors, authored a Model Building Code, which was published by the American School of Correspondence in Chicago. The code emphasized fire protection, and included structural provisions. It was not adopted by jurisdictions with members in the society, which used locally written and prepared ordinances (codes).

Except for this 1913 code, none of the professional organizations was involved in preparation of model codes.

Subsequently, a need for more uniform codes and code enforcement methods developed, partly as a result of efforts of the National Bureau of Standards to develop recommended organization and content for building codes. Further encouragement to develop model codes came from industry, which desired uniformity for product distribution and sales, and performance based codes to permit technological innovation. This provided the impetus for the professional organizations to enter the code development field.

A model code group in the modern context provides complete services for the code official and the building community. Besides publishing a code, these services include code maintenance and revision, evaluation and approval of new products, educational services for code enforcement officials, a plan check service, and similar services needed to support local building code enforcement needs.

Today, there are three principal model code groups.

(a) Building Officials and Code Administrators International (BOCA)

BOCA is a nonprofit organization founded in 1915 and formally incorporated in 1938. The organization pursued a program of mutual aid to its membership, principally through its annual conference. While codes and code requirements were the principal basis for discussion, each jurisdiction had its own local or statewide code. Over one half of BOCA's original membership represented major cities throughout the country. These groups expressed the need for uniformity of code requirements.

While discussions of sponsoring a building code occurred early in BOCA history, no formal program to produce a code was established until 1945. The concerns of uniformity and industry's desire to encourage innovation resulted in publication of the Basic Building Code in 1950. Support activities to maintain and provide services were established in 1951.

After publication of the Basic Building Code in 1950, BOCA published the Basic Housing Code in 1964. The housing code has evolved into a document applicable to both residential and nonresidential structures. It is now published as the Basic Property Maintenance Code and combines housing code requirements with hazard abatement code needs. The Property Maintenance Code was initially published in 1974. BOCA also publishes the Basic Fire Prevention Code (1966), The Basic Plumbing Code (1968), and the Basic Mechanical Code (1971).

BOCA was initially located in New York City, but relocated to the Chicago area in 1957. BOCA maintains the full range of code and code support activities described earlier.

(b) International Conference of Building Officials (ICBO)

ICBO, begun in 1922 as the Pacific Coast Conference of Building Officials, is a nonprofit service organization incorporated in California with offices currently in Whittier. ICBO published the first edition of its model building code, the Uniform Building Code (UBC) in 1927. The arrangement of this code was unique compared to most codes of the day, for it contained the provisions suggested by National Bureau of Standards reports, though it varied somewhat in format from their recommendations. The code arrangement was innovative compared to most building codes in use at that time. Other local codes followed the UBC's format, notably Los Angeles in 1943 and later San Francisco.

A number of other model codes used the Uniform Building Code as their basis, including one published by the New England Conference of Building Officials, called the New England Uniform Building Code.

The Uniform Building Code was the principal document of ICBO through 1958, when the first edition of the Uniform Housing Code was published. Mechanical requirements were published in a separate Uniform Mechanical Code in 1967, and ICBO published its own ICBO Plumbing Code in 1978. (Another group, the International Association of Plumbing and Mechanical Officials (IAPMO) has published the Uniform Plumbing Code since 1945.) ICBO developed the Code for the Abatement of Dangerous Buildings in 1964, and in cooperation with the Western Fire Chiefs Association first published the Uniform Fire Prevention Code in 1971.

ICBO provides the complete services required to support building code enforcement activity. It has field offices in Seattle, Washington, and Kansas City, Missouri.

(c) Southern Building Code Congress International (SBCCI)

SBCCI is "a nonprofit, nonpolitical association" founded in 1945 composed of, supported and sustained by, its active membership of cities, towns, counties, and states. They pool their resources to publish the Standard Building Code, first printed in 1945. The Code is intended to be used by small towns as well as large metropolitan areas to promote uniformity in building regulations.

The Southern Building Code Congress also publishes the Standard Gas Code (1953) and the Standard Plumbing Code (1955). To meet the needs of its members a Standard Housing Code was published in 1960. The Standard Mechanical Code was added in 1973, and the Standard Hazard Abatement Code published in 1977.

SBCCI provides the full range of model code group services described earlier.

(5) THE ROLE OF PROFESSIONAL SOCIETIES AND ASSOCIATIONS IN DEVELOPING OR PROMULGATING CODES

Professional societies have played a major role in the development and promulgation of various model codes.

(a) Plumbing Codes

Since its organization in 1883, the National Association of Master Plumbers has been vitally concerned with plumbing codes and their improvement. Association members had to comply with such codes in their daily work and thus had intimate knowledge of the good and bad points of plumbing system regulations. Standardization committees of the Association were continuously active in promoting development of standards for all types of plumbing equipment and materials. In 1933, the Association's standardization committees developed and published a model plumbing code. It was generally based on a model developed by the National Bureau of Standards in the 1920s and was recommended to code-writing authorities as a suitable standard. In 1942, the National Association of Master Plumbers published a new code which had been recommended to code-writing authorities as a modern standard, reflecting revisions to the 1933 code based on research carried out at the State University of Iowa.

In 1942 the American Society of Sanitary Engineers also published a set of standards for use in plumbing installation. Subsequently, the Society collaborated with other organizations in the effort of the American Standards Association (ASA) to develop a plumbing code. Under sponsorship of the American Society of Mechanical Engineers and the American Public Health Association, ASA's A40 section committee approved the American Standard Plumbing Code, A407-1949, published in 1949. This document subsequently was improved, and adopted by ASA in 1955 as the American Standard National Plumbing Code, A408-1955.

In 1971, the National Association of Plumbing-Heating-Cooling Contractors (NAPHCC), successor to the National Association of Master Plumbers, revised and published the American Standards Association's 1955 National Standard Plumbing Code. It was published subsequently in 1973, 1975, 1978, and 1980, and adopted by one-fourth of the jurisdictions in the United States (as reported by NAPHCC).

(b) Heating, Cooling, and Ventilating

The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) has been active in publishing standards related to the heating, cooling and ventilating of buildings. These standards traditionally have been referenced in building codes. More recently, with the growing concern for energy conservation, ASHRAE published Standard 90-75 (dealing with energy conservation in new building construction), which was adopted as a model code and promulgated by the three model code groups—BOCA, ICBO, and SBCCI.

(c) Mechanical Codes

Mechanical codes, addressing the design and installation of various types of mechanical equipment in buildings, have been published by the three model code groups. These codes refer extensively to standards published by various societies and associations, and by the American National Standards Institute (ANSI) and its predecessor, the American Standards Association (ASA). Mechanical regulations are not discussed in this report for two reasons: first, they evolve in response to technological progress rather than concern for health and safety; and second, mechanical equipment in buildings usually is replaced long before the building ceases to be used, and therefore is likely to be up to date. Therefore, it will suffice just to name some of the relevant societies and associations:

- Air Conditioning and Refrigeration Institute (ARI)
- American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE)
- American Society of Mechanical Engineers (ASME)
- American Society for Testing and Materials (ASTM)
- Manufacturers Standardization Society of the Valve and Fittings Industry (MSS)
- National Fire Protection Association (NFPA)
- Sheet Metal and Air Conditioning Contractors National Association (SMACNA)
- Underwriters Laboratory (UL)

(d) Specialty Codes

The role of professional societies and associations in the development of specialty codes (gas, elevator, pressure vessels, etc.) is similar to that of mechanical codes, and needs no further elaboration.

(6) THE NATIONAL BUREAU OF STANDARDS AND CODE DEVELOPMENT

The National Bureau of Standards (NBS) is a federal research laboratory within the United States Department of Commerce. The NBS began testing building materials and structural systems in the early part of the century. In 1921, the NBS focused on building regulations, the impetus coming from then Secretary of Commerce Herbert Hoover. Between 1921 and 1932 the NBS published 18 documents in the unique Building and Housing Series.

In May 1921, Hoover created a Building Code Committee in response to the following defects in then existing building laws:

- raised the cost of building and made the building industry inactive;
- failed to recognize modern methods;
- based codes on compromises rather than on scientific data; and
- lacked uniformity in principles.

The Building Code Committee had the following purposes:

- to study current codes, the disagreement they entailed and their oppressiveness to industry;
- to develop information regarding minimum safe and proper requirements;
- to prepare and publish recommended regulations;
- to investigate new materials and recommend their use if acceptable; and
- to use the Committee's influence to further other measures.

The development of a complete new building code was not an immediate objective of the Committee.

In November 1921, the Subcommittee on Plumbing was created by the Building Code Committee. Its objective was to simplify plumbing equipment and to overcome the diversity of local plumbing codes then in existence. (An additional committee was the Advisory Committee on Zoning, of which Lawrence Veiller, discussed above in a much earlier context, was an active member.)

The Building Code Committee developed the following documents as part of the Building and Housing Series:

BH1 Recommended Minimum Requirements for Small Dwelling Construction, July 20, 1922. (A model prescriptive code for small residential buildings.)

BH6 Recommended Minimum Requirements for Masonry Wall Construction, June 26, 1924.

BH7 Minimum Live Loads Allowable for Use in Design of Buildings, November 1, 1925.

BH8 Recommended Practice for Arrangement of Building Codes, July 15, 1925. (Contained an outline for a building code. It formed the basis for the 1931 revision of the National Building Code, which from then on followed the same basic format, and also provided a model for the formats of the later 1950 Basic Building Code and 1945 Standard Building Code.)

BH9 Recommended Building Code Requirements for Working Stresses in Building Materials, June 1, 1926.

BH14 Recommended Minimum Requirements for Fire Resistance in Buildings, 1931. (Provided specific requirements for Chapter 3 "Classifications", Chapter 4 "General Building Restrictions", and Chapter 11 "Fire Protection" of the model outline of BH8.)

BH18 Recommended Minimum Requirements for Small Dwelling Construction, 1932, superceding BH1.

The Subcommittee on Plumbing developed the following documents:

BH2 Recommended Minimum Requirements for Plumbing in Dwellings and Similar Buildings, July 3, 1923. (A complete model plumbing code. Part I discusses the relationship of plumbing and health, the then chaotic condition of plumbing regulations, and basic plumbing principles. Part II is the recommended model code. Part III reports on experiments carried out at NBS, which formed the basis of some of the recommended requirements, and discusses the physics of plumbing systems and standardization of plumbing materials. Included is a minority report by the trade union representative, objecting to the absence of a requirement for separate venting of each fixture trap.)

BH13 Recommended Minimum Requirements for Plumbing, August 30, 1928. (Expanded BH2 to cover all buildings. It is the first comprehensive model plumbing code, and is often referred to as the "Hoover Code". It has served as the basis for all subsequent model plumbing codes, except the Uniform Plumbing Code developed in 1938 by the Western Plumbing Officials Association (later IAPMO).)

The Advisory Committee on Zoning developed the following documents:

BH3 A Zoning Primer, 1922.

BH5 A Standard State Zoning Enabling Act, 1924.

BH10 A City Planning Primer, 1928.

BH11 A Standard City Planning Enabling Act, 1928.

BH16 The Preparation of Zoning Ordinances, July 1, 1931. (Includes a brief history of zoning in the United States and points out that 36 states had used the Standard State Zoning Enabling Act (BH5), and that 67 percent of the urban population, and 82 of 93 principal cities were covered by zoning.)

The remaining five publications in the BH series deal with home buying, home financing, and home repair and maintenance.

In 1914, the NBS began collecting data to use in formulating the National Electrical Safety Code, and by 1918 had a Safety Codes Section whose scope included work on safety requirements for automobiles, airplanes, homes, and industrial operations. The Section participated in the work of formulating or revising many safety codes and standards including the National Electrical Code, the Elevator Safety Code, the Code for Protection Against Lightning, the Code for Protection of Heads, Eyes, and Respiratory Organs, and many industrial safety standards. Through the technical knowledge and research of other members of the NBS staff, safety standards were created for filter lenses suitable for welders, color specifications for traffic signal lights, light patterns for headlight lenses, and the reference tests for measuring the thickness of zinc coatings on steel.

Although there was some overlap in the scopes of the National Fire Protection Association's National Electrical Code and the National Electrical Safety Code, the latter was used by electrical utilities in the construction and operation of electric lines, generating plants, and substations. State Utility Commissions also used it in the regulation of the utilities under their jurisdiction. The National Electrical Code applied to electrical installations on premises and in buildings completed by contractors and electricians and was enforced by city, county, and state Building Code Commissions that had adopted the NEC. Part III of the original National Electrical Safety Code dealing with utilization equipment overlapped the scope of the NEC. But this part received little use and has not been kept up to date, unlike the parts used by the electric utilities and the state regulatory commissions. During the early years of the NESC, the NBS sponsored a Conference of State Utility Commission Engineers. Annual meetings were held in which information useful to revising requirements in the NESC was presented by members.

Through reorganization, the work of the NBS's Safety Code Section has been eliminated or dispersed, although the NBS still has some representation on the National Electrical Code. They transferred sponsorship of the National Electrical Safety Code to the Institute of Electrical and Electronic Engineers and dropped their position as joint sponsor on many other safety codes and standards.

The National Electrical Code was originally developed to prevent fire loss in buildings from electrical installations. The Code was expanded in the 1937 edition to provide for the safeguarding of persons and buildings and their contents from all electrical hazards arising from the use of electricity.

The Building and Housing publication series were succeeded at NBS by the Building Materials and Structure Reports (BMS series), and in the 1960s by the Building Science Series (BSS). These dealt with testing and criteria of a range of building-related and code-related issues. Many issues concerned the structural properties of assemblies and materials, while others concerned fire tests of various kinds. Perhaps most notable in the fire safety area was BMS 92, Fire-Resistance Classification of Building Construction, October 1942, which provided much of the basis for the "Guideline on Fire Ratings of Archaic Materials and Assemblies", Rehabilitation Guidelines 1980, U.S. Department of Housing and Urban Development, October 1980.

NBS did further work in plumbing. BMS 65, 1940, presented updated methods for predicting plumbing loads based on probability. BMS 66, Plumbing Manual, November 22, 1940, was a continuation of the earlier NBS work. It concentrated on economies and low-cost housing, and was used extensively by other federal agencies. After World War II much of NBS's plumbing research (e.g., development of venting tables) was sponsored by the Housing and Home Finance Agency, and later by HUD.

In the standards area, NBS provides much of the scientific base for product and material standards, many of which are referenced in building codes. NBS is represented on many of the standards making committees of ASTM, ASA (later ANSI), NFPA, and others.

In the last decade, NBS also has worked on the development of codes related to new needs and new technologies. Operation Breakthrough Guide Criteria, 1970, and PBS Performance Specification for Office Buildings, 1971, developed formats for performance codes and standards. At the same time, various NBS projects contributed to the development of model legislation for the regulation of industrialized buildings and mobile homes. NBS served as the first secretariat to the National Conference of States on Building Codes and Standards, formed in 1969, which has been active in the promotion of statewide codes and code uniformity.

NBS research has directly contributed to code-related developments in energy conservation, active and passive solar systems, and fire safety.

(7) OTHER FEDERAL AGENCIES AND CODE DEVELOPMENT

It would be impossible in this report to discuss all the federal agencies which play a role in some aspects of the building regulatory system. The following discussion touches only on some highlights.

The role of the Department of Housing and Urban Development (HUD) and that of its precedessor, the Housing and Home Finance Agency, in funding NBS research already has been mentioned. HUD actively entered the arena of building regulation in 1964. That year's amendment to the National Housing Act of 1954 strengthened the workable program requirement by making community adoption of a housing code a precondition for obtaining funding under the urban renewal program. That amendment led to widespread adoption of housing codes, and to the active entry of the model codes groups into the field of housing code publication and promulgation. In 1965, the Federally Assisted Code Enforcement (FACE) program, otherwise known as the concentrated code enforcement program, combined rehabilitation grants, low interest loans, and housing code enforcement in designated neighborhoods.

HUD also maintains its own building regulatory system. These are the various Minimum Property Standards, which are criteria for participation in various HUD housing assistance programs. Some HUD developed standards, such as that dealing with lead paint, have found their way into building codes. Overlap between the regulation of buildings through codes and the HUD Minimum Property Standards is the subject of current research sponsored by HUD with the aim of simplifying building regulation.

Other federal agencies created to deal with specific problems often interface with the building regulatory system. The Occupational Safety and Health Administration (OSHA) issues and enforces standards of safety in the workplace. Inasmuch as buildings constitute the large majority of workplaces, OSHA regulations often deal with similar building attributes and building systems regulated by building and property maintenance codes—rail heights and sanitary facilities, for example.

The National Institute for Occupational Safety and Health (NIOSH), under the Department of Health and Human Services, performs research on health and safety matters intended as input into OSHA regulations.

The Consumer Product Safety Commission (CPSC) is concerned with safety of products. Various building elements have been dealt with under this category, such as glazing, windows, bathtubs, stairways, fabrics, etc.

The Environmental Protection Agency (EPA) is concerned with a wide range of environmental hazards. To the extent that such hazards are related to building materials and products, EPA decisions may affect the regulation of both new and existing buildings. Recent examples are polyvinyl chloride (PVC) and asbestos.

The Department of Energy's concern with energy conservation in buildings has lead to specific building regulations. DOE sponsored research lead to the adaptation of the ASHRAE 90-75 standard for energy conservation in new building construction into a model code promulgated by the three model code groups. Another area related to building regulation is current research by DOE into the problem of minimum ventilation requirements and indoor air quality.

(8) CITIES AND STATES IN EARLY CODE DEVELOPMENT

Although physical and social housing problems in the United States existed in many cities from Colonial times, the first major legislation to deal with such problems was the Tenement House Act of 1867 enacted by New York State for the City of New York.

Lawrence Veiller, then Secretary to the New York Tenement Commission, submitted an exhaustive report on housing conditions, laws and ordinances in 27 United States cities. From this work, the Commission developed the New York [State] Tenement House Code, which with some modifications was promulgated and enacted as the New York [State] Tenement House Act of 1901 (amended in 1902 and 1903). A Buffalo, N.Y. ordinance, passed as a result of the concerted efforts of the Tenement House Committee of the Buffalo Charity Organization Society, is credited by Veiller as being a model for the New York State law.[11] "This [1901] legislation excluded one-family and two-family dwellings from compliance. However, it did establish some standards for 'tenement' houses that were enforced by the courts. The provisions of this law dealt with protection from fire, including exit facilities; light and ventilation, including water closet accommodations, cellar and basement occupancy, and overcrowding; and 'remedies', including requirements for building permits, registration of owners and administrative details."[12]

The 1901 Tenement House Act also served as a model for many cities and several states. By 1910, over one-fourth of the states had passed similar laws. In that year, too, Veiller developed A Model Tenement House Law.[12]

Columbus, Ohio, is credited as being the first city to adopt a housing law[12]. The Columbus Housing Code of 1911 followed Veiller's examples, but for the first time coverage was extended to include single and attached dwelling houses. In turn, in 1914 Veiller followed Columbus' example and included dwellings along with tenement houses in the first edition of his A Model Housing Law.

C. ATTRIBUTES

(1) FIRE SAFETY

(a) Introduction

When the first modern building code was published in May, 1905, the authors recognized that change was inevitable:

> "In the presentation of these suggestions for a Building Code, the Committee realizes that perfection has not been attained. In soliciting criticisms it became apparent that changes might be made indefinitely. The Committee, therefore, has decided to present the Code in this form, knowing that the National Board of Fire Underwriters will closely follow the evolution of building construction and the introduction of new material and patent devices, and through amended editions be able in the future to suggest to the public the newest and safest methods of construction."[13]

And what change there has been! The first National Building Code contained 242 pages of actual text, and that was with large type and headnotes in very wide margins. The 1976 edition, printed in much smaller type and with much thinner margins, is 687 pages long. The other model codes have grown similarly.

Are we that much smarter? Are we that much safer? Are the model codes even reflective of reality? Why all this change?

Codes change for different reasons. Each has different implications for existing buildings. Some changes reflect advancements in construction techniques or materials. Nothing has been found harmful or wrong, but there is simply another way to achieve the same, or even better, result cheaper or more efficiently.

A code change after a fire loss is quite different. For whatever reason, an existing building has not performed. The proposed change is to eliminate similar future danger. But no systematic effort is made to correct other existing buildings similar to the one that prompted the change. Existing buildings are not addressed by the code change process.

This inattention to existing buildings is like eliminating a disease by innoculating only new-born babies and waiting for the rest of the population to die, whether by the same disease or any other reason. In the harshness of cost-effectiveness analysis, this may be the best course. But the code change process is not that rational. Ironically, some fire safety products have been banned and recalled for other health reasons. Children's sleepwear treated with TRIS, carbon tetrachloride extinguishers, and asbestos insulation are but three examples. And it is noteworthy that this remedial action is rarely taken by the originator of the code rule or regulation.

Some code changes pose no special technical problems for existing buildings. Hiding pipes and wires inside existing walls and ceilings can raise costs and make the aesthetics more difficult. But EXIT signs, emergency lighting, automatic sprinklers, and smoke detectors are no different in existing buildings than in new ones.

Changes outside of the building code can also affect fire safety—both good and bad. Fire departments and city water systems have vastly improved since 1900. Industry is now largely separated from stores and residences, and much of the populace has left the dense inner city for the suburbs. The relative safety of existing buildings has been improved, though the buildings have not changed. But we also use more energy and have more electrical appliances. Today, home heating systems are the rule; in 1900 they were the exception. Buildings have more contents of all types, especially those made from plastics and other synthetics that burn hotter and faster, and often more toxic, than the basic material of the early 1900s—wood.

The code changes most burdensome to existing buildings are those that affect the physical structure. Changes in egress or allowable heights and areas could require major structural renovations if an existing building were made to comply. These are the types of changes that warrant the closest study.

Yet the most noticeable change in the codes is in the level of detail. Seventy-five years of "fine tuning" has cluttered the codes, obscuring the original intent. The National Building Code through the 1931 edition had explanatory notes, pictures, and diagrams throughout. Today, there is only legalese, too much detail, too little policy, no statement of intent, and far too many exceptions to poorly stated general rules. This lack of clarity is not good for existing buildings because the exercise of flexibility and good judgment is made difficult when the intent is not clear.

We do not really know how to measure fire safety. There is no magic "building thermometer". And with some 18,000 local governments, there is no way to know how each has regulated its buildings for the last 80 years. The model building codes at least provide a temporal record of fire protection principles and ideals, even if not always reflective of reality. What can be said with confidence is that the scale of the problems being addressed has reduced over the years. In 1900, confining a fire to the block of origin was considered success. Today, the point of focus is on protecting the individual within the room of origin.

The National Building Code was first published by the National Board of Fire Underwriters in 1905. The International Conference of Building Officials began publishing the Uniform Building Code in 1927. The other two model codes, the Basic and Standard codes, were not published until 1950 and 1945, respectively. By then, the codes were fairly consistent. The National and Uniform codes were analyzed for this report because they cover best the period 1900 to the present, and because they reasonably reflect the significant changes in other, later model codes.

(b) Fire Zones

Introduction

It was the major conflagrations in our cities that led to the first model building code in 1905. This code, the National Building Code, had one primary goal--to end these conflagrations by limiting the spread of fire from one structure to the next.

The concept of a fire zone was developed to focus special regulatory attention on those areas of a community with the greatest economic importance and/or conflagration potential. Generally, the principal business district (or high value district as it was often called) would be declared a fire zone or to be within the "fire limits". The exact geographical boundaries were often set out right in the building code.

The basic regulatory scheme prohibited new construction of wood frame buildings (including limiting the rehabilitation or rebuilding of existing wood frame structures) and increased emphasis upon the fire resistance of exterior party and fire walls, parapets, protection of windows and other openings in exterior walls, wider streets, and improved fire department access.

Today it is sometimes difficult to remember that horses, not automobiles ruled the streets in 1900. Zoning had not yet been accepted as a valid governmental power, so industry, business, and residences were mixed together. Fires could, and did, burn for blocks.

Fire zones are not as important today because cities are different. Suburbs and shopping centers have replaced many large, congested, highly combustible downtown business districts. Smaller commercial areas are spread throughout the community where land is cheaper and more readily available. The hazards of industrial and commercial operations have been separated from business and residential areas. High land values in downtown areas make high-rise buildings an economic necessity, and high-rise buildings must be of fire resistive construction.

National Building Code (NBC)

Fire limits have been in the NBC since the first edition in 1905. The most important provision was to prohibit wood frame construction within the fire limits. Repairs, additions, or alterations of existing wood frame buildings were discouraged. Major attention was also given to the fire resistance of exterior walls and windows, though these specific provisions were in other sections of the code. The intent was to confine a fire from within and form a barrier against a fire from without. There have been no major changes since 1905.

Uniform Building Code (UBC)

The first edition of the UBC in 1927 established four levels of fire zones. Fire Zone 1 was the general retail district and the most heavily congested areas. Fire Zone 2 included those areas adjacent to the major retail districts in Fire Zone 1. Fire Zone 3 included the general residential areas. Fire Zone 4, which was deleted by the 1935 edition, included the heavy commercial and industrial areas. Like the NBC, wood frame construction was prohibited within Fire Zone 1, and the fire ratings of exterior walls were controlled.

The chapter on fire zones was deleted from the 1979 UBC. The basic requirements for protection against exposures are still there, and are addressed by other sections of the code. Today, the permitted construction type (i.e., wood frame v. fire resistive) is more a function of the intended occupancy and size of the building. Zoning has largely assumed the task of controlling congestion through setbacks and land use density. Zoning or other community planning regulations have isolated the heavy commercial and industrial areas.

The reasons for fire zones are still valid, and these goals are being met. It is the form of regulation that is different.

(c) Heights and Areas

Introduction

The allowable height and area of a building is a function of the intended use or occupancy of the building and the type of construction. Increases are given for added features such as automatic sprinklers and improved fire department access. Along with zoning and other land use regulations, height and area requirements are economically significant because they determine the amount of usable space a property owner may realize from any given piece of land.

Heights and areas also control the demand for public fire suppression services (e.g., fire department, water supply). Either by limiting the size of the buildings or requiring built-in fire protection systems, the code is shifting some of the responsibility and cost for fire safety back onto property owners.

National Building Code (NBC)

The first NBC in 1905 limited the height of a "fireproof" building to 125 feet. The height limitation on fire resistive buildings was removed in 1931.

The allowable number of stories for ordinary and wood frame construction has decreased—usually by one. Not all occupancies, though, are limited to a specific number of stories. However, the overall allowable heights also have decreased over the years, and this likely offsets any benefit from no limitation on the number of stories.

Early area restrictions on fire resistive buildings were likewise ended in the 1931 NBC. The base area of one story buildings of ordinary construction increased in 1949, and then again for buildings of all heights in 1955. The original base area for wood frame buildings was reduced in 1915. It eased somewhat in 1955, but was still less than originally permitted in 1905. The 1955 increase did not benefit assembly occupancies of wood frame construction. In fact, changes in 1976 now prohibit larger assembly occupancies in wood frame buildings.

The NBC has always allowed an area increase for automatic sprinklers, which has risen from a low of 33-1/3 percent in 1905 to a maximum of 300 percent in 1976 under special conditions. The current average increase is 200 percent.

Area increases for fire department access, offered since 1905, essentially doubled in 1955. The 1915 and 1931 editions allowed area increases for buildings outside the fire limits at the discretion of the building official. This "discretionary" standard was replaced by specific increases, such as the use of fire retardant lumber (1949) and providing one hour fire resistance to combustible construction types (1955). These credits have tended to increase.

The 1955 NBC allowed sprinklered, wood frame multifamily (apartment) buildings to be increased in height from two to three stories. Hotels were included in 1976. The 1976 NBC also permitted sprinklered, four story apartments and hotels of ordinary construction— a one story increase.

In 1931, residential buildings of ordinary construction with either no basement or a two hour fire resistant ceiling over the basement or cellar were allowed an increase of one story and 10 feet in overall height. Multifamily (apartment) buildings subdivided by fire partitions (two hours fire resistance) and floors of one hour fire resistance (in addition to the two hour fire resistant ceiling over the basement or cellar) were allowed an additional one story and 10 feet (for a total of two stories and 20 feet). The allowable area between fire partitions increased in 1945, and the number of permitted stories increased from five to six in 1967. But in 1976 the entire credit was deleted. The fire resistance requirements, previously optional, were largely made mandatory without allowing an increase in height. The only height increase presently available is the one for automatic sprinklers noted above.

Buildings of unlimited area of other than fire resistive construction were first permitted in the 1955 NBC. Complete sprinkler protection, limited height, exterior separation, and noncombustible construction are the basic requirements for this exception. This early exception permitted the early shopping centers. Later, a separate section was added to the code specifically addressing malls, a case where new developments in marketing and retail practices coupled with cheap and open land in the suburbs provided the impetus for code change.

Uniform Building Code (UBC)

The UBC has always permitted fire resistive buildings to be of unlimited height and area.

For ordinary and wood frame construction, the overall height limits in the UBC have increased slightly, but the number of permitted stories has decreased by one. The area requirements were tightened around 1943 when the total floor area of a multistory building was limited to twice the area of a single story building. This rule has no effect on fire resistive buildings because their area is unlimited. But it meant a sharp reduction in the area of buildings of lesser types of construction.

The first allowances from the base height and area requirements were not made until 1943, when an increase in height and area was given for combustible construction types protected with one hour fire resistance. Area increases were also permitted for automatic sprinklers and fire department access. The 1952 edition granted an additional increase for sprinklered buildings only one story in height. The 1952 edition also gave buildings outside the fire limits an additional area increase, which was incorporated into the base area table when fire zones were eliminated from the UBC in 1979.

The UBC first allowed buildings of unlimited area of other than fire resistive construction in 1943. The special conditions were similar to those in the NBC: automatic sprinklers, limited height, exterior separation, and noncombustible construction.

Conclusion

It is difficult to generalize, for decreases in base heights and areas may be more than offset by increases in both the type and amount of special credits. But particularly for assembly and other commercial uses, it is likely that without these special credits, existing buildings would not comply with the height and area requirements for new construction. Fire resistive buildings have no height or area limits, so they do not have this problem.

(d) Fire Resistance

Introduction

Fire resistance is the ability of a building to withstand structural attack by fire from both within and without. There were major conflagrations because fire spread from the building of origin to adjacent structures. The fire spread not only by direct flame impingement, but also by intense heat radiation across great open distances that shattered plain glass windows and ignited combustible building contents, along with combustible exterior walls and even combustible windows, frames, and sills in noncombustible masonry walls. Few buildings had party or fire walls with parapets unpierced from the ground through and above the roof. Burning flying brands driven by fire storms ignited combustible roofs.

The codes increasingly required separations between different occupancy uses. A particularly troublesome problem in older tenements was fire spread from basements and first floor stores to the apartments on floors above. Literature in the 1910s and 20s had many accounts of such fires. Lower floor tenants usually escaped. Those on upper floors often perished or were seriously injured.

A Note in the 1915 National Building code implored:

> "Fire walls are as useful in protecting school buildings, hospitals, hotels, state and county buildings, large residence buildings, and in fact any building having considerable area, as they are in other types of buildings. In such public buildings where numerous people are housed, many of whom may be invalids or infirm, the life saving features of properly constructed fire exits through fire walls, cannot be overestimated. The additional expense of such cut-offs is slight, and neither the architectural effects, nor the utility of the building, need be affected by their introduction. Necessary openings in such walls when not large, can be efficiently protected by fire doors as artistic in finish as ordinary doors. It is no longer necessary to be restricted to the unsightly tin clad fire door for such use."[14]

Firestopping, enclosed stairs and shafts, and fire rated floor/ceiling assemblies and corridor walls can contain fire within a specified area, minimizing danger and giving people enough time to escape. In larger buildings (especially high-rise buildings) evacuation is not practical. Occupants must be "protected in place", so the building must remain structurally sound. Fire fighters need safe access to the fire.

There is a fire protection philosophy and design approach called "compartmentation". The idea is that a fire should never escape from the "compartment" where it began. At first, the "compartment" was the entire building. Thus the early emphasis on fire resistant exterior walls and openings.

Over time, the acceptable "compartment" has gotten smaller. More floors and ceilings, corridor walls and partitions, and enclosed stair, elevator and other shafts divided a building into smaller and smaller pieces. Today, fire spread beyond the room of origin is a failure, and researchers are studying fire spread from the item first ignited—an improvement since 1900.

The difference between "fire resistance" and "noncombustible" must be understood. Noncombustible means something will not burn, such as glass, steel, or brick. Fire resistance is the time a material or assembly (e.g., wall, floor/ceiling) will resist a fire without either collapsing or allowing fire to spread. Steel is noncombustible, but loses its strength and will collapse at temperatures produced by a fire. Plain glass is noncombustible, but will shatter and allow fire to spread. Large wood beams and columns, prevelant in older buildings, are combustible, but of such mass and size they can be more fire resistant than bare steel. The 1915 National Building Code noted:

> "It is well known that steel begins to lose its strength at about 500° Fahr., and at 1,000° Fahr., approximately 70% of its strength is gone. Temperatures such as these are easily reached in an ordinary fire, and if maintained even for a short time are almost sure to produce collapse of exposed steel structural members.
>
> "Loaded cast iron columns are very liable to fracture and collapse when highly heated, especially when struck by a stream of water. A simple sub-standard protection as here suggested would prevent such failures, and might easily save a building from complete ruin.
>
> "Heavy timber construction will resist collapse from fire better than unprotected steel work. The wooden members will burn and help spread a fire, but it takes considerable time to burn them deep enough to reduce the strength sufficient to cause failure."[15]

Noncombustible building materials do not necessarily guarantee fire resistance. Noncombustible simply means that the structure will not burn or provide a source of fuel for the fire. With limited exception, the codes do not control or limit the contents of a building. And building contents have increased since 1900, both in quantity and type. The biggest change is in the use of plastics and other like synthetic materials, which tend to burn hotter and quicker and contain more "energy per pound" than paper and other wood-based products. Often, the contents alone are more than enough fuel to allow flashover—simultaneous ignition of all combustible material within the space. A more demanding fire places greater strain on a building, and could shorten the time it will withstand the fire.

Construction materials and practices also have changed since 1900. The key difference is the reduction in the weight or mass of a building. In 1900, fire resistive buildings had massive brick walls and thick reinforced concrete floors. The sheer weight of these building components may have constrained developers and builders by limiting the height of buildings and adding to costs, but the massiveness provided an incredible degree of fire resistance and structural stability. On July 28, 1945, an Army bomber lost in the fog literally flew into the side of the Empire State Building. Though 14 died from the crash and ensuing fire, the building was essentially undamaged.

Not that the World Trade Center would collapse under a similar stress, but the factor of safety gained through the inherent over-design of earlier construction methods and materials is lacking. Key to fire resistance is mass—the more material, the more heat energy that can be absorbed without damage. Today's buildings are designed just to the limits of the code, and they are lighter and have less mass.

When a material or assembly is tested for fire resistance, all that is important from the regulatory perspective is the length of time before failure. Nothing in the code requires the test sample to be usable or even salvageable upon completion of the test. If a code requires, for example, a wall of three hours fire resistance, that wall must remain structurally sound and contain the fire for three hours. It does not matter whether the wall is intact or damaged beyond repair—even enough to require condemnation were it the real world.

These issues have been discussed at length for two reasons. The first is that the code requirements are highly specific and extremely detailed, which makes summary difficult. Also, the codes do not identify, for example, the acceptable "compartment" that can be involved in fire (for example, building, floor, or room). It can be intuitively inferred, but is difficult to document.

The second reason is that many of the changes that impact upon the fire resistance of a building and its components are outside the scope of the codes. The degree to which the code writers have considered these non-code forces is not documented and therefore unknown. Each community will have to study its own prevalent building types, construction practices and materials, and building uses and contents and reach an independent assessment.

National Building Code (NBC)

The standard fire resistance test ASTM E-119 was not formally accepted by the American fire protection community until 1918. The major benefit of this test is that code writers can specify a desired level of performance without the exact details of construction. Fire resistance is expressed as a function of time, usually in hours. Any building component that can "resist" the fire for the specified time is acceptable.

It is difficult to define exactly the fire resistance specified by the 1905 NBC. Eight inch thick brick interior partitions and shaft or stair enclosures could have five or six hours fire resistance; a 12 inch brick wall could be nine hours or more. This far exceeds the hourly ratings specified after the adoption of the E-119 test.

The 1915 NBC was a transition edition. Both the exact details of construction and the fire resistance in hours were specified. "Fireproof construction"* required four hour floors; two hour partitions; three hour stair, elevator, and other large shaft enclosures; and one hour fire doors, outside shutters, and windows. These hourly ratings are not that dissimilar from the requirements today, having changed little since 1931.

The early codes were not always as encompassing as in later editions, but the basic concepts and fundamental requirements have been in the NBC since the first edition.

Fire resistant ceilings over basements and cellars were required in the taller "non-fireproof" apartments and tenements to prevent fire spread to the upper floors. Buildings over 55 feet in height had to be of fire resistive construction, three stories or 45 feet after 1931. Basement and cellar stairs had to be separated from the stairs to the floors above. Apartments were separated from the stores and businesses below. Fire spread from these occupancies, particularly at night when people were asleep, was a known and serious problem.

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* The term "fireproof" remained in the NBC until the 1955 edition, notwithstanding the 1915 Note following the definition of fireproof: "It is recognized that the term 'fireproof' is misleading and should be abandoned for the more correct term 'fire-resistive'; but until the latter term has been authoritatively defined in a manner expressive of its elastic interpretation, it seems advisable to continue the use of the more common though objectionable word." Fireproof was defined in relevant part as "materials or construction not combustible in the temperatures of ordinary fires, and which will withstand such fires without serious impairment of their usefulness for at least one hour". [This definition of fireproof is different than "fireproof construction". Fireproof construction refers to the building construction classification, in which all the major structural elements are fire rated. The "one hour fireproofing" was structural protection for non-fireproof buildings: wood frame, ordinary, heavy timber, and later noncombustible. This came to be known in the codes as "protected" construction.][16]

Fire spread through light and ventilation shafts and elevators was also addressed in the 1905 NBC. So too stairs and hallways. By 1915, partitions between apartments (as well as between an apartment and the hallway) had to have some minimum fire resistance. This completed the "compartment" around an individual apartment unit.

The trend has been to require more things to have some degree of fire resistance, to enclose more things. But the degree of fire resistance may be slightly lower. Common materials and construction methods developed since 1900 provide approximately one hour's fire resistance anyway. And it is cheaper and easier to build a wall out of wood studs and gypsum wallboard than four inches of solid brick. So, in this sense, it is easier to build a fire resistant assembly today than in 1900.

Uniform Building Code (UBC)

The UBC fire resistance requirements are a function of the type of construction, the building occupancy, and, for exterior walls and openings, the distance to the lot line or another building. Fire resistance has been comprehensively regulated since the first edition in 1927. Fire rated corridors, though, were not required until 1946.

The hourly fire resistance ratings for exterior protection have decreased slightly, but the distance aspect of these regulations has increased. In other words, buildings farther apart must still comply with the same requirements. This may be due to a better understanding of fire spread by thermal radiation. Requirements for party walls and occupancy separations are basically unchanged.

For fire resistive and wood frame construction, the fire resistance of internal structural elements is basically unchanged. Ordinary construction was not regulated until 1935, when buildings four or more stories in height needed one hour fire resistance. The formal distinction between "protected" (i.e., one hour fire resistance) and "unprotected" types of construction was first made in 1952, the practical difference being the tighter control of allowable height, area, and occupancy uses in buildings of unprotected construction. The fire resistance requirements since then are basically unchanged.

A requirement was added in 1943 limiting the maximum area of an enclosed, combustible attic space to 2,500 square feet; larger spaces had to be subdivided into areas not exceeding this amount. A 200 percent area increase for automatic sprinklers was added in 1952. The base area increased to 3,000 square feet in 1970.

Conclusion

Fire resistance requirements fulfill many fire safety purposes. They can prevent the spread of fire from one building to another, or from one portion of a building to another. They are to keep stairs and other exitways clear and safe for emergency use, and to protect those who, for whatever reason, cannot escape but must wait until fire fighters can arrive.

These requirements have become extremely complex and detailed, which makes summary difficult. But the basic concepts and requirements have been in the codes since 1905. Changed height and area requirements for non-fire resistive buildings would likely pose a greater regulatory burden to the re-use of an existing building. One key exception could be unenclosed stairs or other openings.

Being able to document the "fire resistance" of an existing building or assembly can be a problem for buildings constructed before the E-119 test method was developed and accepted, or where the original test report or documentation is no longer available. The Guideline on Fire Ratings of Archaic Materials and Assemblies, part of an eight volume series on building rehabilitation published by the U.S. Department of Housing and Urban Development, is a valuable source document that can solve this problem. This Guideline also contains guidance on how to upgrade fire resistance should this be necessary.

Intuitively, buildings today are more "fire resistant". But more through better control of fire spread than an increase in the required hourly fire resistance ratings. If anything, these hourly ratings have tended to decrease. Controlling open shafts, exit corridors, enclosing stairs, etc. has produced the greatest benefits. These building features are traditionally lacking whenever a large loss of life occurs. And it should be noted that these unsafe features are not only found in older buildings. Smoke spread through elevator shafts at the 1980 MGM fire in Las Vegas appears to have been responsible for many of the deaths.

A community can easily determine whether there is a problem. The fire department need only be consulted as to how and how far the fires it fights are able to spread. These problems tend to be well defined, and though perhaps politically unpopular, easily addressed through retroactive regulations if the community deems that remedial action is necessary.

(e) Number and Size of Exits

Introduction

The only exit from 18th century tenement houses was a single, usually unenclosed, stair. In essence, there was no path of safe escape. Early tenement codes began to require fire escapes, but often this was nothing more than a vertical ladder bolted to the side of a building. Hardly useful for women dressed in the long skirts of the day, children, the elderly, and the disabled.

By the late 18th century, more substantial fire escapes began to be required, but the interior stairs still were not being enclosed. In a fire, open stairs act just like a chimney. Fires that began in the basement or ground floor stores were sucked up the stairs, trapping the people on the floors above. There were no smoke detectors or alarms in those days to provide early warning.

The first truly "protected" means of egress came when the model codes required interior stairs to be enclosed. Fire escapes were a secondary means of egress, but they were falling into disfavor, as the 1915 National Building Code noted:

> "The ordinary so-called 'fire escapes' . . . are considered very inefficient and unsafe means of exit. If any considerable number of people attempt to use such an exit in time of fire panic, it quickly becomes so congested that travel is very much impeded or entirely blocked. If fire occurs on the floor below that from which people are endeavoring to escape, and the windows facing such exit are not protected by wired glass, the fire escape is worthless; and even with wired glass the exit is of doubtful value because of the intense heat which radiates through the windows. Such means of exit should never be permitted except upon existing buildings, where the number of people to be accommodated by them is small, and where structural conditions are such that it is impossible to secure anything better. They are not recognized as a required means of exit in this Code."[17]

Though fire escapes were no longer recognized, the notion of two exits from a building remained in the codes. In a sense, the second exit had been moved inside the building. In time, the codes completed the egress system by connecting these two exits with fire rated corridors and protected passageways to the street.

This is the crudest of accountings. The number of exits is a function of the number of people, the area of the building, the number of stories, the type of construction, the occupancy, and even the location and type of other exits. Different combinations yield different results. Some buildings need only one exit while others more than two; some stairs may be open while others must be enclosed.

If there is any logic to the development and changes in egress requirements, it is these two principles:

- The greater the perceived hazard, the more stringent the requirements.
- Egress requirements should allow the most efficient and economically beneficial use of building space.

These principles are not always compatible. The number and complexity of egress requirements reflect many years of compromise amidst changing societal values and expectations.

National Building Code (NBC)

Like the Uniform code, the first NBC defined the number of exits as a function of the building area. Offices, stores, factories, hotels, lodging houses, and schools larger than 2,500 square feet needed "at least two continuous lines of stairs remote from each other" (plus one additional exit for every 5,000 square feet over the first 5,000 square feet).[47]

This changed in 1915, as the following Note explained:

> "In all building codes the treatment of exits must necessarily be largely theoretical until more systematic study of the subject has been made, and the correctness of conclusions based thereon have been demonstrated under practical service conditions.
>
> "As a fundamental principle, exit requirements are a function of the occupancy of a building and not of the area. To promote safety to life, two means of egress should be required from every floor of every building subject to exit specifications, irrespective of its area. Beyond this, exit calculations should be based solely upon the number of occupants.
>
> "The method herein employed for computing exit requirements, is not claimed to be all that could be desired. It is an attempt to provide safety without too drastic demands, and is based upon the best information available. Experience may prove that changes should be made."[18]

The 1915 NBC required two exits from a building and from each story or floor above the first. Floors above the first needed one "stair exit", and the second exit could be either another "stair exit" or a "horizontal exit".* Further, one exit had to open to a "street or fireproof passage leading to the street, and one [exit] may open to a yard or other space deemed safe by the Superintendent and of sufficient area to accommodate all persons in the building".[53] One exception was dwellings—only buildings greater than three stories needed two exits.

Apartments required "at least two independent means of egress located remote from each other and extending continuously to the street, or to a court or yard connected with the street".[19] One exit had to be an enclosed interior stair; the second exit could be a stair exit or a horizontal exit. Additionally, there had to be direct access to this second exit from every apartment "without passing through a public hallway".[20] Under special conditions, buildings with apartments located over stores or businesses required at least one continuous enclosed stair that passed without openings through the business floors. This isolated the exit from any fire which began in the businesses below.

The 1931 and later editions backed off from a hard rule of a minimum of two exits. The 1931 NBC set a threshold limit of 75 people on the ground floor and more than 2,500 square feet on floors above before the second exit was required. However, any apartment without a "direct exit" to the street still needed two separate and independent exits as specified in 1915.

In 1949, buildings under 2,500 square feet needed only one exit. The "two exit" rule for apartments was limited to buildings over two stories above the basement or where more than six apartments shared a "common exit way". The 1955 NBC allowed only one exit if there were less than 45 people per floor, 60 per floor in fire resistive buildings. Any story of a residential occupancy with 10 or more people needed two "separate" exits (fire resistive apartments two stories or less with not more than 12 units, and apartments of heavy timber, noncombustible, or ordinary construction two stories or less with not more than eight units, were allowed with a single exit).

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* A "stair exit" was an enclosed interior stair, smokeproof enclosure, or an outside stair (not a fire escape). [§45(10)] Stairs, horizontal exits and smokeproof enclosures are discussed further in Section C(1)(f), C(1)(j) and C(1)(k), respectively.

The 1967 NBC, as a general rule, only required one exit (stores needed two exits, except under very limited conditions). Each occupancy had its own requirements, which were functions, variously, of a particular story of the building or the overall height, travel distance, number of occupants, and even the type of exit. These provisions were largely more restrictive, though, because two exits were usually required for an occupant load of 10 or more. This is less than the 45 or 60 people specified in the 1955 edition. The requirements for residential occupancies were unchanged, except that apartment buildings with one or more units above the second story now needed two separate exits.

The general rule implicit in the 1976 NBC is that there should be a minimum of two exits—a return to the 1905 and 1915 NBC position. Buildings with one exit are the exceptions. This is philosophically different than the 1931-1967 editions, when the general rule was one exit, and only two "if . . .". In practical terms, the restrictions on buildings with single exits have increased over the years. So fewer buildings are allowed with a single exit.

The codes also specify the number of exits or doors from a single room or space. The first requirement came in 1915, when rooms with more than 75 people needed two doors. The 1931 NBC added rooms over 1,000 square feet in area. In 1949, rooms with over 100 people or larger than 1,000 square feet needed at least two "exit ways". The 1955 NBC required two doors from "every room, gallery, balcony, tier or other space" with 100 or more occupants; two exits were required from these spaces when the occupant load exceeded 200 people (three exits for over 600 people, four exits for over 1,000). In hotels, offices, and assembly occupancies, the 1976 NBC requires at least two exits from rooms with 50 or more people, or where any part of the room or space is more than 50 feet from a door in an exterior wall (100 feet in offices).

After the number of exits has been established, the capacity of these exits must be checked to insure that they are adequate for the number of people present. The 1905 NBC had no direct regulations on exit capacity, though minimum widths were specified for some exit components (e.g., stairs). But since 1915, the size of the exit has been a function of the number of people.

Exit capacity is usually expressed as "X" people/unit of exit width.* The theory is that for every unit of exit width, there is enough time for "X" people to safely escape. This time assumes people

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* Twenty-two inches was not accepted as the standard unit of exit width for all types of exits until 1955. When possible to calculate, and a different base was used, the number of people based upon a 22 inch unit is given in parenthesis after the actual code-specified values. For example, 100 people/12 inches (183).

walking at some constant pace and/or able to hold their breath for so long. There is not enough information in the codes to explicitly calculate this "safe time" for escape.

There are two main categories of exits: level (e.g., doors, corridors, passageways) and stairs. The capacity of stairs is less than for level travel because travel on stairs is slower (though no distinction is made between travel up and down stairs).

Under the 1915 NBC, street level halls or corridors serving as exits from stairs had to be 44 inches wide for the first 50 people served (25), plus an additional six inches/50 people beyond that (183). The number of people was based upon the "story having the largest occupancy served by said corridor".[65] In apartments, "public hallways" serving as a means of egress had to be 44 inches clear width plus eight inches/apartment over three apartments per floor. When individual doors were less than 40 inches clear width, one doorway was required for every 22 inches of required width of corridor or stairway leading to the door. Stairs were based on 14 people/22 inches width of stairs plus one person/three square feet of hallway floor and stair landings. In sprinklered buildings, stair capacity was increased 50 percent to 21 people/22 inches; 50 people/22 inches when there was a horizontal exit.

A new concept, minimum "occupant loads", was a major improvement in the 1931 edition. The code recognized that the number of people in a building changed constantly, so a minimum "occupant load" based upon a certain number of "square feet/person" was presumed.

The floor or building area divided by the occupant load defines the number of people allowed in the building or space. The allowable number of people establishes the minimum necessary exit capacity. For example, no more than 10 people would be permitted in a 1,000 square foot building with an occupant load of 100 square feet/person (1,000 square feet divided by 100 square feet/person = 10 people). The exit(s) must be sized to accommodate 10 people. [Note: Within limits, more people could be permitted provided the exit(s) had adequate capacity.]

Different occupancies had different occupant loads. Buildings traditionally crowded (e.g., public assembly) needed more and larger exits. The 1915 approach lacked this flexibility. Since 1931, the minimum occupant loads have increased, which means that the number and capacity of the exits is based upon a smaller number of people. But the point may be largely moot because other thresholds used to determine the number of exits have been reduced. And the minimum dimensions for stairs, corridors, doors, etc. often results in excess exit capacity.

In 1931, passageways and hallways were rated at 100 people/12 inches (183). Doors were rated at 100 people/22 inches—almost half the capacity of hallways and passageways. Stairs in assembly occupancies were rated at 100 people/22 inches; in other occupancies, the stairs were sized based upon one person/3-1/2 square feet of floor surface of halls, landings, and stair treads. The needed stair capacity could be reduced by one-third to one-half in sprinklered buildings, depending upon the construction. A two-thirds reduction was given for a horizontal exit.

The idea behind the latter method for sizing stairs seems that there should be enough room for all people to fit into the stairs and hallways leading thereto at the same time, i.e., "simultaneous" evacuation of the building. Queues or lines of people waiting to enter a stair have been found to be a problem, particularly in taller buildings. This problem, though, seems independent of the age of the building.

In 1949, stair capacity was determined solely on the 22 inch unit of exit width. This based the capacity on the width, rather than the area of the stairs. Like occupant loads, stairs were rated differently for different occupancies. The 1949 NBC deleted the credit for a horizontal exit, and was the last edition to offer a credit for automatic sprinklers.

Direct comparison with earlier years is difficult because the methods are not mathematically consistent. But for several occupancies, the rated capacity increased significantly over earlier years. This increase allows either more people to use the same exit or for the same number of people to use a smaller exit. Since 1949, the capacities per unit of exit width for stairs have decreased most for assembly occupancies (i.e., more strict), remained essentially unchanged for mercantile (stores) and business (office) occupancies, and increased substantially for residential occupancies (i.e., less strict).

The capacity of hallways in the 1949 NBC was unchanged at 100 people/12 inches (183). Doors were still rated at 100 people/22 inches. In 1955, the approach used for stairs was extended to "level" exits as well—the 22 inch unit of exit width, first used in 1915, became the standard measure for all exits of every type.

With this change, the exit capacity for doors, hallways, and passageways became identical. From 1949 levels, the capacity of hallways and passageways decreased for most occupancies by over 50 percent, almost 80 percent for residences. For doors, the capacity decreased 20 percent for most occupancies, 60 percent for residences. A decrease in exit capacity translates into wider exits.

As noted above, all level exits had the same rated capacity after 1955. However, like stairs, level exits were rated differently for different occupancies. The capacity of level exits did not change from1955 to 1976, when the capacity for most occupancy groups was changed back to the 100 people/22 inch unit of exit width previously specified for doors—a 25 percent increase for most occupancies, 150 percent for residences. The net result has been no change in the exit capacity of doors, but approximately a 45 percent reduction in the exit capacity for hallways and passageways.

The sometimes significant changes in exit capacities (both level exits and stairs) has brought greater uniformity, but the reason for the changes are not stated. Perhaps the travel rate has been found to be independent of the occupancy.

Finally, the 1905 NBC required every apartment above the first story without a room fronting on a street or yard to open "directly to an outside fire escape from at least one room other than a bathroom or water closet compartment, and shall not include a window of a stair hall".[50] There was a whole cadre of building types and uses, even some existing buildings, that needed "such good and sufficient fire escapes, stairways, or other means of egress . . . as shall be directed by the Commissioner of Buildings".[51] Fire escapes were not recognized as exits by the 1915 NBC. In 1931, they were again accepted. But only for existing buildings, and in limited circumstances. This is still true.

Uniform Building Code (UBC)

Egress requirements were relatively unchanged from 1927 to 1946. The number of exits was based upon a chart of "Basic Areas for Computing Required Number of Stairways". The chart had two parts—essentially fire resistive and non-fire resistive construction. Given the occupancy, the chart prescribed the maximum building area permitted for a given number of exits.

Height was also a factor. The base areas assumed a three story building. For two story buildings, the base areas were increased by 50 percent, which reduces the number of needed exits. The base areas were reduced for buildings taller than three stories (2 percent per floor, 10 percent maximum), which increases the number of needed exits. The base areas could be increased by one-third in sprinklered buildings.

As a general rule, only one exit was required from a building; additional exits were required only when the area exceeded the base amount.

In 1946, the UBC adopted the "occupant load" approach, and based the number of exits on the number of people within a building. The load values assigned to the various occupancies were similar to those in the NBC. The reason for the change is not known, but the practical result was an increase in the level of performance, i.e., more exits.

Originally, the 1946 UBC required two exits from all occupancies with an occupant load of more than 50 people. In 1952, hotels/ motels and apartments with an occupant load of more than 10 people needed two exits; the limit remained at 50 people for other occupancies. In 1955, the occupant load limit was reduced to 10 people for all occupancies (except dwellings). By 1961, these limits had been eased to basically the present values. Unchanged since 1970, they are: over 10 people in residential occupancies, 30 people in businesses, 50 people in assembly occupancies, and 50 people (1st floor) or 10 people (floors above 1st) in mercantiles (stores). Though changes since 1946 have gone up and down, the net effect has still been an increase in the required number of exits.

For example, in 1946, hotels and apartments required a second exit when the area exceeded 5,000 square feet (50 people x 100 square feet/person). Previously, a two-story building did not need a second exit until the area exceeded 7,500 square feet. In 1952, a second exit was required when the occupant load exceeded 10 people, so the maximum area with a single exit was reduced to 1,000 square feet (10 people x 100 square feet/person). The building area per occupant increased from 100 to 200 square feet/person by 1961. This raised the allowable area with one exit to 2,000 square feet (10 people x 200 square feet/person), but it is still substantially less than the 7,500 square feet in 1927.

Other occupancy uses show similar results. Only offices over 7,500 square feet required two exits in 1927; today, that area is 3,000 square feet. For mercantile uses, the area has been reduced from 7,500 square feet to 1,500 square feet (1st floor) or 500 square feet (floors above).

The occupant load for dwellings (300 square feet/person) has not changed since first given in 1946. However, no specific mention of dwellings was made until 1955, when an exception explicitly permitted only one exit from an upper floor in a dwelling. In 1961, this changed to two exits from a dwelling when the occupant load exceeded 10 people. This is the rule today.

The 1927 UBC required at least two exits in buildings three or more stories in height. This requirement was deleted in 1946, when the number of exits was solely a function of the occupant load. This changed in 1955 to two exits for all floors above the first, and basements used for other than service of the building. The 1967 UBC went back to the original requirement of two exits in buildings with three or more stories; a second exit was required for the second floor when the occupant load exceeded 10 people. The 1955 provision for basements was not changed. These are the current requirements.

While the second exit was required sooner, the requirements for exits beyond that became more liberal. Under the old system (1927-1943), three exits weren't required until the base area exceeded 9,000 square feet in hotels/motels or apartments and 12,000 square feet in stores or offices. Today, three exits are required when the number of people exceeds 500. This translates into an area of 100,200 square feet for hotels/motels and apartments, 50,000 square feet for offices, and 15,030 to 25,050 square feet for stores. The same is true for the fourth exit, which today is required when the occupant load exceeds 1,000 people. With minor exceptions, these requirements have not changed since 1946.

The 1967 UBC changed the method for computing the number of exits from a story in a building. A percentage of the occupant load from other floors "which exit through the level under consideration" had to be added to the occupant load of that floor.[46] This could increase the number of exits required, particularly in smaller buildings or where the unadjusted occupant load was near a breakpoint. This method had been used since 1946 to calculate the "width" or capacity of exits from a floor.

The UBC computes the capacity of exits differently than the NBC. The occupant load is computed the same, but the unit of exit width is different. The NBC's unit of exit width is 22 inches. The UBC uses one foot, unchanged since first introduced in 1946.

The total "width" of exits (in feet), divided approximately equally among the number of exits required, is the occupant load divided by 50. No distinction is made between level travel and stairs. Under the NBC, one unit of exit width—22 inches—is rated for 100 people (level travel). The UBC would require two feet or 24 inches (100 people divided by 50 people/foot = 2 feet). Approximately 10 percent wider, the UBC is more restrictive than the NBC for level travel exits. It is more lenient than the NBC for stairs and other non-level exits.

Finally, the UBC uses the phrase "building or usable portion thereof"; the early codes used the expression "maximum area" when regulating the number of exits. Though it is easiest to think in terms of an entire building, the concepts are applied to sections of a building, individual floors, and even individual rooms. Particularly today, the policy is that for any space in a building, the people so present must be afforded means of escape adequate for their number.

Conclusion

On balance, the requirements for the number and size of exits have become more restrictive over time. The Egress Guideline for Residential Rehabilitation, part of an eight-volume series published by the United States Department of Housing and Urban Development, offers guidance and some possible solutions for existing buildings that must meet new code requirements. The Egress Guideline not only addresses the number of exits, but also many of the other egress features discussed in the following sections.

Though not mentioned in this section, the codes also specify minimum dimensions for various exits and exit components, such as stairs, doors, and corridors. Many times, the exit capacity provided to comply with these minimum dimensions far exceeds that necessary for the calculated occupant load. The minimum dimensions for various exit components are given in their respective sections of this report.

(f) Stairs and Stair Enclosures

Introduction

It is fundamental law that people should be able to walk safely from a burning building. From upper floors, there is only one way to do this—down a stair. Elevators are not favored because they are subject to power failures. There are also reported incidents where the elevator doors opened on the fire floor and would not close, exposing the occupants. Work continues on more fire-safe elevators, but the use of elevators by other than fire department personnel (who have direct control of the elevator) is not recommended in an emergency.

There are different types of stairs recognized by the codes: interior stairs (open or enclosed), exterior stairs (not fire escapes), and smokeproof towers (open air and vestibule). Though there are obvious fundamental differences, the basic design criteria are nearly identical. They also further common goals:

- to allow building occupants to safely exit,
- to allow fire fighters to safely enter, and
- to prevent fire and smoke from spreading through the stair shaft.

The issues most relevant to existing buildings are:

- whether the stairs must be enclosed,
- the fire resistance rating of the enclosure, and
- the minimum acceptable width.

These issues are important because upgrading to new construction standards could require substantial changes to the physical structure. This can be very expensive. The Egress Guideline for Residential Rehabilitation addresses these issues in greater detail. The Guideline also contains suggested solutions to some more common problems in meeting new construction standards.

Traditionally, stairs have been regulated in the context of an emergency situation—when large numbers of people would have to be evacuated in a very short time. But accident data seem to indicate that the greatest number of accidents and related injuries occur during normal or "non-emergency" use of stairs. (See the discussion on Stairs in the accompanying report, Existing Buildings and Building Regulations.) For this reason, stairs are discussed here as well as under Accident Safety, Health, and Sanitation, Section C(2)(j) below.

National Building Code (NBC)

The 1905 NBC required enclosed stairs in stores, warehouses, factories, fire resistive apartments, and theaters. They were also required in other assembly occupancies as directed by the Commissioner of Buildings. Hotels with more than one stair needed at least one to be enclosed. Fire resistive buildings other than apartments could have open stairs if not over three stories or 40 feet in height, and non-fire resistive apartment buildings needed enclosed stairs only if four stories and basement in height with two or more apartments per floor. No mention is made of offices.

In 1915, enclosed stairs were required in buildings used above the first floor for business (offices and stores), manufacturing, and public assembly, and other buildings more than three stories or 40 feet in height. Apartments above the "entrance floor" required two independent means of egress, of which one had to be an enclosed interior stair.*

The 1931 NBC was much clearer. "All interior stairways in buildings other than dwellings connecting two or more stories whether required as exits or not, shall be enclosed . . . ."[39] This remains the general rule, though there are a few highly specific exceptions.

The 1905 and 1915 NBC regulated the fire resistance of the stair enclosure mostly as a function of the building construction. The 1905 NBC was published before there were "hourly" fire resistance ratings, and enclosing partitions of brick, block, or reinforced concrete provided higher hourly ratings than required in later years. There were different specifications for fire resistive and non-fire resistive construction.

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* The second exit had to be another enclosed interior stair, smokeproof tower outside stair (not a fire escape), or horizontal exit. All of these are "protected" exits. There was a similar provision in 1931.

In 1915, there were separate requirements for fire resistive, ordinary, and wood frame buildings. Partitions enclosing stairs in fire resistive buildings had three hour ratings. Stair enclosures in ordinary buildings were likely two hours, but at least one hour. Enclosures in wood frame buildings were at most one hour, and possibly less.

In 1931 and 1949, the emphasis shifted more to a mixture of the occupancy, the height of the building, and in some instances the number of people and whether or not the stair was a "required exit". Beginning in 1931, stair enclosures had either two hours or one hour fire resistance. Multifamily (apartment) buildings three or more stories need two hour stair enclosures; this was raised to four or more stories in 1949. In 1931 and 1949, buildings exceeding 30 feet to the floor of the topmost story, or with 40 people above or below grade (75 people above, 40 below grade in 1949) also needed two hour stair enclosures.

Since 1955, the fire resistance has been solely a function of the height—two hour fire resistant stair enclosures for buildings four or more stories, one hour enclosures for buildings three stories or less.

The NBC has always been very restrictive as regards exit discharge from stairs. The 1905 NBC required enclosed stairs in non-fire resistive apartments to "have a connecting hallway . . . to the street, inclosed with suitable walls of brick, or other fireproof materials, including ceiling . . . ."[40] There was a similar requirement for fire resistive apartments, and stores, warehouses, and factories needed at least one "stair hall" with a "like connecting enclosure" to the street.[48]

The 1915 NBC was more direct. "All stairways that serve as a required means of exit for one or more of the upper four stories of every building . . . shall lead by a direct line of travel to the first story, and open directly on the street, or to an open-air or fireproof passage leading to the street, or to a yard or court connected with the street."[41] This broadened to every "required stairway" in 1931, and is basically unchanged. An exception was made in 1976 for mercantile and hotel occupancies—a maximum of 50 percent of the stairs could discharge through the first floor space provided other fire protection measures are taken (e.g., sprinklers, travel distance limitations, fire resistant separations).

The 1915 NBC required exit stairs to be interrupted at street level by partitions or doors. The purpose was to "prevent trapping in the basement or cellar . . . people who are trying to escape to the street".[55] This provision remains in the code. This was also the first edition to require emergency lighting in stairs—"an adequate system of lighting, arranged to insure reliable operation when through accident or other causes the regular lighting is extinguished".[56] (Emergency lighting has only been required for certain occupancies.)

The 1905 NBC required stairs in offices, stores, factories, hotels, lodging houses, and schools to be at least 42 inches "in the clear between handrails". Additionally, stairs could be "increased in width when in the opinion of the Commissioner of Buildings an increased width is necessary for the safety of the occupants, up to five feet".[47] This changed in 1915 to a general requirement of 44 inches (within limits, handrails could now project into the stairs). The 1931 NBC added a 36 inch minimum width for single tenant buildings with an occupant load of 40 or less people, dwellings, and apartments. In 1955, the minimum widths remained 44 inches and 36 inches, but size was determined solely by the occupant load—44 inches when the occupant load was 45 or more people. In 1976, the dividing point was eased to an occupant load of 50 or more people. The 1949, 1955, and 1967 editions specifically excluded dwellings. But in 1976, the minimum width of stairs in dwellings was explicitly set at 36 inches, the original 1931 provision.

The 1905 NBC required "proper banisters or railings and handrails".[38] In 1915, two handrails were required, except in dwellings. An intermediate handrail was needed for stairs 84 inches or more in width. This eased in 1931, when only stairs 44 inches or more in width needed handrails on both sides; the minimum width of stairs needing an intermediate handrail was also raised from 84 inches to 88 inches. The "one handrail" exception was deleted in 1976.

The 1905 NBC did not allow winders in theaters. In 1915, they were proscribed for all occupancies, except in "public and other special buildings where the use and arrangement is approved by the Superintendent".[54] The 1931 NBC did not allow winders in "required stairs". This is the rule today.

The 1905 through 1931 editions had varying requirements for stairs extending to the roof. This was more important then because buildings were closer together—most early tenements had shared walls on both sides. People could go up the stairs to the roof and seek refuge or escape through an adjacent building. The 1976 NBC discusses stairs extending to the roof, but does not explicitly require that they do so.

Uniform Building Code (UBC)

Stair enclosure provisions have become more stringent. Originally, only stairs in buildings three stories or more had to be enclosed. In 1946, this was changed to encompass all stairs. Stairs in dwellings and private apartments have always been excepted. An exception for certain communicating stairs eased somewhat in 1970, when an unenclosed stair to "only one adjacent floor" was allowed.[66] Previously, the stair was limited to between the first and second floors.

In 1927, the fire resistance of the stair enclosure was a function of the building construction: two hour enclosure for fire resistive; one hour for ordinary and wood frame. This changed in 1946 to the present system, where the fire resistance is a function of the building height: two hours for buildings greater than four stories; one hour for buildings four stories or less. The fire resistance of stairway doors in buildings requiring a two hour enclosure was increased from one hour to 1-1/2 hours in 1946. Other hourly requirements for stairway doors were unchanged.

The 1927 UBC permitted 50 percent of the enclosed stairs to end at an exterior second floor balcony only 3 x 5 feet in area. A counterbalanced stair or ladder was required only if the balcony floor was more than 12 feet above grade. In 1946, all exits were required to lead directly or through a protected passageway to the street. The only exception permitted today is that 50 percent of the enclosed stairs in an office building may discharge into a sprinklered street floor lobby.

Construction details for stairs have been very stable. The original minimum width of stairs was 44 inches, 36 inches in dwellings. These dimensions have not changed, but became a function of the occupant load in 1946: 44 inches for an occupant load served greater than 50 people; 36 inches for 50 or less; and 30 inches for less than 10. The 30 inch minimum stair width was changed in 1979 to a private stair serving an occupant load of less than 10.

A minimum of one handrail has always been required. The second handrail began and is today required when the width exceeds 44 inches. (The width changed in 1946 to 36 inches, in 1961 to 42 inches, and in 1970 back to 44 inches.) Winders have never been permitted, except in dwellings. The requirement for stairs extending to the roof has eased. Originally, 50% of the stairs in buildings three or more stories in height had to extend onto the roof. This changed in 1946 to <u>at least</u> one stair to the roof, and in 1970 to only one stair in buildings four or more stories in height.

A barrier interrupting stairs extending below the story of exit discharge was first required in 1946. The 1946 UBC also first required emergency lighting for selected occupancies.

(g) <u>Doors</u>

<u>Introduction</u>

The attributes of doors most relevant to the regulation of existing buildings are: minimum width, direction of door swing, fire resistance, and exit capacity. Changes in exit capacity are discussed under "Number and Size of Exits", Section C(1)(e) above.

A fire resistant door is necessary to protect openings in fire resistant assemblies. Otherwise, fire could penetrate the "compartment", and the value of the other fire resistive components would be wasted. Doors in fire rated corridors, passageways, stairs, horizontal exits, and fire and party walls are common examples.

There are three main classes of fire doors, each with a different hourly fire resistance rating. Class A doors (three hours) are used in separations between buildings. Class B doors (1-1/2 and one hour) are used to protect openings in shafts or interior building separations, such as elevator shafts, stairs, and horizontal exits. Class C doors (3/4 hour) are used to separate one room space from another, such as doors to hazardous areas or from a room to a corridor or hallway.

A recent development has been the 20 minute rated "smoke control" door. As the name implies, these doors are intended to resist the passage of smoke to other parts of a building not directly involved in the fire. They are not intended as a major fire barrier.

Fire doors, while providing a major fire barrier, do not always stop the passage of smoke. The standard fire resistance test for doors allows the doors to deform, within limits, in their frames. This deformation can be enough to allow harmful quantities of smoke to spread throughout a building. Smoke control doors have less fire resistance, but they must be more resistant to deformation. This keeps the smoke from passing through the opening. The entire issue is still being developed and is not firmly in place in the codes.

The fire resistance requirements for doors are too detailed to set out below. Like fire resistance requirements in general, there have been more changes in where rated doors are required than in the hourly ratings themselves. The Guideline on Fire Ratings of Archaic Materials and Assemblies, published by the United States Department of Housing and Urban Development, lists the fire ratings of some archaic door types, presents a method for documenting fire resistance when unknown, and suggests a possible means to upgrade fire resistance when necessary.

The direction of door swing is important because in a panic or rush, the crowd of people pushing from behind may not allow the time or space to open the door inward. There have been tragic losses, when victims have been found stacked against the door. A 1915 NBC Note had an interesting twist to the fundamental practice that exit doors should swing in the direction of travel:

"In schools where pupils are trained in fire drill, it is considered essential that classroom doors should open inwards, as they are better adapted to positive control by the teachers in time of panic. If necessary, a teacher can back against a door and hold it until the pupils are in marching order, and the proper time arrives for them to file out."[21]

Any increase in the minimum width of doors presents an obvious problem to existing buildings. The only way to meet new construction standards would be to widen the opening and replace the door and frame. This can get expensive. Some believe that consumer pressures (everything from easier passage to moving furniture) and access for the disabled (e.g., wheelchairs), more than fire safety concerns, are the impetus for change. This may be, for even the earliest minimum widths often resulted in excess exit capacity.

National Building Code (NBC)

The 1905 NBC had no specific dimensional requirements for doors. In 1915, the minimum width of doors was 28 inches "in the clear". This increased to 36 inches clear width in 1931. In 1949, the NBC changed again. Doors serving more than 40 people had to be 34 inches clear (nominal 36 inch door). No minimum was specified for occupant loads of 40 or less people, other than the minimum 22 inch unit of exit width. The 1955 NBC returned to the 1915 requirement of 28 inches clear width.

In 1915, doors to smokeproof towers and exterior stairs (not fire escapes) had to be at least 40 inches clear width. There were no explicit requirements in later editions until 1976, when a clear width of 40 inches was again specified for doors to smokeproof towers.

Under the 1905 NBC, auditorium doors and "all doors of exit or entrance" from theaters and other like places of "public amusement" had to "open outwardly".[49] In 1915, all required exit doors in the first or street floor, including doors in vestibules, had to open outwards, though dwellings and apartments were excepted. Fire doors in smokeproof towers and all exit and entrance doors from theaters also had to swing in the direction of exit travel. The 1931 NBC added to this list doors from rooms with more than 15 people.

The 1949 NBC still required all exit doors in places of assembly and smokeproof towers to swing in the direction of exit travel. But doors from rooms and doors to the street, including doors in vestibules, did not have to swing in the direction of exit travel unless the occupant load was 40 or more people. This was raised to 45 or more people in 1955. Doors to stairs serving 45 or more people also had to open in the direction of travel.

The 1967 NBC added a requirement that fire doors in horizontal exits swing in the direction of exit travel, and if used as an exit in both directions, there had to be "adjacent doorways with signs indicating direction of travel".[67]

There was a major change in 1976, when the NBC required that all doors in a "means of egress . . . shall swing in the direction of exit travel".[68] The only exceptions were for dwellings and rooms or spaces occupied by not more than 50 people. Though less restrictive for "rooms or spaces" (the threshold limit was raised from 45 to 50 people), the code was far more restrictive for other doors in exits (particularly where the 45 person threshold had applied before).

Uniform Building Code (UBC)

The basic requirements for egress doors are unchanged since first introduced in 1946, and are applicable when the occupant load is greater than 10.

The minimum width of a doorway and the maximum width of a single door leaf remains 36 inches and 48 inches, respectively. Doors in assembly occupancies were always required to swing in the direction of exit travel. This was expanded to include hotels/motels and apartments around 1935, and changed further to the present general requirement for all doors serving an occupant load of fifty or more in 1946.

(h) Travel Distance and Dead-Ends

Introduction

The codes specify the maximum allowable distance to an exit because heat, smoke, and other fire gases can make access to an exit extremely difficult. Poor visibility and difficulty in breathing are particular problems. Controlling dead-ends is important because people traveling down a corridor may turn onto a dead-end and become lost, confused, or trapped. People within the dead-end have access to only one exit. Should fire block this path, there is no alternative route.

Travel distances have tended to increase over the years, while limitations on dead-ends have become more restrictive. Both, though, can be problems for existing buildings because the construction of additional exits can necessitate major structural changes and substantial expense. The Egress Guideline for Residential Rehabilitation discusses travel distance and dead-ends in greater detail, and offers some alternative solutions to new construction requirements.

National Building Code (NBC)

The 1905 NBC did not regulate travel distance. In 1915, no part of any floor above the first could be more than 100 feet from an entrance to an exit. The 1931 NBC added a provision that where the floor area was subdivided into rooms (e.g., hotels, offices), the travel distance could be increased to 125 feet and measured from the door of the room to the hallway.

The 1949 edition added a 50 percent increase when the building was either sprinklered or of "fireproof" or "semifireproof" construction. In 1955, the travel distance in assembly and business (office) occupancies was increased to 150 feet (up from 100 feet). Travel distance in hotels, apartments, and offices could still be measured from the corridor room door, but the previous 125 foot limit was reduced to 100 feet. The 50 percent increase for automatic sprinklers remained, but the increase for superior construction was limited to buildings "occupied exclusively by stocks of noncombustible material not packed or crated in combustible material".[23] The 1967 edition changed the travel distance in assembly occupancies back to 100 feet.

In 1976, the maximum travel distance from any point in an assembly occupancy to an exit was 100 feet (150 feet if sprinklered). On the ground floor, the allowable distance was 150 feet (200 feet if sprinklered). The travel distance in business (office) occupancies increased to 200 feet (300 feet if sprinklered), but this must be measured from "any point in a story" rather than the door to the corridor as allowed previously. The travel distance in mercantiles (stores) remained at 100 feet (150 feet if sprinklered), but in areas not used for sales subdivided into rooms, the travel distance could be measured from the room door (except that no point in the room could be more than 50 feet from the door). In apartments and hotels, the travel distance to an exit from the door to sleeping rooms along a "hallway or corridor connecting two or more exits" cannot exceed 100 feet (150 feet if sprinklered). Except at street or grade level, all parts of a living or sleeping room must be within 50 feet of the door to the corridor.[65]

Dead-ends were not regulated until 1949. In that edition, hallways "above the first story" in hotels, multifamily (apartment) houses, and offices were allowed a maximum dead-end length of 50 feet. A 50 percent increase was given for automatic sprinklers or "fireproof" or semifireproof" construction. These increases were deleted in the 1955 edition, and the 50 foot limit on dead-ends applied to all occupancies.

In 1976, aisles in assembly occupancies, and hallways in businesses (offices), hotels, and apartments above or below the story of exit discharge were limited to a maximum 20 foot dead-end. The length of dead-ends was cut from 50 feet to 20 feet, but the occupancies affected returned to the original 1949 provisions. On balance, regulations on dead-ends have become more restrictive, particularly so since there were no real limits at all prior to 1949.

Uniform Building Code (UBC)

The maximum travel distance of 150 feet to an exit is basically unchanged from the first edition in 1927. However, there have been a number of modifications during this period. The 1927 UBC limited the travel distance in buildings three stories or more to 75 feet, but this was deleted by the 1935 edition.

Surprisingly, the 1946 edition contained no direct regulations on travel distance. Whether this was an oversight or deemed unnecessary given the comprehensive changes in other egress requirements is uncertain. However, the requirements for travel distance were reinstated by the 1952 edition, which added a 50 foot increase in sprinklered buildings. An increase for fire resistive construction was also introduced in 1952, but this was deleted by 1970. The 1979 edition added a 100 foot increase if the last 150 feet is a fire rated corridor.

The early editions only prohibited dead-end corridors in schools, places of detention, and buildings with "sleeping rooms". In 1946, corridors above the first floor serving more than 10 people could have no dead-ends. The code now applied to all relevant occupancies, instead of the three listed previously. The 1952 UBC eased a bit, allowing dead-ends of 12 feet, but the 1961 edition ended the distinction between the first and upper floors of a building and allowed a dead-end (20 feet maximum) only when the occupant load was 10 or less. Dead-end corridors of any length on any floor which served more than 10 people were not permitted.

The 1967 UBC eased, and corridors with an occupant load of more than 10 were allowed a 20 foot dead-end. In 1970, corridors serving less than 10 people (one less person than before, i.e., more restrictive) were again excluded from any limitation on dead-ends.

So, since the early codes, the total ban on dead-end corridors expanded from schools, places of detention, and buildings with "sleeping rooms" to include all relevant occupancies, but eased to exclude corridors serving less than 10 people and allow dead-ends of 20 feet all other times. On balance, limits on dead-ends have become more severe.

(i) Corridors

Introduction

A means of egress has three parts: the exit access, the exit itself, and the exit discharge. The codes have not always been consistent in their terminology, but a "corridor" provides access to an exit, while a "passageway" is a protected path to safety when an exit does not discharge directly to the street.

The codes have long required exits to discharge to the street or through a protected passage to the street, so requirements for passageways should not be a major problem for existing buildings. Where there are problems, the likely issues would be fire resistance, too many exits discharging into a common passageway, or an exit discharging into another building space without a protected path to the outside.

The need for a protected exit access was not viewed as strongly as the need for a protected exit discharge, especially in the early codes. But fewer buildings, particularly in the crowded inner cities, had the long corridors and travel distances more common today. Thus, a protected access has become more important, or perhaps more necessary. Also, early codes required exits to be "independent" and "separate" of each other. Once corridors were allowed to connect to more than one exit, there was an even greater need to prevent a fire in a room adjoining the corridor from blocking access to the various exits.

Codes have regulated the fire resistance of corridors in three different ways:

- as a function of the occupancy class,
- as a function of the type of construction, and
- as a means of egress regardless of the construction type or occupancy class.

The reason for these varying approaches is not known.

National Building Code (NBC)

The NBC has never required a fire rated corridor in the context of a means of egress. It has, though, required them as a function of the occupancy and, in the early codes, the type of construction.

The 1905 NBC required "All hall partitions or permanent partitions between rooms in fireproof buildings . . . [to] be built of fireproof material . . . ."[60] This would seemingly include corridors leading to an exit. Other specific provisions are unclear because such terms as "stair halls", "staircase halls", "hall stairs", "stair hall inclosure", "hall inclosures", and "hallway" were used but not defined.

The "staircase halls" in stores, warehouses, factories, and certain non-fire resistive apartments had to be "inclosed" with brick or other like materials. "Stair halls" in fire resistive apartments were treated similarly. Specific mention is made of a protected "hallway" from the stairs to the street, but with the exception of the general requirement for "fireproof" hall partitions in fire resistive buildings, no reference is made to a hall to a stair.

The 1915 NBC was more direct. A special provision limited to "non-fireproof" apartments required partitions "to separate apartment from apartment, or any part of an apartment from the public hallway or other public part of the building".[61] In fire resistive buildings, "public hallways" had to be "enclosed and separated from the rest of the floor space" by two hour partitions.[62]

In 1931, the special provision for "non-fireproof" apartments expanded to include all apartments, regardless of the type of construction.* Buildings of ordinary or frame construction needed one hour partitions; other construction types needed two hours. Since 1949, only one hour partitions have been required.

The 1931 NBC no longer required fire rated corridor partitions in fire resistive buildings, though only "incombustible material . . . [could] be used in the construction of corridor partitions".[63] "Semi-fireproof" construction generally required one hour partitions, though no special mention was made of corridor partitions. There were no relevant requirements for the other construction types.

The 1949 NBC modified the general requirement noted above for semifireproof buildings. One hour rated partitions were needed only when the partition contained combustible materials. Noncombustible partitions did not have to be fire rated. Therefore, as of 1949, fire rated corridor partitions were no longer required as a function of the building construction classification.

There were no other changes until 1976, when the requirement for one hour corridors in apartments was expanded to include schools, day care centers, health care facilities, and hotels.

The 1915 NBC specified a minimum width for "public hallways" of 44 inches plus an additional eight inches for each apartment over three per floor. In 1931, the minimum width was still 44 inches, but was reduced to 36 inches in dwellings, apartments, or where there were less than 40 people served. In 1955, the minimum width was reduced to 36 inches for 45 people or more; 30 inches if less than 45 people. The 1976 NBC had no section on corridors or hallways, but the index cross-referenced "hallways" to "exit passageways". The minimum widths there eased to 36 inches, but only for 50 people or more—30 inches for less than 50 people.

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* The 1931 NBC required two "separated independent" exits from apartment buildings. Access to these exits could not be through a common corridor or hallway unless the enclosing partitions had at least one hour fire resistance. Considering the general requirement for fire rated corridors in apartments, this provision seems redundant. A similar requirement in the 1949 edition applied to all occupancies. However, in the 1955 NBC, two or more exits could share a common corridor without any special conditions.

However, under a new section "Access to Exits", the minimum width "of an exit access" is only 28 inches, unless otherwise provided for a specific occupancy. Exit passageways are not normally "exit access", so 28 inches seems the new minimum. Hallways from sleeping rooms in dwellings must be at least 36 inches wide.

Uniform Building Code (UBC)

The 1927 UBC required "permanent" partitions to have a one hour fire rating in all fire resistive and heavy timber buildings and in buildings of ordinary construction four stories or more in height. The 1943 UBC no longer required one hour partitions in buildings of ordinary construction, but the 1952 edition came back with a general requirement for one hour partitions in fire resistive, heavy timber, and all "protected" construction types (i.e., one hour fire resistance for all major structural components). This is unchanged.

The 1927 edition excepted single tenant stores and offices with partitions less than three-fourths of the height of the room and the upper one-fourth of glass. The exception seems to address a method of subdividing a large open area into separate offices or work stations, rather than a typical situation with separate rooms off a corridor. In 1943, this exception was cut back to only "temporary" partitions, though the design specified was no different than described above.

By 1961, the exception expanded to permit noncombustible partitions, but the entire exception was limited to designs when the non-rated partitions did not "establish a public corridor or a private corridor serving an occupant load of 30 or more . . . ."[64] In 1967, the limitations on "temporary" partitions was deleted, and the distinction between "public" and "private" corridors became a general limitation of less than 30 people served. There have been no changes since.

The means of egress chapter has had a section on corridors since the first edition in 1927. But fire rated corridors were not explicitly required until 1946, and then only for an occupant load of more than 10 people. This applied to all occupancies, except one-story buildings occupied as stores and offices. By 1961, "private" corridors serving an occupant load of less than 30 people and drinking and dining establishments with less than 100 people were also excepted. The 1967 UBC excepted only corridors serving less than 30 people in a single tenant one-story building used as a store, office, or drinking/dining establishment. In 1970, the general requirement for a rated corridor was raised from an occupant load of more than 10 people to an occupant load of 30 people or more. This made the previous exceptions unnecessary, and they were deleted.

Transoms, the major category of unprotected openings in corridor or hallway partitions, were also prohibited in 1946 in buildings more than one story in height with "sleeping rooms" (i.e., hotels), regardless of the occupant load. The 1961 edition allowed ventilation louvers with automatic fire shutters in fire rated corridor walls. This provision was deleted in 1970, when the requirement for doors in fire rated corridors was changed from a standard fire door to a tight-fitting smoke or draft stop fire assembly. These changes reflected an increased sensitivity to the problem of smoke and other fire gases. The 1976 UBC required corridor doors to be either automatic or self-closing. Automatic closing doors could only be activated by a smoke detector; heat detectors were not acceptable.

The 1927 UBC specified a minimum width for corridors of 36 inches. This was increased in 1946 to 44 inches, though the entire section applied only to corridors serving as a required exit for an occupant load of more than 10 people. No minimum was specified for an occupant load of 10 or less. An exception was made in 1979 for dwellings and within dwelling units of hotels and apartments—regardless of the occupant load, a minimum width of 36 inches is required.

(j) Horizontal Exits

Introduction

A horizontal exit is a protected way of passage from one building space to another, through or around a fire rated wall or partition. The fire resistance rating is normally two hours. These spaces may be different parts of the same building, or different buildings either adjacent or connected by a bridge or passageway. The appeal of horizontal exits was clearly articulated by the 1915 National Code:

> "As a means of rapid and safe egress from a burning building, the use of horizontal exits through or around a fire wall or a fire exit partition are very strongly recommended. Such an exit would afford an area of quick refuge upon either side. An important feature of the horizontal exit is that it removes necessity for hasty flight down long stairways in case of fire. The physical effort of hurrying down stairs from a height of even eight or ten stories is excessive, especially for those who are not strong. In still higher buildings there is always danger of stairways becoming blocked by people collapsing from exhaustion before reaching the street level. Much of this danger is removed when people know they are safe."[22]

Particularly where travel distance is a problem, constructing a horizontal exit can be a way to relieve exiting problems in existing buildings. Horizontal exits are also discussed in the Egress Guideline for Residential Rehabilitation developed by the United States Department of Housing and Urban Development.

National Building Code (NBC)

No mention was made of horizontal exits in the 1905 NBC. In 1915, buildings over 90 feet in height required one means of exit to be either a horizontal exit or a smokeproof tower. The 1915 NBC also allowed a reduction in the width of stairs when horizontal exits were provided. The capacity of these stairs increased from 14 people to 50 people per unit of exit width. In 1931, the needed width of stairs could be reduced by two-thirds.

Under the 1915 NBC, an opening in a fire wall used as a horizontal exit needed a self-closing fire door on one side of the wall and an automatic fire door on the other. The self-closing fire door was a substitute for the normal second automatic fire door "to prevent the passage of smoke through the opening, which might under certain conditions, render an adjoining floor area untenable before the heat would be sufficient to close the automatic door."[52] This appears to be the first "smoke barrier" ever required in modern codes.

To insure adequate room for people on both sides of the horizontal exit to gather, the 1915 NBC required an available floor area sufficient to hold the joint occupancy on the basis of 3 square feet/person. This was raised to 3-1/2 square feet/person in 1931, but reduced back to 3 square feet/person in 1949.

The 1915 NBC also required at least one enclosed stair on each side of the horizontal exit. In 1931, there had to be either an enclosed stair or smokeproof tower on each side adequate for the number of people on "either side". Under the 1949 NBC, the stair had to be sized for the number of occupants on "that side" of the horizontal exit. The 1976 edition fell between the 1931 and 1949 editions, requiring the stair or other exit on each side of the horizontal exit to be not "less than 50 percent of the number of units required for the building or connected building".[59] Very old existing buildings may not meet these requirements. But there should not be a major problem unless the number of people is large.

The 1967 NBC added that horizontal exits intended to be used from both directions needed two doors, with one swinging in each direction and marked accordingly.

Uniform Building Code (UBC)

Horizontal exits have always been in the UBC. There were no significant changes until 1946, when a requirement was added for an exit to grade on the other side of a horizontal exit. Adequate floor space on the basis of three square feet/person was also first required in 1946. Unlike the NBC, the floor space is based on the number of people using the horizontal exit, not the combined occupant load.

The fire rating of the wall forming the horizontal exit was downgraded from a "fire wall" to an "occupancy separation wall" in 1943. This was a reduction from 3-4 hours of fire resistance to 1-2 hours. The fire resistance was explicitly stated at one hour by 1962, but raised to the present requirement of two hours in 1970.

The first UBC originally required one hour protection for openings, and doors could be held open with heat-sensitive fusible links. This remained unchanged until 1970 when the opening protection was raised to 1-1/2 hours, normal for a two hour wall. In 1979, doors had to be "automatic-closing" upon activation of a smoke detector. Heat activated closing devices were no longer permitted.

(k) Smokeproof Stairs

Introduction

"Smokeproof stairs" is not a code term. The Uniform code has called them smokeproof enclosures since 1946; the National Code has called them both smokeproof towers (1915, 1967, 1976) and fire towers (1931, 1945). But they are essentially enclosed interior stairs with one key difference—access to the stair is through a protected space either open to the outside air or otherwise ventilated. This "air lock" between the building and the stair enclosure is added protection designed to keep the exit free of smoke and heat.

National Building Code (NBC)

Smokeproof towers were first mentioned in the 1915 NBC. Smokeproof towers, enclosed interior stairs, and outside exit stairs (not fire escapes) were the only recognized "vertical" exits. This is still true.

In 1915, buildings over 90 feet in height needed at least one exit to be either a smokeproof tower or a horizontal exit. Stores, restaurants, and factories over 55 feet in height without an enclosed interior stair with "hallways enclosed with fireproof partitions" required at least one smokeproof tower.[57]

The 1931 NBC changed the name to "fire towers". At least one fire tower was required in buildings greater than 60 feet in height, 100 feet in sprinklered buildings with two or more "conforming" stairs. The 1949 NBC had no explicit requirement for fire towers to be installed, though there were design criteria. For an unknown reason, fire towers were not mentioned in the 1955 NBC. "Smokeproof" towers were back in the 1967 edition, but like the 1949 NBC, they were not explicitly required to be installed. Smokeproof towers were made part of the high-rise or "tall buildings" code package in 1976. Every building over 75 feet in height and five stories needs at least one smokeproof tower.

The NBC has always required a balcony or vestibule open to the outside air between the building and the stair enclosure. Likewise, the doors at both ends of the vestibule had to be self-closing fire doors swinging in the direction of exit travel. The 1915 and 1976 editions specified a minimum door width of 40 inches. Other details are the same as for interior stairs, and the access to the exit is regulated as a hallway.

The 1915 and 1949 NBC required smokeproof towers to be enclosed the same as interior stairs. The 1931 edition specified eight inches of brick or reinforced concrete. In 1967 and 1976, two hour fire resistant enclosures were specified. Any difference between the three approaches is likely not significant.

Smokeproof towers have to discharge directly to a street or into a protected passage to the street.

Uniform Building Code (UBC)

Originally called smokeproof towers, the name was changed to smokeproof enclosures in 1946. They have always been addressed in the code. Basically, buildings five stories or more in height were required to have at least one smokeproof enclosure. This eased in 1970 to buildings with a floor more than 75 feet above the highest grade. Another 1970 change allowed the vestibule or "air lock" between the building and the stair enclosure to be mechanically or naturally (i.e., open to the outside air) ventilated.

The fire resistance of the stair walls, floors/ceilings, and supporting structural frame has lessened somewhat over time, but is still within the same basic range. Like the NBC, a two hour rated enclosure is now required.

The provisions for doors changed in 1970 when the UBC first recognized mechanical ventilation (ventilation of some form is needed to keep smoke and hot gases from entering the stairs). Requirements for doors to naturally ventilated smokeproof enclosures did not change—one hour doors at both ends of the balcony or vestibule. Mechanically ventilated smokeproof enclosures, though, needed a 1-1/2 hour fire door between the building and the vestibule and a "tight-fitting" door between the vestibule and the stair. In 1979, this "tight-fitting door" was changed to a "tight-fitting smoke and draft control door having a 20-minute fire-resistive rating".[58]

Discharge from smokeproof enclosures has always been either direct to grade or through a protected passageway. Openings into the passageway have never been permitted; the fire rating of the passageway walls was reduced from 4 hours to 2 hours in 1952.

(1) Interior Finish

Introduction

Combustible interior finish materials are not only a source of fuel, but they furnish a path along which a fire can spread. This combustible path permits a fire to spread from the room of origin, and often leads to the blockage of otherwise available exits. In extreme cases, the exits themselves may become involved in fire. Interior finish materials may produce great amounts of smoke, and the combustion products of some may be extremely toxic.

Codes have long realized the hazardous properties of some materials. The 1905 National Building Code controlled the use of wainscotting. But interior finish was not seriously regulated until the standard performance test ASTM E-84 was refined in the late 1940s. Like fire resistance, it became possible to specify a level of performance without the detail.

The main performance measure is "flame spread", which is how far and how fast flames can spread across the surface of the test sample. The resulting flame spread rating is expressed as a number on a continuous scale. A higher number denotes a greater hazard. A similar scheme is used for smoke production. No single method has yet been developed and accepted to measure toxicity.

Interior finish was not as serious a problem in the early 1900s because most finishes were inorganic and did not burn. Plaster was the most common finish. When wood was used, it generally was thicker, which has a lower flame spread rating than the thin veneers used today. The development of synthetic materials, often petroleum based, exposed insulation, certain vinyl and other like wall coverings, and new uses such as carpeting on walls, has aggravated this problem in recent years.

Combustible interior finish and decorations were a major factor at the Cocoanut Grove Night Club fire (1942: 491 dead). There were numerous articles on the dangers of combustible fiberboard ceiling tiles during the 1950s, and combustible ceilings were a factor in several large loss fires around this time. A concealed combustible ceiling was believed to have fueled the Beverly Hills Supper Club fire (1977: 165 dead), and flammable decorations in a dormitory hallway brought tradegy at Christmas (1977: 10 dead).

The codes today are more stringent in their control of interior finishes. This has been necessary to keep pace with the growth of the problem.

National Building Code (NBC)

The 1905 NBC did not permit wood sheathing to be used on walls or ceilings, except in dwellings and private clubs. An additional exception was made for theaters, where wainscotting up to six feet in height was permitted; however, all spaces behind the wainscot had to be solidly filled with plaster. (This alters the burning characteristics and reduces the hazard.)

In 1949, no combustible wall or ceiling finish was permitted in public buildings and places of assembly and "exits therefrom" that would "spread flame over its surface more rapidly than over one-inch (nominal) wood boards covered with ordinary paint or varnish".[42] This rather loose standard was replaced in the 1955 NBC by the E-84 test discussed above.

The interior finish requirements have changed little since the 1955 edition. The most significant change in 1967 tightened a previous exception for business occupancies by reducing the allowable flame spread in rooms or spaces less than 1500 square feet. In 1976, the allowable flame spread of exits in assembly occupancies was reduced, and dwellings were regulated for the first time. A separate section was added on floor coverings based upon a "flame propogation index".* Neither smoke production nor toxicity has been regulated.

Uniform Building Code (UBC)

The UBC did not control interior finish until 1952. The standard scale used to measure flame spread was divided into three acceptable classes, with Class I being the most restrictive. The interior finish of enclosed stairs had to be of Class I. Other exits required Class II materials. The finish in other rooms and areas had to be Class III. The code allowed a Class I or II material to be replaced by one of the next lower class when automatic sprinklers were installed.

The dividing point between Class I and II materials tightened slightly around 1961. The numerical range of materials acceptable as Class III was also reduced at this time, and reduced again in 1976. Dwellings were not regulated until 1979, though finish materials in kitchens and bathrooms are still excluded.

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* This test method has not been widely accepted, but is similar to another test method, the "radiant panel test", which has undergone greater study and is slowly gaining acceptance. For reasons beyond the scope of this report, test results for floor coverings from the E-84 test have been criticized as unrealistic. Thus the effort to develop a new standard test for floor coverings.

The use of finish materials more toxic than burning untreated wood was prohibited in 1961. This requirement was deleted in 1979, likely due to the difficulty in defining the toxicity of untreated wood. A similar requirement for smoke production was also added in 1961. This was changed in 1973 to a numerical rating which is part of the E-84 test.

(m) Automatic Sprinklers

Introduction

The invention of the automatic sprinkler in 1874 marked a new era in fire protection. There were few, if any, municipal water systems, and manual fire fighting equipment was primitive at best. Automatic sprinklers offered a reliable source of protection.

Automatic sprinklers were primarily installed in industrial and commercial properties. But their use spread to other occupancies as the effectiveness of automatic sprinklers became known. The insurance companies also enhanced the benefits of automatic sprinklers through insurance credits for properly installed and maintained systems. The 1915 National Building Code observed:

> "It is generally recognized among fire protection engineers that . . . an approved system of automatic sprinklers in a factory . . . not only furnishes excellent security against fire, but that it soon pays for itself by the reduction in insurance premiums. The period necessary . . . usually varies from four to seven years depending upon the condition surrounding the risk. The automatic sprinkler installation is therefore an excellent financial investment aside from the protection it affords to life and property against fire."[24]

Even today, the economic incentive provided by insurance credits is often the deciding factor in whether or not to install automatic sprinklers. But a more immediate incentive has been the growth of code requirements for automatic sprinkler protection beyond the factory setting, and trade-offs of other building features when sprinklers are installed (e.g., height and area increases, reductions in fire resistance).

National Building Code (NBC)

Outside of factories, the 1905 NBC required automatic sprinklers in basements and cellars of mercantile properties. Sprinklers were also required when "more than two fireproof or non-fireproof buildings communicate, although protected by double standard fireproof doors, . . . where occupied as stores, warehouses, and factories".[25] This latter requirement was in the section on Fire Walls, but the 1915 Note to that section shows the importance given to automatic sprinklers as part of a comprehensive fire protection plan:

"The great value of solid walls in restricting the spread of fire is so well known, argument should be unnecessary to insure their use wherever suitable. A fireproof factory or warehouse with properly restricted areas between fire walls, equipped with automatic sprinklers, and having proper protection to vertical openings and windows, would be practically impossible to burn. The truth of this statement has been demonstrated many times. The folly of building otherwise is a self-evident verity.[14]

The requirement for sprinklers in communicating buildings was deleted in 1931, but the provisions for sprinklers in basements remained. The most significant change occurred in 1931, when a minimum area "trigger" of a 2,500 square foot basement was added.

The 1915 NBC broke new ground when it required sprinklers in "hazardous" areas and for select buildings and uses that exceeded some basic height or area:

"It is the intent of the above requirement to provide sprinkler equipments in buildings or parts of buildings where conditions likely to originate fire exist, and in all buildings of excessive height or area. It must be recognized that automatic sprinkler equipments not only lessen the danger of serious spreading fires, but are the greatest safeguard known in reducing the life hazard in occupancies requiring a congestion of people in conjunction with readily inflammable material."[26]

The combinations of height, area, construction type, and occupancy use that require automatic sprinklers are very detailed. It is sufficient to note that they have increased in scope without relevant exception.

The 1949 NBC required certain buildings without "suitable access" to be sprinklered. "Suitable access" was a "usable opening through the wall at each story" of certain specified dimensions on at least one side of the building.[43] The concern was over access by fire fighters and hose streams.* The 1967 NBC limited this provision to windowless residential buildings of varying areas and construction types. This provision was deleted in 1976 because buildings without "suitable access" in exterior walls are not permitted by other sections of the code.

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* The early editions required roughly one-third of any fire shutters installed on exterior windows to be operable from the outside of the building.

The 1915 through 1949 editions allowed the capacity of the exits to be reduced when sprinklers were installed. This credit ended in 1955, but as discussed in Heights and Areas above [Section C(1)(c)], there have always been area increases for automatic sprinklers. Though phrased in terms of an "increase" in area, the intent of the code is to "limit" the potential hazard to proportions manageable by the fire department. As the 1915 NBC noted:

> "It is generally conceded that five stories is the maximum height to which water can be thrown effectively by a fire department from the street level, and that 50 feet is the maximum distance inside a building which can be reached by a stream through a window. These facts have been a governing consideration in the establishment of the limits of heights and areas in this Code. In addition, the width of the street upon which a building fronts and the height of the building should be considered; a building endangers adjacent property in proportion to its size and proximity to other property.
>
> . . .
>
> "The areas given in this section are based upon an average street width of 60 feet. For less than this width, it does not appear unreasonable to require sprinklers for even smaller areas than herein given, particularly for buildings over two stories high. This could well be placed in the hands of the Chief of the Fire Department."[27]

The 1915 NBC required sprinkler systems to have two independent water supplies, one of which had to be "automatic". Thus the wooden water tanks atop many older buildings. By 1949, enough confidence had been gained in municipal water systems that a single water supply was deemed adequate.

Uniform Building Code (UBC)

The number of building spaces or occupancies requiring automatic sprinklers has grown steadily since 1927. Originally, sprinklers were required in cellars of buildings of various sizes and occupancy because poor or no fire department access made it difficult to fight a fire. Gradually, the requirements were expanded to include various basements (a basement must have a minimum portion of the room space above street level, whereas a cellar could be entirely below street level).

About 1952, "windowless buildings" were required to be sprinklered. Again, the consideration seemed to be lack of fire department access. In 1961, portions of a building more than 75 feet from an exterior wall opening also had to be sprinklered. This too relates to the ability of the fire department to fight a fire deep within a building.

A requirement for sprinklers in rubbish and linen chutes, except in dwellings, was added in 1970, along with any retail sales area greater than 12,000 square feet in a single floor area or more than two stories in height. This changed in 1979 to a single retail sales area of 12,000 square feet or a total sales area of 24,000 square feet on all floors. Sprinklers in exhibition hall display areas larger than 12,000 square feet were first required in 1970; this remains unchanged.

From 1927 through 1943, the number of exits was a function of the building area. These areas could be increased one-third in sprinklered buildings.

(n) Standpipes

Introduction

Standpipes can be designed for use by either the fire department or building occupants, or both. They are particularly useful to the fire department in tall buildings because they eliminate the need to lay hose lines from the street to the fire floor. They serve a similar purpose in large area buildings as well, where fire fighting from the exterior may not be practical. Fire department standpipes are required to be within stair enclosures wherever possible. This provides fire fighters a protected staging area from which they can advance their hose lines onto the fire floor.

National Building Code (NBC)

The 1905 NBC required fire department standpipes in buildings greater than 55 feet in height. The size of the standpipe was related to the height of the building. Existing buildings were also required to have standpipes (though existing standpipes of lesser dimensions than permitted for new construction could be retained). The building height v. standpipe size was tightened in 1915, and again slightly in 1949, but returned to essentially the 1915 dimensions in the 1976 edition. Perhaps this was in recognition of the improvements in fire department apparatus, which are used to supply water and to pressurize the standpipe system.

The NBC also specified the number of standpipes needed. In 1905, a standpipe was required at each end of a building more than 100 feet deep fronting on two or more streets; "large area" (not defined) buildings needed one standpipe at each stairway, or within each stairway enclosure. This changed in 1915 to one standpipe for each separate fire area exceeding 2,500 square feet, with at least one standpipe within 75 feet of every exterior wall in the building. [The Note quoted in Automatic Sprinklers [Section C(1)(m)] stated that 50 feet is the maximum effective reach of a fire hose stream through a window.] The final change came in 1931—every part of a floor must be within 30 feet of a nozzle connected to 100 feet of hose.

The 1905 NBC required standpipes to be "within fireproof stairway enclosures where . . . of such construction, and as near stairways as possible where they are not so enclosed."[28] This is essentially the same today.

Standpipes suitable for use by building occupants were required in the 1915 NBC. (The forces produced by hose streams supplied from fire department standpipes could injure untrained users.) Standpipes for "private protection" were required in new and existing buildings three stories or more in height. No further mention of private standpipes was made until the 1976 NBC. Though there are design criteria, there appears to be no specific requirement that they be installed.

Uniform Building Code (UBC)

Dry standpipes are intended for use by the fire department, and the water is drained after every use. Originally required in 1927 for buildings three or more stories in height, this changed to four or more stories in 1952. The number was a function of the building area, basically one standpipe per 10,000 square feet of floor area. There was a slight easing but practically no change until 1970.

The 1967 UBC required that dry standpipes "shall be located within stairway enclosures or as near . . . as possible or shall be on the outside of, embedded with, or immediately inside of an exterior wall and within one foot (1') . . . of an opening in a stairway enclosure or the balcony or vestibule of a smokeproof tower or an outside exit stairway".[35] This section does not require standpipes—this was done by another section of the code—only where they may be located.

In 1970, the section was rearranged and the sub-section "Number Required" was deleted. Instead, the sub-section "Location" directed "There shall be one dry standpipe outlet connection . . . at every floor . . . above the first floor of every required enclosed stairway or smokeproof enclosure."[36] This changed language seems mandatory—one standpipe in <u>every</u> enclosed stairway or smokeproof enclosure. Additionally, no point in the building could be more than 130 feet travel distance from an outlet. This could increase the number of standpipes even more.

By 1976, the 130 foot travel distance limitation had been deleted, and the number of outlets changed to a "connection at every floor . . . above the first story of every required stairway and each side of the wall adjacent to the exit opening of a horizontal exit".[37]

As to location, outlets at enclosed stairs had to be within the enclosure. In 1967, they only had to be "within stairway enclosures or as near such stairways as possible . . .".[35] The 1970 UBC also required "portions of dry standpipe systems" not within a stair or smokeproof enclosure to be "protected by a degree of fire resistance equal to that for vertical enclosures in the building in which they are located".[36]

In 1979, standpipes were no longer classified as "wet" or "dry". Instead, there were three classes. Class I was intended for fire department use. Apparently, they could be either wet or dry (i.e., either filled with water or empty when not in use). Class II was designed for use by building occupants. Class III could be used by either building occupants or the fire department. One outlet was for the fire department, and had no hose supplied; the outlet for building occupants had a hose and nozzle usable by untrained people.

There was no change in the number and location of Class I (previously dry) standpipes.

The size of dry (now Class I) standpipes was originally a function of the number of stories. This changed by 1935 to a performance requirement based upon a specified water flow—effectively three hose streams. In 1970, the size became a function of the building height measured in feet. The hydraulic equivalency of these three schemes is unclear, but the present provisions seem slightly more lenient.

Wet (now Class II) standpipes are normally filled with water and are intended to be used by building occupants. Since 1927, they have been required in many large assembly occupancies, plus others, primarily retail stores, offices, hotels/motels, and apartments, over a certain height or area. The number of people, building height, or area exempted has eased somewhat over time.

The number of wet standpipes has always been determined by the distance from the standpipe connection to any point in the building. But the permitted distance has increased from within "reach" of a 75 foot hose, to within 20 feet of a nozzle on a 75 foot hose in 1970, to within 30 feet of a nozzle on a 100 foot hose by 1976. There was no change in 1979 for Class II (previously wet) standpipes.

The size of wet standpipes has decreased, likely due to improvements in municipal water systems. The hydraulic performance requirements, i.e., how much water must be deliverable to the user, are difficult to compare because the design approach changed in 1970. It seems, though, that the present requirements are reasonably identical or perhaps slightly more lenient than in the past.

In 1970, combination standpipes were required in every stairway or smokeproof enclosure in buildings more than 150 feet in height. A combination standpipe has hose lines for use by building occupants plus outlets for heavier hose streams that could only be safely handled by trained fire department personnel. This requirement is unchanged.

However, under the 1979 UBC, combination standpipes are known as Class III standpipes. "Combination standpipes" in the 1979 UBC are now systems where the standpipe outlets and automatic sprinkler system are supplied by common piping.

(o) Fire Detection and Alarm

Introduction

There are three parts to a fire detection and alarm system. The system "detects" the fire and sends a signal. The signal is processed, and the alarm is sounded. Fire detection and alarm systems can either be automatic or manual. Manual systems need a "human detector" to sound the alarm. An automatic system can detect a fire and transmit an alarm without human intervention.

Detection and alarm technology has improved greatly since 1900. Indeed, the fire protection success of the 1970s was the residential smoke detector. It is estimated that roughly 50 percent of all households have at least one smoke detector, though the households that need them most are in the unprotected 50 percent.

This surprising public acceptance is credited more to free enterprise and mass marketing (plus a tremendous reduction in price through volume sales and technological innovation) than code administration and enforcement efforts. Detectors have only been required for new construction since the mid-1970s, and there have not been that many all-encompassing retroactive regulations.

Today, fire detection and alarm systems can do much more than ring bells. Fire and smoke barrier doors can be closed, elevators safely recalled, ventilation systems adjusted, and pre-recorded emergency instructions automatically given. Computers control the larger and more sophisticated systems.

This sophisticated equipment notwithstanding, the basic fire detection and alarm systems required by the codes are those familiar little red manual alarm boxes located by stairs, doors, and elevators and smoke detectors.

National Building Code

The 1931 NBC required buildings exceeding 75 feet in height, other than multifamily buildings (apartments), to have an "automatic fire alarm system covering all portions of the building".[44] Supervised watchman service and a manual fire alarm system could be substituted for the automatic alarm system. There was no similar provision in the 1949 NBC. However, existing non-fire resistive hotels and public buildings could be one story higher without needing automatic sprinklers if equipped with an automatic alarm system.

The 1955 and 1967 editions had no requirements for automatic and manual alarms. The 1976 NBC, though, did require both types of systems. Large assembly occupancies must have a manual alarm by the main exit, and an alarm must notify either the fire department or a central station as well as the building occupants. (A central station is a service which for a fee provides trained personnel to monitor alarms and transmit them to the fire department.) Hotels and multifamily buildings greater than three stories but less than 75 feet were required to have a similar system, though alarm boxes were required by all exits and the elevators.

Business occupancies (e.g., offices) occupied by more than 1,000 people (or more than 200 people above the first or ground floor) also require manual alarm systems. This system only has to sound a local alarm. A local alarm only sounds within a particular building. Further action is needed to summon the fire department.

The 1976 NBC also required smoke detectors in the hallways, corridors, and public and service areas of hotels and any multifamily building greater than three stories but less than 75 feet. Like the manual alarm system, these smoke detectors must sound a local alarm plus notify the fire department. Buildings protected with automatic sprinklers were excepted from this requirement.

Smoke detectors were required in dwellings and individual dwelling units in multifamily buildings, but these detectors only had to sound a local alarm.

The 1976 NBC also required an automatic detection system similar to that for new construction in existing multifamily buildings greater than three stories and hotels. Detectors, though, are not required in individual dwelling units or guest rooms. Smoke detectors are required in existing private dwellings.

Uniform Building Code (UBC)

A manual alarm system was first required for institutional occupancies in 1970. In 1973, manual alarms were required in apartments three or more stories in height and with more than 15 units, and in hotels/motels three or more stories in height with 20 or more rooms. The requirements are unchanged since then.

Smoke detectors were first required in residential occupancies in 1973. Since then, the scope of the regulation has expanded to include all types of residential uses: hotel/motel, apartments, and dwellings.

(p) High-Rise Buildings

Introduction

High-rise buildings pose particular fire safety problems because large numbers of people and property are situated far above the reach of the fire department. The recent fires at the MGM Grand and Hilton Hotels in Las Vegas are stark illustrations of these special dangers. To address these unique problems, the codes have enacted special provisions for high-rise buildings.

There was special concern after several high-rise fires in New York City in the early 1970s. Soon after, the federal government's General Services Administration (GSA) sponsored the Airlie House Conference on high-rise fire safety. The application of fault trees and other logic systems to fire protection problems and the code "package" adopted by the model code groups for high-rise buildings grew from the work and attention begun at this Conference.

National Building Code (NBC)

The 1905 NBC controlled high-rise buildings essentially by limiting the maximum height of any building to 125 feet and requiring buildings over 55 feet to be of fire resistive construction. In 1915, height was limited to 10 stories or 125 feet, but the height limitation for fire resistive buildings was deleted in the 1931 NBC.

The 1905 NBC also required buildings over 100 feet high to have a passenger elevator in "readiness" for fire department use. A supply of fire hooks, pails, spanner wrenches, and other equipment was also required to be on hand. Standpipes were required in buildings over 55 feet tall.

The 1915 NBC required at least one exit in buildings greater than 90 feet tall to be either a smokeproof tower or horizontal exit. This requirement did not appear in later editions.

The 1931 NBC required an automatic fire pump for the standpipe system in buildings greater than 150 feet in height. (This was the first NBC which allowed buildings of unlimited height.) A new section "Special Protection of High Buildings"[29] specified an automatic alarm system or supervised watchman service with manual alarm for non-sprinklered buildings, other than multifamily, greater than 75 feet in height. Also, undivided floor space exceeding 5,000 square feet in area and more than 75 feet above grade needed "an approved protective system by which water or other extinguishing agent . . . [could] be applied to or directed at the fire by operating suitable control devices from outside the area affected".[29]

There were no special provisions for "high buildings" in the 1949, 1955, and 1967 editions. In 1976, there was again a section on "Tall Buildings", which were defined as buildings more than 75 feet tall.[45] Tall buildings must have a supervised automatic sprinkler system throughout. This differs from the UBC, which allows a design choice between compartmentation and automatic sprinkler protection. The high-rise package also requires at least one smokeproof tower, a fire emergency control station, fire department communication systems, smoke detectors in elevator lobbies and other elevator controls, manual fire alarms, emergency power, and control over air conditioning and ventilating systems for smoke control.

Uniform Building Code (UBC)

The UBC has always permitted fire-resistive buildings of unlimited height. Fire department standpipes were required in buildings three or more stories in height, first raised to four or more stories in 1952.

The first specific requirement for high-rise buildings was in 1970, when combination standpipes were required in buildings over 150 feet in height. (In 1970, a combination standpipe was one usable by both the fire department and building occupants.) The first comprehensive package of high-rise provisions was adopted in 1973, and revised in 1979. These provisions apply to offices, apartments, and hotels/motels with floors used for human occupancy located more than 75 feet above the lowest level of fire department access. The code requires either automatic sprinkler protection or compartmentation of individual floors to provide separate areas of refuge. The maximum area permitted in 1973 was 30,000 square feet. This was reduced to 15,000 square feet in 1979. Elaborate alarm, communication, smoke control, elevator recall, and standy power and lighting systems are other key parts of the high-rise package.

(q) Existing Buildings

Introduction

With limited exception, building codes are intended to regulate only new construction. Existing buildings are exempted, or "grandfathered", as it is often called. This is discussed briefly in Section A(4) of this report, and at length in the accompanying report Problems with Existing Building Regulatory Techniques.

The early editions of the National Building Code regulated both new and existing buildings. Some provisions applied equally; others set out separate requirements for new and existing construction. Today, the general practice is to regulate existing buildings through a separate ordinance rather than the building code.

National Building Code (NBC)

The 1905 NBC addressed such topics in existing buildings as unenclosed elevator shafts, standpipes, and fire escapes. Existing frame buildings more than three stories were limited to occupancy by no more than six families. The 1915 NBC was more aggressive in requiring the enclosure of stairs, elevators, and other shafts.

Where exits were found to be "inadequate", the Superintendent of Building Construction had authority under the 1915 NBC to require additional exits, automatic sprinklers, or other measures as deemed necessary. The 1931 NBC stated that "where existing exit facilities are inadequate for the safety of the occupants, [buildings] shall be provided with such means of egress as shall be directed in a written order by the building official".[30]

Since 1949, the NBC has had a separate chapter on existing buildings. Unlike the UBC, this section is within the main body of the code. Thus, a community which adopted the NBC by reference would also adopt its retroactive provisions, unless the chapter on existing buildings was specifically deleted.

The provisions are lengthy and detailed, but generally address the number and location of exits and the enclosure of vertical openings. In certain occupancies, the allowable floor loading must be determined and posted. The 1955 NBC added interior finish to the list of regulated attributes, and the 1976 NBC added requirements for detectors in the corridors and public spaces of multifamily buildings and hotels. Detectors were also required in dwellings.

Uniform Building Code (UBC)

The UBC contains an Appendix Chapter that deals with existing hotels/motels and apartments three or more stories in height. A community has to specifically adopt the Appendix Chapter for the provisions to apply. Otherwise, the provision has no legal effect. The Appendix specifies a minimum of two exits, one of which can be a fire escape. Interior stairs and other vertical openings must be enclosed or otherwise protected. Transoms and other like openings are not permitted and must be sealed. These requirements are essentially unchanged since first introduced in 1952.

A 1979 code revision requires smoke detectors to be installed in dwellings when alterations, repairs, or additions require a building permit and exceed $1,000 in value. Battery powered smoke detectors are accepted in existing buildings, whereas smoke detectors in new buildings must be wired directly to the building's electrical system. These provisions are a part of the building code, unlike the Appendix Chapter discussed above.

(2) ACCIDENT SAFETY, HEALTH AND SANITATION

(a) Light and Ventilation

Introduction

Codes regulate light and ventilation through control of various building features. Natural light and natural ventilation are assured by specifying where windows are required, the minimum area of windows, the openable area, the obstruction of windows in terms of distances to adjacent buildings (to meet the light and ventilation requirements), percent of lot occupied, and certain internal space arrangements. Where artificial lighting and mechanical ventilation are allowed by the code, they are specified in various ways.

Site Planning Regulation

In the late 19th and early 20th centuries, site planning considerations of building height, percent of lot covered, and minimum yard requirements were included in tenement laws and early building codes. It was only after the passage of the first comprehensive zoning ordinance in New York City in 1916, and subsequent NBS efforts in the 1920s, that zoning became widespread in the United States. It is beyond the scope of this study to trace the trends in zoning regulation relating to site planning considerations. Thus, the following discussion is limited to trends in the building and housing codes.

Early Codes

Before 1900, the New York Tenement Laws specified maximum lot coverage as 65 to 75 percent for interior lots. By 1901, it was fixed at 70 percent. In 1910, interior lot coverage was reduced to 60 percent. Building height limits were related to street width. By 1910, the height limit was reduced from a multiple to equal the width of the street.

The 1867 New York Tenement Law required windows in rooms to be no less than one-tenth the room floor area and no less than 12 square feet in area. At least one window had to be over 7'6" high, with the top half openable. By 1879, every living and sleeping room was required to have at least one window opening on a street or yard. As of 1900, windows in bathrooms and water closets had to have an area of three square feet or more, and one foot minimum width.

The minimum room window area requirements, as well as the 7'6" height and openability requirement, remained unchanged through the 1901, 1902, and 1903 New York Tenement House Act, and the 1910 Model Tenement House Law, except that the 1910 model law required water closet and bathroom windows to be at least one-tenth of the floor area (rather than three sqare feet).

Prior to 1900, yards were generally specified as 10 feet wide.

By 1901, the New York Tenement House Act recognized courts, in addition to streets and yards, for required window exposure.

After 1901, the minimum width of courts and yards was related to the building height, in a manner that assured 12-foot yards and 12' x 24' inner courts between buildings 60 feet high. Increases and reductions were allowed above and below the 60 foot height, with a minimum of 10'6" x 21'. The Model Tenement House Law of 1910 required courts and yards to be slightly larger, with the 12-foot yard and 12' x 24' inner court minimum specified for 48-foot high buildings.

Inner courts were required in 1901 to be vented by one intake to a street or yard of at least five square feet. By 1910, two intakes of 3' x 7' minimum were required.

Water closet and bathroom windows could open onto a vent shaft (5' x 4' for 60-foot buildings with respective area increase or decrease as a function of building height).

Window requirements in the 1914 Model Housing Law were somewhat stricter than the contemporary National Building Code (discussed below). Minimum window area was one-seventh the floor area, all openable, at least one window had to open on a street, or proper yard or court, to be at least 12 square feet, and to be at least 7'6" high (the latter in multiple dwellings). Alcoves had to be separately lighted and ventilated. Bathrooms and water closets required aggregate window area of at least six square feet, all openable.

These requirements were unchanged in the 1920 revision of the model law, except that all required windows were to open on a street or proper yard or court, and provision for through ventilation by transom, doors or windows was specified. Separate requirements for windows in public corridors and stairways were slightly reduced in area.

The 1914 Model Housing Law also contains elaborate requirements for percent of lot coverage, building height, and yard and court requirements. In 1920, rear yard minimum requirements were reduced (15 feet to 10 feet), but court requirements were made stricter for buildings over two stories in height.

The foregoing details are provided because the tenement laws provide the baseline for subsequent code development. Noteworthy is the trend by 1910 toward improved light and ventilation, as a result of increased yard and court dimensions in relation to building height.

National Building Code (NBC)

The first edition of the "Building Code" recommended by the National Board of Fire Underwriters (later, the National Building Code) was published in 1905. Through the fourth edition in 1915, the NBC included tenement house provisions that were very similar to the New York Tenement House Act.

Percentage of lot coverage for tenements and apartment houses remained at 70 percent until 1915 when it was reduced to 65 percent for deeper lots. Through 1915, the NBC minimum room window requirements, the 7'6" window height and openability requirement, were the same as those of the tenement laws. In 1905, slightly larger minimum window areas were required in basement and cellar rooms. The NBC recognized alcoves, and required them to be lighted and ventilated as required for other rooms from 1905 through 1915. One exception was sleeping rooms in buildings other than apartments or tenements, which could be designed as an alcove to a second, well-lighted room.

The 1905 NBC specified minimum court sizes about half of the previous tenement law minimums (i.e., 6' x 12' for a 4-story building on a lot line, assuring a 12' x 12' inner court), and smaller allowable vent shafts for water closets and bathrooms. By 1915, however, the NBC followed the minimums in the 1901 Tenement House Act (as amended). Several detailed provisions of the 1915 NBC show increased sensitivity to natural lighting and cross ventilation. For example, transoms or interior windows were required for rooms facing narrow courts, and wherever else required by the building official. More significantly, intervening courts were required for rooms deeper than 18 feet in small apartments, apparently to improve the uniformity of lighting and to assure cross ventilation. Also in 1915, water closets and bathrooms could no longer be lit and ventilated from vent shafts (except for existing buildings).

After 1915, window minimums were slightly reduced, but court requirements were significantly increased. The 1913 NBC reduced the minimum window area from 12 to 10 square feet (while keeping the one-tenth floor area requirement) and dropped the 7'6" height requirement. Bathroom window minimums, however, were increased from 3 to 6 square feet. Also, in 1931, kitchens were recognized for the first time as "habitable rooms" and subjected to the window requirements. These window dimensions remained unchanged through the 1976 NBC, except that bathroom minimums returned to 3 square feet in 1949.

Apartment bathrooms could be ventilated by windows opening into vent shafts, and, since 1949, by mechanical ventilation.

Transom and other cross ventilation requirements were deleted in 1931. (Today, interest in such features is being revived due to energy conservation considerations.)

By 1949, alcoves were no longer required to be independently lit and ventilated, but could be considered as part of the adjacent room for area calculation purposes, and kitchens could be designed as alcoves. Both features probably reflect design preferences and market trends, though they may indicate reduced lighting and ventilation performance. By contrast, court requirements became stricter after 1915. In 1931, court width had to be at least one-third the height of the building at every level, with a length of one and a half times the width, for courts serving habitable rooms. By 1955, this minimum court width was increased to equal the height of the building.

Vent shafts (serving nonresidential bathrooms only in 1931), which were much larger earlier, were reduced to a minimum area of 9 square feet or one-fifth the height in square feet in 1931. By 1949, such shafts also could serve residential bathrooms, and from 1955 on this was changed to an area of a half square foot per bathroom served (retaining the nine square foot minimum), which seems to be a reduction in requirement.

In summary, the requirements governing building density as related to light and ventilation became stricter over the years, while window requirements became slightly less strict. Details enhancing uniform lighting and cross ventilation were dropped from the code entirely. This probably reflects the use of mechanical ventilation, permitted for residential bathrooms since 1949, and for all non-residential spaces since 1935.

Uniform Building Code (UBC)

The first edition of the Uniform Code, published by the Pacific Coast Building Officials Conference in 1927, required all windows providing light and ventilation to occupiable rooms in all types of occupancies to be at least one-eighth of the floor area. In residential occupancies, this requirement covered all eating, living, and sleeping rooms. Artificial light and mechanical ventilation could be substituted for natural light and ventilation in all but residential occupancies. The 1927 code did not specify the required exposure of a window for it to qualify, nor was the openable portion of the window area specified.

These requirements remained unchanged until 1946, when the window requirement was extended to all "habitable rooms", including kitchens in residential occupancies. Minimum window areas of 12 square feet for habitable rooms and 3 square feet for bathrooms were added in addition to the one-eighth area requirement. One-half of the minimum window area was required to be openable for ventilation, except that "adequate" mechanical ventilation was permitted in bathrooms. Windows had to open on streets, yards, courts, or porches to qualify, and minimum yard and court widths were specified.

The 1946 light and ventilation requirements were unchanged until 1967, except for a significant reduction in the required cubic feet per minute/occupant of mechanical ventilation in nonresidential occupancies in 1952 (significantly increased again in 1979), and for the specification of hourly air changes for bathroom mechanical ventilation in 1958.

In 1967, minimum yard and court widths were increased significantly to 15 feet or 18 feet instead of 9 feet for a 14-story building.

1970 brought more changes. The minimum required window area was decreased from one-eight to one-tenth of the floor area (retaining the 12 square foot and three square foot minimums). Mechanical rather than natural ventilation was allowed in <u>all</u> habitable rooms, and the number of required air changes in bathrooms was reduced from the 12 specified in 1958 to five. Finally, in 1976, the 12 square foot minimum required window area was reduced to 10 square feet.

In summary, required window areas were reduced slightly over time, while yard and court requirements were increased significantly in 1967.

Standard Building Code (SBC)

Light and ventilation requirements have undergone little change since the SBC's first edition in 1946. Habitable rooms and bathrooms and toilet rooms required minimum windows of at least one-tenth of the floor area (three square feet minimum for bathrooms), and at least half of that had to be openable. In 1979, the one-tenth was reduced to 8 percent of the floor area (or 1/12.5). Since 1946, a building official could substitute skylights, vents, louvers, or mechanical ventilation for windows when providing adequate light and ventilation. This flexibility, however, was reduced in 1973, when mechanical ventilation was prohibited as the only means of ventilation for sleeping rooms.

The SBC specifies that windows must face a street, yard, court or adequate light exposure, but it has never included minimum yard and court requirements.

Some change can be found in two other areas. The first concerns alcoves, which did not require separate windows if 80 percent of the common wall opened to an adjoining room (however, the alcove area had to be added to the room's area for computing required window area). This requirement was reduced to at least 50 percent opening in 1969 (an apparently significant reduction in performance), and modified in 1979 to specify a minimum opening in the common wall (an increase in performance).

The second change relates to classrooms, which from 1946 required directional natural light and a specific provision for natural ventilation. The natural ventilation provisions were gradually reduced, and in 1973, the entire requirement was made optional in apparent recognition of the trend to windowless classrooms and open plan school designs.

In summary, the SBC has shown little change in light and ventilation requirements in the past 34 years.

Basic Building Code (BBC)

Here too, light and ventilation requirements have undergone little change since the BBC's first edition in 1950.

Window requirements were the same as specified in the SBC (one-tenth of floor area, three square feet minimum in bathrooms and toilets, and half openable) and were reduced in 1978 from 10 percent to 8 percent. The BBC always has specified that windows must open on a street, alley, public open space, yard or court, and minimum yard and court dimensions (related to building height) have not changed since 1950.

The BBC allows both mechanical ventilation and artificial light when minimum requirements for natural ventilation and lighting cannot be met. The minimum mechanical ventilation performance specifications (in terms of air changes per hour) for various types of rooms have changed from time to time, some upwards and some downwards.

APHA Standards and Proposed Housing Ordinances

The 1939 APHA Standards established very elaborate requirements, but not for yard or court. Minimum window areas were related to latitude (for example, 15 percent of floor area for Washington, D.C., 30^{o} latitude) with increases required for buildings obstructed on narrow streets. Windows required 30-inch sills, and were to extend almost to the ceiling, and open to the "outdoors". Six foot candles of natural illumination were specified (but this was unenforceable without also specifying standard outdoor conditions). Ten percent of the floor area had to be openable, direct outside exposure was required for each room, and cross ventilation was required for each dwelling unit.

In 1952, APHA simplified and standardized the minimum window requirement at 10 percent of floor area (i.e., a reduction at some latitudes and increase in others), allowed skylights at 15 percent of area, and specified that windows obstructed at a distance of 3 feet or less were not to be counted. Openable area for ventilation was at least 45 percent of window or skylight area. Continuous mechanical ventilation was allowed in water closets. In 1975, APHA reduced some requirements (skylights: 15 percent to 10 percent of floor area; mechanical ventilation need not be continuous), and allowed mechanical ventilation in kitchens.

Model Housing Codes, Uniform, Standard

(Note: The Basic Housing Code, and Basic Property Maintenance Code have not been analyzed.)

The Uniform Housing Code (UHC), published since 1955, has included identical light and ventilation requirements to the contemporary editions of the UBC, except for slight differences related to air-change requirements in bathrooms and water closets.

The Standard Housing Code (SHC) published since 1960, contains light and ventilation requirements based, apparently, on the 1952 APHA Housing Ordinance, reflecting, therefore, a few minor inconsistencies with the SBC (for example, skylight minimum area 15 percent in SHC, but based on building official's judgment of adequacy in SBC). Windows obstructed at a distance of five feet or less could not be counted.

Very few changes were introduced in subsequent editions. In 1969, mechanical ventilation could be substituted for natural in all habitable rooms except sleeping rooms (prior to that, this was allowed only in bathrooms and water closets). Note that since 1946 the SBC has permitted this, a rare example of the housing code being stricter than the building code. Finally, in 1979, minimum window areas were reduced to eight percent of floor area (for consistency with the SBC), and the minimum obstruction distance was reduced to three feet.

(b) Space and Dimensions

Introduction

Codes regulate space as an amenity, primarily in residential occupancies, by specifying minimum room areas, minimum room widths, and minimum ceiling heights. Some codes also specify minimum area or volume of the entire apartment, as a function of the number of occupants, although this latter attribute may be difficult to enforce, since number of occupants is not a physical feature of the building.

In general, minimum room areas and widths were decreased in the 1930s, and have been increasing continuously since the late 1940s. In contrast, minimum ceiling heights have decreased slightly over the past 80 years.

Early Codes

The New York Tenement Laws did not specify room dimensions prior to 1900. Minimum height and minimum cubic feet were specified separately for adults and children.

By 1901, 1902, and 1903, the New York Tenement House Act, while retaining the volume requirements, specified a nine foot minimum ceiling height (except in attics, where a nine foot minimum was specified for at least half the area), and minimum room areas were: at least one room — 120 square feet; all other rooms — 70 square feet.

The Model Tenement House Law of 1910 retained the 9 foot ceiling height minimum, but increased the area requirement to: at least one room — 150 square feet; all other rooms — 90 square feet.

The Model Housing Law's space requirements were similar to the 1910 New York Tenement Law, and slightly stricter than contemporary NBC requirements. In 1914, the Model Housing Law required the following minimums: at least one room (in multiple dwellings) — 150 square feet; all rooms except water closet and bathroom — 90 square feet; room width — 7 feet; ceiling height — 9 feet.

In 1920, the Model Housing Law introduced some slight reductions, as follows: kitchenette -- 50 square feet; kitchenette width — 5 feet; ceiling height in one- and two-family dwellings — 8 feet.

National Building Code (NBC)

The 1905 NBC adopted the 1902 New York Tenement House Act's area minimums (120 and 70 square feet) and ceiling height minimum (9 feet), except that it allowed eight foot minimum ceilings in basements and cellars, and seven foot ceilings in basements and cellars of existing buildings converted into apartments. These dimensions remained virtually unchanged until 1931, except that a minimum room width of seven feet was specified in 1915.

In 1931, substantial reductions were introduced, as follows: minimum room area — 60 square feet; minimum ceiling height — 8 feet (over at least 60 square feet); minimum room width — 6 feet.

The 1931 NBC introduced a minimum volume requirement in all sleeping and living rooms of 480 cubic feet per adult and 300 cubic feet per child.

1949 saw a further reduction of minimum room height to 7'6" (over at least 60 square feet), and some elaboration of room areas, as follows: minimum habitable room area — 70 square feet; minimum kitchen area — 60 square feet; minimum combined kitchen and dining -- 90 square feet; minimum room width -- 7 feet.

However, the volume requirements were deleted, thus making it difficult to determine if the change resulted in increased or reduced space.

The 1949 requirements remained unchanged until 1976, when elaborate new requirements were introduced. The 7'6" minimum ceiling height was required over 90 percent of the required area of dwelling units and sleeping rooms. Minimum areas were as follows: living room — 160 to 180 square feet (depending on number of bedrooms); dining room — 100 to 120 square feet (depending on number of bedrooms); one bedroom — 120 square feet; other habitable rooms — 80 square feet; room width — 8'11" (depending on type of room).

Larger minimum areas also were established for combination rooms, as a function of the number of bedrooms. Finally, requirements were established relating number and area of habitable rooms to the number of occupants (based, apparently, on the 1952 APHA Proposed Housing Ordinance, see below).

Uniform Building Code (UBC)

Residential room size requirements did not appear in the UBC until 1946, at which time the following minimum areas were specified: habitable room (except kitchen) — 80 square feet; kitchen — 50 square feet.

Minimum ceiling heights were specified as 8 feet over 50 percent of room area, and 5 feet as the absolute minimum.

These requirements were unchanged until 1961 when minimum habitable room area was increased to 90 square feet, and ceiling height was reduced from 8 feet to 7'6". 1967 brought further increases in area and reduced ceiling heights, as follows: minimum area of one habitable room — 120 square feet; minimum area of other rooms — 90 square feet plus 50 square feet per occupant over two; minimum area of combined rooms — 150 square feet.

Seven-foot ceilings were allowed in halls. A minimum room width of 7 feet and special minimum areas for efficiency apartments were introduced in 1967.

The final UBC change in minimum areas was made in 1973, as follows: one room — 150 square feet (increase); other rooms (except kitchen) — 70 square feet (reduction). Ceiling heights were further reduced by allowing 7 foot ceilings in all but habitable rooms in 1976, and in kitchens in 1979.

Standard Building Code (SBC)

The SBC did not specify minimum areas until 1976, at which time the following area requirements were established (identical to 1976 UBC): one room — 150 square feet; other rooms (except kitchen) — 70 square feet; room width — 7 feet.

Ceiling height for habitable rooms was 7'6", and for bathrooms, halls, etc. — 7 feet. The only significant change in 1979 was to allow 7 foot ceilings also in kitchens.

Basic Building Code (BBC)

Since its first edition in 1950, the BBC has included residential room dimensional requirements.

The 1950 minimum ceiling heights for habitable rooms were 7'4", 7'6" (first floor) and 8 feet (basement). Minimum room area was 70 square feet, and width — 7 feet. In 1955, 7'6" minimum ceiling heights were specified for most stories. These requirements were unchanged until 1978, when 7 foot ceiling heights were allowed in kitchens, bathrooms, halls, etc., and one habitable room was required to have at least 150 square feet.

APHA Standards and Proposed Housing Ordinances

In 1939, the APHA Standard established minimum space requirements by type of room, as follows: living room (for two or three persons) — 150 square feet; major bedroom — 120 square feet; minor bedroom — 80 square feet.

The standard required two rooms for sleeping, and established no width or height requirements. However, 400 cubic feet per occupant were required in habitable rooms.

In 1952 (and unchanged in 1975), the APHA required dwelling units to contain 150 square feet of habitable room area for the first occupant, plus 100 square feet for each additional occupant. Single occupant bedrooms could be 70 square feet, but 50 square feet had to be added for each additional occupant. Finally, 7 foot minimum ceiling heights were permitted (also, sloping down to 5 feet over less than one-half the area).

Model Housing Codes (SHC, UHC)

The UHC requirements from 1955 were more extensive, and different from those of contemporary editions of the UBC. The 1955 UHC required the following minimums (larger areas and lower ceiling than UBC until the 1967 edition!): area of one room — 120 square feet; sleeping room — 90 square feet, plus 50 square feet per occupant over two; kitchen — 50 square feet; combined cooking and living — 150 square feet; width — 7 feet; ceiling height (all rooms) -- 7'6".

These requirements were unchanged until 1967, when requirements for efficiency apartments were introduced as in the UBC of that year. Subsequently, the UHC requirements were similar to those of contemporary editions of the UBC, with some requirements being slightly reduced (for example, 7 foot ceilings allowed in bathrooms and toilets in 1970, versus 1976 UBC). One apparent inconsistency between UHC and UBC, and tightening of the requirements, was introduced in the 1976 UHC, where the minimum room areas (150, and 70 square feet) were to be increased by 50 square feet per occupant over the first two occupants.

While the SBC contained no minimum room dimensions until 1976, the SHC included requirements with its first edition in 1960. The SHC requirements were similar to those of the 1952 APHA Proposed Housing Ordinance except that until 1969 the incremental dwelling unit area per occupant over the first four occupants, and the incremental sleeping room area per occupant under 12 years of age, were reduced. These requirements had not changed through 1979.

(c) Sanitary Facilities

Introduction

Codes regulate sanitary facilities by specifying the minimum requirements for lavatories, sinks, toilets, bathtubs/showers, garbage facilities, etc.

Early Codes

Prior to 1900, the New York Tenement Laws required a sink with running water in each apartment, adequate water on each floor of a tenement house, and at least one water closet, which could be located in a public hallway, for every two families. Garbage receptacles also were required.

In 1901, 1902, and 1903, a water closet in a separate compartment was required within each apartment; this requirement carried through the 1910 Model Tenement House Law.

The Model Housing Laws of 1914 and 1920 required one sink and one water closet in a separate compartment per dwelling unit. The water closet could not be of wood, and required a waterproof floor.

National Building Code (NBC)

In 1905, the NBC required one water closet for every 15 occupants of tenement houses, and one water closet per apartment (with some exceptions for smaller apartments) in apartment houses. By 1915, a separate water closet in a separate compartment in each apartment was required in all housing as well as a proper sink with running water. The latter requirement was changed in 1931 to require a kitchen with running water in every apartment. The 1931 NBC also established fixture requirements for other than residential occupancies, which were subsequently deleted in 1949. Trash and garbage receptacles were required in 1931.

The two requirements for a water closet and a kitchen with running water went unchanged until 1967, when the kitchen sink requirement was expanded to specify hot and cold running water.

Finally, the 1976 NBC required a bathroom with water closet, lavatory, bathtub or shower, a kitchen in every dwelling unit, and hot and cold running water at all lavatories, bathtubs, showers, and kitchen sinks.

Uniform Building Code (UBC)

The 1927 UBC included a reference to applicable housing laws regarding sanitation. This was unchanged until 1946 when a toilet was required in each apartment and a kitchen sink in every kitchen. The water closet was required not to communicate with food preparation areas.

With the exception of varying references to state laws, these requirements went unchanged until 1961 when a water closet, lavatory, and bathtub or shower were required in a "minimum bathroom facility" in every dwelling unit, in addition to a kitchen sink in every kitchen. Finally, in 1979, hot and cold water were required in the bathroom.

Standard Building Code (SBC)

The SBC has required a toilet in every dwelling unit since 1946, and has referenced the Standard Plumbing Code, published since 1955, for fixture requirements. Since 1946, no toilet could open directly into a kitchen. Facilities for separate sexes were required in all but residential occupancies.

In 1979, the SBC introduced a requirement for waterproof joints in all showers and bathtubs.

Basic Building Code (BBC)

The BBC contains no requirements related to sanitary facilities, but references the Basic Plumbing Code.

APHA Standards and Proposed Housing Ordinances

In 1939, the APHA Standards established extensive requirements in this area. Every dwelling unit had to have a private water closet, lavatory, and bath. In addition, a kitchen was required with range (oven and three or four burners), refrigerator or icebox, shelving and kitchen sink. Closets were required in bedrooms and in the dwelling unit as a whole.

In 1952 a flush water closet was specified, the bath could be replaced by a shower, hot and cold running water were required to all sinks, lavatories and bath or shower, and only a kitchen sink was required for the kitchen. The ordinance suggests a spatial separation between the water closet with lavatory and the bath or shower. This suggestion was eliminated in 1975, but the lavatory could be adjacent to a room. The fully equipped kitchen was also required in 1975. Incinerators, or other means of garbage disposal, have been required since 1939.

Model Housing Codes (SHC, UHC)

The 1955 UHC required that every dwelling unit be equipped with a water closet, lavatory, tub or shower, and kitchen sink (not wood), all connecting to approved sewage disposal. Hot and cold running water were required for the sink, lavatory, and tub or shower. These requirements have not changed through 1979. Since 1961 they have been the same as those specified in contemporary editions of the UBC, except that hot and cold running water to fixtures has been explicitly required since 1955 (versus 1979 in the UBC).

The SHC, since 1960, has required a water closet, kitchen sink, lavatory, and tub or shower in each dwelling unit, as well as hot and cold water to kitchen sink, lavatory, and tub or shower; rubbish storage; and garbage disposal or storage. Also required for each dwelling unit is a connection to a potable water supply and to an approved sewage disposal system. These requirements have been essentially unchanged through 1979.

(d) Privacy

Introduction

Codes sometimes regulate privacy in residential occupancies by specifying aspects of room arrangement and relationships.

Building Codes

The 1905 NBC specified that in an apartment with three or more rooms, access to any living room, bedroom or water closet could not be through a bedroom. Similar requirements were included in earlier New York Tenement Laws.

In 1931, this requirement was expanded to preclude access to kitchens through bedrooms. However, water closet access through bedrooms was allowed, provided every bedroom had such direct access.

In 1955, the room access requirements were deleted, except for water closets, but a requirement forbidding access to a dwelling unit through another dwelling unit was added. This has remained the same ever since.

The other model building codes do not regulate privacy.

Housing Codes

The housing codes analyzed do not regulate privacy.

(e) Heating

Building Codes

The New York Tenement Laws, from 1867 through 1910, required that every apartment have chimneys with open fireplaces, grates, or a place for a stove. A similar requirement was contained in the 1905 NBC. The Model Housing Laws of 1914 and 1920 contain no heating requirements.

It was not until 1976 that the NBC required heating facilities or appliances in multi-family buildings. The code called for the ability to maintain 68°F in habitable rooms. A similar requirement (specifying 70°F) was introduced into the UBC in 1967.

Housing Codes

In 1939, the APHA Standard required heating with a minimum of 65°F and maximum of 75°F, and an optimum of 70°F (at knee height). In 1952 the minimum temperature was specified as 70°F, three feet above the floor, and in 1975 was reduced to 68°F.

The Standard Housing Code since 1960 has included a requirement to heat at 70°F three feet above the floor. The Uniform Housing Code has included a similar requirement since 1955.

(f) Basements and Cellars

The use of cellars for habitation was forbidden in the New York Tenement House Acts of 1901, 1902, and 1903, the 1910 Model Tenement House Law, and the Model Housing Laws of 1914 and 1920. However, under certain conditions, basements could be used for this purpose.

The 1905 NBC defined cellar as a story of which three-fourths or more of the height is below grade. In 1915, this was reduced to at lease one-half the height. In 1905, rooms for living purposes were permitted in cellars with ceilings at least 2'6" above grade, with separate water closet, and light and ventilation that satisfied the requirements. In 1915, rooms in cellars were permitted under certain conditions. They required a ceiling at least 4'6" above grade, and no water closet. The 1931 NBC apparently allowed cellar and basement apartments, provided light and ventilation requirements were met. In 1949, the NBC dropped the term cellar, and defined basement as any space with floor over 2'6" below grade. This definition was revised in 1955 to a space with half its height below grade. No limitations were placed on basement dwellings (other than light and ventilation) until the 1976 NBC, which prohibited habitable rooms with over half their height below grade (i.e., in basements).

The three model codes contain various definitions of cellars and basements. In general, however, all allow habitable rooms meeting the light and ventilation requirements to be located in such spaces.

In 1952, the APHA Standard precluded habitable rooms in cellars, allowing them only in basements which were waterproofed and met the light and ventilation requirements.

The 1960 Uniform Housing Code similarly precluded living spaces in cellars, allowing them only in basements which were watertight, met ceiling height provisions, and satisfied the light and ventilation requirements with above-grade windows. In 1969, however, the UHC lessened the requirements by permitting cellar living spaces under the same conditions as those for basements.

(g) Glazing

Glass and glazing must meet structural requirements to resist wind loads. But codes also control the safety of glass in hazardous locations, where human accidents may occur (with glass doors, fixed panels, shower doors, tub enclosures, etc.). All the model codes regulate this feature by reference to an ANSI standard. These requirements entered the model codes in the late 1960s.

(h) Acoustics

Only in recent years have codes addressed residential acoustic privacy, through minimum noise isolation requirements between dwelling units and between private and public areas. In fact, only two of the model codes, the National and the Basic, now include such requirements, and they have done so only in the most recent editions, 1976 and 1978, respectively.

The 1939 APHA Standard established maximum noise levels for dwelling units and for bedrooms. These were subsequently deleted (1952 and 1975).

(i) Plumbing

Plumbing regulations and codes were developed in the large urban areas of the United States in the last quarter of the 19th century. (The first separate plumbing code was Washington, D.C.'s, developed in the 1870s.) These regulations were developed and enforced by health officials.

These early plumbing codes emphasized the disposal of human wastes; they said little about protecting the water being supplied to make the plumbing operative. In fact, it is reported that only one late 19th century plumbing code (New York City, 1883) mentioned the need to protect the water supply against contamination from the waste water, and even this was later ignored in the same code.[31]

The early codes, in addition to controlling such physical aspects of a plumbing installation as ventilation, room location, size, and the fixture itself, also controlled the sizes and materials, and the configurations of the piping. In doing so, the early codes merely wrote into the laws and regulations, in a detailed, prescriptive way, what experience had shown would work satisfactorily and for a reasonable period of time.

The early codes, reflecting contemporary plumbing practice, recognized the liquid trap seal as the most appropriate way to protect the occupied space against infiltration of filth, odor and disease from the waste side of the plumbing system. The seal was originally proposed in 1847.

By the early 20th century, plumbing fixtures as we know them today were coming into general use. (The design and materials of earlier fixtures made them unsanitary in some ways.)

The profusion of local plumbing codes continued until 1923, when the National Bureau of Standards published the "Recommended Minimum Requirements for Plumbing in Dwellings and Similar Buildings" (the "Hoover Code"), which, as discussed above, formed the basis for most subsequent model plumbing codes in this country. It should be noted, however, that these model codes remain detailed and prescriptive.

In the early 1930s, regulations requiring pressure and temperature relief valves in the hot water supply system were introduced in most plumbing codes. This was in response to frequent explosions, and a recognition of the applicable product development.

By 1935, regulations prohibiting below-rim water supply connection to fixtures (to prevent contamination of the water supply from backflow of drain water), were introduced into most plumbing codes. This was an apparent response to an amoebic dysentery epidemic in Chicago in 1933. By 1938, regulations were introduced addressing permissible vacuum-breaker installations on fixtures whose proper functioning depends on a below-rim water supply connection.

By the late 1930s, the principal sanitary attributes of plumbing systems were regulated. Since then, model codes have generally evolved as follows:

- periodic introduction of acceptable new materials;
- slow liberalization (reduction) of prescriptive dimensional requirements (for example, pipe sizes, trap arm lengths), and especially those relating to venting, including limited use of wet venting and stack venting;

- introduction (recently) of specific engineered plumbing systems;
- provisions (recently again) reflecting concern for water conservation.

Since plumbing fixtures and piping usually have a shorter life than most other building elements, and in light of the steady liberalization of plumbing codes since the late 1930s, a plumbing system legally installed in a building at some time in the past (in accordance with a plumbing code) would most likely conform to current regulations.

(j) Stairs

Introduction

Stairs have been regulated in the context of an emergency situation—when large numbers of people would have to be evacuated in a very short time. To be sure, inadequate capacity and/or the number of exits have been a factor in several major fires. But the data seem to indicate that the greater number of accidents and related injuries occur during normal or "non-emergency" use of stairs. (See the discussion on Stairs in the accompanying report, Existing Buildings and Building Regulations.) For this reason, stairs are discussed here as well as in the section on Fire Safety above.

Two key attributes related to the safe use of stairs are: (1) tread and riser dimensions, and (2) uniformity. Tread and riser dimensions were first specified by the French architect Francois Blondel in 1672. They have changed little since. Interestingly, the "inch" used by Blondel is larger than the "inch" of today (slightly more than five percent). Yet it is unclear whether the model codes have made the necessary adjustment.

National Building Code (NBC)

The 1905 NBC required stair treads to be at least 10 inches wide. This was reduced to 9-1/2 inches in the 1915 edition, and finally to 9 inches in 1955. The maximum height of stair risers was first specified as 8 inches, but was tightened in 1915 to 7-3/4 inches. However, in 1976, it was returned to the original maximum height of 8 inches.

An additional requirement was added in 1931. The product of the tread width times the riser height [in inches] had to be between 70 and 75, or:

tread width x riser height [in inches] = 70 - 75

The origin of this formula is unknown. Though the mathematical computations are beyond the scope of this report, it can be noted that this equation is not truly consistent with Blondel's formula.

The width of treads and height of risers in any one flight of stairs must be uniform. This has been required since 1905, though the 1976 edition now allows a maximum variation of 3/16 inch.

Uniform Building Code (UBC)

The basic tread and riser requirements have not changed since the first edition in 1927. Risers cannot exceed 7-1/2 inches in height, and treads must be at least 10 inches wide. The 1979 edition, though, added that risers must be at least 4 inches high.

The 1927 edition contained an exception for dwellings, where treads and risers of 9 inches and 8 inches, respectively, were permitted. Though the dimensions have not changed, this exception was broadened in 1946 to include any stairway serving less than 50 people. The exception was tightened in 1970 to only "private stairways" serving an occupant load of less than 10 people.

The 1927 code required that all treads in a flight of stairs be uniform, though risers could vary a maximum 3/16 inch. This 3/16 inch variation for treads was not permitted until the 1946 edition. The allowable variation for treads and risers was raised to 1/4 inch in 1976, and again to 3/8 inch in 1979.

Standard Building Code (SBC)

The basic tread and riser dimensions have not changed since the first SBC (1946-1947 edition) was adopted in 1945. Treads must be at least 9 inches wide, and risers may not exceed 7-3/4 inches in height. Likewise, the SBC has always required that the width of treads and the height of risers be uniform in any one flight of stairs.

Blondel's formula, noted above, requires that the sum of two risers and one tread be not less than 24 inches nor more than 25 inches, or:

(2 x riser height) + tread width = 24 - 25 inches

The SBC has always required stairs to satisfy Blondel's formula.

Basic Building Code (BBC)

The original tread and riser requirements in the 1950 edition were not changed until 1975.

Originally, the maximum riser height in one- and two-family dwellings was 8-1/4 inches and the minimum tread width was 9 inches. In 1975, the maximum riser height was reduced to 8 inches, but returned to the original 8-3/4 inches in 1978. There was no dimensional change in 1981, but stairs within private apartments were added to this category.

In other residential occupancies (apartments, hotels, etc.) the original requirements varied only slightly. The minimum tread width was also 9 inches, but the maximum riser height was a slightly more restrictive 8 inches. These dimensions remained unchanged from 1950 to 1981, when the "all others" category, discussed below, was tightened.

The 1950 through 1970 editions explicitly regulated assembly and business occupancies. Both required a minimum tread width of 9-1/2 inches, and the maximum riser heights were 7-1/2 inches and 7-3/4 inches, respectively. In 1975, the minimum tread width for assembly occupancies was increased from 9-1/2 inches to 10 inches. Business occupancies were lumped into a new "all others" category, which eased the minimum tread dimension from 9-1/2 inches to 9 inches, but tightened the maximum riser dimension slightly from 7-3/4 inches to 8 inches.

In 1981, the tread and riser dimensions for the "all others" category (which now included assembly occupancies) were significantly changed. The maximum riser height was reduced from 8 inches to 7 inches, and the minimum tread width was increased from 9 inches to 11 inches. Also added were a minimum riser height of 4 inches and maximum tread width of 14 inches.

Blondel's formula was first added in the 1978 edition, though one- and two-family dwellings were excepted. However, this requirement was deleted from the next edition of the BBC in 1981.

The 1950 through 1970 editions of the BBC had no explicit requirement for uniform treads or risers. The 1975 edition limited variations in the height of risers to 3/16 inch. The 1978 edition extended this limitation to treads as well as risers "within any flight". The 1981 edition changed the 3/16 inch maximum variation from "within any flight" to "adjacent" treads or risers, and added that "the tolerance between the largest and smallest <u>riser</u> shall not exceed <u>3/8 inch in any flight</u>". (emphasis added)

(3) STRUCTURAL SAFETY

(a) Introduction

At the turn of the century, building codes provided for structural safety through prescriptive requirements for conventional construction (brick walls with wood floor systems) and Factor of Safety criteria for new materials such as iron and steel, and concrete.

In early codes, the design criteria for specific occupancies were typically set forth in chapters containing all detailed requirements for each occupancy group. Additional chapters provided for material quality and allowable stresses, and factors of safety for specific building elements and materials.

Early codes required design and analysis to follow the methods specified by Trautwine[32], Kidder[33], or the United States Military Academy at West Point. Structural analysis methods were developed early in the 19th century, and acceptable design methods were determined by consensus of the profession before 1900.

While early building code requirements for "conventional construction" were based on a body of experience of structural failures (see accompanying report, Existing Buildings and Building Regulations), new industrialized materials were being developed that required structural analysis and design. These new materials included cast and wrought iron and steel, rolled steel, and reinforced concrete.

Building codes across the country apparently followed New York City's code in both organization and in technical requirements. The development of the National Building Code (NBC) by the National Board of Fire Underwriters in 1905 also provided the basis of many local codes. The NBC appears to have generally followed the New York City codes for its structural requirements (see Appendix A, Tables).

The Model Building Code by F. W. Fitzpatrick, published in 1913 by the American School of Correspondence, Chicago (see Section A(4) above), contained structural provisions almost identical to the New York City code.

In 1915, Mr. R. Fleming of American Bridge Company compared wind requirements of codes around the country and found significant variation in forces and in allowable stress increases. He wrote, "It might seem that our American municipalities have exhausted the combination of wind pressures and wind stresses that can be made"[34]. By way of example, he noted that the Chicago, San Francisco, and Akron codes all specified a 20 psf wind force. Chicago and San Francisco each permitted a 50 percent stress increase, while Akron permitted no increase in allowable stress.

In the 1920s, the United States Bureau of Standards (National Bureau of Standards--NBS) developed the Building and Housing series (BH) of publications (see Section A (8) above). The series had a profound effect on the structural provisions of building codes. They established the format and technical basis of modern codes. Specific issues of importance for structural design were:

BH1 Recommended Minimum Requirements for Small Dwelling Construction, July 20, 1922.

BH6 Recommend Minimum Requirements for Masonry Wall Construction, June 26, 1924.

BH7 Minimum Live Loads Allowed for Use in Design of Buildings, November 1, 1925.

BH9 Recommended Building Code Requirements for Working Stresses in Building Materials, June 1, 1926.

BH18 Recommended Minimum Requirements for Small Dwelling Construction, 1932 (succeeding BH1).

These documents, developed by a committee representing the design professions, government, contractors, and researchers, represent the design requirements of codes promulgated after the mid-1920s. A reference cross-section of allowable stresses is discussed below.

The American National Standards Institute (ANSI) currently maintains ANSI Standard A-58—Loads of Buildings which contain the criteria for building design. This standard is referenced in the current model codes.

(b) Vertical Loads

Floor Loads

Typically, building codes specify floor live load based on the type of occupancy. In the New York City code of 1891, specified floor loads varied from 75 to 150 pounds per square foot (psf) for different occupancies. The 1901 New York City code revised these values to 60 psf for dwellings to 150 psf for storage occupancies. Current loads are 40 psf for dwellings and 100-150 psf for storage occupancies. This is consistent with national consensus standards.

Roof Loads

Codes also specify loads for roof design. The 1891 New York City code lacked a roof design criterion, but the 1901 code required a 50 psf load for flat roofs. The current New York City code calls for a 30 psf load for a similar roof. Roof loads are usually adjusted locally in areas of heavy snow; there is therefore little consistency in these criteria among such cities.

Tables 1, 2, 3, and 4 of Appendix A include roof and floor loads in the New York City, National, Los Angeles, and Uniform codes, respectively. Tables 5 and 6 compare the codes in the first decade of the 20th century and again in 1940.

(c) Wind Loads

Most early codes specified design for wind forces. While the 1891 New York City code was silent on this subject, the 1901 code specified a design force for wind of 30 psf. It also stipulated that the overturning moment not exceed 75 percent of the righting dead-load moment. It further provided that buildings with obvious stability (4:1 height to width ratio) need not be evaluated for wind stability. The basic wind criteria have not changed significantly over the years, except to account for increased wind force at higher elevations above grade. (See Appendix A, Tables 1, 2, 3, and 4.)

(d) Seismic Loads

In the view of early designers and building officials, seismic safety could be provided for in a manner similar to wind design. The inertial nature of seismic forces was not generally recognized until the early 1920s.

The 1927 Uniform Building Code included optional seismic design requirements based on building mass and soil type. Following the 1933 Long Beach earthquake, these requirements were adopted almost unchanged in the California Administrative Code. These minimum state requirements remained basically the same until 1943, when Los Angeles adopted a new design formula which considered building height. San Francisco adopted similar expanded requirements in 1947.

In response to earthquake experiences both in the United States and abroad, seismic design requirements have continued to change, becoming more severe and detailed. The 1964 Alaska earthquake, the 1967 Caracas earthquake, and the 1971 San Fernando earthquake each resulted in code changes. Engineers now believe the design values are realistic, and are directing their attention to "non-structural" damage such as ceilings, partitions, curtain walls, and pipes. (See Appendix A, History of Building Code Provisions Related to Earthquakes.)

(e) Foundation (Geotechnic) Requirements

The 1901 New York City code specified allowable foundation pressures, soft clay at one ton per square foot (TSF); wet clay and sand at two TSF; and hard stiff gravel at four TSF. Greater values were allowed for bedrock. These varied from six to ten TSF.

Current codes, in the absence of a geotechnical report, have lower values for soil bearing. The values for clay and sand are about 50 percent of those allowed at the turn of the century. These reduced soil bearing values appear to be in response to settlement and other foundation failures, which, while not catastrophic, can produce many building problems such as sticking doors, windows, and sloping floors.

(f) Local Strength

Masonry Walls

As mentioned earlier, prescriptive requirements for masonry walls were included in the codes at the turn of the century (New York City, Boston, etc.). These requirements were based on several bracing factors, including the unsupported height of the wall, the distance between cross walls or buttresses, and the span of floor joists. Exterior walls and bearing walls required greater thickness—probably for both wind and fire resistance—than was required for interior non-bearing walls.

Interior Partitions

One other general local damage control criteria was first required in the 1961 edition of the Uniform Building Code. Since that edition, the Uniform Building Code contains performance criteria for interior partitions with brittle finishes. Cracking is prevented by limiting deflection with a horizontal specified load.

Railings

Guard and stair railing design forces were first included in the 1949 National Building Code. The code specified a load of 50#/foot, horizontally applied to the top of the railing. This appears to be based on a similar provision in the early Uniform Building Code. Currently, the Uniform Building Code specifies rail load of 20#/foot applied at the top of the rail.

(g) Materials Criteria

Codes typically include provisions for material quality. Turn-of-the-century codes granted the building official broad authority to accept or reject materials. Cast iron, for example, called for consistent gray color and an inspection hole to permit the inspector to verify the thickness of the column walls.

(h) Factors of Safety and Allowable Stresses

Pre turn-of-the-century codes specified a factor of safety for building elements in bending (beams), compression (columns), and tension (trusses). This factor of safety was to be used with the ultimate strength of materials specified by Trautwine in The Civil Engineers Pocketbook (1872[32] and later editions published through the early 1930s), and designed in accordance with the principles of mechanics of the United States Military Academy at West Point, or the works of Kidder[33], and others.

The 1891 New York City code specified a factor of safety of 3 for beams, 6 for columns, and 6 for tensile members. By the time the 1901 New York City code was enacted, actual working stresses were included in the code. Listed materials included cast and wrought iron, steel, and wood. The stresses permitted in the 1901 code remained essentially unchanged for the next 20 years. (See Appendix A, Tables 7, 8, and 9 for allowable stresses specified in the New York, NBC, and UBC, respectively.)

The 1901 New York City code also introduced some innovations. One was allowable stress increases when combining wind forces and dead and live loads. A stress increase of 50 percent was allowed. The code also permitted a reduction of live loads in footings and columns. The reduction was 5 percent per story with a 50 percent maximum. (See Appendix A, Table 1.)

The design factor of safety was eliminated from most building codes by the mid 1920s as the allowable stress method of design became common. This method specified allowable stresses for various materials. As a result of building failures, early codes varied widely in their allowable stress for the same material. (See Appendix A, Tables 10 and 11.)

The allowable stress accounts for the factor of safety for materials. The factor of safety has been reduced over the years as more accurate design methods have evolved from industry-supported research and better quality control of materials and construction. This "reduced factor of safety" should not be considered as a reduction in safety but reflecting a better understanding of stresses in and performance of building materials and elements.

There are some exceptions to the trend of reduced factors of safety. For example, 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.

(i) Conclusions

The changes that have occurred since about 1930 are refinements in design methods based on ongoing research by industry; they result from new, higher strength materials, and such new materials as aluminum, glue-laminated wood, and prestressed concrete. Design methods such as ultimate strength design for concrete and seismic design have been added.

Some modifications to some live loads have been made, particularly the allowable reductions.

Requirements for vertical loads in building codes were reduced over the years, based on both research and experience. This trend continued until the mid-1920s, when the NBS BH Series established an initial consensus for design criteria. Since then, they have changed very little. Wind requirements have changed little except to become more consistent. Seismic loads have generally increased based on earthquake damage experience. Foundation pressures have been reduced over the years and are generally more conservative unless a geotechnic investigation is conducted.

(4) ELECTRICAL SAFETY

(a) Introduction

All aspects of electrical safety in buildings are regulated by the National Electrical Code (NEC), which in most local jurisdictions is adopted or forms the basis for modified local regulations.

Since 1900 new editions of the National Electrical Code have been issued in:

1901, 1903, 1905, 1907, 1909, 1911, 1913, 1915, 1918, 1920, 1923, 1925, 1928, 1930, 1931, 1933, 1935, 1937, 1940, 1974, 1951, 1953, 1956, 1959, 1962, 1965, 1968, 1971, 1975, 1978, 1981.

Supplements to the Code were issued in 1926 and in 1949, and extensive rearrangement or rewording of the requirements were made in 1923, 1937, 1959, and 1975.

Early editions of the NEC contained considerable detail on equipment, which was later omitted as it became suitably covered in individual product standards.

While the early editions of the NEC also covered wiring in street railway cars and in marine vessels, these applications were later deleted.

Housing codes usually include a limited amount of requirements for electrical safety in existing residential buildings. They address electrical safety in two ways. First, they state, in general terms, that the electrical system should be safe and in good condition. Second, they establish specific requirements related to overcurrent protection and to receptacles and outlets on branch circuits.

(b) Working Space and Guarding

National Electrical Code

The 1918 NEC required that live parts of service switches be enclosed or guarded (§23a). In 1925, this requirement also applied to the live parts of fuse cutouts and circuit breakers (§405i). In 1933, two new tables were added giving specific values for working space about exposed live parts of electrical equipment and isolation by elevation for voltages from 600 to 132,000 volts (§5009). In 1940, working space about live parts of equipment which must be handled while alive at not over 600 volts was divided into that operating above and below 150 volts (§111.a.). At not over 600 volts, equipment located at least eight feet above the working platform was considered to be isolated by virtue of elevation (§1111.c.).

After the 1933 NEC providing for specific working spaces in front of equipment with exposed live parts, experience indicated that provisions for head room and illumination were needed. These were added to the 1965 NEC. In 1978, the minimum working space in front of equipment was increased from 2-1/2 to 3 feet so that workmen would be less apt to contact live parts [§110-16(a)].

(c) Services

National Electrical Code

The number of service disconnecting means has received considerable attention during the past 50 years because of the need to arrive at a compromise given the demands for increased capacity, safety, convenience, and cost.

At the turn of the century, the NEC required overcurrent protection for service conductors. It also required that a single disconnecting means, opening all ungrounded conductors, be located at the nearest accessible point to where the service conductors entered the building. The 1907 code prohibited use of single pole switches as the service disconnecting means (§22c.). In 1923, the code was revised to include an Article 4 on Services, and Section 405 required that the service switch or circuit breaker be externally operable. The 1928 code required only one set of service entrance conductors to a building, in the absence of some specific needs, such as an emergency system, large capacity, or other class of service (§401). In 1933, the code allowed up to four disconnecting means for each set of service conductors if not more than 150 volts to ground (§405b.), and in 1937, the number of disconnecting means was increased to six. At this time, new requirements were added for service over 600 volts (§2386 to §2393).

In 1971, the NEC acquired a provision for ground fault protection for three phase wye services of more than 150 volts to ground and not exceeding 600 volts, rated 1000 amperes or more. This type of protection was intended to prevent burndowns which were occurring on 277-480 volt wye systems rated over 1000 amperes (§250-95).

When enclosed switches were limited to 600 amperes, more than one would obviously be needed when the actual service load exceeded this level. Now that very large equipment is available, consideration must be given to large fault currents. The requirement for ground fault current protection was introduced to prevent burndown from arcing faults. The limitation of six disconnecting means is somewhat arbitrary and may place some economic burden on multi-occupancy buildings. It thus continues to be reviewed in revision proposals submitted for each new edition of the code.

Minimum rating of service equipment has been required in the NEC since 1940. Since then the minimum has gradually increased, reflecting increased use of electrical appliances. The following list summarizes this progression:

1940 Minimum 30 amp switch limited to two 15A branch circuits (§2357).

1947 Same as 1940, but not less than calculated load (§2357).

1951 Not less than calculated load.
Minimum 60 amp if switch.
Minimum 50 amp if circuit breaker.
Exception: 30 amp for not more than two 2-wire branch circuits (§2357)

1953 Same as 1951 but adds ratings of equipment in parallel (§2357).

1959 Same as 1953
Exception: For dwelling, minimum 100 amp for 10 KW load or minimum 30 amp for two 2-wire branch circuits (§230-71).

1968 Same as 1959 except revision of the Exception as follows: For dwelling, minimum 100 amp for 10 KW or if more than five branch circuits (§230-71).

1975 Changed to apply to rating of disconnect
Minimum rating not less than load
(a) Not less than 15 amp for one branch circuit
(b) Not less than 30 amp for two 2-wire branch circuits
(c) For single family dwelling, minimum 100 amp if 10 KW or more load or if six 2-wire branch circuits or more
(d) All others minimum 60 amp (§230-71).

1981 Same as 1975 (§230-71).

Housing Codes

In 1965, the Standard Housing Code established requirements for minimum capacity of service supply between 60 (for 0-600 square feet) and 200 amps (for over 1500 square feet) as a function of the gross area of habitable space. In 1969, the service supply requirements were modified to relate to the number of lighting electrical outlets rather than area. These were established as 60 amps for 0-24 outlets and 100 amps for 25-50 outlets.

(d) Branch Circuits

National Electrical Code

The very early editions of the NEC limited the size of the branch circuits based on the wire size used and did not allow the load of those used to supply lamp holders for incandescent lamps to exceed 660 watts (§21d.). By 1911, the branch circuits of 110 volts were limited to six amperes (§23d.) and this size circuit was considered to protect No. 18 Awg fixture wire or flexible cord used to connect fixtures. In 1913, a provision was added to use up to 20 amperes on branch circuits that supply large chandeliers, electric signs, and outlets in theaters (§23d.). In 1918, the ampere rating for 110 volt branch circuits was increased to 10 amperes (§23d.) and in 1923 to 15 amperes (§807).

In 1935, it was stated that No. 12 Awg conductors must be used for the appliance circuit in residential occupancies (§2005) and that at least one receptacle be provided in each room of the residence (§2011).

The 1937 code, in Article 210, specified the use of multioutlet branch circuits rated 15, 20, 25, 35, and 50 amperes, and described what type of loads could be used on these circuits. The requirement for receptacles in residential occupancies was increased, by specifying that no space along the wall at floor level would be more than 10 feet from a receptacle (§2110). A receptacle was also required in the laundry area for the connection of laundry equipment.

In the 1940 code, a separate small appliance circuit rated 20 amperes was required for the receptacles in the kitchen, laundry, pantry, dining room, and breakfast room; this circuit could be used for no other outlets (§2109). In 1956, the required distance from any space along the wall to a receptacle was reduced to 6 feet (§2124b.) and in 1959, at least two small appliance branch circuits were required in the kitchen [§220-3(b)].

Maximum distance between receptacle outlets was reduced in order to decrease the need for extension cords to supply appliances. It was known that permanent wiring was safer than flexible cord. The rating of the small appliance circuit in the kitchen and other food preparation rooms was increased from 15 to 20 amperes so there would be less incentive to overfuse the branch circuit to avoid tripping it through the simultaneous use of several electrical appliances. The addition of a second small appliance branch circuit in dwellings was also intended to prevent overloading when meeting the needs of the appliance users.

Housing Codes

The 1939 APHA/NAHO Practical Standards for Modern Housing required that all rooms have at least one switch-operated light fixture, and convenience outlets as follows: living room - 2; bedrooms - 1; kitchen - 1 appliance outlet plus refrigerator outlet, if supplied.

The 1952 APHA Proposed Housing Ordinance required light fixtures only in water closets, bathrooms, laundry and furnace rooms, public halls, etc. For habitable rooms, a minimum of two convenience outlets, or one plus a ceiling electric light fixture, were required, representing a slight reduction from 1939 (living rooms). The 1952 requirements were unchanged in 1975, except for the requirement that the convenience outlets be of the duplex type.

In the 1955 Uniform Housing Code, the requirements were identical to those of the 1952 APHA Ordinance, subject, however, to the condition "when service is available within 300 feet." This requirement has remained the same through 1979.

The 1960 Standard Housing Code included similar requirements, and by 1965, they were identical to those of the 1952 APHA Ordinance.

The 1969 SHC slightly increased the outlet requirements—two convenience outlets in habitable rooms, and in addition, a light fixture in bedrooms and kitchens. These requirements remained unchanged until 1979, when further increased requirements specified three outlets for kitchens, and at least one convenience outlet in addition to the required light fixture in bathrooms and laundry rooms.

(e) Grounding

National Electrical Code

Grounding of systems and equipment is recognized as an important safety requirement for several reasons: it reduces the possibility of electric shock under fault conditions, prevents the energizing of metal enclosures through leakage current, and assists the proper operation of overcurrent protective devices under ground fault conditions. The code has been continually revised to make grounding even more effective and to accommodate plastic water pipe that has replaced metal water pipe.

Systems

In 1900, the NEC required that metal conduits containing conductors be grounded and that the voltage between the dynamo and any point on the grounded return wire not exceed 25 volts (§12n.). Grounding was recommended for alternating current systems derived from transformer secondaries and, if these were grounded, they had to be connected to ground at the neutral of the transformer. Such systems were also required to have additional grounds every 250 feet for overhead wiring and 500 feet for underground systems (§13Ab.). In 1907, a new provision called for grounding the electrical system to an underground water piping system at a point inside the building served (§13Ag.). In 1913, ac systems not over 150 volts to ground, were required to be grounded (§15b.) and the requirement for grounding at intervals along the system were deleted. In 1918, the code established sizes for the grounding conductor based on overcurrent protection of the circuit. It also required a water pipe electrode not to exceed 3 ohms and a made electrode not to exceed 25 ohms. However, the latter could exceed 25 ohms if a second electrode was provided, this one having no maximum resistance.

The grounding electrode conductor was required to be at least a No. 6 Awg in size, at least one-fifth the size of the supply conductors, and not larger than No. 0. This was based on the largest size cartridge fuse being 600 amperes for the service equipment. In later years, when fuse sizes were increased, the maximum size of the grounding electrode conductor was also increased where a water pipe ground was present. Although many detailed requirements have subsequently been added, the basic requirements adopted in the 1918 edition of the code continue to be applied.

In 1968, the Ufer ground consisting of steel reinforcing bars in concrete foundations was recognized as a satisfactory grounding electrode. The Ufer ground provides a satisfactory substitute for the underground metal water piping system and is superior to a driven electrode.

Because of the introduction of plastic water pipe and its use as a replacement for corroded metal water pipe, the 1978 code required that a water pipe electrode be supplemented by a made electrode [§250-81(a)].

Equipment and Enclosures

The very early codes recognized the need to keep the circuit impedance low by running the equipment grounding conductors with the circuit conductors. Detailed requirements were added from time to time to insure that this was accomplished. As circuits grew larger and conductors were run in parallel in different conduits, a separate equipment grounding conductor was needed in each non-metallic conduit. The size of the grounding conductor was based on the overcurrent device protecting the circuit as indicated in Section 250-95 of the 1971 code, since each such conductor could be subject to the entire fault current and would not be subject to division into the other parallel conductors.

The 1928 code specified the size of the equipment grounding conductor based on overcurrent devices only up to the rating of over 500 amperes. However, the 1930 code extended the table to cover up to 1200 amperes (§905j.). In the 1968 code, the rating was extended to 6000 amperes (§250-95).

Portable Equipment

As a result of reported accidents, the number of appliances required to be furnished with grounding means has gradually increased. It was not until 1947 that the code included specific requirements to cover the grounding of portable equipment. At that time, all exposed metal was required to be grounded under the following conditions (§2545):

(a) in hazardous locations;

(b) If circuit is over 150 volts to ground
Except: (1) Motors if guarded
(2) Heating appliances
(3) X-Ray tubes used in therapy;

(c) In nonresidential occupancies, appliances used in damp or wet locations or by persons standing on the ground or working inside metal tanks,
Exception: Where supply is insulated and not over 50 volts.

In 1962, this requirement (changed in 1959 to §250-45) was retained, and one additional requirement for residential occupancies was added. Grounding was required for clothes-washining, dish-washing, clothes-drying, and portable hand-held tools as well as for appliances of the following types: drills with a chuck larger than one-eighth inch, hedge clippers, lawn mowers, wet scrubbers, sanders, and saws. Double-insulated tools and appliances were excepted. In 1965, sump pumps were added, and in 1968, refrigerators, freezers, and air-conditioners. The basis for coverage was changed to cord and plug connected and the term portable was dropped. In addition, the appliances listed for residential occupancies was repeated for the non-residential. In 1975, aquariums were added. In 1978, the grounding requirements were extended to all hand-held motor operated tools, portable lamps, and snowblowers.

Receptacles

The code requirements for grounding type receptacles paralleled the requirement for portable equipment grounding, and reflected the development and perfection of products which would safely provide the necessary grounding.

In 1947, a grounding type receptacle was required in the laundry of a dwelling [§2124(b)]. In 1956, open porches, breezeways, garages, or places where a person using the appliance may be standing on the ground, were added to the required locations. Since 1962, all 15 and 20 amp receptacles have been required to be of the grounding type [§210-21(b), and later, §210-7(a)].

It should be noted that buildings constructed before 1962 contain many receptacles not of the grounding type.

(f) Overcurrent Protection

National Electrical Code

The NEC has always required that conductors be protected at their current carrying capacity by overcurrent protection. While some latitude is provided for minor differences in rating, the 1962 NEC (§240-5) did not permit these variations to extend above the conductor ratings for the larger conductor sizes. Provisions in the 1940 NEC (§1114) require the overcurrent protection to be capable of interrupting the maximum current available at the voltage employed at the location of the overcurrent device. The 1965 NEC (§110-10) required that the overcurrent device be selected in such a way that it will clear a fault without extensive damage to any of the circuit's components. This was in addition to the total impedance and other characteristics of the circuit. The 1959 NEC incorporated requirements for marking interrupting ratings on cartridge fuses and circuit breakers over 10,000 amperes [§240-2(c) fuses, §240-25(f) CBS].

The safety of overcurrent devices has continued to improve through stiffer performance requirements, the addition of specific requirements for the larger available short circuit currents, and the need for protection of the wiring and equipment from let-through energy. Required marking has helped determine acceptability of installations. Safety has also been increased through the recognition of tamper resisting plug fuses and the non-interchangeability of other fuses, which has restricted misapplication during fuse replacement.

(Specific history of the code requirements pertaining to plug fuses, cartridge fuses, link fuses, and circuit breakers appears in Appendix B, Methods of Overcurrent Protection.)

(g) Conductors

National Electrical Code

With the introduction of new types of conductor insulations, safety has been enhanced through longer life, higher temperature ratings, increased resistance to abrasion, larger ampacities, and smaller diameter. The smaller diameters and larger ampacity allow the supply of larger loads in rewiring of buildings where existing conduits are reused. This can make the rewiring economically feasible.

As early as 1900, the NEC recognized aluminum as well as copper conductors, and indicated aluminum's current capacity as 85% that of copper. In the 1915 code, the use of a lead covering was recognized as protection for insulation subjected to wet conditions (§50c). In 1920, varnished cambric insulated conductors were added to the rubber, slow burning, and weatherproof conductors recognized by the code. It was not until 1940 that a new table on conductor capacities was added to the code. This table was based on extensive heat tests of conductors, both in raceway and in the open. Derating factors were established for high ambient conditions and for more than three conductors in conduit or cable. Performance and heat resistant grades of rubber insulation were added along with thermoplastic and several combination asbestos types. In 1947, the old code grade rubber insulation, with a rating of 49°C., was increased to 60°C., and the recently established performance grade of Type RP was deleted from the code.

Where the neutral conductor only carries the unbalanced current of the phase conductors, it need not be counted as a current carrying conductor. If all phase conductors are not present, the neutral conductor must be counted as a current carrying conductor in determining the derating factor for a number of conductors. Also, if the load on the conductors is from electric discharge lighting, there may be harmonic currents present in the neutral which may classify it as a current carrying conductor. These two provisions were added to Note 11 to Tables 310-12 through 310-15 of the 1968 code.

Specific types of conductors have been added and/or deleted from the NEC from 1900 to the present. (See Appendix B, Types of Insulated Conductors, for a historic summary of this activity.)

Fixture Wire

While fixture wire is used primarily for the wiring of fixtures, it has other uses as well, such as remote-control, low energy power, low voltage power, signaling, fire protective signaling, and communication. Although the thickness of fixture wire insulation varies, specifications for some of the applications other than fixture use require a minimum of 1/32 inch of thickness.

Specific types of fixture wire have been added and/or deleted from the NEC from 1900 to the present. (See Appendix B, Types of Fixture Wire, for a historic summary of this activity.)

Flexible Cord

Flexible cord in the form of extension cord sets is a convenient way to extend power from a fixed outlet to the point of use of an electrical appliance. Because of the abuse to which a flexible cord is frequently subjected, the NEC has attempted to limit this form of use to portable devices or to those applications where the cord does not serve as a substitute for permanent wiring.

The early editions of the NEC recognized a pair of rubber insulated conductors, twisted together, with a braid over each conductor. This form of cord was eventually designated as a Type C flexible cord. A Type T stage cable was recognized in the 1911 code for use on theater stages.

Outstanding improvements have been made in new types of flexible cord which, in addition to improved performance in the areas of aging, abrasion, and temperature, have been designed to withstand water immersion or exposure to oil or other chemicals.

Specific types of flexible cord have been added and/or deleted from the NEC from 1900 to the present. (See Appendix B, Types of Flexible Cord, for a historic summary of this activity.)

(h) Wiring Methods

National Electrical Code

At the turn of the century, the method of wiring consisted of either mounting the wiring on insulated knobs, kleets, or tubes either in the open or concealed, or placing the rubber insulated conductors in metal conduit or mouldings made of wood or metal. Methods of wiring were continually expanded over the years, as may be seen in Appendix B, Table of Wiring Methods. When new methods that were introduced fell into disuse, they were dropped from the code.

The big increase in the number of wiring methods provides the design engineer or installer with many more ways to meet individual needs. Some of the methods may permit safer installation through a more convenient location for outlets, reducing the use of flexible cord. Many of the wiring methods added to the code permit more economical ways to extend wiring in existing buildings or better means of rewiring existing buildings to safely provide for load growth.

Specific wiring methods have been added to the NEC from 1900 to the present. (See Appendix B, Table of Wiring Methods, for a historic summary of this activity.) Some methods subsequently dropped from use have been deleted from the code.

(i) Boxes and Cabinets

At the turn of the century, outlet boxes were required to be of metal with a corrosion resistant coating of galvanizing, enamel, or other material that resists oxidation. Cabinets could be of wood with a lining of marble, slate, or asbestos board. In 1911, a requirement was added to prohibit the use of wood cabinets with metal conduit systems (§70). In 1913, provision was made for gutter space to contain the conductors running from terminals to their point of exit (§70). The 1915 code required that cabinets used outdoors be weatherproof (§70). Requirements added in 1918 specified that conduit or cable entering a box be secured to the box by a clamp or threaded connection or fitting (§59). The 1937 code restricted the number of conductors that a box could contain based on the space within the box (§3705). It also recognized the use of nonmetallic boxes with nonmetallic wiring methods (§3716). In 1940, the code established pull box dimensions based on the size of the conduit entering the box and the number and location of such entries. In 1947, provision was made for wire bending space where conductors were attached to terminals within cabinets or cutout boxes (§3736).

With the introduction of small diameter insulated conductors and the resultant increase in the number of conductors in a conduit, outlet boxes became crowded where the conductors were tapped or spliced. Additional space was provided by decreasing the number of conductors permitted in the boxes. Where very large conductors entered cabinets or cutout boxes, there was insufficient space for bending so that the conductors could be inserted into the terminals of panelboards. Therefore, in the revised requirements, additional space was specified for wire bending purposes.

(j) Panelboards

Although the NEC has always required overcurrent protection of conductors, it was not until these protective devices were located in panelboards in large numbers that overheating became a problem. It was in the 1933 code that a limit of 42 overcurrent devices was placed on lighting and appliance branch circuit panelboards (§1303). In 1935, the code required that main protection for these panelboards be supplied for ratings of over 200 amperes. In 1953, a definition was added for a lighting and appliance branch circuit panelboard (§3881) and provision for 125 percent capacity was required for panelboards supplying continuous loads (§3883). In 1965, lighting and appliance branch circuit panelboards were required to be protected at their rating (§384-16) and in 1978, the use of the Delta breaker was prohibited [§384-16(e)]. This requirement prohibited using a three pole circuit breaker in a panelboard lacking a bus for each pole, since such use allowed backfeed to the panelboard when the main disconnect was opened.

Experience indicated that where full load was placed on panelboards for large periods of time, the fuses or overcurrent elements in thermal circuit breakers caused overheating unless the load was reduced, and this necessitated the derating of panelboards subject to continuous loads. In order to prevent improper connections, it was required that switchboards and panelboards used on 4-wire Delta connected systems having the midpoint of one phase grounded must be suitably marked to identify the phase with a higher voltage to ground. This phase also had to be designated as the "B" phase and located in the middle. The phase arrangement on three-phase busses are required to be A, B, C from front to back, top to bottom, or left to right as viewed from the front of the switchboard or panelboard.

(k) Fixtures

The early editions of the NEC contained detailed requirements on arc lamps, but these were gradually replaced by requirements for incandescent lamps as these came into prominent use. While fixtures were first required to be insulated from metal mounting surfaces and from the metal raceway used for the supply conductors, the 1935 code required grounding of fixtures unless supplied by nonmetallic wiring methods (§1403). It also required metal fixtures supplied by circuits of over 150 volts to be grounded. In 1937, fixtures in clothes closets were required to be located on the ceiling or on the wall over the door and pendant lampholders in clothes closets were prohibited (§4162). In 1947, fixtures located in damp or wet locations were required to be approved for such use (§4111). The 1947 code also introduced detailed requirements for recessed fixtures and electric discharge lighting units (Art. 411). It also provided for easier maintenance of fluorescent lamp fixtures by requiring the connection by cord and plug to receptacles located directly over them (§4125).

In 1959, the medium base lampholder was limited to use with lamps rated not over 300 watts and the mogul base lampholder to 1,500 watts (§410-49). Because of a large number of ballast failures in fluorescent lamp fixtures, the 1965 code required that the ballasts be provided with thermal protection (§410-71). Later editions of the code required that this thermal protection be integral with the ballast. In 1968, provision was made for the use of cord and plug connected show cases, and in 1978 portable lamps were required to have polarized attachment plugs (§410-42). The 1978 code also required that metal guards on portable hand-held lamps be grounded.

In order to protect people in bathtubs from electric shock, the 1981 NEC requires that any hanging fixture be installed not less than eight feet above the top of the tub.

(l) Places of Assembly

National Electrical Code

Specific requirements for theaters and for motion picture machines have been in the NEC since the first decade of this century. These have been changed from time to time, and a history of these changes may be found in Appendix B, Theaters.

The 1975 NEC separated "Places of Assembly" from the Article on Theaters, and established a new Article (§518) for them that was applicable only where there was provision for more than 100 persons. This article allows the wiring to consist of armored cable or nonmetallic sheathed cable where the assembly area is in a building not required to be of "fire rated construction by the applicable building code". It notes that, "fire rated construction is the fire-resistive classification used in building codes." It is unclear whether this wording adequately defines when such wiring may be used.

(m) Ground Fault Circuit Interrupter Protection

National Electrical Code

In a proposal for the 1975 NEC to require ground fault circuit interrupters to protect dwelling receptacles, various accidents were cited and it was shown that 96.7 percent of them could have been prevented by the use of these devices. Thus this form of protection was first introduced into the code that year. These circuit interrupters were required for 120 volt, 15- and 20-ampere receptacles used under the following conditions: outdoors for dwellings [§210-8(a)], in dwelling bathrooms [§210-8(a)], at construction sites where the receptacles are not part of the permanent wiring [§210-8(b)], outside in mobile home parks [§550-23(c)], in patient care areas of hospitals subject to wet conditions where interruption of power under fault conditions can be tolerated [§517-52(b)], and near swimming pools where receptacles are located from 10 to 15 feet from the inside walls of the pool [§680-6(a)]. Ground fault circuit interrupter protection was also required for the electrical equipment used with storable swimming pools (§680-31) and fountains [§680-41(a)]. It was required, too, for underwater lighting fixtures for swimming pools not specifically designed to be free of shock hazard under any likely combination of fault conditions.

In the 1978 editions of the code, ground fault circuit interrupter protection was required for 120 volt, 15- and 20-ampere receptacles used in garages of dwellings [§210-8(a)], in recreational vehicle parks (§550-42), and on piers and wharfs other than those supplying shore power to boats (§555-3). The 1981 NEC requires ground fault circuit interrupter protection for the internal wiring of an outdoor portable sign where the sign is located so as to be readily accessible (§600-11).

(n) Other

The regulation of mobile homes, recreation vehicles, and swimming pools by the National Electrical Code is beyond the scope of this report. Nevertheless, since these facilities are closely related to housing, and since the regulations deal with obvious hazards, Appendix B, Miscellaneous includes historic discussion of these regulations.

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APPENDIX A

STRUCTURAL SAFETY

MINIMUM DESIGN LOAD COMPARISONS BY CODES

The following presents several codes. It illustrates the changes over time of live loads.

Terms used in these charts are:

a) psf - pounds per square foot.

b) psi - pounds per square inch.

c) ksi - kips per square inch (one kip equals 1,000 pounds).

d) DL - dead load

e) LL - live load

f) 4:12 - (or similar) slope of roof vertical/horizontal (relates to reduced live load on sloped roof).

g) Two-number limits shown for some occupancies, such as 125/100, indicate the live load for the first floor and the live load for upper floors. Thus, 125 psf for the first floor and 100 psf for the upper floors.

h) Earthquake loads are generally calculated as a function of the mass or weight of the building and the number given (8%) indicates the percent of building weight to be used in calculation.

i) LL Red - designates percentage reduction of live load in a multi-story building.

TABLE 1 **DESIGN CRITERIA** NYC Building Code Edition

VERTICAL LOADS		1891	1901	1917	1945	1970/current
Loads given in pounds per sq. foot ROOF:	FLAT	---	50	40	40	
	SLOPED	---	40>28°	30>20°	30>3:12	30 20°
FLOORS RESIDENTIAL:	SING. FAM.	75	Load reduc. 5% story 50% max 60	Same as 1901 4000# safe load 40 / in steel frame bldgs	40	40/30
	APT/TENANT	75	60	40	40	40
OFFICE		75	150/75	60	50	50
MERCANTILE		120	120	120	100	100/75
PUBLIC ASSEMBLY		120	90	100	100	100
EDUCATIONAL		120	75	75	60	40
WAREHOUSE		150	150	120		100-150
MANUFACTURING		---	120	120	120	100
LATERAL LOADS						
WIND		---	30	30>150'	20>100 ft ht	0-100'-20
EARTHQUAKE		---	---	---	---	101-300' 25 300-600' 30

TABLE 2

DESIGN CRITERIA

NATIONAL BUILDING CODE EDITION

VERTICAL LOADS		1905	1915	1931	1949	1955
ROOF:	FLAT	50psf<20°	50psf	30psf	20psf	
	SLOPED	30psf>20	30psf>20°	20psf>4:12		
FLOORS RESIDENTIAL:	SING. FAM.	60	60/40	40	40	40/30
	APT/TENANT	60	60/40	40	40	
OFFICE		150/75	120/75	50	80	80
MERCANTILE		120	120	125	125-250	
PUBLIC ASSEMBLY		90	120	100	100	
EDUCATIONAL		75	90/75	50	40	
WAREHOUSE		150	200	125	125-250	
MANUFACTURING		150	120	100	125	
LATERAL LOADS						
WIND		30psf	20psf	15psf<40'	20<50' 24-50'-100' 28-100'-199'	15psf>30' 20psf-30-50
				30psf>40'	30>200	
EARTHQUAKE				5%-10%	5%-10%	same

TABLE 3

DESIGN CRITERIA

Los Angeles Building Code Edition

VERTICAL LOADS		1904	1911	1923	1940 (1)	1960
Load given in pounds per sq. foot ROOF:	FLAT	40		30	20	20
	SLOPED				16>4:12	
FLOORS RESIDENTIAL:	SING. FAM.	50		40	40	40
	APT/TENANT	75		50	40	40
GRANDSTANDS				125		100
OFFICE		75	75	75	50	50
MERCANTILE		250	125	125	100	100
PUBLIC ASSEMBLY		125	125	125	100	100
EDUCATIONAL		---	---	75	50	50
WAREHOUSE		400	150	150	100-200	100-200
MANUFACTURING		400	150	150	100	100 min
LATERAL LOADS						
WIND						15psf 60'
EARTHQUAKE		---	---	---	8-16%	13.3%

(1) In 1943 a new multi-story mass distribution formula for seismic design was incorporated in the Los Angeles code.

TABLE 4

DESIGN CRITERIA

UNIFORM BUILDING CODE

VERTICAL LOADS		1927	1940	1961	1979
ROOF:	FLAT	30psf		20psf	20
	SLOPED	>4:12 25psf		>4:12 16psf	> 4:12 16
FLOORS RESIDENTIAL:	SING. FAM.	40	40	40	40
	APT/TENANT	40	40	40	40
OFFICE		50	50	50	50
MERCANTILE		75	75	75	75
PUBLIC ASSEMBLY		100	100	100	100
EDUCATIONAL			40	40	40
WAREHOUSE				125-250	125-250
MANUFACTURING		75-125	75-125	75-125	75-125
LATERAL LOADS					
WIND		10psf <40 20psf >40	15psf < 60 20psf > 60		15psf < 50 20 - 30 - 50
EARTHQUAKE		7 1/2-10% DL + LL	8%-10% DL+1/2 LL	13.3% DL RIGID	18.6% DL STRUCTURE

TABLE 5

DESIGN CRITERIA — CODE CRITERIA 1905 Comparison

VERTICAL LOADS		NYC 1901	NBC 1905	Los Angeles 1909		
ROOF:	FLAT	50	50psf< 20	40psf		
	SLOPED	30>20°	30>51°>20°			
FLOORS						
RESIDENTIAL:	SING. FAM.	60	60	50		
	APT/TENANT	60	60	75		
OFFICE						
MERCANTILE						
PUBLIC ASSEMBLY						
EDUCATIONAL						
WAREHOUSE						
MANUFACTURING						
LATERAL LOADS						
WIND						
EARTHQUAKE						

TABLE 6

DESIGN CRITERIA

CODE CRITERIA COMPARISON 1940

VERTICAL LOADS		NYC 1945	NBC 1931	LA Bldg 1940	UBC 1940 UBC
ROOF:	FLAT	40	30 psf<4:12	20psf	20psf
	SLOPED	30 > 3:12	20 psf>4:12	16>4:12 Pitz 4	16 psf>4:12
FLOORS RESIDENTIAL:	SING. FAM.	40	40	40	40
	APT/TENANT	40	40	40	40
OFFICE		50	50	50	50
MERCANTILE		100	125	100	75
PUBLIC ASSEMBLY		100	100	100	100
EDUCATIONAL		60	50	50	40
WAREHOUSE		---	125	100-200	---
MANUFACTURING		120	100	100	75-125
LATERAL LOADS					
WIND		>100' 20psf	15 psf < 40' 30 psf > 40'	15 psf<40'	15psf<60' 20psf>60'
EARTHQUAKE			5%-10%	8-16%	8-16%

TABLE 7

NYC BLDG CODE

MATERIAL STRESS CRITERIA	1891			1901			1917			1945			1970/current		
IRON AND STEEL	fc	ft	fb	fc	ft	fb	fc	ft	fb	fc	ft	fb	fc	ft	fb
	F.S.			F.S.			F.S.			F.S.			F.S.		
CAST IRON				16ksi	3ksi	16/3 ksi	16	3	16/3	16	3	16/3			
WROUGHT IRON				12ksi	12ksi	12ksi									
STEEL				16ksi	16ksi	16ksi	16	16	16	formula	18	18			
REINFORCING STEEL							16ksi/20ksi			18ksi					
TIMBER				500/1550	800/1500	600/1200	1400/800	60/1200	800/1600	Reg grade and spec					
							1:6								
MASONRY															
BRICK: UNREINFORCED															
REINFORCED															
HOLLOW CLAY TILE															
STONE							1:10								
CONCRETE															
PLAIN							150/500								
REINFORCED							650 psi			650/800					

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NATIONAL BUILDING CODE

TABLE 8

MATERIAL STRESS CRITERIA	1905			1915			1931			1949			1955		
IRON AND STEEL	fc	ft	fb	fc	ft	fb	fc	ft	fb	fc	ft	fb	fc	ft	fb
	F.S.			F.S.			F.S.			F.S.			F.S.		
CAST IRON	16 1:4	3	12/3	16	3	16/2.5		3	16/3						
WROUGHT IRON	12	12 1:4	12												
STEEL	16	12	16	16	16	16	18	18	18						
REINFORCING STEEL		—			—		18								
TIMBER	500/1200	600/1200 1:6	600/1200			1000/1600			1200/600		CONVENTIONAL INDUSTRY STANDARDS				
MASONRY	X														
BRICK: UNREINFORCED	X														
REINFORCED	X														
HOLLOW CLAY TILE	X														
STONE	X														
CONCRETE															
PLAIN	208-230 psi			500 psi			400								
REINFORCED	X			250-750 psi			650								

TABLE 9

UNIFORM BUILDING CODE

MATERIAL STRESS CRITERIA	1927			1940			1961			1979					
IRON AND STEEL	fc	ft	fb	fc	ft	fb	fc	ft	fb	fc	ft	fb	fc	ft	fb
	F.S.			F.S.			F.S.			F.S.			F.S.		
CAST IRON	10	0	--	Formula	0	-									
WROUGHT IRON															
STEEL	18	18	form.	form.	20	20	Form.	20	20	Perf std					
REINFORCING STEEL	16000-20000 pn			20000			20000			fy-40 fy-60					
TIMBER	600-1750			std			std			std reduced tension					
MASONRY															
BRICK: UNREINFORCED				175 125			175 125			175 125					
REINFORCED				400-500			250					250			
HOLLOW CLAY TILE	varies			70-80			70			70					
STONE	320-800			320-800			140-100			140					
CONCRETE															
PLAIN	1500														
REINFORCED	1500-3000 psf			2000-3750			2000-3750			2000-5000					

TABLE 10

SUMMARY OF WOOD STRESS FOR VARIOUS SPECIES OF LUMBER REQUIREMENTS OF 117 CODES NATIONAL LUMBER MANUFACTURERS ASSOCIATION

BENDING (2)

Species of Timber	No. Codes giving stresses	No. Codes with no stresses	Range of require-ments(1)	No. Codes giving stresses	No. Codes with no stresses	Range of require-ments(1)		
Douglas Fir								
Dense	61	56	1800- 800	60	57	750- 80		
Sound	71	96	1600-1000	18	99	350-85		
Hemlock								
Western	68	49	1300- 600	62	55	250-40		
Western	30	87	1500- 600	32	85	160-40		
Norway	46	71	1250- 700	43	74	150-40		
Pine								
Yellow Pine								
Dense	100	17	1800- 500	101	16	400-70		
Sound	59	58	1500- 900	58	59	350-70		
Spruce	85	82	1350- 250	86	31	500- 50		
Tamarack	9	106	1200- 900	9	108	170-95		
Western								
White Pine	81	76	1500- 250	77	40	500-40		

COMPRESSION (3)

Species of Timber	Parallel to grain "short columns"			Perpendicular to grain				
	No. Codes giving stresses	No. Codes with no stresses	Range of require-ments(1)	No. Codes giving stresses	No. Codes with no stresses	Range of require-ments(1)		
Douglas Fir								
Dense	58	59	1600- 100	60	57	800-200		
Sound	15	102	1500- 100	18	99	400-200		
Hemlock								
L. Western	62	55	1200- 80	70	47	1000-150		
Western	31	86	1500-80	26	91	500-150		
	99	18	1500-100	99	18	1000-250		
Norway	67	50	1000- 100	43	74	400-100		
Southern								
Yellow Pine								
Dense	98	19	1800- 820	102	15	1500-250		
Sound	57	60	1200- 750	62	55	800-170		
Spruce	83	34	3000- 650	88	29	1000-180		
Tamarack	9	108	1000- 750	9	108	350-220		
White Pine	81	36	1100- 800	80	37	1000-150		

NOTE: DENSE AND SOUND IN THE FOREGOING INCLUDES VALUES FOR NO. 1 AND NO. 2 STRUCTURAL LONG LEAF, SHORT LEAF, ETC., RESPECTIVELY.

SOURCE - NBS WORKING PAPERS - 1928 (Partial listing)

(1) Stresses are given in pounds per square inch (psi)
(2) Bending indicates wood acting as a beam.
(3) Compression indicates wood acting as a column.

TABLE 11

ANALYSIS OF CONCRETE STRESS REQUIREMENTS OF 73 BUILDING CODES
FROM DATA FURNISHED BY THE PORTLAND CEMENT ASSOCIATION
MARCH 1923

TYPE OF STRESS	No. Codes giving maximum allowable	MAXIMUM Given as % of ult.	MAXIMUM Given as lbs. per sq. in. (2)	MINIMUM Given as % of ult.	MINIMUM Given as lbs. per sq. in (2)
direct bearing	57	29	650	20	200
axial compression on columns(1) without spiral reinforcement	53	29	650	22.5	400
axial compression on columns with spiral reinforcement	46	35.5	850	25.0	500
compression in extreme fiber at center of span--	61	37.5	800	32.5	500
under side of supports--	16	37.5	750	37.5	650
Shear and diagonal tension without web reinforcement--	57	2.5	75	2.0	40
with full reinforcement--	33	6.0	150	5.0	65
punching shear--	18			5.0	100
Bond--					
Bond--					
Plain bars--	52	4.0	90	3.5	50
Deformed bars--	45	6.67	150	5.0	50
Reinforcing Steel					
Structural Grade--	51	33.3(3)	16000	25.0(3)	14000
Medium Grade--	54	33.3(3)	20000	25.0(3)	16000
High Grade--	56	33.3(3)	20000	25.0(3)	16000

SOURCE - NBS WORKING PAPERS - 1928 (Partial Listing)

(1) On conrete alone.
(2) Based on 2,000 pound per square inch concrete.
(3) Percent of elastic limit stress.

HISTORY OF BUILDING CODE PROVISIONS RELATED TO EARTHQUAKES

The hazard posed by earthquakes to buildings has long been known. The danger was first formally recognized when the San Francisco Building Code was revised in 1906, in response to the major earthquake in the city that year. The provision required buildings to be designed for a thirty pound per square foot wind force. This was thought to be adequate for both wind and earthquakes. This concept of using higher wind loads to design for earthquake forces prevailed until the mid 1920s. During the early twenties, engineers gained an understanding of the inertial effect of building masses, and of the fact that wind and seismic forces are not equivalent. Such simple Newtonian concepts were first required in the 1927 edition of the Uniform Building Code (UBC), which provided for lateral force design as a function of the mass of the building.

This UBC provision also varied the earthquake force in proportion to the foundation load or soil pressure. This appears to reflect some early understanding of the effect soils play on the actual forces on the building.

There were no other regulatory or legislative activities until the 1933 earthquake in Long Beach, California, although research was initiated by the United States Coast and Geodetic Survey in response to the 1925 Santa Barbara earthquake. This research led to the development of strong motion seismographic equipment. Some of this equipment was in place for the 1933 earthquake and the acceleration record was obtained, although the range of the equipment was exceeded.

In 1928, the California State Chamber of Commerce recognized the need for a building code for earthquake safety. Studies under the group's sponsorship provided a foundation for future codes. In 1933, the Long Beach earthquake destroyed many buildings. Among these were public schools, and there was much concern over what would have happened had the earthquake occurred during school hours. The California State Legislature in 1938 adopted what is commonly known as the Field Act, which included a set of standards the state was to use to approve plans for public schools. For masonry buildings, the act required a lateral force design of 10 percent of the dead-load plus a portion of the live load. There were also provisions based on soil pressure. This was significantly in excess of existing code requirements at the time.

Along with the Field Act, California also passed the Riley Act in 1938, which required seismic design of all structures, except certain types of dwellings and agricultural buildings. A seismic coefficient of 2 percent of the total vertical design load was the design criterion.

In 1937, requirements for Field Act school buildings were revised to make the seismic coefficient between 6 percent and 10 percent for buildings of three stories or less. Buildings more than three stories with a complete moment resisting frame had lower coefficient of 2 percent to 6 percent. Again the range of values was related to soil pressures. In 1941, the coefficients required were 6 percent to 10 percent depending on the type of foundation materials. Some work was initiated after the war. In 1953, a coefficient for seismic design as a function of the number of stories of the building was developed, $\frac{60}{N} + 4.5$ where N is the number of stories.

The Riley Act was amended in 1953 to specify a coefficient of 3 percent for buildings of less than 40 feet in height and 2 percent for buildings over 40 feet.

Local building ordinances throughout California also attempted to deal with seismic design. In 1933, the Los Angeles Building Code required a coefficient of 8 percent of the dead load plus half the live load. This factor was also used in the Uniform Building Code. The UBC also included areas of seismic probability and different force factors based on the building's seismic zone. The 1935 Uniform Building Code also incorporated different design values based on the soil pressure or the type of soil.

By 1943, the Los Angeles City Code recognized the influence of flexibility on earthquake design coefficients (C) and used a formula based on the number of stories $C = \frac{60}{N} + 4.5$. Much effort was devoted to establishing a coefficient that could be used for buildings of any number of stories. Prior to 1959, Los Angeles had a 13 story limit and all the equations were related to this maximum number. In 1959, a new formula for the seismic load of multi-story buildings was developed. The intent was to retain existing design methods for 13 story buildings and not make them suddenly inadequate or obsolete. This 1959 formula was developed by a large committee of California structural engineers, who sought to develop approved uniform seismic provisions for inclusion in a building code.

These provisions, <u>Recommended Lateral Force Requirements</u>, are commonly known as the SEAOC Code (Structural Engineers Association of California), or, frequently, the "Blue Book", after the traditional color of its cover. The code was intended to address the dynamic nature of structural response to earthquakes, with attention to past experience, available research and studies of actual damage. The initial edition noted that this was to be an interim code, as any progressive code should be, since so much further research was required.

The SEAOC Code reflected the different design approaches and methods used in Northern and Southern California. The seismic code essentially attempts to provide for an equivalent static design of a dynamic process, in a form that is simple enough to accommodate most buildings.

While Los Angeles was moving ahead in its seismic provisions it wasn't until 1947 that San Francisco had any more stringent code provision than the Riley Act. In 1947, a table of variable coefficients was adopted: the maximum value for a one-story building--8 percent, and a minimum value for a 30-story building—3.7 percent; both variable according to soil conditions. These were also applied to design vertical loads. In 1948, a joint committee on lateral forces was established by the Structural Engineers of Northern California, a subgroup of the American Society of Civil Engineers. After several years of study this committee recommended that seismic coefficients be related to the fundamental period of the structure, so that building design would relate to dynamic forces. The coefficients applied only to the deadload plus a portion of the live load, rather than both in their entirety. With slight modifications, they were adopted in the 1956 San Francisco Building Code.

The 1960-61 edition of the UBC incorporated in the first statewide seismic provisions, developed previously by the Structural Engineers Association of California (SEAOC), discussed earlier.

These 1960 requirements included two important variables in the criteria. The first is the fundamental period of the structure, the other is dependent upon the type of structural system.

In 1966, the SEAOC Code was revised to repeal the 160 foot height limitation placed on concrete structures. This reflected the research on moment resisting frames conducted by the Portland Cement Association; also included were requirements for shear walls with moment frames. Other changes include an increased force at the roof line, the inclusion of an overturning formula and some force increases for elevated water towers and other structures. Other minor changes were made in 1967. These included a dynamic analysis option for some structures.

The next revision occured in 1973, after the Caracas, Venezuela, and San Fernando earthquakes. This edition brought in consideration for dynamic design and greater requirements for highrise concrete and steel buildings. Included were recommendations for limiting drift (story to story deflection).

The UBC requirements incorporate the SEAOC recommendations with minor changes. The UBC, since it is used in many areas of the country, incorporates a factor for seismic zoning. It also requires analysis of certain mechanical equipment.

Additional changes in the 1976 UBC included a soil factor (S), which reflects the possible increase or decrease of seismic forces depending on the type of structure. Another factor is the "I" or importance factor which requires a greater design force for structures that must operate after an earthquake, such as hospitals, and police and fire stations.

Other model, statewide, and local codes have essentially adopted the UBC provisions for seismic design. Much new research has been accomplished as a result of the 1971 San Fernando earthquake. Through HUD, NBS, and NSF funding, the research has provided a greater understanding of seismic forces and dynamic design. The "ATC provisions" developed by the Applied Technology Council of SEAOC and funded by NSF and NBS is now out for review. Certain elements of this new document are currently being proposed for inclusion in the San Francisco Building Code. They will no doubt be included in future model codes.

APPENDIX B

ELECTRICAL SAFETY

METHODS OF OVERCURRENT PROTECTION

The following pages contain the historic development for provisions in the National Electrical Code for specific methods of overcurrent protection.

Plug Fuses

At the beginning of this century, Edison-base plug fuses in Edison-base fuse holders were used in ratings 0-30 amperes to protect branch circuit conductors. Because of ready interchangeability, a 30 ampere fuse could be used where actually a smaller rating was required to properly protect the conductor. Also a penny could be inserted into the fuse holder behind the plug fuse and serve to bypass the fuse protection. Because of these deficiencies, the Type S fuse was developed which was tamper resistant and had classifications of 0-15 and 16-30 amperes (801). These fuses and corresponding fuse holders were introduced into the 1933 edition of the code and became mandatory in the 1940 edition (2453). However, mandatory application was set aside during the war because of shortage of materials during and after the war. When the committee voted to reinstate the requirement in the 1947 Code, it was set aside by the Board of Directors of the National Fire Protection Association until the 1959 NEC (240-21), when it was again accepted to become effective January 1, 1961. It has been in effect since that date. The Edison-base plug fuse has continued to be manufactured for replacement purposes and the Edison-base fuse holders can be converted to Type S by the use of an adaptor. In 1971, a limitation on the use of Edison-base plug fuses was added to the code (240-20) which served to stop their use in existing installations where there was evidence of overfusing or tampering.

Cartridge Fuses

In the 1901 NEC (52) cartridge fuse cut-out bases were rated 0-250 volts with six classifications covering 0-500 amperes, and for 251-600 volts, six classifications for 0-500 amperes. Over the years, minor changes were made, but it was not until the 1959 edition that the classifications were increased to include up to the 6,000 ampere classification at 600 volts. The fuses, while rated at 600 volts, can be used for the lower voltage ratings. Although a 300 volt classification of fuse was introduced in the 1965 NEC (240-23) and offered improved performance because of low energy loss in the fuse, it has not been widely used because of the convenience offered by circuit breakers.

Link Fuses

Link fuses represented one of the early forms of fuse protection and were inexpensive because only the fuse metal needed to be replaced after operation. However, tools were needed and thus replacement was intended to be done only by a qualified person who would have knowledge about not only the hazards involved, but also in using the proper link for replacement. While special permission was necessary in some editions of the code in order to use link fuses, and this gave some control over their use, it was in the 1971 NEC that provision for their use was deleted from the code.

Circuit Breakers

Since the beginning of the NEC, circuit breakers have been recognized as an acceptable means of overcurrent protection for wires and equipment. The circuit breaker has been available in either adjustable or non-adjustable types with magnetic or thermal activation and with instantaneous or time delay trip features. Circuit breakers were selected to match the rating of the conductors with a small factor added to prevent nuisance trip out. It was not until 1953 that standard ratings (2461) were established for circuit breakers. In 1968, the same classification requirements [240-5(b)] were applied to both fuses and circuit breakers.

TYPES OF INSULATED CONDUCTORS

Code Year	Action	Conductor Types
1900		R, SBW, SB, WP
1913	Adds	RS
1915	Adds	RD, RSL, RDL
1920	Adds	UC
1937	Adds	A, Paper
1940	Adds	RP, RH, RW, RHT, RPT, RU, SN, AVA, AVB, AVL, AI
1947	Adds	T, TA, AA, AIA
	Deletes	RP
1953	Adds	RUH, RUW, TW
1956	Adds	RHH, RHW, MI
	Deletes	SBW
1959	Adds	TBS, SA
	Deletes	WP
1962	Deletes	SB
1965	Adds	THHN, THWN, SIS, FEP, FEPB
1968	Adds	XHHW, MTW
1971	Adds	TFE
1975	Adds	UF, USE
1978	Adds	PFA, PFAH, FEPW, Z, ZW

A = Asbestos

RH = Heat-Resistant Rubber

RUW = Moisture-Resistant Latex Rubber

AVA = Asbestos and Varnished Cambric

AVB = Asbestos and Varnished Cambric

AVL = Asbestos and Varnished Cambric

AI - Asbestos

T = Thermoplastic

TA = Thermoplastic and Asbestos

AA = Asbestos

AIA = Asbestos

RUH = Heat-Resistant Latex Rubber

RHH = Heat-Resistant Rubber

RHW = Moisture and Heat-Resistant Rubber

MI = Mineral Insulation (Metal Sheathed)

TBS = Thermoplastic and Fibrous Outer Braid

SA	=	Silicone-Asbestos
THHN	=	Heat-Resistant Thermoplastic
THWN	=	Moisture and Heat-Resistant Thermoplastic
SIS	=	Synthetic Heat-Resistant
FEP	=	Fluorinated Ethylene Propylene
FEPB	=	Fluorinated Ethylene Propylene
XHHW	=	Moisture- and Heat-Resistant Cross-Linked Synthetic Polymer
MTW	=	Moisture-, Heat-, and Oil-Resistant Thermoplastic
TFE	=	Extruded Polytetrafluorethylene
UF	=	Underground Feeder & Branch-Circuit Cable-Single Conductor. (For Type UP cable employing more than one conductor see Article 339)
USE	=	Underground Service Entrance Cable-Single Conductor. (For Type USE cable employing more than one conductor see Article 338)
TW	=	Moisture-Resistant Thermoplastic
R	=	Rubber covered (early code)
SBW	=	Slow burning weatherproof
SB	=	Slow burning (interior)
WP	=	Weatherproof - early impregnated cotton braid (exterior)
RS		(No documentation)
RD	=	Multiconductor - rubber insulation
RSL	=	Lead sheathe - single
RDL	=	Lead sheathe - multiconductor
UC		(No documentation)
RP	=	Performance grade rubber
RW	=	Rubber - weatherproof
RHT	=	(transition, used only short time)
RPT	=	(transition, used only short time)
RU	=	Gum rubber (latex) thinner diameter - high performance
SN	=	Early synthetic
PFE	=	Teflon
PFAH	=	Special high performance plastics
FEPW	=	High performance plastics
Z	=	Silicone
ZW	=	Silicone for wet conditions

TYPES OF FIXTURE WIRE

The following table indicates the types of fixture wire and the time of their introduction into, or deletion from, the National Electrical Code.

Code Year	Action	Conductor Types
1900		Rubber insulated
1909	Adds	Slow-Burning
1911	Adds	F-64, F-32
1928	Adds	AF, RF-64, RF-32, RF, SBF, AF
1930	Adds	CF, FF-64, FF-32, FF
1937	Deletes	RF and FF
1940	Adds	R, RP, RH, RHT
1947	Adds	TF, TFF
1951	Adds	RUB, RUFF
1953	Deletes	RF-64, RF-32, FF-64, FF-32
	Adds	RF-1, RF-2, FF-1, FF-2, RFH-1, RFH-2, FFH-1, FFH-2
1956	Adds	SF-1, SF-2, SFF-1, SFF-2
1968	Adds	TFN, TFFN, PF, PGF, PFF, PGFF
1971	Adds	PTF, PTFF
1975	Deletes	RF-1, RF-2, FF-1, FF-2
1978	Adds	KF-1, KF-2, KFF-1, KFF-2, HF, HFF, ZF, SFF, PAF, PAFF

TYPES OF FLEXIBLE CORD

The following table indicates the types of flexible cord and the time of their introduction into, or deletion from, the National Electrical Code.

Code Year	Action	Types
1900		Approved insulation
1911	Adds	C, CWp, P, PWp, PO, PA, T, B, E
1913	Adds	CB, CC, PS, CA, PkWp, PAWp
	Deletes	CWp
1920	Adds	PD
	Deletes	PS
1923	Adds	SJ, S, H
1928	Adds	PO-64, PO-32, P-64, P-32, PWP-64, PWP-32
	Deletes	T
1930	Adds	AT, CT, AFC, CFC, K
	Deletes	CB, B, CC
1931	Adds	HC, HPO, HPD
	Deletes	H
1933	Adds	AFPO, AFPD, CFPD, CFPO, POSJ, ES, AFS, AFSJ
	Deletes	HPO
1935	Adds	POSJ-64, POSJ-32, HSJ
	Deletes	POSJ
1937	Adds	ATJ, CTJ, SV
	Deletes	ES
1940	Adds	SJO, SO, AVPD, AVPO
	Deletes	PA, PAWP
1947	Adds	POT-64, POT-32, SVT, SJT, ST, EO
1949	Adds	ST, SU, SUO
1953	Adds	TP, TPT, TS, TST, PO-1, PO-2, SP-1, SP-2, SPT-1, SPT-2, P-1, P-2, PW-1, PW-2, PW, HS, HPN, SR, SRT, ET
	Deletes	AT, CT, ATJ, CTJ, PO-64, PO-32, POSJ-64, POSJ-32, P-64, P-32, SU, SUO, PWP-64, PWP-32, PWP, POT-64, POT-32
1956	Adds	SPT-3
	Deletes	STO
1959	Adds	SP-3
	Deletes	CA
1962	Adds	SRD, SRDT
	Deletes	SR, SRT
1965	Adds	SVO, SVTO, SJTO, STO, HSJO, HSO
	Deletes	PW-1, PW-2, PW
1968	Adds	EN, ETP
	Deletes	AFPO, CFC, CFPO, K, P-1, P-2, P
1971	Adds	DDP, ETLB, ETT
	Deletes	DPT
1978	Deletes	PO-2, PO-2, PO, SUHT, HC, AVPO, AVPD
1981	Adds	SPE-1, SPE-2, SPE-3, SVE, SVOO, SVOOT, SJE, SJOO, SJTOO, SE, SOO, STOO, SRDE

TABLE OF WIRING METHODS

The following table indicates wiring methods and the time of their introduction into, or deletion from, the National Electrical Code.

Code Year	Reference	Requirements
1900	24g.	Open work
	24l. and m.	Moulding work (wood and metal)
	24n.,o.,p.	Conduit
	24q.,r.,s.,t.,u.	Concealed knob and tube
1907	24A	Armored cable
1928	504	Surface Metal Raceway
	506	Underfloor Raceway
	507	Nonmetallic Sheathed Cable
	508	Electrical Metallic Tubing
	510	Underplaster Extensions
	514	Surface Wooden Raceway
1930	509	Cast-in-Place Raceway
1931	511	Wireways and Busways
	512	Auxiliary Gutters
	515	Bare Bus-Bars and Risers
1933	516	Nonmetallic Surface Extensions
1935	513	Service Entrance Cable
	517	Nonmetallic Wiring Systems for Use in Wet Places
1937	Art. 328	Bare-Conductor Feeders
	Art. 340	Nonmetallic Waterproof Wiring
	Art. 342	Nonmetallic Surface Extension
	Art. 350	Flexible Metal Conduit
1940	Art. 356	Cellular Metal Floor Raceway
1951	Art. 351	Liquidtight Flexible Metal Conduit
1953	Art. 330	Mineral Insulated Metal Sheathed Cable
	Art. 353	Multi-outlet Assembly
1956	Art. 339	Underground Feeder and Branch Circuit Cable
	Art. 358	Cellular Concrete Floor Raceways
1962	Art. 331	Aluminum Sheathed Cable
	Art. 334	Metal-Clad Cable
	Art. 347	Rigid Nonmetallic Conduit
1965	Art. 318	Continuous Rigid Cable Supports
	Art. 357	Structural Raceways
	Art. 365	Cablebus
1971	Art. 337	Shielded Nonmetallic Sheathed Cable
	Art. 363	Flat Cable Assemblies
1975	Art. 332	Copper-Sheathed Cable
	Art. 340	Power and Control Tray Cable
	Art. 345	Intermediate Metal Conduit
	Art. 366	Electrical Floor Assemblies
1978	Art. 326	Medium Voltage Cable
	Art. 349	Flexible Metallic Tubing
1981	Art. 321	Messenger Supported Wiring
	Art. 328	Flat Conductor Cable

THEATERS

Although specific requirements for theaters were introduced into the 1907 NEC under Section 31A, there were already requirements in the code for motion picture machines (65A). Theaters were required to have two sources of electrical energy to supply the necessary exit lighting connected to the emergency system. These requirements applied only where there was seating capacity for at least 400 persons. All wiring on the stage side of the proscenium wall, other than border and switchboard wiring, was required to be in approved conduit. Wiring in the auditorium and in dressing rooms was required to be in approved conduit, except that for existing buildings, armored cable could be used. Exit lights were required to provide lighting for all passageways leading to the street. In 1911, the reference to seating capacity was deleted.

In 1923, these requirements were rearranged into a new Article 39. The type of flexible cord used on the stage was required in the 1937 code to be Type K or S, and it was then that the Article was changed to 520 on theaters with a reference to Article 540 on motion picture projectors that required professional type projectors to be located in a fire resistant enclosure. Revision was made in 1947 to recognize Types SO and ST flexible cord.

MISCELLANEOUS

Mobile Homes and Recreational Vehicles

In the 1965 National Electrical Code (NEC), new articles were added (550 and 551) to provide detailed requirements for mobile homes and recreational vehicles. Because of their compact nature, deviations from the requirements for conventional dwellings were necessary. Also where equipment is subject to travel over roads, it is subject to vibration and other conditions that need to be provided for. While these equipments are required to conform to basic safety provisions in the NEC, the special requirements established for them are intended to have precedence and apply wherever difference in requirements occur. The supply conductors contain an equipment grounding conductor which is separate from the grounded circuit conductor. This is required to prevent a dangerous condition existing which would allow the exposed metal to reach line voltage potention where a single conductor is used for both functions and a loose connection in the grounded circuit occurs. Where the supply conductors consist of a cord and plus connection, the possibility of a loose connection is considered likely.

Swimming Pools

Reports of fatal electrical shock in swimming pools caused the Electrical Correlating Committee of the NEC to appoint a Technical Subcommittee to make recommendations for requirements for inclusion in the NEC which would insure safety to those using swimming pools having underwater lights, circulating pumps, and other equipment and associated wiring in and around swimming pools.

Accident statistics on swimming pool fatalities were collected for a number of years in establishing electrical requirements for wiring and equipment used in swimming pool installations. This material was submitted to NFPA and should be in their files.

The recommendations of the Technical Subcommittee resulted in specific requirements introduced into the 1962 NEC which provided protective grounding to all metal around the pool which could become energized through breakdown of electrical insulation. General use receptacles were prohibited in the area 10 feet from the inside walls of the swimming pool.

In 1975, the NEC introduced the ground fault circuit interrupter and such protection was required for receptacles located between 10 and 15 feet from the swimming pool (680-6).

Ground fault circuit interrupter protection was also required on circuits supplying underwater lighting fixtures operating at more than 15 volts. In 1978, fixtures that depended on submersion for safe operation were required to have a low water cutoff which would protect against low water level in the pool and also for the condition where the fixture was removed from its niche and placed on the deck for relamping or other maintenance purposes.

These requirements on grounding and ground fault protection have assured users of swimming pools reasonable protection from electric shock during use and maintenance of swimming pools.