NFPA 914

Recommended Practice for Fire Protection in Historic Structures

1994 Edition

NFPA

National Fire Protection Association, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101
An International Codes and Standards Organization

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This edition of NFPA 914, *Recommended Practice for Fire Protection in Historic Structures*, was prepared by the Technical Committee on Protection of Cultural Resources and acted on by the National Fire Protection Association, Inc., at its Annual Meeting held May 16–18, 1994, in San Francisco, CA. It was issued by the Standards Council on July 14, 1994, with an effective date of August 5, 1994, and supersedes all previous editions.

The 1994 edition of this document has been approved by the American National Standards Institute.

Origin and Development of NFPA 914

The Committee on Protection of Cultural Resources: Libraries, Museums, Places of Worship, and Historic Structures was first organized as the Committee on Libraries, Museums and Historic Buildings in 1940. The first committee document, published in 1948, was the manual, *Protecting Our Heritage: Historic Buildings, Museums and Libraries.* A second edition of the manual was published in 1970.

The committee has revised and updated this material as a recommended practice to incorporate changes in the state of the art, to make the document more usable, and to reflect the new technology of both fire detection and fire extinguishing systems. NFPA 913, *Recommended Practice for the Protection of Historic Structures and Sites,* was adopted at the 1987 Annual Meeting in Cincinnati.

The committee approved a request in November 1984 to develop a publication similar to NFPA 913 for buildings rehabilitated for new uses. A recommended practice was prepared in draft form for the 1988 Annual Meeting but was not considered by the committee to be ready for publication. The committee continued to revise and organize the material, and the document was submitted once again at the 1989 Annual Meeting in Washington, DC, where the first edition was adopted. The original title was *Recommended Practice for Fire Protection in Rehabilitation and Adaptive Reuse of Historic Structures.*

Since the 1989 edition of NFPA 914, a great number of historic structures have been extensively damaged or destroyed by fire. It is hoped that this 1994 edition, with its expanded fire protection guidelines, will assist the management of historic structures to recognize the need for an overall fire protection plan and to emphasize their responsibility to address fire protection and to preserve the historic integrity of these irreplaceable artifacts of history and culture.

Note that the title of the document has been changed to *Recommended Practice for Fire Protection in Historic Structures,* to more accurately depict the content of the revised document and to recognize that existing NFPA 913 is in the process of being combined with NFPA 911, *Recommended Practice for the Protection of Museums and Museum Collections.* It is anticipated that NFPA 913 will be withdrawn at the Association's annual meeting in 1995.

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

Committee Scope: This Committee shall have primary responsibility for documents on fire safety recommendations for libraries, museums, places of worship, and historic structures and their contents but shall not overlap the provisions of NFPA *101®, Life Safety Code®*.

Contents

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Information on referenced publications can be found in Chapter 7 and Appendix E.

Chapter 1 Introduction

1-1 Scope. This document describes principles and practices of fire safety for historic structures and for those who operate, use, or visit them. It covers ongoing operation and rehabilitation and acknowledges the need to preserve historic integrity.

1-1.1 Operation. Continuous monitoring of fire safety is a necessary component of the management and operation of historic structures.

1-1.2 Rehabilitation. Buildings undergoing renovation present unique conditions for three reasons: acutely increased susceptibility to fire loss, application of a separate set of regulatory requirements, and opportunity for nonintrusive installation of fire protection devices and systems.

1-1.3 Historic Integrity. Historic structures are irreplaceable artifacts of history and culture with unmeasurable intangible value. Special consideration is necessary to design fire and life safety into such structures without sacrificing historic integrity.

1-1.4 Libraries and Museums. This document does not cover library and museum collections, which are the subjects of NFPA 910, *Recommended Practice for the Protection of Libraries and Library Collections*, and NFPA 911, *Recommended Practice for the Protection of Museums and Museum Collections*, respectively.

1-2 Purpose. The purpose of this recommended practice is to reduce fire losses in and to historic buildings. The document provides guidance on fire prevention and protection of historic buildings in several different areas of functional responsibility.

1-2.1 Management. Whether it is a manager, owner, architect, or contractor, someone is managerially responsible (knowingly or otherwise) for fire safety in each historic structure. This document will familiarize management with the problems of fire safety in historic structures and with the means of addressing them.

1-2.2 Authority Having Jurisdiction. Most ordinances regulating building construction and fire safety have a provision that accords special consideration for historic buildings. The intent of such provisions is to encourage greater flexibility in the regulation of structures that are important to our cultural heritage. This document will assist authorities having jurisdiction in the administration of these provisions.

1-2.3 Historic Preservation. The objective of historic preservation is to avoid the loss of culturally significant structures, and one of the greatest threats to older buildings is damage or destruction by fire. This document focuses on the preservation from the effects of fire with minimum intrusive impact.

1-2.4 Fire Safety Specialist. Historic buildings pose a unique fire safety problem. Special consideration must be given to implementing fire safety without destroying or impacting the significant historic character of a building. This document emphasizes the additional limitations imposed on the fire safety specialist and provides guidance on how to work within these limitations.

1-2.5 Design Professional. Architects and engineers involved in the rehabilitation or restoration of historic structures need guidance on incorporating fire safety objectives in the design phase and providing adequate fire protection during renovation. This document provides planning and design solutions appropriate for historic buildings.

1-3 Equivalency Concepts.

1-3.1 Nothing in this document is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety as alternatives to those described by this recommended practice, provided technical documentation is submitted to the authority having jurisdiction to demonstrate equivalency, and the system, method, or device is approved for the intended use.

1-3.2 The specific recommendations of this document may be permitted to be modified by the authority having jurisdiction to allow alternative arrangements that will secure the level of fire protection intended by this document.

1-4 Background.

1-4.1 Historic Preservation. In the last several decades, recognition of the importance of historic buildings has increased around the world. Although such structures as house museums and public monuments have long been identified as having historical and cultural significance, the types and quantities determined to be worthy of protection have expanded greatly and now include a wide variety of building types.

Thousands of buildings are listed or registered by national agencies, individually or as components of historic districts. Local jurisdictions also can designate historic or heritage buildings. Designation is intended to protect the architectural character and integrity of a structure, including all original and significant exterior and interior spaces and features.

Review of proposed rehabilitation or maintenance work might be required by a local, regional, or federal authority for a variety of regulatory requirements or incentive programs. These reviews are separate from those conducted for building code and fire protection purposes.

Where local design review commissions have authority, approval typically is necessary for exterior work only. Higher level administrative authorities are usually involved where government funds or tax incentives are used; the scope of these reviews is likely to include all exterior and interior work. Similarly, guidelines for treatment of historic buildings might be contained in local ordinances or in national standards. For example, in the United States, the Secretary of the Interior's Standards for Rehabilitation and Guidelines for Rehabilitating Historic Buildings are used for all federally funded or assisted projects, and in many cases for projects receiving local funding and permits.

As early in the rehabilitation process as possible, the authorities having jurisdiction for review should be consulted. Historic preservation organizations and agencies can be of assistance in identifying those authorities, consultants, and architects who specialize in historic preservation. (*See Appendix B.*)

1-4.2 Consequences of Fire. Historic structures are susceptible to many perils, including humidity, pollution, insects, mold, theft, vandalism, and weather. However, fire is the most serious because it can destroy quickly and completely. Conservation efforts can restore structures damaged by perils other than fire, but once the historic fabric is burned, it is lost forever. Even if the structure is not completely destroyed, it is important to recognize that a small fire can quickly inflict massive damage to decorative features and building contents. Recent fires in historic buildings illustrate the severity of the problem. (*See Chapter 2.*)

1-4.3 Life Safety. An even greater concern is the threat to the lives of persons inside a burning building. Preservation of the structure and its contents is secondary to saving human life. Providing life safety can present difficult problems, since most historic structures predate the development of modern building codes. Historic buildings tend to be combustible and seldom have adequate means of emergency egress by contemporary standards. Open stairways, absence of smoke and fire barriers, and flammable finishes allow fire to develop and spread rapidly. Exit signs and emergency lighting might not have existed when these structures were built, but their absence can leave visitors confused as to how and where to leave the building in an emergency situation. Special plans for occupant protection and emergency evacuation might be necessary to avoid unacceptable risk of injury or death from fire in a historic structure. (*See NFPA 101®, Life Safety Code®.)*

1-4.4 Building Codes and Standards. Building regulations are written primarily for new construction. They establish a minimum standard for building construction through the use of prescriptive standards that specify allowable materials or techniques, or they establish performance standards that specify the level of performance any proposed material or assembly must meet. Most codes determine allowable construction techniques or materials by weighing the degree of safety provided by the building (its construction classification) against the degree of hazard presented by the user (occupancy classification) and by taking into account such factors as installed fire detection and suppression systems. Most codes make reference to specific standards prepared by government agencies or private associations, such as NFPA. These standards typically are narrowly focused and provide more detailed information than codes.

Most code documents are modified at regular intervals in response to new safety precepts and technological advances. Each modification has the potential to exacerbate inherent conflicts that exist between a code and the historic or existing building constructed prior to adoption of that code. The conflicts typically must be resolved by local officials with the authority to approve noncomplying alternatives in special circumstances, or through variance hearings, usually conducted at a higher level of authority.

1-4.5 Responsibility. Owners, governing boards, and staffs of historic structures have a significant responsibility for the preservation and protection of property entrusted to their care. Such stewardship might rest with managers, curators, or administrators who are qualified in conservation but have little knowledge or experience in fire safety. Nevertheless, it is the duty of persons responsible for historic structures to manage and operate their buildings to prevent fires, reduce losses, and respond appropriately to emergencies. There is an obligation to ensure that fire hazards are identified and analyzed by qualified staff or consultants and that corrective measures are taken without negative impact on structure integrity. Those in charge must recognize that there are fire problems inherent in operating a historic structure and that appropriate policies and procedures need to be developed and implemented.

1-5 Definitions.

Adaptive Use. A use for a building other than that for which the structure was originally designed or intended.

Addition. An extension or increase in the floor area or height of a building or structure.

Approved. Acceptable to the authority having jurisdiction.

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

Atrium. A floor opening or series of floor openings connecting two or more stories that is covered at the top of the series of openings and is used for purposes other than as an enclosed stairway, elevator hoistway, escalator opening, or utility shaft used for plumbing, electrical, air conditioning, or communication facilities.

Authority Having Jurisdiction. The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

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

Collections. An assemblage of objects, works of art, and historic documents or natural history specimens, or both, collected according to a rational scheme and maintained so they can be preserved, studied, or interpreted for public benefit. Collections might be used in museum exhibits, as furnishings in period rooms, for research, or they might be kept in storage.

Compartment. See "Fire Compartment."

Compliance. Adherence or conformance to laws and standards.

Conservation. The broad range of practices involved in the preservation of historic and artistic works. Conservation encompasses four explicit functions: examination, documentation, preservation, and restoration. Examination is a procedure used to determine the nature, method of manufacture, or properties of materials and the causes of their deterioration. Documentation procedures record the condition of an object before, during, and after treatment and outline, in detail, treatment methods and materials used. Preservation is action taken to prevent, stop, or retard deterioration. The process includes both the stabilization of the condition of a work of art by conservation and the stabilization of the environment surrounding a work of art by preventative conservation methods to minimize the effects of agents of deterioration. Restoration is the reconstruction of missing parts in an effort to recreate the original appearance of a damaged work of art.

Early Warning. A signal provided by a system that detects fire in its earliest stages of development to enhance the opportunity of building occupants to escape and to commence manual suppression of the fire prior to arrival of fire service units.

Equivalency. An alternative means of providing fire safety greater than or equal to that afforded by strict conformance to specification standards.

Exit. That portion of a means of egress that is separated from all other spaces of the building or structure by construction or equipment to provide a protected way of travel to the exit discharge.

Exit Access. That portion of a means of egress that leads to an entrance to an exit.

Exit Discharge. That portion of a means of egress between the termination of an exit and a public way.

Fire Barrier. A continuous membrane, either vertical or horizontal, such as a wall or floor assembly, that is designed and constructed with a specified fire resistance rating to limit the spread of fire, and that also will restrict the movement of smoke. Such barriers might have protected openings.

Fire Compartment. A space within a building that is enclosed by fire barriers on all sides, including the top and bottom.

Fire Hazard. Any situation, process, material, or condition that, on the basis of applicable data, can cause a fire or explosion or provide a ready fuel supply to augment the spread or intensity of a fire or explosion and that poses a threat to life or property.

Fire Resistance Rating. The time, in minutes or hours, that materials or assemblies have withstood a fire exposure as established in accordance with the test procedures of NFPA 251, *Standard Methods of Fire Tests of Building Construction and Materials.*

Fire Stop. A fire-resistant material, barrier, or construction installed in concealed spaces or between structural elements of a building to prevent the extension of fire through walls, ceilings, and the like.

Hazardous Areas. Areas of structures, buildings, or parts thereof having a degree of hazard greater than that normal to the general occupancy of the building or structure. Examples include storage or use of combustibles or flammables; toxic, noxious, or corrosive materials; or use of heat-producing appliances.

Historic Building. A structure and its associated additions and site deemed to have historical, architectural, or cultural significance by a local, regional, or national jurisdiction. Designation might be in an official existing or future national, regional, or local historic register, listing, or inventory.

Historic Character. The essential quality of a historic building or space that provides its significance. The character might be determined by the historic background, including association with a significant event or person, the architecture or design, or the contents or elements and finishes of the building or space.

Historic Fabric. Original or added building/construction materials, features, and finishes that existed during the period deemed to be most architecturally or historically significant, or both.

Historic Preservation. Generic term that encompasses all aspects of the professional and public concern related to the maintenance of a historic structure, site, or element in its current condition, as originally constructed, or with the additions and alterations determined to have acquired significance over time.

Historic Structure. A structure built or constructed, such as a building, monument, or bridge, that is deemed to have historical, architectural, or cultural significance by a local, regional, or national jurisdiction.

Horizontal Opening. An opening through a wall.

Means of Egress. A continuous and unobstructed way of exit travel from any point in a building or structure to a public way.

Means of Escape. A way out of a building or structure that does not conform to the strict definition of means of egress but does provide an alternate way out.

Noncombustible. Material that, in the form in which it is used and under normal conditions anticipated, will neither aid combustion nor add appreciable heat to an ambient fire.

Occupancy. The purpose for which a building or portion thereof is used or intended to be used.

Occupant Load. The total number of persons that may be permitted to occupy a building or portion thereof at any one time.

Preservation. The act or process of applying measures to sustain the existing form, integrity, or materials of a building, structure, or artifact and the existing form or vegetive cover of the site.

Protection. The act or process of applying measures designed to affect the physical condition of a building, structure, or artifact by guarding it from deterioration, loss, or attack or to cover or shield it from damage. Protection in its broadest sense also includes long-term efforts to deter or prevent vandalism, theft, arson, and other criminal acts against historic resources.

Rehabilitation. The act or process of returning a structure to a state of utility through repair or alteration that makes possible an efficient contemporary use, including the preservation of those portions or features of the structure that are significant to its historical, architectural, or cultural values.

Restoration. The act or process of reestablishing accurately the form and details of a structure, site, or artifact as it appeared at a particular period in time by means of removal of later work or by the reconstruction of missing earlier work.

Separation. See “Fire Barrier.”

Self-closing. Equipped with an approved device that will ensure closing after having been opened.

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

Smoke Barrier. A continuous membrane, either vertical or horizontal, such as a wall, floor, or ceiling assembly, that is designed and constructed to restrict the movement of smoke. A smoke barrier might or might not have a fire resistance rating. Such barriers might have protected openings.

Vertical Opening. An opening through a floor or roof.

Chapter 2 Historic Building Fire Experience

2-1 Fire Ignition Factors. Common causes of fires in historic structures include faulty electrical wiring, arson, careless or illicit smoking, malfunction of heating equipment, improper use of heat-producing appliances, open flames and sparks, exposures from nearby burning structures, storage, and burning vegetation. Electrical service and central heating systems might be inadequate for contemporary use, might have been installed many years ago, and might not have been properly upgraded for contemporary use. Many historic structures employ candles, fireplaces, forges, stoves, and a variety of other open-flame devices to interpret the structure and life of a previous period. Fires can occur at any time; however, experience shows that fire hazards increase when a structure is undergoing renovation, maintenance, or rehabilitation. Additional details pertaining to fire ignition hazards are presented in 3-4.1.

2-2 Fire Spread Factors. Fire growth and spread occurs because of inadequate barriers, delayed detection and alarm, absence of automatic suppression systems, and delayed or difficult manual suppression. The first few minutes following ignition are critical. A small fire can grow large in only a few minutes. This is particularly true in historic structures, which are often of combustible construction or contain combustible contents. In the absence of automatic fire detection, discovery is left to an occupant, security personnel, or chance. At the point of discovery, the fire could be so well established that the loss will be substantial.

Though historic properties require painstaking attention to details for the preservation of historic authenticity, it is possible to provide an appropriate level of fire protection for the site and personal safety for staff members and visitors without jeopardizing the original historic fabric or appearance.

The structure fires described briefly in Section 2-3 illustrate conditions under which fires spread or were confined to their origin and the resultant direct damage.

2-3 Representative Fire Examples. The following is a partial list of fires that have occurred in various historic structures. Losses are to direct property and do not include long-term impact (e. g., business interruption), which can equal or exceed direct loss.

Windsor Castle

Windsor, England — November 20, 1992

Original construction — 1358

Estimated loss — in excess of £30 million

A fire of accidental origin severely damaged this English royal home. Ignition occurred when an improperly placed, high intensity electrical lamp ignited adjacent combustible curtains. Despite the efforts of over 200 fire fighters, severe damage occurred in the castle’s Chester Tower, Queen’s Chapel, St. George’s Hall, Queen’s Guard Chamber, Waterloo Chamber, Grand Reception Room, Brunswick Towers, Crimson Drawing Room, Star Chamber, and Long Corridor. Lost in the fire were several fine artifacts and objects, including a nineteenth century Henry Willis pipe organ. Also lost were many ornate construction features.

Factors contributing to the loss included unsafe work practices, inappropriate fire barriers, concealed construction, and lack of automatic fire sprinklers. The fire occurred during renovations, and much of the artwork had been removed prior to the fire. The fire could have destroyed this art had it been present.

Grafton Village Store

Grafton, Vermont — December 20, 1991

Original construction — 1841

Estimated loss — $250,000

A fire of electrical origin started in the basement of this historic town store. Flames spread across the back portion of the building and traveled to the second floor via internal ventilation ducts. Prompt response by the local fire department ultimately controlled the blaze before total loss of the structure. The store remained closed to the public for approximately six months while repairs were made.

Factors contributing to the loss included limited horizontal and vertical fire barriers and lack of automatic fire detection and suppression systems.

Savoy Theatre

Central London, England — February 12, 1990

Original construction — 1910, refurbished 1929

Loss — £10 million

This famous theatre in London's Strand district was severely damaged by a fire during renovation less than two weeks before reopening. The fire caused collapse of the auditorium ceiling, destroying much of the historic art deco interior. This area was not protected by automatic sprinklers or detection. The stage area was protected by automatic sprinklers, preventing fire damage to that area. Fire spread beyond the auditorium was also prevented by fire doors. In addition to direct losses, additional resources were required to relocate theater operations.

Loss factors included improper use of open-flame paint removers; readily ignitible dry timbers; lack of automatic fire detection, suppression, and alarm; and difficult manual fire-fighting access.

Chiado

Lisbon, Portugal — August 25, 1988

Original construction — 13th century, rebuilt 1755; several construction modifications through the years.

Fire began at the Armazens Grandella commercial building and spread to partially or totally destroy eighteen buildings in the periphery of the "Baixa Pombalina." Delayed fire detection allowed the fire to grow to an excessive size before manual fire fighting began. When fire fighters arrived, further delay resulted due to difficult access caused by narrow streets and automobile parking.

Factors contributing to the loss included a late alarm, total absence of vertical and horizontal fire barriers, combustible finish materials, high volumes of combustible contents, lack of automatic detection, lack of automatic and manual suppression equipment, and narrow streets and difficult access.

Home of Franklin D. Roosevelt National Historic Site

Hyde Park, New York — January 23, 1982

Original core construction — early 19th century

Extensive remodeling — 1915

Estimated loss — $1,220,000, structural; $1,010,000, collections

A fire suspected to be of electrical origin started in the attic of this historic house museum during a contract to replace old electrical wiring. Flames spread throughout the attic and third floor of the central portion of the house resulting in severe structure damage. Water and smoke damage extended to the lower floors. Fire service response, including 200 fire fighters and 35 pieces of emergency apparatus, saved the structure from total loss. National Park Service rangers and curators worked through the night with fire fighters to salvage historic furnishings. The building was closed for an extensive period for repairs.

Factors contributing to the loss included limited fire barriers, aged wiring, and lack of automatic fire suppression. A primary factor was a decision to save approximately $2,500 by not installing heat detectors in the attic when the fire detection system was installed throughout the rest of the house.

Chapter 3 Identification and Evaluation of Existing Conditions

3-1 Introduction. Providing adequate fire protection to a historic building while protecting historic character can be a difficult task. The effort requires a thorough building survey to identify critical historic elements, spaces, and features; restoration and preservation objectives; code deficiencies; and existing fire and life safety hazards by qualified professionals. This survey provides the basis for all planning and design decisions, and it is essential for rehabilitation projects of all types, including those intended for original or existing uses and those that involve new uses.

3-2 Identification of Historic Elements, Spaces, and Features.

3-2.1 Exterior. Exterior historic elements consist of those features outside of the building that define the structure's character. These include the building's exterior construction, adjacent structures, and the site grounds.

3-2.1.1 Construction Features. Construction features include sheathing or facade materials, roofing materials, chimneys, skylights, cornices, windows and doors, and extensions such as porches, railings, and other attached building components. Major and minor facades should be studied such that, if exterior modifications or additions are necessary, they can be located on the least visible and significant elevation in order to keep the impact to a minimum.

3-2.1.2 Adjacent Structures. Adjacent structures are those independent buildings and edifices that could have an effect on the historic building's mission and could impact or be impacted by fire safety improvements. These structures might be part of, or independent of, the historic building site. Adjacent structures might include buildings, sheds, vehicles, and displays.

3-2.1.3 Site Elements. Site elements include exterior components that help define the historic building. These elements could impact or be impacted by fire safety improvements. Site elements include vegetation, roads and driveways, walking paths, fencing and exterior use.

3-2.2 Interior. Interior historic elements consist of those features within the building that are important in and of themselves or in conjunction with other features, or both. These include construction features, floor plans, and individual spaces.

3-2.2.1 Construction Features. Construction features are distinctive architectural details of significant form or historic function that are characteristic of the period. Historic fabric and spaces include those original to the building and changes to originals that have acquired significance in their own right. Specific elements might include wainscoting, parquet flooring, picture molding, mantels, ceiling medallions, built-in bookshelves and cabinets, crown molding, and arches, as well as simpler, more utilitarian features, such as plain windows and doors and associated trim. The significance of some architectural features might be that they are worked by hand, exhibit fine craftsmanship, or are particularly characteristic of the building style.

Some features might indicate later changes and alterations that have gained significance over time, such as lobby alterations, changes to wall and floor finishes, and later millwork.

3-2.2.2 Floor Plans. Floor plans might be an important characteristic of the building type, style, period of construction, or historic function. Even if the plan has been altered over time, it might have historic significance. For example, alterations that are additive (large rooms divided into smaller ones) rather than subtractive (where walls have been removed) might be easily corrected to restore the building's integrity.

3-2.2.3 Significant Spaces. Significant spaces are rooms or other interior locations that are typical of the building type or style or are associated with specific persons or events.

The sequence of consciously designed spaces could be important to the understanding and appreciation of the building or original architect. Examples are a foyer opening into a large hall; front and rear parlors connected by pocket doors; an office lobby opening into an elevator hall; and a hallway leading to a stairwell.

Spaces might have distinctive proportions, such as ceiling height to room size, or significant or unusual room shapes or volumes such as rooms with curved walls, rooms with six or eight walls, or rooms with vaulted ceilings.

3-2.3 Historic Documentation. Relevant information might exist in the files of local or national historic organizations. If the historic resource is listed in a register or listing of historic places, a careful review of the official register nomination should be the first step in this assessment. An understanding of why and when the individual building or historic district achieved significance will help in evaluating those spaces and features that are significant for their association with specific events or persons, architectural importance, or information potential.

In some cases, older register listings might neglect to describe all architectural spaces and features of the building's exterior and interior. This should not be construed to mean that the building possesses no character-defining elements. In such cases, professional preservation judgment can be of great assistance.

3-3 Code, Standard, and Regulation Compliance. The existing conditions evaluation should include a review of all safety-related requirements to determine if and where the historic building is deficient with respect to applicable codes. Specifically-mandated codes might vary from place to place. Contact should be made with local fire and building authorities in order to determine the codes and standards in effect.

The code review will illustrate those areas of the building where code requirements are most stringent and conflicts between code requirements and historic preservation concerns are most likely to occur. In some examples, this review might assist in determining building use and designs that cause the least damage to historic character.

Typical code or safety deficiencies found in historic buildings might relate to construction, building systems, egress systems, use and occupancy, fire protection systems, and site concerns. Some deficiencies can be addressed readily without damage to the historic character of the building, while others require innovative solutions outside the strict compliance with codes and standards for new construction. Several of these deficiencies with some solution options to achieve compliance with fire safety code and standard objectives are described in 3-3.1 through 3-3.6.

3-3.1 Common Building Construction Deficiencies. Common building construction deficiencies might include inadequate fire resistance of interior or exterior walls, insufficient interior compartmentation, deficient fire stopping, inadequate tenant separation, insufficiently protected combustible construction, excessive building height and fire area, and combustible materials or flammable finishes.

3-3.2 Common Building System Fire Safety Deficiencies. Common building system fire safety deficiencies might include inadequately sized mechanical and electrical systems; insufficient dampers, inadequate chimney design, height, or lining; and inappropriate mechanical or electrical enclosures.

3-3.3 Typical Egress System Deficiencies. Typical egress system deficiencies might include insufficient number of exits; undersized exit route width; inadequate fire resistance of exit corridors, doors, or stairways; exit routes that do not lead directly to the exterior; dead-end corridors; excessive exit travel distance; inappropriate exit route configuration; and unenclosed monumental stairs.

3-3.4 Building Use and Occupancy Code Deficiencies. Building use and occupancy code deficiencies might include a use or occupancy not permitted in the particular construction type, incompatible uses, excessive or inappropriate human occupancy, and hazardous activities or processes.

3-3.5 Fire Protection System Deficiencies. Fire protection system deficiencies might include inoperative or insufficient automatic sprinkler protection; lack of manual fire-fighting systems (e.g., standpipes, fire extinguishers); inadequate water supply for fire protection use; insufficient smoke detectors, manual fire alarm stations, and audible alarms; unmonitored fire detection, suppression, and alarm systems; and nonexistent or inadequate lightning protection.

3-3.6 Site Concerns. Site concerns might include inadequate separation distance between buildings, incompatible site uses, exterior fire hazards, and difficult access for fire-fighting vehicles.

3-4 Fire Hazards. A fire hazard is a condition that might contribute to the start or spread of a fire or to the endangerment of people or property by fire. The general elements of fire hazards are ignition sources, combustibility of materials, and structural fire hazards.

3-4.1 Ignition Sources. Ignition is the initiation of combustion. It originates with the heating of a fuel by a heat source. When the temperature of the material is raised sufficiently, it begins to pyrolyze or decompose from heat into simpler substances, primarily combustible gases and vapors. Different substances are produced at varying rates and temperatures. When an adequate mass of combustible gases and vapors is mixed with oxygen or air and exposed to an energy source of sufficient intensity, ignition will take place.

Any form of energy is a potential ignition source. Most often the source is open flames or electrical wiring and appliances. Smoking, candles, solid-fuel heating, and similar combustion processes represent likely sources of ignition. Certain occupancies such as restaurants and repair facilities significantly increase the number and variety of heat sources. An example of a more unusual ignition source associated with historic buildings is the capacity of historic "bull's eye" glass to focus rays of the sun. (*See Goldstone, "Hazards from the Concentration of Solar Radiation by Textured Window Glass."*)

3-4.1.1 Electricity. Inadequate electrical service and misuse of appliances are also common hazards. Electricity starts a fire when current flowing through a conductor encounters resistance, which generates heat. When the conductor is of proper size, this heat is dissipated. Excessive heat can be generated by overloads, arcing, faults, high resistance at poor connections or lack of adequate cooling or heat dissipation. Conditions leading to electrically caused fires most often involve wiring. A fire threat exists wherever protective wire insulation is damaged by heat, moisture, oils, vibration, impact, or operating conditions that result in loose connections. Motors are the next most frequent source of electrical fire ignition. Motor fires result from electrical malfunction (faults, arcing, lightning surges), overheating, and bearing failure (i.e., inadequate lubrication).

3-4.1.2 Arson. In recent decades, deliberately set fires have become a significant problem. Arson is a major threat to fire safety and always should be considered. Loss experience indicates that infrequently attended occupancies are the most frequent arson target. Building storage areas offer large amounts of potential fuel and are usually unoccupied. These are favorable conditions for an arsonist. Mercantile and other public access areas are the next most frequent incendiary target due to large amounts of combustibles and easy circulation.

3-4.1.3 Smoking. Smoking is a major fire cause. Improperly handled and disposed cigarettes and matches used by smokers present a threat that can be minimized by control and education. Where smoking is allowed, precautions should be enacted to minimize associated hazards. Total prohibition of smoking in a building could result in occupants smoking in hidden, combustible-filled areas.

3-4.1.4 Overheated Materials. Many processes use heated flammable liquids or baking, drying, or other high-temperature operations. Excessive overheating can lead to generation of flammable vapors and ignition of combustibles. Several fires have been started by the hot surfaces of electrical equipment, piping, boilers, furnaces, ovens, dryers, flues, ductwork, and incandescent light bulbs. Heat conducted from this equipment can ignite adjacent combustibles. Friction in machinery components is also a potential fire cause. Loose or worn moving parts rubbing against each other can generate enough heat to ignite nearby combustibles, such as lint and paper dust. Common friction sources include misaligned drive belts and worn or improperly lubricated bearings.

3-4.1.5 Open Flames. Improperly used open flames from portable torches, space heaters, cigarette lighters, and matches are a significant fire problem. In older structures, chimneys are particularly dangerous if not properly lined and pointed. Torches used for cutting, welding, soldering, and brazing can ignite adjacent combustibles. Space-heating equipment can be knocked over or used in close proximity to combustibles, resulting in fire.

3-4.1.6 Exposures. A building fire could start because of heat generated from a fire in a nearby structure, yard storage, or vegetation. Important factors include physical separation between exposed hazards, combustibility of the exposed building's exterior, and extent and protection of openings.

3-4.1.7 Spontaneous Ignition and Chemical Reactions. Some materials undergo self-oxidation, giving off heat. When confined, more heat will be generated than will be dissipated, with ignition the likely result. Typical products subject to spontaneous ignition include rags or paper soaked in finishing, animal, and vegetable oils. Paint deposits containing drying oils can heat up and ignite.

Chemical reactions can result in fires and explosions. Typical adverse reactions occur when chemicals react with other materials and when decomposition of unstable chemicals and hazardous processes are out of control.

3-4.1.8 Lightning. Fires can be started by direct lightning strikes and lightning induced surges (overvoltage) in electrical circuits. The installation of lightning (surge) arresters on power and communication lines where they enter structures is recommended and is covered in NFPA 70, *National Electrical Code*®, Article 280.

3-4.2 Combustibility of Materials.

3-4.2.1 Material Properties. The tendency of a material to ignite is a function of its chemistry, physical state, surface texture, and moisture content. Different chemical compositions have different minimum temperatures at which they will ignite. Ignition is a function of time as well as temperature. A potential fuel subjected to a relatively high temperature for a short period of time might not ignite, while the same fuel can undergo ignition when exposed for a longer duration to a lower temperature. For example, wood products have a normal ignition temperature of 400°F to 500°F (204°C to 260°C), but they have been found to ignite when subjected to a much lower heat source of 228°F (109°C) for four days. (*See NFPA Fire Protection Handbook.*)

The contents of most buildings consist of combustible materials. Accumulations of readily ignitible items constitute a fire hazard. Construction materials, such as siding and roofing, can increase the possibility of fire spread from other buildings. This is especially true of wood shingles that are not fire-retardant treated.

3-4.2.2 Flame Spread. Combustibility is the principal factor contributing to the spread of flame across surfaces. Once ignition takes place, the flame heats surrounding material, causing it to ignite and thereby spread across the surface. The rate at which flame spread occurs is measured by test. (*See NFPA 255, Standard Method of Test of Surface Burning Characteristics of Building Materials.*) Most building codes and NFPA *101*, *Life Safety Code*, place restrictions on the use of materials with high flame-spread rates.

A single layer of paint and most wall coverings add little fuel to a fire. Even if paint or coverings burn completely, only a small amount of heat is liberated and little damage results. On the other hand, the substrate on which the paint or paper is applied can have a great influence on flame spread. Paint on a metal ceiling might not ignite at all under fire exposure because the heat is dissipated by the metal.

Walls in older buildings might have been repeatedly painted or papered. Where multiple layers of paint and paper are present, flame spread can be significantly increased.

The existence of interior wood paneling, as found in many historic structures, adds to the fuel and thereby increases flame spread. Combustible composition ceiling and wall materials and plastics, in the form of both high density solids and expanded foam products, also can contribute to flame spread. Flame spread in low density cellulosic materials, used extensively in some older buildings for ceiling tile and wall panels, will likely be rapid.

3-4.2.3 Environmental Factors. Sustained burning of the fuel material depends on its combustibility and on additional factors, such as interaction of surfaces, fluid flows, and thermal absorptions. These factors are neither well defined nor predictable outside of the laboratory. Observed conditions that produce these effects include arrangement of combustibles, wall materials, and room dimensions.

Furnishings and other combustibles that are close together will cause fire to spread easily from one item to another. A fire starting in a corner will grow in size about four times faster than a fire in the middle of a room. Flame spread is much faster on vertical surfaces than on horizontal surfaces.

In general, fire develops more slowly in larger spaces. This is particularly true with respect to the height of the ceiling. A high ceiling is inherently more fire-safe than a low colonial ceiling. Fires that can vent to the outside through windows or other means are slower to spread to other parts of a building.

3-4.3 Structural Fire Hazards. Structural features of buildings that constitute fire hazards are of two types. There are structural conditions that promote the vertical and horizontal fire propagation, as well as conditions that could lead to structural failure during a fire.

3-4.3.1 Fire Spread. Most buildings form a connected series of compartments. As such, they are inherently safer from fire if a fire can be contained to the compartment of origin. Unfortunately, design, construction, and use practices create many avenues for fire spread. For example, some construction can create virtual chimneys in the stud channels, allowing fire to spread the full height of the building. Paths of fire spread can be either horizontal or vertical.

3-4.3.1.1 Means of Horizontal Fire Spread.

Means of horizontal fire spread include:

Doorways.

Ceiling voids over walls.

Floor cavities under walls.

Utility and service chase-through walls.

Voids in projecting eaves or cornices.

Wall failure.

Openings produced by distortion or failure of structural members in a fire.

Open attic spaces and cocklofts.

Corridors.

3-4.3.1.2 Means of Vertical Fire Spread.

Means of vertical fire spread include:

Stairways.

Conduction of heat through hearth slab to supporting timbers below.

Wall cavities penetrating floor.

Utility and service chases penetrating floor.

Shafts for elevators, dumbwaiters, laundry chutes, and trash chutes.

Breaching of floor or ceiling by fire.

Atriums.

Windows or other exterior openings.

3-4.3.2 Structural Integrity. The ability of structural framing to resist the effects of a severe fire is dependent on the framing material and its dimensions. Wood members, while combustible, might have a limited fire resistance, which depends on size, since fire resistance is a function of the surface-to-mass ratio of a member. Large-dimensioned lumber, such as that used in heavy timber construction, provides significant endurance from the effects of fire. Studs and joists have little fire resistance, although older, fully dimensioned members are significantly better than modern thin-webbed, or strap-hung construction. Steel, although noncombustible, is subject to decreased structural capacity at relatively low fire temperature. Structural members can be protected to improve their resistance to fire.

3-5 Means of Egress.

3-5.1 Occupant Evacuation. Evacuation of occupants is the primary approach to life safety from fire. Egress problems in existing buildings generally arise with respect to number of exits, exit capacities, arrangement of exits, or construction details.

3-5.2 Egress Codes. NFPA *101*, *Life Safety Code*, and most building codes detail specific requirements for ensuring adequate means of egress. NFPA *101* requires exits to be separated from other spaces of the building to provide a protected way of travel to a safe area.

3-5.3 Number of Exits. Codes specify the number of exits that must be provided for each floor as well as for the entire building. Minimum exit requirements are established to increase the reliability of the egress system. A minimum of two means of egress is a fundamental life safety principle, and codes permit very few exceptions to this rule. The intent is that, for any single fire situation that prohibits travel to one exit, there will be an alternate exit available. Additional exits might be required after consideration of the arrangement or capacity of exits.

3-5.4 Exit Capacities. Codes regulate the capacity of exits by establishing a relationship between the required width of various exit elements and the number of occupants they serve and by establishing minimum widths for each of the exit elements. It is the intent of the codes to provide an exit capacity large enough to move the total expected number of occupants into the safety of the exits before access to the exits becomes difficult.

3-5.5 Exit Arrangement. In addition to code requirements for exit number and capacity, codes generally require that exits be located to facilitate their use in a fire emergency. Requirements address remoteness, maximum travel distance, direct exit to the exterior, and maximum dead-end travel distance.

3-5.5.1 Remoteness. Codes generally require that exits be as remote from each other as practical and that they be arranged to allow direct access in separate directions. The intent of providing exit remoteness is to minimize the probability that access to all exits will be blocked by a single fire. The term "remote" is subjective and frequently is a matter of interpretation.

3-5.5.2 Travel Distance. Code requirements governing travel distance to an exit are intended to establish a maximum interval of time for an occupant to reach an exit. Travel distances are measured by mapping the path of travel to an exit. When combined with requirements for minimum number of exits and exit remoteness, the limitations on travel distance ensure that even if one exit is blocked by a fire, an occupant will still be able to reach another exit or a location of refuge before the fire has spread in a manner that would prevent escape. The actual time for escape implied by maximum travel distance limitations is not explicitly stated in the codes.

3-5.5.3 Dead-End Travel. Dead-end corridors of any length are undesirable features in buildings for two reasons. First, people who use a dead-end corridor to reach an exit could be trapped by fire or smoke between themselves and the exit. Second, it is possible to mistakenly enter a dead-end corridor rather than an exit and, under smoky or poor light conditions, become trapped or confused.

3-5.6 Egress Route Identification. In general, exit routes must be clearly marked to assist occupants with evacuation path identification. During a fire emergency, visibility can become rapidly obscured by smoke and fire products. Rapid exit identification by occupants is necessary before conditions become untenable. Identification methods include exit signage, escape route diagrams, and emergency illumination.

3-5.7 Construction Details. Codes provide many requirements for the details of various exit components that make up a building's egress system. Typical areas covered include means of separation from other spaces, allowable materials, handrails, tread and riser design, landings, platforms, guards, door hardware, alarms, and lighting. The intent of these provisions is to ensure a quality design that will promote safe and easy passage. Individual code requirements tend to be numerous and highly specific.

Chapter 4 Planning and Design

4-1 Objectives in Rehabilitation Planning. The primary fire protection objective in rehabilitation planning is to achieve the best protection program for the historic building while maintaining its historic integrity and character. Because of the unique character of each historic structure, achieving this objective necessitates an understanding of historic preservation and fire protection concepts.

4-1.1 Historic Preservation. Historic buildings should be treated with the sensitivity prescribed by conventional historic preservation criteria and standards.

4-1.1.1 Secretary of the Interior's Standards. In the United States, the Secretary of the Interior provides guidelines for rehabilitation and operation of historic sites. This information is provided as an example of national criteria.

(a) Every reasonable effort shall be made to provide a compatible use for a property which requires minimal alteration of the building, structure, or site and its environment, or to use a property for its originally intended purpose.

(b) The distinguishing original qualities or character of a building, structure, or site and its environment shall not be destroyed. The removal or alteration of any historic material or distinctive architectural feature should be avoided when possible.

(c) All buildings, structures, and sites shall be recognized as products of their own time. Alterations which have no historical basis and that seek to create an earlier appearance shall be discouraged.

(d) Changes which may have taken place in the course of time are evidence of the history and development of a building, structure, or site and its environment. These changes may have acquired significance in their own right, and this significance shall be recognized and respected.

(e) Distinctive stylistic features or examples of skilled craftsmanship which characterize a building, structure, or site shall be treated with sensitivity.

(f) Deteriorated architectural features shall be repaired rather than replaced wherever possible. In the event replacement is necessary, the new material should match the material being replaced in composition, design, color, texture, and other visual qualities. Repair or replacement of missing architectural features should be based on accurate duplications of features, substantiated by historic, physical, or pictorial evidence rather than on conjectural designs or the availability of different architectural elements from other buildings or structures.

(g) The surface cleaning of structures shall be undertaken with the gentlest means possible. Sandblasting and other cleaning methods that will damage the historic building materials shall not be undertaken.

(h) Every reasonable effort shall be made to protect and preserve archaeological resources affected by or adjacent to any project.

(i) Contemporary design for alterations and additions to existing properties shall not be discouraged when such alterations and additions do not destroy significant historical, architectural or cultural material, and such design is compatible with the size, scale, color, material, and character of the property, neighborhood or environment.

(j) Wherever possible, new additions or alterations to structures shall be done in such a manner that if such additions or alterations were to be removed in the future, the essential form and integrity of the structure would be unimpaired.

4-1.2 Administrative and Review Requirements.

4-1.2.1 Historic Preservation. Depending on funding sources and federal, state, or local legislation, review by state or federal preservation offices or local historic review commissions might be required to ensure that the historic building is treated with sensitivity. Projects should be discussed with the appropriate preservation authorities as early as possible in the planning stages.

4-1.2.2 Code Enforcement. Proposed rehabilitation projects should be discussed with the appropriate building and fire code officials as early as possible in the planning stages to determine if code or safety conflicts exist. Many codes have special provisions for historic buildings (*see Appendix B*) and for the consideration of alternative methods or systems that will provide levels of safety equivalent to those required for new construction (*see NFPA 101, Life Safety Code, Section 1-5*). In some cases, special appeal or variance boards exist and should be requested to address those situations where fire safety and protection concerns and historic preservation goals cannot be resolved acceptably by the standard review process. Most building code officials are willing to work with owners, architects, and engineers and will consider alternative construction methods, provided a reasonable or equivalent level of life and property protection is proposed.

4-2 Concepts of Fire Safety Planning.

4-2.1 Management Responsibility. The key to any successful fire protection program lies in the effort extended by the management. Without the active participation and direction of high level management, the effectiveness of the fire protection effort will be seriously hindered. This is true in an operational facility as well as in a facility undergoing rehabilitation.

Fire safety is an essential and permanent part of historic structure operations and should be a key consideration when that structure is scheduled for rehabilitation. Owners and others entrusted with the management or operation of buildings having historic significance have prime responsibility for ensuring that the historic structure is protected against the disastrous effects of fire.

Using advice from qualified fire safety professionals (*see Appendix B*), the management team should develop fire safety objectives and a fire safety plan for the complete facility. As part of this plan, the management should decide how the building, its contents, and the occupants are to be protected during the rehabilitation process as well as when it is completed.

Regardless of the complexity or size of the project, management should collaborate with preservation architects, structural engineers, fire protection engineers, fire service representatives, risk management specialist, and others with experience and expertise in the design of fire protection systems and the historic building interface.

4-2.2 Elimination or Control of Fire Safety and Life Safety Hazards. The planning process for the rehabilitation of a historic structure should include provisions to control hazards that are not an inherent part of the historic fabric of the structure or its operation. Fire safety problems identified in the evaluation of existing conditions (*see Chapter 3*) should be ranked by priority to help identify the most undesirable conditions. These hazards might include life safety issues, such as exit facilities, as well as fire ignition and material combustibility considerations. Every effort should be made to eliminate as many of the identified hazards as possible.

Where a specific hazard is an essential part of the historic fabric of the building, the threat to the building and contents should be controlled by providing special protection for the hazard. The approach taken can use any or a combination of the elements discussed in Section 4-3.

As part of the elimination and control of fire hazards, a planned rehabilitation should be based upon the building's inherent fire safety features and not introduce new fire hazards. Alterations might change the conditions that previously have kept the building fire-safe.

4-3 Elements of a Fire Safety Plan.

4-3.1 Management Involvement. Management involvement in fire safety planning is critical to successful program implementation. Management should consider the following four steps to ensure the fire safety of the historic property both during and after the rehabilitation process:

(a) Evaluate fully the existing conditions of the building.

(b) Educate and train appropriate personnel in the importance and implementation of a sound fire prevention program. Provide or have available trained, properly equipped fire-fighting and salvage organizations.

(c) Institute management and operation practices that eliminate the cause of fire both during and after the planned rehabilitation. Construction contracts should specify methods of control of combustibles and hazards, including measures such as those provided in NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations.* (*See Chapter 5.*)

(d) Incorporate appropriate fire protection measures in the rehabilitation effort in order to limit any damage if a fire occurs; appropriate measures include structural compartmentation, automatic detection and alarm, and fixed extinguishing systems.

4-3.2 Prevention.

4-3.2.1 General. When planning for the rehabilitation of a historic building, great care should be exercised to provide for the abatement of fire hazards throughout the construction period and following rehabilitation.

4-3.2.2 Design. To reduce the possibility of fire, existing fire safety standards such as NFPA 70, *National Electrical Code®*, and other NFPA and industry standards should be consulted during the design of electrical, mechanical, and similar systems.

4-3.2.3 Education and Training. For buildings that will be occupied during the rehabilitation process, staff members should be instructed to identify obvious fire hazards and report them to a designated individual. Staff members also should receive hands-on training in the use of the fire suppression equipment provided. They should be instructed to report a fire and evacuate the area before attempting to extinguish the fire. If this level of training is not practical for the entire staff, then specific staff members should be designated for such training.

A fire response team or floor marshal plan can help organize specific staff members to react quickly to any fire emergency. Team members should be kept apprised of the rehabilitation work in progress and the possible hazards that will be introduced or will arise during construction.

4-3.2.4 Operation and Maintenance. Special precautions should be taken during the demolition and construction processes necessary to complete the rehabilitation project. See Chapter 5 for a discussion of specific hazards and processes.

4-3.2.5 Enforcement. The responsibility for enforcement of fire prevention measures should be clearly assigned and should include enforcement of the construction contract requirements relating to fire perils. Authority should be given to stop work pending correction of flagrant abuses. Responsible local authorities, such as fire and building departments, should be consulted.

4-3.3 Limiting Combustibility.

4-3.3.1 Construction Materials. Careful consideration should be given to the use of fire-resistive materials and methods wherever they will not damage the structure's historic character. This is especially true in concealed areas and other areas not exposed to the public.

Inert or fire-resistive materials should be used where appropriate, including in some cases where the structure is to be substantially rebuilt or where items used in original construction are unavailable. Ingenuity can produce fire-safe components that simulate wood roofing and numerous other products. In some instances, the use of substitute materials for original wood might be appropriate. For example, rough-sawn wood can be duplicated in appearance by casting concrete in a mold or form that bears the marks that are desirable on the surface of the finished product, or wood shingles can be easily simulated with fire-resistant materials. Wood siding, wood shingles, and shakes that have been given a fire-retardant treatment are commercially available. Wood frame structural members and siding materials can be protected with spray-applied coatings or membrane-applied protection to enhance the fire resistance of the materials or assemblies where properly maintained. Even if community fire regulations and codes do not require the use of such materials, they should be considered.

Mechanical systems should be designed to minimize the use of combustible materials or lubricants. Noncombustible insulation materials should be used where such materials are to be installed.

Scaffolding and forms should be of noncombustible materials. Where noncombustible materials cannot be substituted, scaffolding and form lumber should be fire-retardant treated. Tarpaulins, if used, should be fire-retardant treated.

4-3.3.2 Interior Finish Materials. Choice of furnishings and interior finishes should be given careful consideration. For example, where highly combustible wood veneer paneling must be replaced, it might be appropriate to substitute a fire-resistive product. Fire-retardant treated wood products used as interior finishes are readily available. Fire-resistant carpeting is available, and draperies of glass fiber or other fire-resistive materials should be considered.

Coatings are available that will effectively reduce the surface flamespread rating of many combustible materials. Although they do not render a material noncombustible, they significantly reduce the ease with which a material will ignite. Such coatings should be considered whenever a noncombustible substitute is either unavailable or not suited to a particular application. Caution is necessary to avoid a coating that contains a chemical or other product that will damage or unacceptably alter the appearance of any historic material to which it is applied.

4-3.3.3 Furnishings and Contents. Noncombustible materials should be used as much as possible for furnishings and other contents of the building. Where the intended occupancy of the building introduces combustible contents for which there are no substitutes, the building's fire loading should be considered when fire suppression systems are designed.

4-3.4 Compartmentation.

4-3.4.1 Horizontal Fire and Smoke Barriers. The planning for the rehabilitation of a historic structure should consider the use of fire-rated walls and doors to subdivide building areas into separate fire areas and to segregate specific hazards, such as furnaces, boilers, or storage areas, from the remainder of the building. These fire-rated barriers should be designed to resist the passage of smoke. Other walls also should be designed to resist smoke passage and to confine the effects of a fire where possible. Such designs often can be incorporated while maintaining the historic fabric and character of the structure.

4-3.4.2 Vertical Enclosures. Provisions should be made to enclose stairways, ventilation shafts, and other vertical openings with fire-rated construction to prevent the vertical spread of fire and smoke. Where the historic fabric of the building prevents such enclosures, alternative protection, such as sprinkler systems, should be provided.

4-3.4.3 Fire Stops. Fire stops should be provided in concealed spaces to prevent the spread of fire within walls and between rafters and floor joists. Filling concealed spaces with inert material, such as mineral wool insulation or other similar fire-resistive materials, can further retard the spread of fire. However, it is necessary to guard against the damaging effects of condensation within the insulation in exterior wood frame or furred masonry walls by using an appropriate vapor barrier.

4-3.5 Structural Protection. The existing structural fire resistance should be determined wherever possible. For older structures, the U.S. Department of Housing and Urban Development has developed the "Guideline on Fire Ratings of Archaic Materials and Assemblies," in their series of rehabilitation guidelines, to assist in identifying approximate fire resistance qualities of older construction methods and materials.

Wherever possible, new materials to be installed should be selected based on their ability to enhance the fire resistance of the basic structure. Gypsum wallboard, plaster, and other finish materials can improve the fire resistance rating of structural members if applied correctly.

4-3.6 Detection and Alarm. Significant improvement in protection from fire can be achieved by installation of a detection and alarm system connected to an alarm monitoring service or a fire department. Fire has much less chance of doing great damage if it is detected and contained at an early stage. Furthermore, structures can be evacuated more quickly if prompt warning of a fire is given.

Various types of fire detection and signal systems are described in Appendix A.

4-3.6.1 Fire Detection Systems.

4-3.6.1.1 Various automatic fire detectors can detect a fire condition from smoke, a critical temperature or rate of temperature rise, or infrared or ultraviolet radiation from the fire. These detectors can provide the warning needed to get people safely out of the structure, notify the fire department, and start fire extinguishing action promptly. In buildings with automatic sprinkler systems, the fire detection system may provide a window of time for manual suppression by building occupants before detection and suppression by the automatic sprinkler(s) directly above the fire. Appropriate specialists should be consulted to determine which kinds of detectors best fit the conditions in different parts of the structure. (*See Appendix B.*)

4-3.6.1.2 Where it is determined that it is desirable to provide an opportunity for building occupants to employ manual fire suppression before the sprinkler(s) over the fire opens, a separate early warning fire detection system should be considered that utilizes the detection device providing the fastest response with respect to the type of fire expected from combustibles in the occupancy.

4-3.6.1.3 Installed detection and alarm systems should not only sound an alarm within the structure but also should transmit a signal to an alarm monitoring service or to a local fire department. Subsequent to an alarm, the fire department should be contacted immediately to verify that the alarm was received.

4-3.6.2 Fire Detectors. Fires produce heat, smoke, flame, and other signatures that detection systems recognize and to which they respond. Fire detectors are most typically designed to detect fire at a specific point in space (spot detectors), requiring a number of properly located units to cover a large area. There are also linear or line-type detectors (wires, pneumatic tubes, and photoelectric beams) that often can be arranged to provide automatic detection less obtrusively and in unusual configurations. (*See Appendix A.*)

4-3.6.2.1 Heat Detectors. Heat detectors are designed to respond when the operating element reaches a predetermined temperature (fixed temperature detector), when the temperature rises at a rate exceeding a predetermined amount (rate-of-rise detector), or when the temperature of the air surrounding the device reaches a predetermined level, regardless of the rate of temperature rise (rate compensation detector). Heat detectors respond best to relatively large, high heat-producing fires.

4-3.6.2.2 Smoke Detectors. In almost every structural fire, measurable amounts of smoke are produced prior to measurable amounts of heat. Thus, smoke detectors are preferred for earlier warning of fire. Smoke detectors respond to the visible or invisible particulate matter produced in fires. Smoke detectors are available for spot placement, line-of-sight linear beam and air sampling applications.

4-3.6.2.3 Manual Alarm Devices. In some instances, a person may discover a developing fire prior to automatic detector operation. Manual alarm stations are provided to permit that person to activate the building fire alarm system.

4-3.6.3 Applications.

4-3.6.3.1 The primary function of an automatic detection system is to alert the occupants of a building to the presence of a fire. This may be especially important under the following conditions:

(a) In large buildings where persons in one part of the building may not be aware of a fire in another part.

(b) In buildings where a fire may start in an unoccupied area.

(c) In occupancies where there is a large number of people, requiring significant time to evacuate.

(d) In situations where there are relatively long travel distances to exits.

(e) In buildings where the nature and arrangement of fuel makes a fast-growing fire possible.

(f) In buildings that do not have sufficient barriers to limit the spread of fire and smoke.

(g) In residential occupancies.

4-3.6.3.2 Automatic fire detection also performs the function of initiating the process of fire suppression by alerting trained occupants or the municipal fire service to respond. Before any suppression can begin, a fire must be detected and the suppression activated. This can be accomplished on-site by individuals trained in the use of fire extinguishers or by a properly equipped and staffed fire department. Fire size at detection will impact the ability of manual suppression to control the fire.

4-3.6.4 Design Considerations. Expected fire size should be considered when designing a fire detection system. (*See NFPA 72, National Fire Alarm Code, Chapter 5.*)

Where ceilings are 20 ft (6.1 m) or greater in height, it is imperative that engineering assistance be obtained. (*See Appendix B.*)

The design of fire detection systems also should consider normal combustion processes in the occupancy to minimize false alarms. Attention should be given to activities that normally produce products of combustion (e.g., food preparation, automobile parking, smoking), steam, or other aerosols.

Generally, system design should include detection throughout the entire building. Partial protection may result in a delayed response to a fire causing larger losses.

4-3.7 Fire Extinguishment.

4-3.7.1 General. An essential element in any fire safety plan is consideration of the means available to suppress a fire once it has begun. Management must make critical decisions as to the type of fire suppression capability that will be provided in the building. Immediate response by operation of an automatic extinguishing system can be crucial in minimizing the damage to historic structures and their contents. Response by trained building personnel with appropriate extinguishing equipment also may minimize damage to historic structures and their contents. Operation of any of these systems should cause activation of an alarm at a constantly attended location, or activation of the building alarm system as described in NFPA *101, Life Safety Code.* The provision of these systems is equally important during the rehabilitation process and afterward.

4-3.7.2 Automatic Fire Extinguishing Systems.

4-3.7.2.1 General. Automatic fixed extinguishing systems are the most effective means of suppressing fires in buildings. Their use in historic buildings is recommended. They should be installed carefully to avoid damage to architectural and historic features and spaces.

Without some type of automatic extinguishing system, a fire can only increase in intensity until the fire department arrives. At that time, the fire department is faced with extinguishing a much larger fire than would have existed if an automatic extinguishing system had activated, and the damage due to extinguishing the fire in this manner would be substantially greater.

Example: A fire department using one or more hose lines inside a building is capable of delivering water at a rate of 250 gal/min (946 L/min) per hose. Automatic sprinkler systems typically discharge water at a rate of 15 gal/min to 25 gal/min (57 L/min to 95 L/min) per sprinkler.

In general, it is considered good engineering practice to utilize total flooding gaseous systems only in combination with automatic sprinkler systems, rather than as an alternative. (*See NFPA Fire Protection Handbook, Section 5, Chapter 18. Also see comparative design attributes in Appendix A.*) The combination of a total flooding gaseous system with an automatic sprinkler system provides a higher probability of confining fire growth to an area less than that typically covered by one sprinkler [e.g., 100 ft^2 (9.3 m^2)]. The total flooding gaseous system becomes a reliable substitute for manual suppression in the window of time between early warning detection and sprinkler operation.

The discharge of gaseous agents and dry chemicals is governed by automatic controls using smoke or heat detection devices. The various types of automatic extinguishing systems are described in Appendix A.

4-3.7.2.2 Automatic Sprinkler Systems. An automatic sprinkler system consists of a network of piping with a sprinkler(s) uniformly spaced along the piping to provide protection to a specified area or building. Water is supplied to the piping from a supply system, such as a municipal or private water distribution system. Effective operation is dependent upon an adequate and dependable water supply.

Different types of sprinkler systems can be designed for specific areas. These include wet-pipe systems, dry-pipe systems, preaction systems and deluge systems; all are discussed in Table A-3. Systems vary in method of operation and whether or not water is normally in the piping system. In most systems, only those sprinklers that are heated to the predetermined temperature will operate; sprinklers in other areas will remain closed. Typically, most fires are controlled by the operation of fewer than five sprinklers.

The potential for water damage from automatic sprinklers is often misunderstood. Some water damage will occur when sprinklers operate to control a fire. However, this damage is usually minimal when compared to the amount of damage the fire would have caused if the sprinkler system had not controlled or extinguished it. Reports of water damage in sprinklered buildings are often exaggerated in comparison to the small amount of fire damage resulting from successful fire control by the sprinklers. Automatic sprinkler systems should be installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems.*

4-3.7.2.3 Halon 1301 Total Flooding Systems. Halon 1301 is a colorless, odorless, electrically nonconductive gaseous agent that leaves no residue and requires no agent cleanup after discharge.

Halon 1301 extinguishing systems can be designed to protect rooms or other enclosures. They are often used to protect occupancies with high-value contents susceptible to damage by other types of extinguishing agents.

Halon 1301 works by interfering with the combustion process, not by diluting or displacing oxygen. Consequently, the usual 5 to 7 percent concentration of Halon 1301 will extinguish most fires. Although Halon 1301 vapor has a low toxicity, its decomposition products during a fire can be hazardous. Therefore, the fire area should be promptly evacuated. The safety precautions described in NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems,* should be followed.

A Halon 1301 system consists of a supply of the extinguishant in one or more containers and a nozzle(s) strategically placed in (throughout) the protected enclosure. The containers can be centrally located and connected to the nozzles by a piping network or placed at various locations in or near the hazard, with each container connected directly to its nozzle or piped to one or more nozzles. The types of nozzles selected, and their number and placement, should be such that their force of discharge will not adversely affect the building or room contents.

The halon discharge is usually released automatically by a fire detection system within the protected hazard, which includes a means for manual release.

It should be noted that, due to the deleterious effect that Halon 1301 and other cholorofluorocarbons (CFCs) have on stratospheric ozone, international health organizations have severely limited current production of CFCs and will totally ban production by the year 2000. However, Halon 1301 may continue to be available for essential uses (for both new systems and for refilling existing systems) by recycling from nonessential uses. It is important that existing systems be serviced and maintained on a regular basis to avoid accidental discharges. Nevertheless, as reserves of Halon 1301 become scarce, this agent can be expected to become expensive for most applications.

4-3.7.2.4 Carbon Dioxide Systems. Carbon dioxide extinguishes a fire by lowering the oxygen level below the 15 percent necessary for flame production. Personnel must be evacuated before agent discharge to avoid suffocation and reduced visibility during and after the discharge period. These systems should not be used in normally occupied areas.

4-3.7.2.5 Clean Agent Systems. Clean agent systems consist of a supply of extinguishant in one or more containers and a nozzle(s) strategically placed in (throughout) the protected, enclosed space. The containers can be centrally located and connected to the nozzles by a piping network or placed at various locations in or near the hazard, with each container connected directly to its nozzle or piped to one or more nozzles. The types of nozzles selected, and their placement, should be such that their force of discharge will not adversely affect the building or room contents.

"Clean" agents are not known to chemically damage artifacts, which often makes them preferred to other types of fire extinguishing systems. To be effective, however, these agents must be tightly contained within the room being protected. They are best suited for protecting the sensitive and delicate contents of a room (not the building structure). Total flooding fixed systems using gaseous agents depend on achieving and maintaining the concentration of the agent needed for effective extinguishment. Openings in the compartment (open windows or doors, ventilation systems that continue to operate) may prevent the achievement of an effective extinguishing agent concentration. Where a high reliability of operation is needed for protection of high-value collections, a back-up system, such as an automatic sprinkler system in combination with a total flooding gaseous agent system, should be considered. The new clean agents, while similar to Halon 1301, may not be compatible with existing containers and other components.

It is good engineering practice to utilize total flooding gaseous systems only in combination with automatic sprinkler systems, rather than as an alternative *(See NFPA Fire Protection Handbook, Section 5, Chapter 18. Also, see comparative design attributes in Appendix A.)* The combination of a total flooding gaseous system with an automatic sprinkler system provides a higher probability of confining fire growth to an area less than that typically covered by the operation of one sprinkler [e.g., 100 ft^2 (9.3 m^2)]. The total flooding gaseous system becomes a reliable substitute for manual suppression in the window of time between early warning detection and sprinkler operation. Human response (e.g., occupant manual extinguishing action) is the least reliable means of fire suppression, especially considering those periods when the building is not occupied and is most vulnerable.

Explicit warning information and instructions for building occupants should be conspicuously posted. Similar precautions may be needed for other special extinguishing systems.

Clean agent systems are described in NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems.*

4-3.7.3 Manual Fire-Fighting Capability.

4-3.7.3.1 Portable Fire Extinguishers. Portable fire extinguishers are important items of fire protection equipment and should be installed in accordance with NFPA 10, *Standard for Portable Fire Extinguishers.* These extinguishers allow the use of a limited quantity of extinguishing agent on a small fire at the moment the fire is discovered and, therefore, should be available in adequate numbers.

The extinguishers should be the type intended for the class of fire anticipated. Multiclass portable extinguishers are available that remove any doubt regarding the correct extinguisher to be used. Extinguishers should be properly located and inspected regularly so they will be in working order when needed. Personnel should know their locations and be instructed in their use. It must be emphasized that the use of fire extinguishers should not delay the transmission of alarms to the fire department.

The selection and use of portable extinguishers should include the following health and safety considerations:

(a) Gaseous agent-type extinguishers contain agents whose vapor may be toxic, and their decomposition products can be hazardous. Where using these extinguishers in unventilated spaces, such as small rooms, closets, motor vehicles, or other confined spaces, operators and others should avoid breathing the gases produced by thermal decomposition of the agent. As in the case of total flooding gaseous suppression systems, production of halogenated extinguishing agents for portable extinguishers terminated on January 1, 1994, due to their ozone-depleting properties. (*See 4-3.7.2.3.*)

(b) Carbon dioxide extinguishers contain an extinguishing agent that will not support life where used in sufficient concentration to extinguish a fire. The use of this type of extinguisher in an unventilated space can dilute the oxygen supply. Prolonged occupancy of such spaces can result in loss of consciousness due to oxygen deficiency.

Also see NFPA 10, *Standard for Portable Fire Extinguishers,* A-2-1, for other health and safety considerations.

4-3.7.3.2 Standpipe and Hose. Where standpipes and hose lines are required or installed to provide reliable and effective fire streams in the shortest possible time, they should be installed in accordance with NFPA 14, *Standard for the Installation of Standpipe and Hose Systems.* Training and skill in the use of hose streams are essential to avoid injury and unnecessary property damage. Building occupants should not attempt to use fire hose unless properly trained in accordance with safety and regulations (e.g., OSHA.) It should be emphasized that the use of standpipe hose lines, as with the use of fire extinguishers, should not delay the transmission of alarms to the fire department. A waterflow alarm should be provided on a wet standpipe system.

4-3.7.3.3 Hydrants and Outside Protection. Where a municipal water system or a private water system with sufficient capacity and pressure is available, fire hydrants should be provided to enable the fire department to quickly connect their pumpers and lay hose lines to the building. Where possible, hydrants should be provided on all sides of the building. Care should be taken to avoid placing hydrants too close to the building so that the fire department will not be prevented from using the hydrant due to fire exposure from the building.

4-4 Developing the Fire Safety Plan.

4-4.1 Selecting Fire Safety Plan Elements.

4-4.1.1 Elements of a fire safety plan should be selected to control or mitigate identified fire hazards appropriate to the objectives of historic preservation and fire safety. The best protection will be afforded by a combination of strategies designed to address specific fire safety problems. In addition, reliability can be greatly improved by the use of redundant or overlapping strategies.

A realistic fire safety objective for the fire safety plan is to provide a high probability of confining fire to the room in which it originates.

4-4.1.2 Fire Hazards. Table 4-4.1.2 shows categories and examples of fire hazards discussed in Section 4-4. Fire safety plan elements should address the specific hazards of each building.

4-4.1.3 Fire Safety Plan Elements. Possible elements of a fire safety plan discussed in Section 4-3 are summarized in Table 4-4.1.3. These are the alternative strategies for dealing with the identified fire hazards.

4-4.1.4 Table 4-4.1.4 shows the categories of fire hazards and categories of fire safety plan elements most likely to be effective at elimination or control of various problem situations. The table emphasizes two points:

(a) There is typically more than one way to deal with a particular fire hazard; and

(b) The same fire safety plan element may be effective in controlling or mitigating more than one fire hazard.

In general, the choice of fire safety plan elements should be based on evaluation of costs and benefits of each alternative. However, removing or changing an essential historic feature represents a cost or loss of value that cannot be readily quantified. The concern for authenticity may be so strong that the feature must be preserved, thus limiting the choice of design alternatives.

Table 4-4.1.2 Categories of Fire Hazards in Historic Buildings

Ignition sources
Arson
Lightning
Chimneys
Exposures
Heating, mechanical and electrical systems
Smoking (management)
Special hazards (e.g., restaurants, laboratories)
Combustibles
Roofing materials
Siding
Construction materials
Interior finish
Contents
Trash (management)
Structural features
Superstructures
Concealed spaces
Horizontal openings (large fire areas)
Vertical openings
Structural assemblies
Means of egress
Number of exits
Capacity of exits
Location of exits
Travel distances
Protection of means of egress

4-4.2 Sources of Information. To develop a fire safety plan successfully, knowledge of the subject and resourcefulness are necessary. The requisite knowledge is available from a number of sources described below. More specific identification of resources may be found in the appendices to this document.

4-4.2.1 Human Resources. Every building is unique, and no two fire safety problems exist under teh same set of conditions. However, experience has demonstrated the value of grouping certain similar sets of conditions and solutions. This expertise is most often found in the organizations and consultants that focus on fire safety. Appendix B identifies some of the resources that may be appropriate for a particular situation.

4-4.2.2 Codes and Standards.

4-4.2.2.1 Model Codes. NFPA *101*, *Life Safety Code*, is the only such code that provides specific chapters for both new and existing buildings.There may be situations where the approach to fire safety of one code is more fitting to particular circumstances than another code. Appendix B lists the most common model building codes and their specific approach to historic buildings.

4-4.2.2.2 Special Legislation. Many states have adopted special legislation to deal with the particular problems of fire safety in historic structures. These ordinances should be consulted to determine alternative approaches to identified fire safety issues.

Table 4-4.1.3 Elements of a Fire Safety Plan

Prevention	Structural protection
Operation and maintenance	Fire resistance
Education and training	
Enforcement	Detection and alarm
	Facilitating egress
	Facilitating suppression
Limiting combustibility	
Material substitution	Suppression systems
Protection with overlayer	Manual
Coating	Sprinklers
Fire retardant treatment	Special hazard systems
Compartmentation	
Enclosure	
Subdivision	
Barriers, doors, dampers	

4-4.2.3 Special Publications. In 1980, a series of rehabilitation guidelines was prepared by the National Institute of Building Sciences for the Department of Housing and Urban Development. They were designed for voluntary adoption and use by states and communities as a means to upgrade and preserve the nation's building stock while maintaining reasonable standards for health and safety. Two of these guidelines, which are particularly applicable to fire safety, are the "Egress Guideline for Residential Rehabilitation" and the "Guideline on Fire Ratings of Archaic Materials and Assemblies."

4-4.2.3.1 Egress Guideline for Residential Rehabilitation. This document lists design alternatives for the components of egress that are regulated by current codes, such as number and arrangement of exits, corridors, stairs, travel distance, dead-end travel, and exit capacity and width. Although written primarily for residential occupancies, it has a much broader application.

4-4.2.3.2 "Guideline on Fire Ratings of Archaic Materials and Assemblies." This document contains fire ratings of building materials and assemblies that are no longer found in current building codes and related reference standards. Introductory material discusses flame spread, the effects of penetrations, and methods for determining ratings of assemblies not listed in the guideline. Information from "Guideline on Fire Ratings of Archaic Materials and Assemblies" is provided in Appendix D.

4-4.2.4 Fire Safety Concepts Tree. One approach used to qualitatively evaluate alternative arrangements for equivalent safety from fire is the NFPA Fire Safety Concepts Tree. This tool is documented in NFPA 550, *Guide to the Firesafety Concepts Tree*. The tree represents all possible means of meeting fire safety objectives. Increasing fire safety measures on one branch of the tree theoretically offsets a lack of required measures on another branch, thus establishing an arrangement for equivalent fire protection.

Table 4-4.1.4 Effective Fire Safety Plan Elements and Associated Fire Hazards

	Prevention	Limiting Combustibility	Compartmentation	Structural Protection	Detection and Alarm	Suppression Systems
Fire Hazards						
Ignition sources	√	√				
Combustibles	√	√	√		√	√
Structural features			√	√		√
Means of egress			√		√	√

Chapter 5 Fire Protection and Safe Practices in the Construction Phase

5-1 Introduction. The potential for fire during the rehabilitation of a building is usually greater than during its normal use and occupancy. During this period, fire protection facilities generally have not been completed, and an unprotected steel or wood structure may be exposed throughout the building. The products of demolition and crating, boxes, cartons, etc., are highly combustible. Welding and cutting operations, plumbing torches, tar kettles, temporary heating equipment, and wiring serve as ignition sources that create a potential rapid-developing fire situation. Frequently, automatic sprinkler protection, yard hydrant systems, and standpipe and hose facilities have not yet been finished, thereby severely hampering fire fighters. Proper steps to improve these conditions must be taken to reduce the loss potential in structures undergoing rehabilitation and restoration.

It is good fire protection practice to complete, and place in service, automatic fire suppression systems, standpipes, detection systems, and fire barriers as early in the project as possible.

Preplanning of the construction phase should include discussions with the owner of the building, the architect, the contractor(s), and project manager about fire safety. Owners should have a designated person who will represent their interests in making sure that fire safety precautions are practiced on the job site. The general contractor should designate a person who will ensure that the job site is maintained in a fire safe manner. The public fire department and other fire protection authorities should be consulted for their guidance. If a facility can be closed to the public during the rehabilitation work, fire safety efforts can concentrate on the construction processes and the hazards introduced to the facility.

When the facility is to remain open to the public during the rehabilitation process, extreme fire safety and life safety hazards can be created. Extra effort must be made to ensure that necessary life safety and fire protection features are not compromised by any construction process. To reduce the level of hazard to occupants and the structure, construction areas should be separated from public use areas as much as possible, including the use of noncombustible partitions. Required exits should be maintained or supplementary routes provided. Guards may need to be employed to help keep the public out of construction areas and to assist the public in exiting when alternate exit routes are required.

5-2 Temporary Construction and Equipment.

5-2.1 Construction Offices and Sheds. Construction of temporary offices, trailers, sheds, and other facilities for the storage of tools and materials, where located closely together or located within the building, on the sidewalk bridging, or within 30 ft (9.2 m) of the building, should be of Type II noncombustible construction, (*see NFPA 220, Standard on Types of Building Construction*). Offices, trailers, sheds, and other facilities of combustible construction should be located at least 30 ft (9.2 m) from the main building and from each other. Only safely installed, approved heating devices should be used in construction offices and sheds. Ample clearance should be provided around stoves and heaters and all chimney and vent connectors to prevent ignition of adjacent combustible materials. (*See NFPA 241, Standard for Safeguarding Construction, Alteration, and Demolition Operations.*)

5-2.2 Construction Equipment and Materials. Internal combustion engine-powered air compressors, hoists, derricks, pumps, etc., should be located such that the exhausts discharge away from combustible materials. When the exhausts are piped outside the building under construction, a clearance of a least 6 in. (152 mm) should be maintained between such piping and combustible materials. Service areas or fuel for construction equipment should not be located within buildings.

Construction materials should be kept to a minimum within the structure. Materials not immediately needed should be safely stored away from the structure. Flammable and combustible liquids necessary for the construction project should be utilized only in quantities necessary to complete a day's work. All other quantities should be stored in accordance with 5-3.3. In addition, they should be stored downgrade and 50 ft (15.2 m) away from the main construction project and away from vehicle travel.

Storage of combustible construction components within the building should be kept to the minimum required to complete a day's project. Where steel construction is present, combustible storage should not be placed in areas where specified fire-resistive coatings have not been applied. Highly combustible materials, such as foam, plastic, or rubber products, should not be stored inside the building. Equipment and materials should be stored in secured areas with sprinkler protection if possible. If such areas are not available, materials should be subdivided and stored in secured noncombustible structures. Where equipment is too large to be stored within the above areas, it should be stored in secured fenced-in yard areas. Storage of construction materials should not impede egress from buildings or access of fire apparatus to hydrants or to the building.

5-3 Construction Processes and Hazards.

5-3.1 Cutting and Welding Operations. Cutting and welding operations on the job site should require a permit that is under the supervision of the designated person in charge of fire protection. Any such operations should be carried out in accordance with the requirements of NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes.*

A permit should not be issued until it has been determined that cutting and welding can be safely conducted at the desired location and combustibles have been moved away or safely covered. The permit should require that a person trained in the use of fire extinguishers be stationed in the vicinity of the cutting or welding operation for the duration of the work and for thirty minutes thereafter to ensure that sparks or drops of hot metal from the work do not start a fire. At the close of the workday, the work should be inspected by the supervisor so that any smoldering may be detected. Storage of flammable gases utilized in the welding or cutting process should be in a safe location protected from vehicle damage and high temperatures.

If the structure has a wooden floor, the floor should be wet down before and after welding or cutting operations are conducted. Adequate precautions should be taken so that wetting down will not introduce a personnel safety hazard or cause damage to historic building materials or finishes. All combustibles in the area should be relocated or be covered with fire-resistive tarpaulins.

5-3.2 Temporary Heating Equipment. As much as possible, the permanent building heating equipment should be maintained in service to provide heat for the workers and to prevent freezing of water pipes. Supplemental heating devices should be situated so they are not likely to overturn and otherwise should be installed in accordance with their listing, including clearance to combustible material, equipment, or construction. Portable equipment using oil or liquefied petroleum gas as fuel should be removed to a safe location and allowed to cool prior to refueling.

Where temporary heating equipment must be used, only steam heaters, approved electric heaters, approved gas-and oil-fired space heaters, or indirect-fired gasoline heaters located outside the building should be permitted. A portable, adequately sized, dry chemical fire extinguisher should be located near all portable heating devices. Sizing of fire extinguishers should be in accordance with NFPA 10, *Standard for Portable Fire Extinguishers.* The design and installation of these heaters should comply with appropriate standards such as NFPA 31, *Standard for the Installation of Oil-Burning Equipment*, NFPA 54, *National Fuel Gas Code*, and NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases.*

Chimney or vent connectors from direct-fired heaters, where required, should be maintained at least 18 in. (457 mm) from combustibles. Temporary heating equipment should be attended and maintained by competent personnel.

5-3.3 Flammable Liquids. The use and storage of flammable liquids should be carefully controlled and monitored. All flammable liquids should be handled only in approved safety cans. Potential sources of ignition should be identified and safeguarded wherever operations involving flammable liquids are to be conducted. Adequate ventilation should be provided for operations involving the use or application of materials that produce flammable vapors. All flammable liquids should be stored in accordance with the provisions of NFPA 30, *Flammable and Combustible Liquids Code.*

5-3.4 Roofing. Asphalt and tar kettles, where used in roofing or other operations, should be located in a safe place on the ground outside the building or on a noncombustible roof to avoid the danger of igniting combustible material below. Used roofing mops should not be stored within the building. Continuous supervision should be required while kettles are in operation, and metal covers should be provided for all kettles to smother flames in case of fire. Suitable fire extinguishers should be provided in the vicinity of such operations.

5-3.5 Plumbing. Plumbing operations involving open flame should be conducted only under the supervision of the person in charge of fire protection. Such work should take place only after it has been determined that the work can be conducted safely at the desired location, that combustibles have been moved away or safely covered, and that a charged fire extinguisher is available. At the close of the workday, the work must be inspected by the supervisor so that any smoldering may be detected.

5-3.6 Demolition Work. If demolition work is necessary during a project, all gas supplies should be shut off at a point outside the building and the outlet should be capped. Electrical service should be reduced or eliminated in the affected area. Flame-cutting should not be done in combustible buildings. Fire walls, fire doors, and cutoffs should be maintained in good repair where possible.

In cold weather areas, heating should be maintained as long as possible to prevent the freezing of sprinkler lines, hoses, and fire extinguishers. Where automatic sprinklers are present, they should remain in service as long as possible. Where sprinklers are removed or extended, lines should be capped and impairment safeguards provided to minimize the downtime of systems. NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations*, should govern all demolition operations.

5-3.7 Other Hazardous Operations. Operations that introduce fire hazards should be reviewed to determine if other, safer methods can be utilized. Paint stripping operations involving open flames should not be permitted. Floor sanders should have their dust accumulation bags emptied before the close of the day. Dust should be disposed of in closed metal containers outside of the building. Other operations should be similarly controlled to reduce the possibility of fire ignition.

5-3.8 Smoking. Smoking should be prohibited altogether or restricted to designated areas. Smoking areas should be selected on the basis of their remoteness from exposed combustible materials, the low degree of danger from an incipient fire that could spread rapidly, and the availability of fire protection equipment and personnel. Receptacles for spent smoking materials should be provided in the smoking area, and housekeeping should be exemplary. Stringent restrictions on smoking also serve to promote general awareness of the need for fire safety. Surreptitious smoking outside designated areas should be dealt with severely.

5-3.9 Housekeeping. Extreme care should be taken to prevent even small accumulations of debris or rubbish inside construction areas or close to an exterior fire hazard. Debris and rubbish should be removed from the site daily and should not be burned in the vicinity. Contractors should be required to provide ample receptacles for rubbish, papers, etc. If a chute is employed for removal of debris, it should be erected on the outside of the building. Burning of waste materials on the premises should not be permitted.

Housekeeping is always an essential consideration in any fire protection plan. During periods of construction, it takes on added importance, since the construction process introduces many temporary hazards.

5-3.10 Electrical. Electrical wiring and equipment for light, heat, or power should be installed in compliance with the requirements of NFPA 70, *National Electrical Code*. Attention should be given to ensure that temporary lighting, bulbs, and fixtures do not come in contact with combustible materials. Circuit breakers for circuits that are not being utilized should be shut off.

5-3.11 Environmental Conditions. Attention should be focused on possible fire exposure hazards created by weather and environment-related conditions. Fire damage may not be confined to the building of origin and could spread to adjacent property. If the fire threat to adjoining or nearby buildings is severe, the provision of fire doors, temporary barriers, or sprinkler water curtains should be evaluated.

Windstorm damage, while not necessarily related directly to loss by fire, may, in fact, contribute directly to an increase in the fire hazard. Open structures are particularly susceptible to damage from high winds that may cause skewing and misalignment of the structure and disrupt existing water supplies or delivery systems for fire protection. Secure, temporary coverings to openings should be provided.

Water supplies may be affected and may freeze in cold weather if temporary doors or window closures are blown away. Roof construction also may be damaged to the extent that freezing of equipment may occur. Entry of wind into a building also may blow debris, lumber scraps, or tarpaulins against heating devices, thereby causing ignition of these materials. Consequently, proper care should be given to eliminating both direct loss from wind and the attendant possibility of resultant fire damage.

5-3.12 Arson. Deliberate and malicious setting of fires is the most common cause of fire incidents in the construction phase of building rehabilitation. Control of access to the property, as described in Section 5-1, is essential in preventing arson. The practice of good housekeeping, as described in 5-2.2 and 5-3.9, will minimize the amount of combustible material readily available to facilitate an arson fire. If a location has experienced labor management difficulty or has sustained a set fire or other vandalism, it is established as a target for arson. Additional security is recommended for target properties.

5-4 Fire Protection.

5-4.1 Fire Barriers. Fire walls and exit stairways, if required for the completed building, should be given construction priority. Fire doors with approved closing devices and hardware should be installed as soon as practical and before combustible materials are introduced. After installation, fire doors should not be obstructed from closing.

5-4.2 Existing Fire Detection Systems. Existing fire detection and alarm systems should be maintained in operating order wherever possible. Should a temporary fire detection system with some form of connection to the fire department be installed, this system should include only heat detectors and manual fire alarm boxes, with smoke detectors installed only in areas that are not affected by the construction. The smoke detectors that are deemed necessary to be used within the construction area must be protected from dust, dirt, and extreme temperatures during construction.

When construction has finished for the day, a security guard or other authorized person should be instructed to uncover the smoke detectors in the construction area to avoid delayed alarms during nonworking hours. Care should be taken to avoid disabling the fire alarm system or causing false alarms during the rehabilitation work.

5-4.3 Fire Fighting.

5-4.3.1 Access. A suitable location at the site should be designated as a command post and provided with plans; emergency information; keys; communications; and fire-fighting, salvage, and medical equipment, as needed. The person in charge of fire protection shall return to the location immediately if a fire occurs.

Access for heavy fire-fighting equipment to the immediate job site should be provided at the start of construction and maintained until all construction is completed.

Free access from the street to fire hydrants and to outside connections for standpipes, sprinklers, or other fire extinguishing equipment, whether permanent or temporary, should be provided and maintained at all times. Protective pedestrian walkways should be constructed so as not to impede access to hydrants, fire department connections, or fire extinguishing equipment.

Prefire planning should be updated periodically with local authorities. For large projects, a fire safety coordinator for the site should be provided. The duty of this coordinator should be to ensure that all procedures, precautionary measures, and safety standards are laid down, understood, and complied with by all personnel on the construction site.

During construction operations, free access to permanent, temporary, or portable first aid fire equipment should be maintained. In all buildings over one story in height, at least one stairway should be provided in usable condition at all times.

5-4.3.2 Water Supply. The water supply for either temporary or permanent fire protection should be made available as soon as construction begins and combustible material accumulates.

The local fire authority should be contacted regarding adequacy of the water supply for hose lines.

Where underground water mains are to be provided, they should be installed, completed, and in service with hydrants or standpipes located as directed by the local fire authority prior to construction work.

5-4.3.3 Standpipes. In all buildings in which new standpipes are required or where they exist in buildings being altered, they should be maintained in accordance with the progress of building activity such that they are always ready for fire department use.

5-4.3.4 Sprinkler Protection. Where automatic sprinkler protection is to be provided, the installation should be placed in service and monitored as soon as possible. Where sprinkler protection existed prior to the rehabilitation project, the system should be kept in service as long as possible during the rehabilitation work to provide continuous protection. Where sprinklers must be taken out of service for modification, they should be returned to service as soon as possible. System downtime must be minimized.

5-4.3.5 Manual Fire-Fighting Equipment.

5-4.3.5.1 Hose and nozzles should be provided and made ready for use as soon as either the temporary or permanent water supply is available.

5-4.3.5.2 For every building operation, including those occurring in a tool house, storeroom, or other structure located in or adjacent to the building under rehabilitation, or within a room or space used for storage, a workshop, or employee clothes changing, the proper type and size of fire extinguishers should be provided and maintained in an accessible location.

At least one approved fire extinguisher also should be provided in plain sight on each floor at each usable stairway.

5-5 Supervision and Watch Service.

5-5.1 A capable and qualified person having the necessary authority should be placed in charge of fire protection and security. Responsibilities should include maintenance and location of fire protection equipment, general supervision of safeguards and location of portable heating equipment, and the establishment and maintenance of safe cutting and welding operations. In addition, only authorized personnel should be allowed within the construction areas to prevent theft, vandalism, or arson. Watch service personnel should be acquainted with developments during the day and receive information on the status of fire protection equipment and emergency procedures.

5-5.2 A public fire alarm box near the premises, telephone service to the fire department, or equivalent facilities should be readily available. Instructions should be issued to notify the fire department immediately in case of fire. Where telephone service is employed, the local fire department number should be conspicuously posted near each telephone. Clear access to the site and buildings should be maintained at all times.

5-5.3 If welding operations have been conducted during the previous working period, the incoming watchperson should be alerted to check the location where welding was done as a part of the regular rounds. Where watch service is not provided, use of gas-operated welding or cutting equipment should be discontinued a minimum of three hours before the end of the workday.

Chapter 6 Operations and Maintenance

6-1 General. Historic structures may house a variety of ongoing uses including, but not limited to, private office and residential, public tour, hotel/bed and breakfast, education, retail/antique space, and restaurants. Several occupancy types may coexist within the same structure.

Each use can introduce unique fire hazards, such as cooking/beverage service, special heating systems, hazardous storage, specialized office or medical systems, and smoking.

Management has the primary responsibility to periodically review fire hazards within their respective facilities and implement appropriate maintenance and protection programs.

6-2 Operations. Regular operations within historic structures often increase fire hazards. While it may not be practical to eliminate all threats completely, fire potential can be minimized through appropriate hazard control procedures.

6-2.1 Heating Plant. Heating plants contain various heat-producing appliances, including furnaces, boilers, and fan motors. Fire risk may be significant. Concerns include failure of heating vessels under pressure, decay of combustion chambers, damaged fuel lines, and ductwork fatigue. Historic buildings often have older heating plants that need more frequent maintenance intervals.

Plant rooms should be cut off from the rest of the building by fire-rated walls, ceilings, and floors. Doors into plant rooms should have fire ratings equivalent to that of their corresponding walls. All pipe chases, utility holes, and ductwork should be sealed in a manner that produces an equivalent wall rating to minimize the spread of smoke and heat to other areas of the building. The temptation to store combustibles such as maintenance supplies, janitorial equipment, and general contents should be avoided.

6-2.2 Electrical Systems. Outdated or overloaded wiring is a common concern in many older buildings. Concerns include degraded insulation or outdated styles (e.g., knob and tube) that are incapable of carrying modern electrical loads.

Frequent tripping of circuit breakers or fuses may indicate a severe overload condition and fire potential. The trip cause should be identified and corrected.

Extension cords should not be used as a substitute for fixed wiring.

6-2.3 Structure. Holes and breaches in walls, floors, and ceilings frequently occur as new electrical and other building systems are installed. Removal or obstruction of doors is a common deficiency. Accelerated spread of fire, smoke, and toxic gases could be the results. All new construction activities should include repairing all breaches to restore the original fire resistance. Doors should be maintained closed or in closable condition. Holes should not be made in doors.

Concealed spaces often provide hidden paths of unrestricted fire travel within walls, ceilings, and floors. Fires originating within these areas are usually difficult to identify and remedy. Installation of fire stops within concealed spaces is advised.

Nearby buildings, woodlands, flame-producing activities (e.g., outdoor barbecues), and debris allowed to accumulate around exterior walls may produce a fire hazard. Refuse and combustible storage should be removed from near building exteriors.

6-2.4 Fireplaces and Wood Stoves. Flame-producing devices, such as fireplaces and wood stoves, are common in historical buildings. Chimneys may become coated with combustion products (pitch), providing an opportunity for chimney fires. Chimney flues may lose bricks or mortar, allowing ignition of combustible structural members. Where insulation deterioration occurs or creosote buildup is found, fireplace and wood stove use should be discontinued until repairs are made.

Sparks and embers escaping from a heating unit are also a fire threat. The floor area in front of a fireplace should be of noncombustible material. Using screens to confine burning contents is recommended. Wood stoves should remain closed when in use. Stove bases should be noncombustible.

6-2.5 Lightning Protection. A lightning protection system should be in place to carry current safely from the building to the ground. All buildings and nearby trees should be protected. Lightning protection systems should not be used for other purposes, such as television and radio antennas. Lightning protection systems should be designed and maintained in accordance with NFPA 780, *Lightning Protection Code.*

6-2.6 Cooking and Beverage Systems. Ovens, stoves, coffee makers, and other heat-producing kitchen appliances are a common fire threat to historic structures. Cooking ranges should be maintained free from adjacent combustibles. Range hoods, exhaust vents, and associated ducts should not be obstructed.

Cooking and beverage equipment (e.g., coffee makers) should be turned off when not in use or when liquid levels are low. The location of a coffee maker should allow enough ventilation to mitigate heat buildup and, in turn, the threat of fire.

6-2.7 Fire Protection Systems. Systems should be inspected and maintained by qualified personnel.

6-2.8 Fire Life Safety. Historic structures were built prior to contemporary fire codes. Providing adequate fire life safety can be difficult. Assigned occupant loads, egress route improvements, proper emergency lighting and exit signs, and interior finishes and furniture control represent possible solutions. NFPA *101*, *Life Safety Code*, and local building or fire authorities should be consulted.

6-3 Maintenance. Fire hazards increase as building systems and appliances age. Failure of mechanical and electrical systems are among the most common sources of fire ignition. Most failures develop over an extended period of time and are predictable. A routine inspection and maintenance program for building systems and occupant use appliances can reduce failure and consequent ignition probability. Dangerous conditions can be identified and remedied before ignition or costly repair, or both.

Motor-bearing wear, electrical insulation breakdown, and drive belt failure are some of the common concerns. Lint and dust accumulation on motors, heating elements, and electrical switches add ignitible fuels. It should be recognized that any mechanical or electrical machine, appliance, or device is capable of producing heat and is a potential ignition source.

6-3.1 Heating Plant. Heating system malfunctions are a major cause of accidental fire. All heating systems should be inspected, cleaned, and serviced annually. Higher frequencies are advised where systems are subject to severe conditions. Procedures should include identification and remedy of excessive heat and wear conditions, bearing lubrication, filter replacement, dust/lint removal, elimination of adjacent combustible storage, fuel line and supply inspection, exhaust duct/flue inspection and cleaning, and burner adjustment.

6-3.2 Electrical Systems. Electrical system malfunctions are responsible for many accidental fires. All electric systems should be annually inspected and serviced. Higher frequencies are advised for where systems are subject to more severe use (e.g., frequent wire flexing, corrosive environments). Procedures should include identification and remedy of excessive heat situations. Specialty electrical equipment (e.g., medical, industrial, or office systems) should be maintained in accordance with the manufacturer's recommendations, with defective equipment repaired or removed.

6-3.3 Structure. Holes and breaches in walls, floors, and ceilings are common deficiencies that can allow the unrestricted spread of fire, smoke, and toxic gases. Regular inspections should identify breaches and repairs that should be made to restore the original fire resistance of the construction.

6-3.4 Fireplaces and Wood Stoves. All fireplaces and wood stoves should be inspected and cleaned as necessary, with increased frequency during significant use periods. Signs of excessive heat or wear should be corrected immediately. A safe clearance should be maintained between fireplaces and stoves and any adjacent combustibles.

6-3.5 Proper maintenance of lightning protection systems is essential to effective protection. Particular attention should be given to ground connections, as rods may be broken or corroded at ground level or just below ground level, where the damage is not apparent. Materials (components) may be missing because of storm damage or stolen because of their value.

6-3.6 Clothes Dryers. Lint accumulations coming in contact with dryer heating elements is a common ignition hazard. Dryers should be cleaned as necessary to remove excess lint buildup.

6-3.7 Cooking and Beverage Systems. Fire protection systems in cooking and beverage areas should be tested and maintained in accordance with Table A-3 and the manufacturer's recommendations. Fuel lines should be periodically inspected. Grease filters should be changed to prevent combustible buildup and loss of ventilation airflow.

6-3.8 Fire Protection Systems. Fire protection systems must be regularly inspected and maintained to ensure reliability. System inspections should include all fire detection, alarm, and extinguishing devices including, but not limited to, manual fire alarm stations, smoke and heat detectors, fire alarm panels and cabling, sprinklers, standpipes, special hazard systems, and water sources. Table A-3 provides information regarding various fire protection systems.

6-3.9 Life Safety Systems. Means of egress must be maintained in proper condition. Obstructions, missing or damaged exit signs, tripping hazards, and other dangerous conditions must be avoided.NFPA *101*, *Life Safety Code*, and local building or fire authorities should be consulted.

Chapter 7 Referenced Publications

7-1 The following documents or portions thereof are referenced within this recommended practice and should be considered part of the recommendations of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

7-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1994 edition.

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*, 1992 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1994 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 1993 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 1993 edition.

NFPA 31, *Standard for the Installation of Oil-Burning Equipment*, 1992 edition.

NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, 1994 edition.

NFPA 54, *National Fuel Gas Code*, 1992 edition.

NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*, 1992 edition.

NFPA 70, *National Electrical Code*, 1993 edition.

NFPA 72, *National Fire Alarm Code*, 1993 edition.

NFPA *101*, *Life Safety Code*, 1994 edition.

NFPA 220, *Standard on Types of Building Construction*, 1992 edition.

NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations*, 1993 edition.

NFPA 251, *Standard Methods of Fire Tests of Building Construction and Materials*, 1990 edition.

NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, 1990 edition.

NFPA 550, *Guide to the Firesafety Concepts Tree*, 1986 edition.

NFPA 780, *Lightning Protection Code*, 1992 edition.

NFPA 910, *Recommended Practice for the Protection of Libraries and Library Collections*, 1991 edition.

NFPA 911, *Recommended Practice for the Protection of Museums and Museum Collections*, 1991 edition.

NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*, 1994 edition.

NFPA *Fire Protection Handbook*, 17th edition, 1991.

7-1.2 Other Publications.

7-1.2.1 BOCA Publication. Building Officials and Code Administrators International, 4051 West Flossmoor Road, Country Club Hills, IL 60477.

BOCA *National Building Code*, 1987.

7-1.2.2 ICBO Publication. International Conference of Building Officials, 5360 South Workman Mill Road., Whittier, CA 90601.

Uniform Building Code, 1988.

7-1.2.3 SBCCI Publication. Southern Building Code Congress International, 116 Brown Marx Building, Birmingham, AL 35213.

Standard Building Code, 1988.

7-1.2.4 U.S. Government Publications. Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

"Egress Guideline for Residential Rehabilitation," Rehabilitation Guideline No. 5, U.S. Department of Housing and Urban Development, 1980.

"Guideline on Fire Ratings of Archaic Materials and Assemblies," Rehabilitation Guideline No. 8, U.S. Department of Housing and Urban Development, 1980.

"The Secretary of the Interior's Standards for Rehabilitation and Guidelines for Rehabilitating Historic Buildings," National Park Service, U.S. Department of the Interior, 1983.

National Register of Historic Places.

7-1.2.5 Goldstone, Barbara M., "Hazards from the Concentration of Solar Radiation by Textured Window Glass," Building Research Establishment Report, Department of the Environment, UK, 1982.

Appendix A Basics of Fire and Fire Protection Systems

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-1 Most fires that occur in historic structures and landmarks can be expected to fall into one or more of the following categories:

Class A. Fires involving ordinary combustible materials, such as paper, wood, and textile fibers, where a cooling, blanketing, or wetting extinguishing agent is needed.

Class B. Fires involving oils, greases, paints, and flammable liquids, where a smothering or blanketing action is needed for extinguishment.

Class C. Fires involving live electrical equipment, where a nonconducting extinguishing agent with a smothering action is needed.

A-2 Glossary of Fire Protection Systems. Tables A-2 and A-3 describe detection, alarm, and extinguishing systems that are appropriate for use in historic structures. Included are comments about the intended or optimum applications of each system and recommendations for their applications. Insofar as possible, nontechnical terminology has been used so that the information presented will be readily understandable to persons who have been delegated fire safety responsibility.

Table A-2 Glossary of Fire Detection and Alarm Systems
Classification of Fire Detection Systems by Method of Detection

Type	Description	Comments
1. Smoke detection systems	These systems use devices that respond to the smoke particles produced by a fire. They operate on the ionization, photoelectric, or cloud chamber principle of operation. Spot-type smoke detectors use either the ionization principle of operation or the photoelectric principle. Line-type smoke detectors use the photoelectric principle. Air sampling-type smoke detectors use either the ionization, photoelectric, cloud chamber, or other particle analysis principle. Properly installed, smoke detectors can detect smoke particles in very early stages of fire in the areas where they are located.	These systems are intended for early warning. Some are designed for installation in ventilation ducts. (*See NFPA 72, National Fire Alarm Code.*)

Table A-2 Glossary of Fire Detection and Alarm Systems
Classification of Fire Detection Systems by Method of Detection

Type	Description	Comments
2. Heat detection systems	These systems use heat-responsive devices of either the "spot" or "line" type. They are mounted either on exposed ceiling surfaces or a sidewall near the ceiling. Heat detectors are designed to respond when the operating element reaches a predetermined temperature (fixed temperature detector), when the temperature rises at a rate exceeding a predetermined value (rate-of-rise detector), or when the temperature of the air surrounding the device reaches a predetermined level, regardless of the rate of temperature rise (rate compensation detector). Some devices incorporate both fixed temperature and rate-of-rise detection principles. Spot-type detectors are usually small devices a few inches in diameter. Line-type detectors are usually lengths of heat-sensitive cable or small bore metal tubing.	These systems are relatively low in cost. They cannot detect small, smoldering fires. Line-type detectors can be installed in a relatively inconspicuous manner by taking advantage of ceiling designs and patterns. (*See NFPA 72, National Fire Alarm Code.*) The air temperature surrounding a fixed temperature device at the time it operates usually is considerably higher than the rated temperature, because it takes time for the air to raise the temperature of the operating element to its set point. This is called thermal lag. Rate compensation devices compensate for thermal lag and respond more quickly when the surrounding air reaches the set point.
3. Flame detection systems	These systems use devices that respond to radiant energy visible to the human eye (approximately 4000 to 7000 angstroms) or to radiant energy outside the range of human vision [usually infrared (IR) or ultraviolet (UV), or both]. Flame detectors are sensitive to glowing embers, coals, or actual flames with energy of sufficient intensity and spectral quality to initiate the detector.	Since flame detectors are essentially line-of-sight devices, special care should be taken in their application to ensure that their ability to respond to the area of fire in the zone that is required to be protected will not be unduly compromised by the permanent or temporary presence of intervening structural members or other opaque objects or materials. (*See NFPA 72, National Fire Alarm Code.*)

Classification of Fire Detection and Alarm Systems by Method of Alarm Reporting

Type	Description	Comments
1. Local fire alarm system	An alarm system operating in the protected premises, responsive to the operation of a manual fire alarm box, waterflow in a sprinkler system, or detection of a fire by a smoke, heat, or flame detection system.	The main purpose of this system is to provide an evacuation alarm for the occupants of the building. Someone must always be present to transmit the alarm to fire authorities. (*See NFPA 72, National Fire Alarm Code.*)
2. Auxiliary fire alarm system	An alarm system utilizing a standard municipal fire alarm box to transmit a fire alarm from a protected property to municipal fire headquarters. These alarms are received on the same municipal equipment and are carried over the same transmission lines as are used to connect fire alarm boxes located on streets. Operation is initiated by the local fire detection and alarm system installed at the protected property.	Some communities will accept this type of system, and others will not. (*See NFPA 72, National Fire Alarm Code, and NFPA 1221, Standard for the Installation, Maintenance, and Use of Public Fire Service Communication Systems.*)
3. Central station fire alarm system	An alarm system connecting protected premises to a privately owned central station whose function is to monitor the connecting lines constantly and record any indication of fire, supervisory, or other trouble signals from the protected premises. When a signal is received, the central station will take such action as is required, such as informing the municipal fire department of a fire or notifying the police department of intrusion.	This is a flexible system. It can handle many types of alarms, including trouble within systems at protected premises. (*See NFPA 72, National Fire Alarm Code.*)
4. Remote station fire alarm system	An alarm system connecting protected premises over telephone lines to a remote station, such as a fire station or a police station. Includes separate receiver for individual functions being monitored, such as fire alarm signal or sprinkler waterflow alarm.	(*See NFPA 72, National Fire Alarm Code.*)

Classification of Fire Detection and Alarm Systems by Method of Alarm Reporting

Type	Description	Comments
5. Proprietary fire alarm system	An alarm system that serves contiguous or noncontiguous properties under one ownership from a central supervising station at the protected property. Similar to a central station system, but owned by the protected property.	This system requires 24-hour attendance at a central supervising station. (*See NFPA 72, National Fire Alarm Code.*)
6. Emergency voice/alarm communication system	This system is used to supplement any of the systems described above by permitting voice communication throughout a building so that instructions may be given to building occupants. During a fire emergency, prerecorded messages may be played, or fire department personnel may transmit live messages, or both.	(*See NFPA 72, National Fire Alarm Code.*)

Classification of Fire Detection and Alarm Systems by Type of Control

Type	Description	Comments
1. Conventional system	This type of fire detection system utilizes copper wire to interconnect all initiating devices and signaling appliances to the fire alarm control panel. The wiring must be installed in a "closed-loop" fashion for each zone circuit to ensure proper electrical supervision or monitoring of the circuit conductors for integrity.	This is the most common type of fire alarm system. It provides basic alarm, trouble, and supervisory signal information and is used for small to medium size systems.
2. Microprocessor-based system	This system is identical to the conventional system, with the exception that the fire alarm control panel has more features available, such as smoke detector alarm verification and system "walk test." Some of these systems "multiplex" information to their attached remote annunciators over four conductors, rather than one conductor per zone.	Most modern systems are microprocessor-based in order to provide features desired by installers, owners, and fire departments.
3. Addressable multiplex system	This system utilizes initiating devices and control points, each assigned a unique three- or four- digit number that is called the detector's "address." The fire alarm control panel's microprocessor is programmed with this address number. All activity by or affecting the device is monitored and recorded at the control panel.	This type of system provides more detailed information about alarm, trouble, or supervisory conditions. Essentially, the system is zoned by device rather than by an entire floor or area. The equipment for addressable multiplex systems is more costly but, generally, installation costs are reduced substantially, operations are more flexible, and maintenance is more efficient.
4. Addressable analog multiplex system	This type of system is identical to the addressable multiplex system, with the exception that the smoke and heat detectors connected to the microprocessor are analog devices. The analog devices sense the fire signature and continuously send information to the control panel microprocessor, which determines the sensitivity, alarm point, and maintenance window of the analog device. Accordingly, this system is also called "intelligent" or "smart."	Analog systems provide the maximum flexibility and information that can be obtained from a fire alarm system. These computer-based systems do demand sophisticated technical expertise to maintain and service, and this should be considered in the design process.
5. Wireless system	This system uses battery-powered initiating devices, which transmit the alarm or trouble signal to a receiver/control panel. Each initiating device can be individually identified by the control panel for annunciation purposes.	The battery in each initiating device will last for a minimum of one year, but must be replaced whenever the initiating device transmits a battery depletion signal to the control panel. Wireless systems can be used where it is not possible or feasible to install the electrical cable needed by hard-wired systems.

Table A-3 Glossary of Fire Extinguishing Systems

Type	Description	Comments
1. Wet-pipe automatic sprinkler system	A permanently piped water system under pressure, using heat-actuated sprinklers. When a fire occurs, the sprinklers exposed to the high heat operate and discharge water individually to control or extinguish the fire.	This system automatically detects and controls fire. Should not be installed in spaces subject to freezing. Might not be the best choice in spaces where the likelihood of mechanical damage to sprinklers or piping is high, such as in low-ceiling areas, and could result in accidental discharge of water. Where there is a potential for water damage to contents, such as books, works of art, records, and furnishings, the system may be equipped with mechanically operated on-off or cycling sprinklers to minimize the amount of water discharged (*see Type 3*). In most instances, the operation of only one sprinkler will control a fire until the arrival of fire fighters. Often the operation of a sprinkler system will make the use of hose lines by fire fighters unnecessary, thus reducing the amount of water put onto the fire and the subsequent amount of water damage. (*See NFPA 13, Standard for the Installation of Sprinkler Systems, and NFPA 22, Standard for Water Tanks for Private Fire Protection.*)
2. Preaction automatic sprinkler system	A system employing automatic sprinklers attached to a piping system containing air that might or might not be under pressure, with a supplemental fire detection system installed in the same area as the sprinklers. Actuation of the fire detection system by a fire opens a valve that allows water to flow into the sprinkler system piping and to be discharged from any sprinklers that are opened subsequently by the heat from the fire.	This system automatically detects and controls fire. Can be installed in areas subject to freezing. Minimizes the accidental discharge of water due to mechanical damage to sprinklers or piping, and thus is useful in areas where it is perceived that system leaks would pose a hazard for works of art, books, records, and other materials susceptible to damage or destruction by water. However, such water damage is rare — 1.6 accidental discharges per year per 1,000,000 sprinklers in use. Failure of the actuation system would prevent operation of the preaction sprinkler system, except by manual operation of the water supply valve, and thus presents a potential failure mode that reduces the reliability of this system compared with wet-pipe systems. Furthermore, the preaction system needs a significantly higher level of regular maintenance, involving additional potential failure modes that further reduce its reliability relative to wet-pipe systems. **Most of these water-sensitive items can be salvaged from wetting, but no way has been found to recover them from ashes.** (*See NFPA 13, Standard for the Installation of Sprinkler Systems, and NFPA 22, Standard for Water Tanks for Private Fire Protection.*)
3. On-off automatic sprinkler system	A system similar to the preaction system, except that the fire detector operation acts as an electrical interlock, causing the control valve to open at a predetermined temperature and close when normal temperature is restored. If the fire rekindles after its initial control, the valve will reopen and water will again flow from the opened sprinklers. The valve will continue to open and close in accordance with the temperature sensed by the fire detectors. Another type of on-off system is a standard wet-pipe system with on-off sprinklers. Here, each individual sprinkler is equipped with a temperature-sensitive device that causes the sprinkler to open at a predetermined temperature and to close automatically when the temperature at the sprinkler is restored to normal.	In addition to the favorable feature of the automatic wet-pipe system, these systems have the ability to automatically stop the flow of water when no longer needed, thus eliminating unnecessary water damage. (*See NFPA 13, Standard for the Installation of Sprinkler Systems, and NFPA 22, Standard for Water Tanks for Private Fire Protection.*)

Table A-3 Glossary of Fire Extinguishing Systems

Type	Description	Comments
4. Dry-pipe automatic sprinkler system	A system employing automatic sprinklers attached to a piping system containing air under pressure. When a sprinkler operates, the air pressure is reduced, thus allowing the dry-pipe valve to open and allow water to flow through any opened sprinklers.	(*See Type 1.*) This system can protect areas subject to freezing. Water supply must be in a heated area. (*See NFPA 13, Standard for the Installation of Sprinkler Systems, and NFPA 22, Standard for Water Tanks for Private Fire Protection.*)
5. Standpipe and hose system	A piping system in a building to which hoses are connected for emergency use by building occupants or by the fire department.	This system is a desirable complement to an automatic sprinkler system. Staff must be trained in order to use hose effectively. (*See NFPA 14, Standard for the Installation of Standpipe and Hose Systems.*)
6. Gaseous automatic system	A permanently piped system using a limited, stored supply of a gaseous extinguishant under pressure and discharge nozzles to totally flood an enclosed space. Released automatically by a suitable detection system. Extinguishes fire by chemical or mechanical means.	This system causes no agent damage to protected books, manuscripts, records, paintings, or other irreplaceable valuable objects; also leaves no agent residue. Clean agents are low in toxicity, but the products of decomposition of some agents during a fire could be hazardous. Therefore, the fire area should be promptly evacuated upon sounding a fire alarm prior to agent discharge. Clean agents might not extinguish deep-seated fires in ordinary solid combustibles, such as paper and fabrics, but are effective on surface fires in these materials. These systems need special precautions to avoid damaging effects caused by their extremely rapid release. The high velocity discharge from nozzles might be sufficient to dislodge substantial objects directly in the path. Where carbon dioxide systems are used, personnel should evacuate before agent discharge to avoid suffocation. (*See NFPA 12, Standard on Carbon Dioxide Extinguishing Systems, NFPA 12A, Standard on Halon 1301 Fire Extinguishing Systems, and NFPA 2001, Standard on Clean Agent Fire Extinguishing Systems.*)
7. Dry chemical system	A permanently piped system that discharges a dry chemical from fixed nozzles by means of an expellant gas. The system either totally floods an enclosed space or applies the dry chemical directly onto the fire in a local application. The dry chemical extinguishes fires by the interaction of the dry chemical particles to stop the chain reaction that takes place in flame combustion. The dry chemical is released mechanically or with a suitable detection system.	This system leaves a powdery deposit on all exposed surfaces in and around the hazard being protected; it requires cleanup. This type of system provides excellent protection from a fire when installed in the ducts and hood over cooking equipment such as deep fat fryers, range griddles, and broilers that may be a source of ignition. May not extinguish deep-seated fires, but is effective on surface fires. (*See NFPA 17, Standard for Dry Chemical Extinguishing Systems.*)
8. High-expansion foam system	A fixed extinguishing system that generates a foam agent for total flooding of confined spaces and for volumetric displacement of vapor, heat, and smoke. Acts on the fire by: (a) Preventing free movement of air (b) Reducing the oxygen concentration at the fire (c) Cooling. Released automatically by a suitable detection system.	Where personnel might be exposed to a high-expansion foam discharge, suitable safeguards should be provided to ensure prompt evacuation of the area. The discharge of large amounts of high-expansion foam can inundate personnel, blocking vision, making hearing difficult, and creating some discomfort in breathing. It also leaves residue and requires cleanup. High-expansion foam, where used in conjunction with water sprinklers, will provide more positive control and extinguishment than either extinguishment system used independently, where properly designed. (*See NFPA 11A, Standard for Medium-and High-Expansion Foam Systems.*)
9. Wet chemical extinguishing system	Operates in the same way as halon systems (*see Type 6*), except uses liquid agent usually released by automatic mechanical thermal linkage. Effective for restaurant, commercial, and institutional hoods, plenums, ducts, and associated cooking appliances.	This system leaves agent residue that is confined to the protection area(s) and requires cleanup. Excellent for service facilities having range hoods and ducts. (*See NFPA 17A, Standard for Wet Chemical Extinguishing Systems.*)

Appendix B Resources

This Appendix is not a part of the recommendations of this NFPA document but is included for informational purposes only.

B-1 APT. Association for Preservation Technology, Box 2487, Station D, Ottawa, Ontario K1P 5W6.

APT is an organization for the preservation of historic resources, rehabilitation and reuse of historic structures, and history of building technology. APT responds to inquiries and provides consulting references. It distributes publications and offers training courses in various aspects of the preservation/rehabilitation field.

B-2 NFPA. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA publishes this and related documents on fire protection and answers inquiries on these documents. It also conducts educational seminars, studies, and literature searches for a fee. NFPA maintains a list of fire protection consultants.

B-3 NICET. National Institute for Certification in Engineering Technologies, 1420 King Street, Alexandria, VA 22314.

NICET certifies technicians in the following areas of fire protection:

(a) Automatic sprinkler system layout;

(b) Special hazards systems layout (automatic and manual foam water, halon, carbon dioxide, and dry chemical systems); and

(c) Fire alarm systems.

Those with NICET certification can also assist in the selection and use of fire protection systems.

B-4 NPS. National Park Service, National Register of Historic Places Branch, Interagency Resources Division, Department of the Interior, 1100 L Street NW, Room 640, Washington, DC 20004.

NPS publishes the "The Secretary of the Interior's Standards for Rehabilitation and Guidelines for Rehabilitating Historic Buildings." NPS answers inquiries, provides reference services, conducts seminars, and makes referrals.

B-5 NTHP. National Trust for Historic Preservation, 1785 Massachusetts Avenue NW, Washington, DC 20036.

NTHP promotes preservation of sites, buildings, and objects. It publishes magazines and books on historic preservation and offers advisory services, conferences, and workshops.

B-6 SFPE. Society of Fire Protection Engineers, 60 Batterymarch Street, Boston, MA 02116.

SFPE is a professional society of fire protection engineers. The Society meets annually, publishes technical information, conducts technical seminars, and supports local chapters. Members are located in all parts of the world. Names and addresses of members in a particular geographic area can be obtained from Society headquarters.

B-7 UL. Underwriters Laboratories, 333 Pfingsten Road, Northbrook, IL 60062.

UL has a certification service through which alarm companies may be qualified to issue certification that installed fire warning systems comply with NFPA standards and are properly tested and maintained. A list of alarm service companies authorized to issue UL certificates is available. UL also publishes safety standards and annual directories of labeled and listed products and fire-resistant assemblies.

Appendix C Bibliography

This Appendix lists publications that are not referenced within this recommended practice but that may provide additional helpful information.

C-1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 910, *Recommended Practice for the Protection of Libraries and Library Collections*, 1991 edition.

NFPA 911, *Recommended Practice for the Protection of Museums and Museum Collections*, 1991 edition.

NFPA 912, *Recommended Practice for Fire Protection in Places of Worship*, 1993 edition.

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"Protecting Our Heritage, A Discourse on Fire Protection and Prevention in Historic Buildings and Landmarks," 2nd edition, 1970.

C-2 Other Publications.

Association of Preservation Technology Bulletin, Vol. 13, No. 2, 1981.

Advisory Council on Historic Preservation, "Fire Safety Retrofitting in Historic Buildings." Washington, DC: Advisory Council on Historic Preservation and the General Services Administration, 1988.

Alsford, Denis, "Fire Safety in Museums," *MUSE*, Summer, pp. 18-23. Ottawa, Ontario, Canada: Canadian Museum Association.

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"Building Codes and Historic Preservation," *Preservation Forum*, Vol. 2, No. 1, Spring 1988, pp. 11-17.

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Departments of the Army, Navy and Air Force, "Maintenance of Fire Protection Systems (Army Tm 5-695; NAVFAC NO-117; Air Force AFM 91-37)." Washington, DC: Departments of the Army, Navy and Air Force, 1981.

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Parnell, Alan, and Ashford, David H., "Fire Safety in Historic Buildings," Technical Pamphlet 6, Society for the Protection of Ancient Buildings and the Fire Protection Association, London, 1978.

Pielert, James H., "Removing Regulatory Restraints to Building Rehabilitation: The Massachusetts Experience," Center for Building Technology, National Bureau of Standards, Washington, DC, October 1981.

"Safety Building Codes, and Historic Buildings," Information Series No. 57, National Trust for Historic Preservation, Washington, DC, 1992. Special issue for CIB W14 (Fire) Subgroup on the Fire Protection of Historical Buildings, *Fire Science and Technology*, Vol. 11, Nos. 1 and 2, Science University of Tokyo, 1991.

Tiszkus, A.T., and Dressler, E.G., "Fire Protection Planning for Cultural Institutions: Blending Risk Management, Loss Prevention, and Physical Safeguards," *Technology and Conservation*, Vol. 5, No. 2, Summer 1980, pp. 18-23.

Wilson, J. Andrew, "Fire Fighters—An Automatic Fire Suppression System Is Among Your Museum's Best and Safest Forms of Insurance," *Museum News*, Vol. 68, No. 6, November/December 1989, pp. 68-72, Washington, DC: American Association of Museums.

Appendix D Guideline on Fire Ratings of Archaic Materials and Assemblies

This Appendix is not a part of the recommendations of this NFPA document but is included for informational purposes only.

Prepared by the National Institute of Building Sciences, Washington, D.C. for the U.S. Department of Housing and Urban Development Office of Policy Development and Research under Cooperative Agreement H-5033.

The contents of this publication do not necessarily reflect the views and policies of the Department of Housing and Urban Development or the U.S. Government.

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Introduction

The *Guideline on Fire Ratings of Archaic Materials and Assemblies* focuses upon the fire-related performance of archaic construction. "Archaic" encompasses construction typical of an earlier time, generally prior to 1950. "Fire-related performance" includes fire resistance, flame spread, smoke production, and degree of combustibility.

The purpose of this guideline is to update the information which was available at the time of original construction, for use by architects, engineers, and code officials when evaluating the fire safety of a rehabilitation project. In addition, information relevant to the evaluation of general classes of materials and types of construction is presented for those cases when documentation of the fire performance of a particular archaic material or assembly cannot be found.

It has been assumed that the building materials and their fastening, joining, and incorporation into the building structure are sound mechanically. Therefore, some determination must be made that the original manufacture, the original construction practice, and the rigors of aging and use have not weakened the building. This assessment can often be difficult because process and quality control was not good in many industries, and variations among locally available raw materials and manufacturing techniques often resulted in a product which varied widely in its strength and durability. The properties of iron and steel, for example, varied widely, depending on the mill and the process used.

There is nothing inherently inferior about archaic materials or construction techniques. The pressures that promote fundamental change are most often economic or technological—matters not necessarily related to concerns for safety. The high cost of labor made wood lath and plaster uneconomical. The high cost of land and the congestion of the cities provided the impetus for high-rise construction. Improved technology made it possible. The difficulty with archaic materials is not a question of suitability, but familiarity.

Code requirements for the fire performance of key building elements (e.g., walls, floor/ceiling assemblies, doors, shaft enclosures) are stated in performance terms: hours of fire resistance. It matters not whether these elements were built in 1908 or 1980, only that they provide the required degree of fire resistance. The level of performance will be defined by the local community, primarily through the enactment of a building or rehabilitation code. This guideline is only a tool to help evaluate the various building elements, regardless of what the level of performance is required to be.

The problem with archaic materials is simply that documentation of their fire performance is not readily available. The application of engineering judgment is more difficult because building officials may not be familiar with the materials or construction method involved. As a result, either a full-scale fire test is required or the archaic construction in question removed and replaced. Both alternatives are time consuming and wasteful.

This guideline and the accompanying Appendix are designed to help fill this information void. By providing the necessary documentation, there will be a firm basis for the continued acceptance of archaic materials and assemblies.

1 Fire-Related Performance of Archaic Materials and Assemblies

1.1 Fire Performance Measures. This guideline does not specify the level of performance required for the various building components. These requirements are controlled by the building occupancy and use and are set forth in the local building or rehabilitation code.

The fire resistance of a given building element is established by subjecting a sample of the assembly to a "standard" fire test which follows a "standard" time-temperature curve. This test method has changed little since the 1920's. The test results tabulated in the Appendix have been adjusted to reflect current test methods.

The current model building codes cite other fire-related properties not always tested for in earlier years: flame spread, smoke production, and degree of combustibility. However, they can generally be assumed to fall within well defined values because the principal combustible component of archaic materials is cellulose. Smoke production is more important today because of the increased use of plastics. However, the early flame spread tests, developed in the early 1940's, also included a test for smoke production.

"Plastics", one of the most important classes of contemporary materials, were not found in the review of archaic materials. If plastics are to be used in a rehabilitated building, they should be evaluated by contemporary standards. Information and documentation of their fire-related properties and performance is widely available.

Flame spread, smoke production and degree of combustibility are discussed in detail below. Test results for eight common species of lumber, published in an Underwriter's Laboratories' report (104), are noted in the following table:

TUNNEL TEST RESULTS FOR EIGHT SPECIES OF LUMBER

Species of Lumber	Flame Spread	Fuel Contributed	Smoke Developed
Western White Pine	75	50-60	50
Northern White Pine	120-215	120-140	60-65
Ponderosa Pine	80-215	120-135	100-110
Yellow Pine	180-190	130-145	275-305
Red Gum	140-155	125-175	40-60
Yellow Birch	105-110	100-105	45-65
Douglas Fir	65-100	50-80	10-100
Western Hemlock	60-75	40-65	40-120

FLAME SPREAD

The flame spread of interior finishes is most often measured by the ASTM E-84 "tunnel test". This test measures how far and how fast the flames spread across the surface of the test sample. The resulting flame spread rating (FSR) is expressed as a number on a continuous scale where cement-asbestos board is 0 and red oak is 100. (Materials with a flame spread greater than red oak have a FSR greater than 100.) The scale is divided into distinct groups or classes. The most commonly used flame spread classifications are: Class I or A*, with a 0-25 FSR; Class II or B, with a 26-75 FSR; and Class III or C, with a 76-200 FSR. The NFPA Life Safety Code also has a Class D (201-500 FSR) and Class E (over 500 FSR) interior finish.

These classifications are typically used in modern building codes to restrict the rate of fire spread. Only the first three classifications are normally permitted, though not all classes of materials can be used in all places throughout a building. For example, the interior finish of building materials used in exits or in corridors leading to exits is more strictly regulated than materials used within private dwelling units.

In general, inorganic archaic materials (e.g., bricks or tile) can be expected to be in Class I. Materials of whole wood are mostly Class II. Whole wood is defined as wood used in the same form as sawn from the tree. This is in contrast to the contemporary reconstituted wood products such as plywood, fiberboard, hardboard, or particle board. If the organic archaic material is not whole wood, the flame spread classification could be well over 200 and thus would be particularly unsuited for use in exits and other critical locations in a building. Some plywoods and various wood fiberboards have flame spreads over 200. Although they can be treated with fire retardants to reduce their flame spread, it would be advisable to assume that all such products have a flame spread over 200 unless there is information to the contrary.

SMOKE PRODUCTION

The evaluation of smoke density is part of the ASTM E-84 tunnel test. For the eight species of lumber shown in the table above, the highest levels are 275-305 for Yellow Pine, but most of the others are less smoky than red oak which has an index of 100. The advent of plastics caused substantial increases in the smoke density values measured by the tunnel test. The ensuing limitation of the smoke production for wall and ceil-

* Some codes use Roman numerals, others use letters.

ing materials by the model building codes has been a reaction to the introduction of plastic materials. In general, cellulosic materials fall in the 50-300 range of smoke density which is below the general limitation of 450 adopted by many codes.

DEGREE OF COMBUSTIBILITY

The model building codes tend to define "noncombustibility" on the basis of having passed ASTM E-136 or if the material is totally inorganic. The acceptance of gypsum wallboard as non-combustible is based on limiting paper thickness to not over $^{1}/_{8}$ inch and a 0-50 flame spread rating by ASTM E-84. At times there were provisions to define a Class I or A material (0-25 FSR) as noncombustible, but this is not currently recognized by most model building codes.

If there is any doubt whether or not an archaic material is noncombustible, it would be appropriate to send out samples for evaluation. If an archaic material is determined to be non-combustible according to ASTM E-136, it can be expected that it will not contribute fuel to the fire.

1.2 Combustible Construction Types. One of the earliest forms of timber construction used exterior load-bearing masonry walls with columns and/or wooden walls supporting wooden beams and floors in the interior of the building. This form of construction, often called "mill" or "heavy timber" construction, has approximately 1 hour fire resistance. The exterior walls will generally contain the fire within the building.

With the development of dimensional lumber, there was a switch from heavy timber to "balloon frame" construction. The balloon frame uses load-bearing exterior wooden walls which have long timbers often extending from foundation to roof. When longer lumber became scarce, another form of construction, "platform" framing, replaced the balloon framing. The difference between the two systems is significant because platform framing is automatically fire-blocked at every floor while balloon framing commonly has concealed spaces that extend unblocked from basement to attic. The architect, engineer, and code official must be alert to the details of construction and the ease with which fire can spread in concealed spaces.

2 Building Evaluation

A given rehabilitation project will most likely go through several stages. The preliminary evaluation process involves the designer in surveying the prospective building. The fire resistance of existing building materials and construction systems is identified; potential problems are noted for closer study. The final evaluation phase includes: developing design solutions to upgrade the fire resistance of building elements, if necessary; preparing working drawings and specifications; and the securing of the necessary code approvals.

2.1 Preliminary Evaluation. A preliminary evaluation should begin with a building survey to determine the existing materials, the general arrangement of the structure and the use of the occupied spaces, and the details of construction. The designer needs to know "what is there" before a decision can be reached about what to keep and what to remove during the rehabilitation process. This preliminary evaluation should be as detailed as necessary to make initial plans. The fire-related properties need to be determined from the applicable building or rehabilitation code, and the materials and assemblies existing in the building then need to be evaluated for these properties. Two work sheets are shown below to facilitate the preliminary evaluation.

Two possible sources of information helpful in the preliminary evaluation are the original building plans and the building code in effect at the time of original construction. Plans may be on file with the local building department or in the offices of the original designers (e.g., architect, engineer) or their successors. If plans are available, the investigator should verify that the building was actually constructed as called for in the plans, as well as incorporate any later alterations or changes to the building. Earlier editions of the local building code should be on file with the building official.

The code in effect at the time of construction will contain fire performance criteria. While this is no guarantee that the required performance was actually provided, it does give the investigator some guidance as to the level of performance which may be expected. Under some code administration and enforcement systems, the code in effect at the time of construction also defines the level of performance that must be provided at the time of rehabilitation.

Figure 1 illustrates one method for organizing preliminary field notes. Space is provided for the materials, dimensions, and condition of the principal building elements. Each floor of the structure should be visited and the appropriate information obtained. In practice, there will often be identical materials and construction on every floor, but the exception may be of vital importance. A schematic diagram should be prepared of each floor showing the layout of exits and hallways and indicating where each element described in the field notes fits into the structure as a whole. The exact arrangement of interior walls within apartments is of secondary importance from a fire safety point of view and need not be shown on the drawings unless these walls are required by code to have a fire resistance rating.

The location of stairways and elevators should be clearly marked on the drawings. All exterior means of escape (e.g., fire escapes) should be identified.**

The following notes explain the entries in Figure 1.

Exterior Bearing Walls: Many old buildings utilize heavily constructed walls to support the floor/ceiling assemblies at the exterior of the building. There may be columns and/or interior bearing walls within the structure, but the exterior walls are an important factor in assessing the fire safety of a building.

The field investigator should note how the floor/ceiling assemblies are supported at the exterior of the building. If columns are incorporated in the exterior walls, the walls may be considered non-bearing.

Interior Bearing Walls: It may be difficult to determine whether or not an interior wall is load bearing, but the field investigator should attempt to make this determination. At a later stage of the rehabilitation process, this question will need to be determined exactly. Therefore, the field notes should be as accurate as possible.

Exterior Non-Bearing Walls: The fire resistance of the exterior walls is important for two reasons. These walls (both bearing and non-bearing) are depended upon to: a) contain a fire *within* the building of origin; or b) keep an exterior fire *outside*

** Problems providing adequate exiting are discussed in length in the *Egress Guideline for Residential Rehabilitation.*

the building. It is therefore important to indicate on the drawings where any openings are located as well as the materials and construction of all doors or shutters. The drawings should indicate the presence of wired glass, its thickness and framing, and identify the materials used for windows and door frames. The protection of openings adjacent to exterior means of escape (e.g., exterior stairs, fire escapes) is particularly important. The ground floor drawing should locate the building on the property and indicate the precise distances to adjacent buildings.

Interior Non-Bearing Walls (Partitions): A partition is a "wall that extends from floor to ceiling and subdivides space within any story of a building". (48) Figure 1 has two categories (A & B) for Interior Non-Bearing Walls (Partitions) which can be used for different walls, such as hallway walls as compared to inter-apartment walls. Under some circumstances there may be only one type of wall construction; in others, three or more types of wall construction may occur.

The field investigator should be alert for differences in function as well as in materials and construction details. In general, the details within apartments are not as important as the major exit paths and stairwells. The preliminary field investigation should attempt to determine the thickness of all walls. A term introduced below called "thickness design" will depend on an accurate (± $\frac{1}{4}$ inch) determination. Even though this initial field survey is called "preliminary", the data generated should be as accurate and complete as possible.

The field investigator should note the exact location from which his or her observations are recorded. For instance, if a hole is found through a stairwell wall which allows a cataloguing of the construction details, the field investigation notes should reflect the location of the "find". At the preliminary stage it is not necessary to core every wall; the interior details of construction can usually be determined at some location.

Structural Frame: There may or may not be a complete skeletal frame, but usually there are columns, beams, trusses, or other like elements. The dimensions and spacing of the structural elements should be measured and indicated on the drawings. For instance, if there are ten inch square columns located on a thirty foot square grid throughout the building, this should be noted. The structural material and cover or protective materials should be identified wherever possible. The thickness of the cover materials should be determined to an accuracy of ± $\frac{1}{4}$ inch. As discussed above, the preliminary field survey usually relies on accidental openings in the cover materials rather than a systematic coring technique.

Floor/Ceiling Structural Systems: The span between supports should be measured. If possible, a sketch of the cross-section of the system should be made. If there is no location where accidental damage has opened the floor/ceiling construction to visual inspection, it is necessary to make such an opening. An evaluation of the fire resistance of a floor/ceiling assembly requires detailed knowledge of the materials and their arrangement. Special attention should be paid to the cover on structural steel elements and the condition of suspended ceilings and similar membranes.

Roofs: The preliminary field survey of the roof system is initially concerned with water-tightness. However, once it is apparent that the roof is sound for ordinary use and can be retained in the rehabilitated building, it becomes necessary to evaluate the fire performance. The field investigator must measure the thickness and identify the types of materials which have been used. Be aware that there may be several layers of roof materials.

FIGURE 1 PRELIMINARY EVALUATION FIELD NOTES

Building Element		Materials	Thickness	Condition	Notes
Exterior Bearing Walls					
Interior Bearing Walls					
Exterior Non-Bearing Walls					
Interior Non-Bearing	A				
Walls or Partitions:	B				
Structural Frame: Columns					
Beams					
Other					
Floor/Ceiling Structural System Spanning					
Roofs					

FIGURE 1 PRELIMINARY EVALUATION FIELD NOTES

Building Element	Materials	Thickness	Condition	Notes
Doors (including frame and hardware): a) Enclosed vertical exitway				
b) Enclosed horizontal exitway				
c) Other				

Doors: Doors to stairways and hallways represent some of the most important fire elements to be considered within a building. The uses of the spaces separated largely controls the level of fire performance necessary. Walls and doors enclosing stairs or elevator shafts would normally require a higher level of performance than between the bedroom and bath. The various uses are differentiated in Figure 1.

Careful measurements of the thickness of door panels must be made, and the type of core material within each door must be determined. It should be noted whether doors have self-closing devices; the general operation of the doors should be checked. The latch should engage and the door should fit tightly in the frame. The hinges should be in good condition. If glass is used in the doors, it should be identified as either plain glass or wired glass mounted in either a wood or steel frame.

Materials: The field investigator should be able to identify ordinary building materials. In situations where an unfamiliar material is found, a sample should be obtained. This sample should measure at least 10 cubic inches so that an ASTM E-136 fire test can be conducted to determine if it is combustible.

Thickness: The thickness of all materials should be measured accurately since, under certain circumstances, the level of fire resistance is very sensitive to the material thickness.

Condition: The method attaching the various layers and facings to one another or to the supporting structural element should be noted under the appropriate building element. The "secureness" of the attachment and the general condition of the layers and facings should be noted here.

Notes: The "Notes" column can be used for many purposes, but it might be a good idea to make specific references to other field notes or drawings.

After the building survey is completed, the data collected must be analyzed. A suggested work sheet for organizing this information is given below as Figure 2.

The required fire resistance and flame spread for each building element are normally established by the local building or rehabilitation code. The fire performance of the existing materials and assemblies should then be estimated, using one of the techniques described below. If the fire performance of the existing building element(s) is equal to or greater than that required, the materials and assemblies may remain. If the fire performance is less than required, then corrective measures must be taken.

The most common methods of upgrading the level of protection are to either remove and replace the existing building element(s) or to repair and upgrade the existing materials and assemblies. Other fire protection measures, such as automatic sprinklers or detection and alarm systems, also could be considered, though they are beyond the scope of this guideline. If the upgraded protection is still less than that required or deemed to be acceptable, additional corrective measures must be taken. This process must continue until an acceptable level of performance is obtained.

2.2 Fire Resistance of Existing Building Elements.

The fire resistance of the existing building elements can be estimated from the tables and histograms contained in the Appendix. The Appendix is organized first by type of building element: walls, columns, floor/ceiling assemblies, beams, and doors. Within each building element, the tables are organized by type of construction (e.g., masonry, metal, wood frame), and then further divided by minimum dimensions or thickness of the building element.

FIGURE 2 PRELIMINARY EVALUATION WORKSHEET

Building Element		Required Fire Resistance	Required Flame Spread	Estimated Fire Resistance	Estimated Flame Spread	Method of Upgrading	Estimated Upgraded Protection	Notes
Exterior Bearing Walls								
Interior Bearing Walls								
Exterior Non-Bearing Walls								
Interior Non-Bearing Walls or Partitions:	A							
	B							
Structural Frame: Columns								
Beams								
Other								
Floor/Ceiling Structural System Spanning								
Roofs								
Doors (including frame and hardware): a) Enclosed vertical exitway								
b) Enclosed horizontal exitway								
c) Other								

A histogram precedes every table that has 10 or more entries. The X-axis measures fire resistance in hours; the Y-axis shows the number of entries in that table having a given level of fire resistance. The histograms also contain the location of each entry within that table for easy cross-referencing.

The histograms, because they are keyed to the tables, can speed the preliminary investigation. For example, Table 1.3.2, *Wood Frame Walls 4" to Less than 6" Thick*, contains 96 entries. Rather than study each table entry, the histogram shows that every wall assembly listed in that table has a fire resistance of less than 2 hours. If the building code required the wall to have 2 hours fire resistance, the designer, with a minimum of effort, is made aware of a problem that requires closer study.

Suppose the code had only required a wall of 1 hour fire resistance. The histogram shows far fewer complying elements (19) than noncomplying ones (77). If the existing assembly is not one of the 19 complying entries, there is a strong possibility the existing assembly is deficient. The histograms can also be used in the converse situation. If the existing assembly is not one of the smaller number of entries with a lower than required fire resistance, there is a strong possibility the existing assembly will be acceptable.

At some point the existing building component or assembly must be located within the tables. Otherwise, the fire resistance must be determined through one of the other techniques presented in the guideline. Locating the building component in the Appendix Tables not only guarantees the accuracy of the fire resistance rating, but also provides a source of documentation for the building official.

2.3 Effects of Penetrations in Fire Resistant Assemblies.

There are often many features in existing walls or floor/ceiling assemblies which were not included in the original certification or fire testing. The most common examples are pipes and utility wires passed through holes poked through an assembly. During the life of the building many penetrations are added, and by the time a building is ready for rehabilitation it is not sufficient to just consider the fire resistance of the assembly as originally constructed. It is necessary to consider all penetrations and their relative impact upon fire performance. For instance, the fire resistance of the corridor wall may be less important than the effect of plain glass doors or transoms. In fact, doors are the most important single class of penetrations.

A fully developed fire generates substantial quantities of heat and excess gaseous fuel capable of penetrating any holes which might be present in the walls or ceiling of the fire compartment. In general, this leads to a severe degradation of the fire resistance of those building elements and to a greater potential for fire spread. This is particularly applicable to penetrations located high in a compartment where the positive pressure of the fire can force the unburned gases through the penetration.

Penetrations in a floor/ceiling assembly will generally completely negate the barrier qualities of the assembly and will lead to rapid spread of fire to the space above. It will not be a problem, however, if the penetrations are filled with noncombustible materials strongly fastened to the structure. The upper half of walls are similar to the floor/ceiling assembly in that a positive pressure can reasonably be expected in the top of the room, and this will push hot and/or burning gases through the penetration unless it is completely sealed.

Building codes require doors installed in fire resistive walls to resist the passage of fire for a specified period of time. If the door to a fully involved room is not closed, a large plume of fire will typically escape through the doorway, preventing anyone from using the space outside the door while allowing the fire to spread. This is why door closers are so important. Glass in doors and transoms can be expected to rapidly shatter unless constructed of listed or approved wire glass in a steel frame. As with other building elements, penetrations or nonrated portions of doors and transoms must be upgraded or otherwise protected.

Table 5-1 in Section V of the Appendix contains 41 entries of doors mounted in sound tightfitting frames. Part 3.4 below outlines one procedure for evaluating and possibly upgrading existing doors.

3 Final Evaluation and Design Solution

The final evaluation begins after the rehabilitation project has reached the final design stage and the choices made to keep certain archaic materials and assemblies in the rehabilitated building. The final evaluation process is essentially a more refined and detailed version of the preliminary evaluation. The specific fire resistance and flame spread requirements are determined for the project. This may involve local building and fire officials reviewing the preliminary evaluation as depicted in Figures 1 and 2 and the field drawings and notes. When necessary, provisions must be made to upgrade existing building elements to provide the required level of fire performance.

There are several approaches to design solutions that can make possible the continued use of archaic materials and assemblies in the rehabilitated structure. The simplest case occurs when the materials and assembly in question are found within the Appendix Tables and the fire performance properties satisfy code requirements. Other approaches must be used, though, if the assembly cannot be found within the Appendix or the fire performance needs to be upgraded. These approaches have been grouped into two classes: experimental and theoretical.

3.1 The Experimental Approach. If a material or assembly found in a building is not listed in the Appendix Tables, there are several other ways to evaluate fire performance. One approach is to conduct the appropriate fire test(s) and thereby determine the fire-related properties directly. There are a number of laboratories in the United States which routinely conduct the various fire tests. A current list can be obtained by writing the Center for Fire Research, National Bureau of Standards, Washington, D.C. 20234.

The contract with any of these testing laboratories should require their observation of specimen preparation as well as the testing of the specimen. A complete description of where and how the specimen was obtained from the building, the transportation of the specimen, and its preparation for testing should be noted in detail so that the building official can be satisfied that the fire test is representative of the actual use.

The test report should describe the fire test procedure and the response of the material or assembly. The laboratory usually submits a cover letter with the report to describe the provisions of the fire test that were satisfied by the material or assembly under investigation. A building official will generally require this cover letter, but will also read the report to confirm that the material or assembly complies with the code requirements. Local code officials should be involved in all phases of the testing process.

The experimental approach can be costly and time consuming because specimens must be taken from the building and transported to the testing laboratory. When a load bearing assembly has continuous reinforcement, the test specimen must be removed from the building, transported, and tested in one piece. However, when the fire performance cannot be determined by other means there may be no alternative to a full-scale test.

A "non-standard" small-scale test can be used in special cases. Sample sizes need only by 10-25 square feet, while full-scale tests require test samples of either 100 or 180 square feet in size. This small-scale test is best suited for testing non-load bearing assemblies against thermal transmission only.

3.2 The Theoretical Approach. There will be instances when materials and assemblies in a building undergoing rehabilitation cannot be found in the Appendix Tables. Even where test results are available for more or less similar construction, the proper classification may not be immediately apparent. Variations in dimensions, loading conditions, materials, or workmanship may markedly affect the performance of the individual building elements, and the extent of such a possible effect cannot be evaluated from the tables.

Theoretical methods being developed offer an alternative to the full-scale fire tests discussed above. For example, Section 4302(b) of the 1979 Edition of the Uniform Building Code specifically allows an engineering design for fire resistance in lieu of conducting full scale tests. These techniques draw upon computer simulation and mathematical modeling, thermodynamics, heat-flow analysis, and materials science to predict the fire performance of building materials and assemblies.

One theoretical method known as the "Ten Rules of Fire Endurance Ratings" was published by T. Z. Harmathy in the May, 1965 edition of *Fire Technology.* (35) Harmathy's Rules provide a foundation for extending the data within the Appendix Tables to analyze or upgrade current as well as archaic building materials or assemblies.

Harmathy's Ten Rules

*Rule 1: The "thermal"*** fire endurance of a construction consisting of a number of parallel layers is greater than the sum of the "thermal" fire endurances*

The minimum performance of an untested assembly can be estimated if the fire endurance of the individual components is known. Though the exact rating of the assembly cannot be stated, the endurance of the assembly is greater than the sum of the endurance of the components.

When a building assembly or component is found to be deficient, the fire endurance can be upgraded by providing a protective membrane. This membrane could be a new layer of brick, plaster, or drywall. The fire endurance of this membrane is called the "finish rating." Appendix Tables 1-5.1 and 1-5.2 contain the finish ratings for the most commonly employed materials. (See also the notes to Rule 2).

The test criteria for the finish rating is the same as for the thermal fire endurance of the total assembly: average temperature increases of 250°F above ambient or 325°F above ambient at any one place with the membrane being exposed to the fire. The temperature is measured at the interface of the assembly and the protective membrane.

Rule 2: The fire endurance of a construction does not decrease with the addition of further layers.

Harmathy notes that this rule is a consequence of the previous rule. Its validity follows from the fact that the additional layers increase both the resistance to heat flow and the heat capacity of the construction. This, in turn, reduces the rate of temperature rise at the unexposed surface.

This rule is not just restricted to "thermal" performance but affects the other fire test criteria: direct flame passage, cotton waste ignition, and load bearing performance. This means that certain restrictions must be imposed on the materials to be added and on the loading conditions. One restriction is that a new layer, if applied to the exposed surface, must not produce additional thermal stresses in the construction, i.e., its thermal expansion characteristics must be similar to those of the adjacent layer. Each new layer must also be capable of contributing enough additional strength to the assembly to sustain the added dead load. If this requirement is not fulfilled, the allowable live load must be reduced by an amount equal to the weight of the new layer. Because of these limitations, this rule should not be applied without careful consideration.

Particular care must be taken if the material added is a good thermal insulator. Properly located, the added insulation could improve the "thermal" performance of the assembly. Improperly located, the insulation could block necessary thermal transmission through the assembly, thereby subjecting the structural elements to greater temperatures for longer periods of time, and could cause premature structural failure of the supporting members.

Rule 3: The fire endurance of constructions containing continuous air gaps or cavities is greater than the fire endurance of similar constructions of the same weight, but containing no air gaps or cavities.

*** The "thermal" fire endurance is the time at which the average temperature on the unexposed side of a construction exceeds its initial value by 250° when the other side is exposed to the "standard" fire specified by ASTM Test Method E-19.

By providing for voids in a construction, additional resistances are produced in the path of heat flow. Numerical heat flow analyses indicate that a 10 to 15 percent increase in fire endurance can be achieved by creating an air gap at the mid-plane of a brick wall. Since the gross volume is also increased by the presence of voids, the air gaps and cavities have a beneficial effect on stability as well. However, constructions containing combustible materials within an air gap may be regarded as exceptions to this rule because of the possible development of burning in the gap.

There are numerous examples of this rule in the tables. For instance:

Table 1.1.4; Item W-8-M-82: Cored concrete masonry, nominal 8 inch thick wall with one unit in wall thickness and with 62% minimum of solid material in each unit, load bearing (80 PSI), Fire endurance: 2-$^1/_2$ hours.

Table 1-1.5; Item W-10-M-11: Cored concrete masonry, nominal 10 inch thick wall with two units in wall thickness and a 2 inch air space, load bearing (80 PSI). The units are essentially the same as item W-8-M-82. Fire endurance: 3-$^1/_2$ hours.

These walls show 1 hour greater fire endurance by the addition of the 2 inch air space.

Rule 4: The farther an air gap or cavity is located from the exposed surface, the more beneficial is its effect on the fire endurance.

Radiation dominates the heat transfer across an air gap or cavity, and it is markedly higher where the temperature is higher. The air gap or cavity is thus a poor insulator if it is located in a region which attains high temperatures during fire exposure.

Some of the clay tile designs taken advantage of these factors. The double cell design, for instance, insures that there is a cavity near the unexposed face. Some floor/ceiling assemblies have air gaps or cavities near the top surface and these enhance their thermal performance.

Rule 5: The fire endurance of a construction cannot be increased by increasing the thickness of a completely enclosed air layer.

Harmathy notes that there is evidence that if the thickness of the air layer is larger than about $^1/_2$ inch, the heat transfer through the air layer depends only on the temperature of the bounding surfaces, and is practically independent of the distance between them. This rule is not applicable if the air layer is not completely enclosed, i.e., if there is a possibility of fresh air entering the gap at an appreciable rate.

Rule 6: Layers of materials of low thermal conductivity are better utilized on that side of the construction on which fire is more likely to happen.

As in Rule 4, the reason lies in the heat transfer process, though the conductivity of the solid is much less dependent on the ambient temperature of the materials. The low thermal conductor creates a substantial temperature differential to be established across its thickness under transient heat flow conditions. This rule may not be applicable to materials undergoing physico-chemical changes accompanied by significant heat absorption or heat evolution.

Rule 7: The fire endurance of asymmetrical constructions depends on the direction of heat flow.

This rule is a consequence of Rules 4 and 6 as well as other factors. This rule is useful in determining the relative protection of corridors and stairwells from the surrounding spaces. In addition, there are often situations where a fire is more likely, or potentially more severe, from one side or the other.

Rule 8: The presence of moisture, if it does not result in explosive spalling, increases the fire endurance.

The flow of heat into an assembly is greatly hindered by the release and evaporation of the moisture found within cementitious materials such as gypsum, portland cement, or magnesium oxy-chloride. Harmathy has shown that the gain in fire endurance may be as high as 8 percent for each percent (by volume) of moisture in the construction. It is the moisture chemically bound within the construction material at the time of manufacture or processing that leads to increased fire endurance. There is no direct relationship between the relative humidity of the air in the pores of the material and the increase in fire endurance.

Under certain conditions there may be explosive spalling of low permeability cementitious materials such as dense concrete. In general, one can assume that extremely old concrete has developed enough minor cracking that this factor should not be significant.

Rule 9: Load-supporting elements, such as beams, girders and joists, yield higher fire endurances when subjected to fire endurance tests as parts of floor, roof, or ceiling assemblies than they would when tested separately.

One of the fire endurance test criteria is the ability of a load-supporting element to carry its design load. The element will be deemed to have failed when the load can no longer be supported.

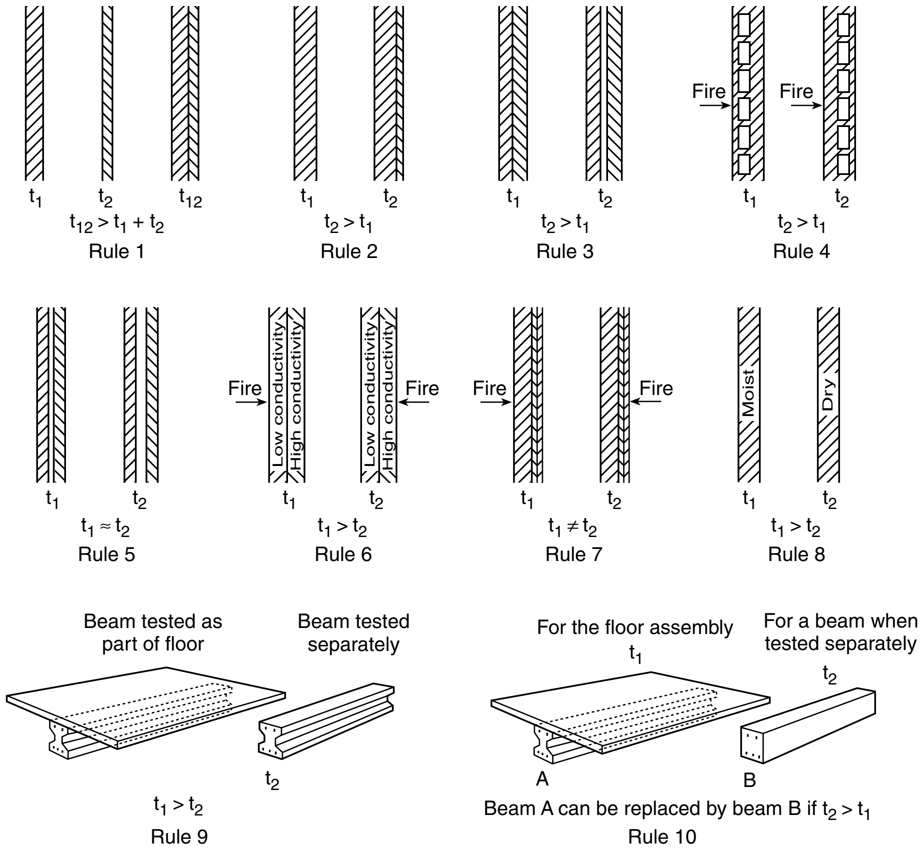
Failure usually results for two reasons. Some materials, particularly steel and other metals, lose much of their structural strength at elevated temperatures. Physical deflection of the supporting element, due to decreased strength or thermal expansion, causes a redistribution of the load forces and stresses throughout the element. Structural failure often results because the supporting element is not designed to carry the redistributed load.

Roof, floor, and ceiling assemblies have primary (e.g., beams) and secondary (e.g., floor joists) structural members. Since the primary load-supporting elements span the largest distances, their deflection becomes significant at a stage when the strength of the secondary members (including the roof or floor surface) is hardly affected by the heat. As the secondary members follow the deflection of the primary load-supporting element, an increasingly larger portion of the load is transferred to the secondary members.

When load-supporting elements are tested separately, the imposed load is constant and equal to the design load throughout the test. By definition, no distribution of the load is possible because the element is being tested by itself. Without any other structural members to which the load could be transferred, the individual elements cannot yield a higher fire endurance than they do when tested as parts of a floor, roof or ceiling assembly.

Rule 10: The load-supporting elements (beams, girders, joists, etc.) of a floor, roof, or ceiling assembly can be replaced by such other load-supporting elements which, when tested separately, yielded fire endurances not less than that of the assembly.

This rule depends on Rule 9 for its validity. A beam or girder, if capable of yielding a certain performance when tested separately, will yield an equally good or better performance when it forms a part of a floor, roof, or ceiling assembly. It must be emphasized that the supporting element of one assembly must not be replaced by the supporting element of another assembly if the performance of this latter element is not known from a separate (beam) test. Because of the load-reducing effect of the secondary elements that results from a test performed on an assembly, the performance of the supporting element alone cannot be evaluated by simple arithmetic. This rule also indicates the advantage of performing separate fire tests on primary load-supporting elements.



*Diagrammatic illustration of ten rules
t = fire endurance

Illustration of Harmathy's Rules. Harmathy provided one schematic figure which illustrated his Rules.* It should be useful as a quick reference to assist in applying his Rules.

Example Application of Harmathy's Rules. The following examples, based in whole or in part upon those presented in Harmathy's paper (35), show how the Rules can be applied to practical cases.

EXAMPLE 1

Problem

A contractor would like to keep a partition which consists of a 3-$^3/_4$ inch thick layer of red clay brick, a 1-$^1/_4$ inch thick layer of plywood, and a $^3/_8$ inch thick layer of gypsum wallboard, at a location where 2 hour fire endurance is required. Is this assembly capable of providing a 2 hour protection?

Solution

(1) This partition does not appear in the Appendix Tables.

(2) Bricks of this thickness yield fire endurances of approximately 75 minutes (Table 1-1.2, Item W-4-M-2).

(3) The 1-$^1/_4$ inch thick plywood has a finish rating of 30 minutes.

(4) The $^3/_8$ inch gypsum wallboard has a finish rating of 10 minutes.

(5) Using the recommended values from the tables and applying Rule 1, the fire endurance (FI) of the assembly is larger than the sum of the individual layers, or

$$FI > 75 + 30 + 10 = 115 \text{ minutes}$$

Discussion

This example illustrates how the Appendix Tables can be utilized to determine the fire resistance of assemblies not explicitly listed.

EXAMPLE 2

Problem

(1) A number of buildings to be rehabilitated have the same type of roof slab which is supported with different structural elements.

(2) The designer and contractor would like to determine whether or not this roof slab is capable of yielding a 2 hour fire endurance. According to a rigorous interpretation of ASTM E-119, however, only the roof assembly, including the roof slab as well as the cover and the supporting elements, can be subjected to a fire test. Therefore, a fire endurance classification cannot be issued for the slabs separately.

(3) The designer and contractor believe this slab will yield a 2 hour fire endurance even without the cover, and any beam of at least 2 hour fire endurance will provide satisfactory support. Is it possible to obtain a classification for the slab separately?

Solution

(1) The answer to the question is yes.

(2) According to Rule 10 it is not contrary to common sense to test and classify roofs and supporting elements separately. Furthermore, according to Rule 2, if the roof slabs actually yield a 2 hour fire endurance, the endurance of an assembly, including the slabs, cannot be less than 2 hours.

(3) The recommended procedure would be to review the tables to see if the slab appears as part of any tested roof or floor/ceiling assembly. The supporting system can be regarded as separate from the slab specimen, and the fire endurance of the assembly listed in the table is at least the fire endurance of the slab. There would have to be an adjustment for the weight of the roof cover in the allowable load if the test specimen did not contain a cover.

(4) The supporting structure or element would have to have at least a 2 hour fire endurance when tested separately.

Discussion

If the tables did not include tests on assemblies which contained the slab, one procedure would be to assemble the roof slabs on any convenient supporting system (not regarded as part of the specimen) and to subject them to a load which, besides the usually required superimposed load, includes some allowances for the weight of the cover.

EXAMPLE 3

Problem

A steel-joisted floor and ceiling assembly is known to have yielded a fire endurance of 1 hour and 35 minutes. At a certain location, a 2 hour endurance is required. What is the most economical way of increasing the fire endurance by at least 25 minutes?

Solution

(1) The most effective technique would be to increase the ceiling plaster thickness. Existing coats of paint would have to be removed and the surface properly prepared before the new plaster could be applied. Other materials (e.g., gypsum wallboard) could also be considered.

(2) There may be other techniques based on other principles, but an examination of the drawings would be necessary.

Discussion

(1) The additional plaster has at least three effects:

a) The layer of plaster is increased and thus there is a gain of fire endurance (Rule 1).

b) There is a gain due to shifting the air gap farther from the exposed surface (Rule 4).

c) There is more moisture in the path of heat flow to the structural elements (Rules 7 and 8).

(2) The increase in fire endurance would be at least as large as that of the finish rating for the added thickness of plaster. The combined effects in (1) above would further increase this by a factor of 2 or more, depending upon the geometry of the assembly.

EXAMPLE 4

Problem

The fire endurance of item W-10-M-1 in Table 1-1.5 is 4 hours. This wall consists of two 3-$^3/_4$ inch thick layers of structural tiles separated by a 2 inch air gap and $^3/_4$ inch portland cement plaster or stucco on both sides. If the actual wall in the building is identical to item W-10-M-1 except that it has a 4 inch air gap, can the fire endurance be estimated at 5 hours?

Solution

The answer to the question is no for the reasons contained in Rule 5.

EXAMPLE 5

Problem

In order to increase the insulating value of its precast roof slabs, a company has decided to use two layers of different concretes. The lower layer of the slabs, where the strength of the concrete is immaterial (all the tensile load is carried by the steel reinforcement), would be made with a concrete of low strength but good insulating value. The upper layer, where the concrete is supposed to carry the compressive load, would remain the original high strength, high thermal conductivity concrete. How will the fire endurance of the slabs be affected by the change?

Solution

The effect on the thermal fire endurance is beneficial:

(1) The total resistance to heat flow of the new slabs has been increased due to the replacement of a layer of high thermal conductivity by one of low conductivity.

(2) The layer of low conductivity is on the side more likely to be exposed to fire, where it is more effectively utilized according to Rule 6. The layer of low thermal conductivity also provides better protection for the steel reinforcement, thereby extending the time before reaching the temperature at which the creep of steel becomes significant.

3.3 “Thickness Design” Strategy. The “thickness design” strategy is based upon Harmathy’s Rules 1 and 2. This design approach can be used when the construction materials have been identified and measured, but the specific assembly cannot be located within the tables. The tables should be surveyed again for thinner walls of like material and construction detail that have yielded the desired or greater fire endurance. If such an assembly can be found, then the thicker walls in the building have more than enough fire resistance. The thickness of the walls thus becomes the principal concern.

This approach can also be used for floor/ceiling assemblies, except that the thickness of the cover† and the slab become the central concern. The fire resistance of the untested assembly will be at least the fire resistance of an assembly listed in the table having a similar design but with less cover and/or thinner slabs. For other structural elements (e.g., beams and columns), the element listed in the table must also be of a similar design but with less cover thickness.

† Cover: the protective layer or membrane of material which slows the flow of heat to the structural elements.

3.4 Evaluation of Doors. A separate section on doors has been included because the process for evaluation presented below differs from those suggested previously for other building elements. The impact of unprotected openings or penetrations in fire resistant assemblies has been detailed in Part 2.3 above. It is sufficient to note here that openings left unprotected will likely lead to failure of the barrier under actual fire conditions.

For other types of building elements (e.g., beams, columns), the Appendix Tables can be used to establish a minimum level of fire performance. The benefit to rehabilitation is that the need for a full-scale fire test is then eliminated. For doors, however, this cannot be done. The data contained in Appendix Table 5.1, *Resistance of Doors to Fire Exposure*, can only provide guidance as to whether a successful fire test is even feasible.

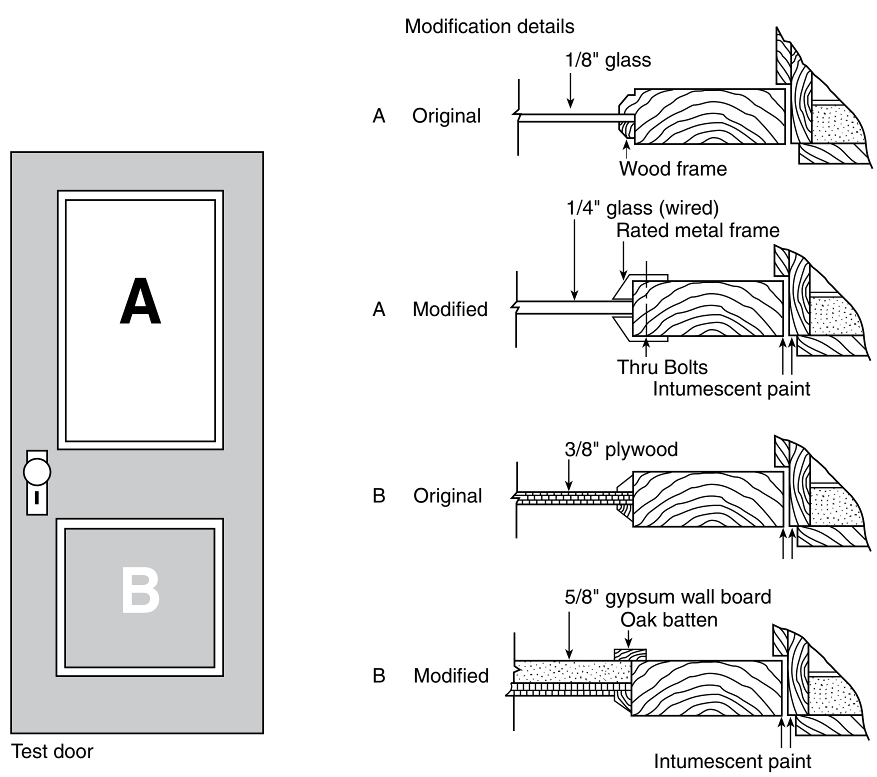
For example, a door required to have 1 hour fire resistance is noted in the tables as providing only 5 minutes. The likelihood of achieving the required 1 hour, even if the door is upgraded, is remote. The ultimate need for replacement of the doors is reasonably clear, and the expense and time needed for testing can be saved. However, if the performance documented in the table is near or in excess of what is being required, then a fire test should be conducted. The test documentation can then be used as evidence of compliance with the required level of performance.

The table entries cannot be used as the sole proof of performance of the door in question because there are too many unknown variables which could measurably affect fire performance. The wood may have dried over the years; coats of flammable varnish could have been added. Minor deviations in the internal construction of a door can result in significant differences in performance. Methods of securing inserts in panel doors can vary. The major non-destructive method of analysis, an x-ray, often cannot provide the necessary detail. It is for these, and similar reasons, that a fire test is still felt to be necessary.

It is often possible to upgrade the fire performance of an existing door. Sometimes, "as is" and modified doors are evaluated in a single series of tests when failure of the unmodified door is expected. Because doors upgraded after an initial failure must be tested again, there is a potential savings of time and money.

The most common problems encountered are plain glass, panel inserts of insufficient thickness, and improper fit of a door in its frame. The latter problem can be significant because a fire can develop a substantial positive pressure, and the fire will work its way through otherwise innocent-looking gaps between door and frame.

One approach to solving these problems is as follows. The plain glass is replaced with approved or listed wire glass in a steel frame. The panel inserts can be upgraded by adding an additional layer of material. Gypsum wallboard is often used for this purpose. Intumescent paint applied to the edges of the door and frame will expand when exposed to fire, forming an effective seal around the edges. This seal, coupled with the generally even thermal expansion of a wood door in a wood frame, can prevent the passage of flames and other fire gases. Figure 3 illustrates these solutions.



Because the interior construction of a door cannot be determined by a visual inspection, there is no absolute guarantee that the remaining doors are identical to the one(s) removed from the building and tested. But the same is true for doors constructed today, and reason and judgment must be applied.Doors that appear identical upon visual inspection can be weighed. If the weights are reasonably close, the doors can be assumed to be identical and therefore provide the same level of fire performance. Another approach is to fire test more than one door or to dismantle doors selected at random to see if they had been constructed in the same manner. Original building plans showing door details or other records showing that doors were purchased at one time or obtained from a single supplier can also be evidence of similar construction.

More often though, it is what is visible to the eye that is most significant. The investigator should carefully check the condition and fit of the door and frame, and for frames out of plumb or separating from the wall. Door closers, latches, and hinges must be examined to see that they function properly and are tightly secured. If these are in order and the door and frame have passed a full-scale test, there can be a reasonable basis for allowing the existing doors to remain.

4 Summary

This section summarizes the various approaches and design solutions discussed in the preceding sections of the guideline. The term "structural system" includes: frames, beams, columns, and other structural elements. "Cover" is a protective layer(s) of materials or membrane which slows the flow of heat to the structural elements. It cannot be stressed too strongly that the fire endurance of actual building elements can be greatly reduced or totally negated by removing part of the cover to allow pipes, ducts, or conduits to pass through the element. This must be repaired in the rehabilitation process.

The following approaches shall be considered equivalent.

4.1 The fire resistance of a building element can be established from the Appendix Tables. This is subject to the following limitations:

- The building element in the rehabilitated building shall be constructed of the same materials with the same nominal dimensions as stated in the tables.
- All penetrations in the building element or its cover for services such as electricity, plumbing, and HVAC shall be packed with noncombustible cementitious materials and so fixed that the packing material will not fall out when it loses its water of hydration.
- The effects of age and wear and tear shall be repaired so that the building element is sound and the original thickness of all components, particularly covers and floor slabs, is maintained.

This approach essentially follows the approach taken by model building codes. The assembly must appear in a table either published in or accepted by the code for a given fire resistance rating to be recognized and accepted.

4.2 The fire resistance of a building element which does not explicitly appear in the Appendix Tables can be established if one or more elements of same design but different dimensions have been listed in the tables. For walls, the existing element must be thicker than the one listed. For floor/ceiling assemblies, the assembly listed in the table must have the same or less cover and the same or thinner slab constructed of the same material as the actual floor/ceiling assembly. For other structural elements, the element listed in the table must be of a similar design but with less cover thickness. The fire resistance in all instances shall be the fire resistance recommended in the table. This is subject to the following limitations:

- The actual element in the rehabilitated building shall be constructed of the same materials as listed in the table. Only the following dimensions may vary from those specified: for walls, the overall thickness must exceed that specified in the table; for floor/ceiling assemblies, the thickness of the cover and the slab must be greater than, or equal to, that specified in the table; for other structural elements, the thickness of the cover must be greater than that specified in the table.
- All penetrations in the building element or its cover for services such as electricity, plumbing, or HVAC shall be packed with noncombustible cementitious materials and so fixed that the packing material will not fall out when it loses its water of hydration.
- The effects of age and wear and tear shall be repaired so that the building element is sound and the original thickness of all components, particularly covers and floor slabs, is maintained.

This approach is an application of the "thickness design" concept presented in Part 3.3 of the guideline. There should be many instances when a thicker building element was utilized than the one listed in the Appendix Tables. This guideline recognizes the inherent superiority of a thicker design. Note: "thickness design" for floor/ceiling assemblies and structural elements refers to cover and slab thickness rather than total thickness.

The "thickness design" concept is essentially a special case of Harmathy's Rules (specifically Rules 1 and 2). It should be recognized that the only source of data is the Appendix Tables. If other data are used, it must be in connection with the approach below.

4.3 The fire resistance of building elements can be established by applying Harmathy's Ten Rules of Fire Resistance Ratings as set forth in Part 3.2 of the Guideline. This is subject to the following limitations:

- The data from the tables can be utilized subject to the limitations in 4.2 above.
- Test reports from recognized journals or published papers can be used to support data utilized in applying Harmathy's Rules
- Calculations utilizing recognized and well established computational techniques can be used in applying Harmathy's Rules. These include, but are not limited to, analysis of heat flow, mechanical properties, ˜deflections, and load bearing capacity.

Appendix
Table of Contents,

Appendix
Table of Contents, continued

Introduction

The tables and histograms which follow are to be used *only* within the analytical framework detailed in the main body of this guideline.

Histograms precede any table with 10 or more entries. The use and interpretation of these histograms is explained in Part 2 of the guideline. The tables are in a format similar to that found in the model building codes. The following example, taken from an entry in Table 1.1.2, best explains the table format.

Item Code	Thickness	Construction Details	Performance		Reference Number				
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92	Notes	Rec Hours
W-4-M-50	$4^5/_8$”	Core: structural clay tile; See notes 12, 16, 21; Facings on unexposed side only; see note 18	n/a	25 min.		1		3, 4, 24	$^1/_3$

1. Item Code: The item code consists of a four place series in the general form w-x-y-z in which each member of the series denotes the following:

w = Type of building element (e.g., W=Walls; F=Floors, etc.)

x = The building element thickness rounded down to the nearest one inch increment (e.g., 4-$^5/_8$” is rounded off to 4“)

y = The general type of material from which the building element is constructed (e.g., M=Masonry; W=Wood, etc.)

z = The item number of the particular building element in a given table

The item code shown in the example W-4-M-50 denotes the following:

W = Wall, as the building element

4 = Wall thickness in the range of 4” to less than 5“

M = Masonry construction

50 = The 50th entry in Table 1.1.2

2. The specific name or heading of this column identifies the dimensions which, if varied, has the greatest impact on fire resistance. The critical dimension for walls, the example here, is thickness. It is different for other building elements (e.g., depth for beams; membrane thickness for some floor/ceiling assemblies). The table entry is the named dimension of the building element measured at the time of actual testing to within ± $^1/_8$ inch tolerance. The thickness tabulated includes facings where facings are a part of the wall construction.

3. Construction Details: The construction details provide a brief description of the manner in which the building element was constructed.

4. Performance: This heading is subdivided into two columns. The column labeled “Load” will either list the load that the building element was subjected to during the fire test or it will contain a note number which will list the load and any other significant details. If the building element was not subjected to a load during the test this column will contain “n/a”, which means “not applicable”.

The second column under performance is labeled “Time” and denotes the actual fire endurance time observed in the fire test.

5. Reference Number: This heading is subdivided into three columns: Pre-BMS-92; BMS-92; and Post BMS-92. The table entry under this column is the number in the Bibliography of the original source reference for the test data.

6. Notes: Notes are provided at the end of each table to allow a more detailed explanation of certain aspects of the test. In certain tables the notes given to this column have also been listed under the “Construction Details” and/or “Load” columns.

7. Rec Hours: This column lists the recommended fire endurance rating, in hours, of a building element. In some cases, the recommended fire endurance will be less than that listed under the “Time” column. In no case is the “Rec Hours” greater than given in the “Time” column.

Section I—Walls

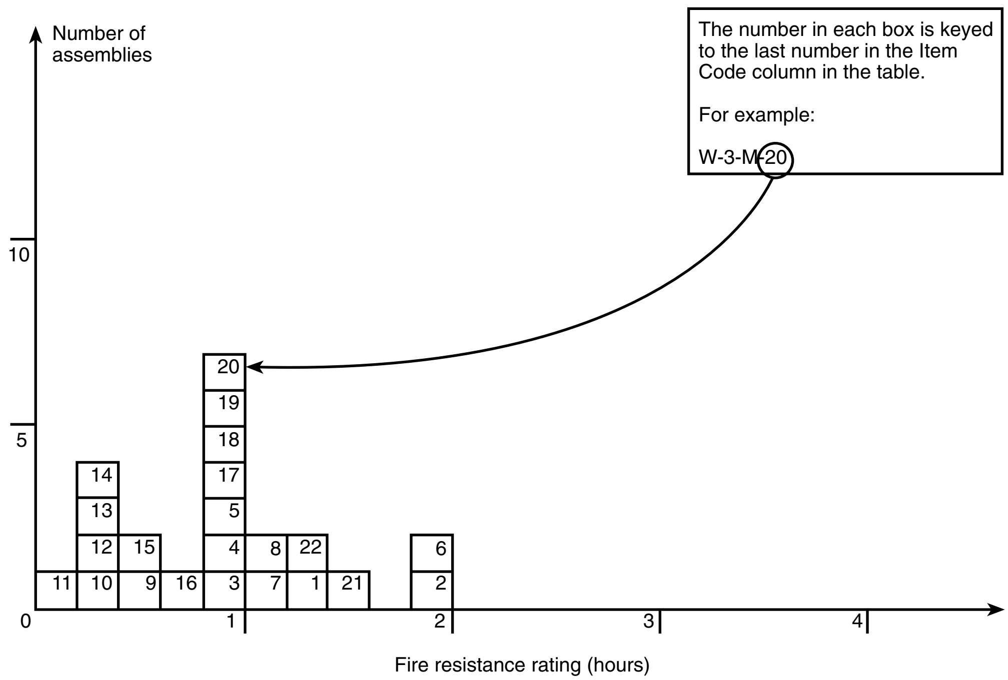


Figure 1.1.1 Walls—Masonry
0" to less than 4" thick

Table 1.1.1 Masonry Walls
0" (0 mm) to less than 4" (100 mm) thick

			Performance		Reference Number				
Item Code	Thickness	Construction Details	Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92	Notes	Rec Hours
W-2-M-1	$2^1/_4$"	Solid partition; $^3/_4$ gypsum plank — 10' × 1'6"; $^3/_4$" + gypsum plaster each side	n/a	1 hr 22 min			7	1	$1^1/_4$
W-3-M-2	3"	Concrete block (18" × 9" × 3") of fuel ash, portland cement and plasticizer; cement/sand mortar	n/a	2 hr			7	2,3	2
W-2-M-3	2"	Solid gypsum block wall; no facings	n/a	1 hr		1		4	1
W-3-M-4	3"	Solid gypsum blocks, laid in 1:3 sanded gypsum mortar	n/a	1 hr		1		4	1
W-3-M-5	3"	Magnesium oxysulfate wood fiber blocks; 2" thick; laid in portland cement-lime mortar; facings $^1/_2$" of 1:3 sanded gypsum plaster on both sides	n/a	1 hr		1		4	1
W-3-M-6	3"	Magnesium oxysulfate bound wood fiber blocks; 3" thick; laid in portland cement-lime mortar; facings: $^1/_2$" of 1:3 sanded gypsum plaster on both sides	n/a	2 hr		1		4	2
W-3-M-7	3"	Clay tile; Ohio fire clay; single cell thick; face plaster $^5/_8$" (both sides) 1:3 sanded gypsum; construction "A"; design "E"	n/a	1 hr 6 min			2	5,6,7 11,12 39	1
W-3-M-8	3"	Clay tile; Illinois surface clay; single cell thick; face plaster $^5/_8$" (both sides) 1:3 sanded gypsum; design "A"; construction "E"	n/a	1 hr 1 min			2	5,8,9 11,12 39	
W-3-M-9	3"	Clay tile; Illinois surface clay; single cell thick; no face plaster; construction "C"; design "A"	n/a	25 min			2	5,10 11,12 39	$^1/_3$
W-3-M-10	$3^7/_8$"	8" × 4 $^7/_8$" glass blocks; width 4 lb. each; portland cement-lime mortar; horizontal mortar joints reinforced with metal lath.	n/a	15 min		1		4	$^1/_4$
W-3-M-11	3"	Core: structural clay tile; see notes 14, 18, 23; no facings	n/a	10 min		1		5,11 26	$^1/_6$

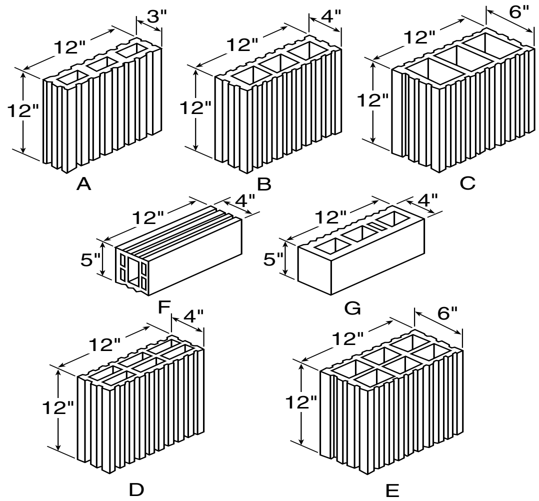
Table 1.1.1 Masonry Walls
0" (0 mm) to less than 4" (100 mm) thick

Item Code	Thickness	Construction Details	Performance: Load	Performance: Time	Reference Number: Pre-BMS-92	Reference Number: BMS-92	Reference Number: Post-BMS-92	Notes	Rec Hours
W-3-M-12	3"	Core: structural clay tile; see notes 14, 19, 23; no facings	n/a	20 min		1		5,11 26	$^1/_3$
W-3-M-13	$3^5/_8$"	Core: structural clay tile; see notes 14, 18, 23; facings on unexposed side per note 20	n/a	20 min		1		5,11 26	$^1/_3$
W-3-M-14	$3^5/_8$"	Core: structural clay tile; see notes 14, 19, 23; facings on unexposed side only per note 20	n/a	20 min		1		5,11 26	$^1/_3$
W-3-M-15	$3^5/_8$"	Core: clay structural tile; see notes 14, 18, 23; facings on side exposed to fire per note 20	n/a	30 min		1		5,11 26	$^1/_2$
W-3-M-16	$3^5/_8$"	Core: clay structural tile; see notes 14, 19, 23; facing on side exposed to fire per note 20	n/a	45 min		1		5,11 26	$^3/_4$
W-2-M-17	2"	2" thick solid gypsum blocks; see note 27	n/a	1 hr		1		27	1
W-3-M-18	3"	Core: 3" thick gypsum blocks 70% solid; see note 2; no facings	n/a	1 hr		1		27	1
W-3-M-19	3"	Core: hollow concrete units; see notes 29, 35, 36, 38; no facings	n/a	1 hr		1		27	1
W-3-M-20	3"	Core: hollow concrete units; see notes 28, 35, 36, 37, 38; no facings	n/a	1 hr		1			1
W-3-M-21	$3^1/_2$"	Core: hollow concrete units; see notes 28, 35, 36, 37, 38; facings on one side, per note 37	n/a	$1^1/_2$ hr		1			$1^1/_2$
W-3-M-22	$3^1/_2$"	Core: hollow concrete units; see notes 29, 35, 36, 38; facings on one side per note 37	n/a	$1^1/_2$ hr		1			$1^1/_4$

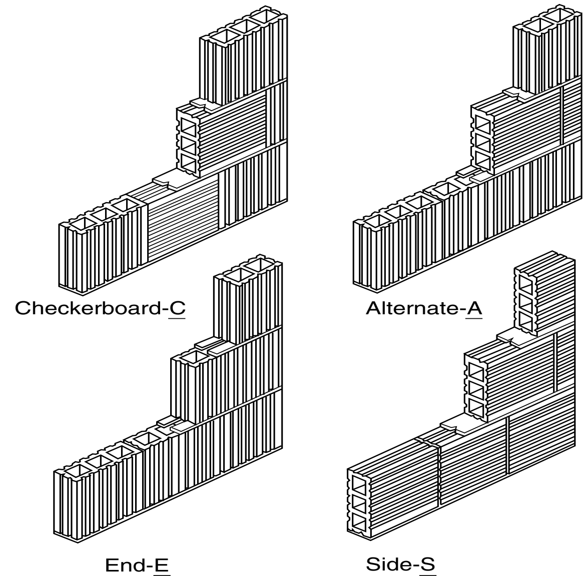
NOTES: Table 1.1.1

1. Failure mode — flame thru.
2. Passed 2-hr fire test (Grade “C” fire res. — British).
3. Passed hose stream test.
4. Tested at NBS under ASA. Spec. No. A2-1934. As non-load bearing partitions.
5. Tested at NBS under ASA Spec. No. 42-1934 (ASTM C-19-33) except that hose stream testing where carried out was run on test specimens exposed for full test duration, not for a reduced period as is contemporarily done.
6. Failure by thermal criteria — maximum temperature rise 181°C (325°F).
7. Hose stream failure.
8. Hose stream — pass.
9. Specimen removed prior to any failure occurring.
10. Failure mode — collapse.
11. For clay tile walls, unless the source or density of the clay can be positively identified or determined, it is suggested that the lowest hourly rating for the fire endurance of a clay tile partition of that thickness be followed. Identified sources of clay showing longer fire endurance can lead to longer time recommendations.
12. See appendix of original report for construction and design details for clay tile walls.
13. Load — 80 PSI for gross wall area.
14. One cell in wall thickness.
15. Two cells in wall thickness.
16. Double shells plus one cell in wall thickness.
17. One cell in wall thickness, cells filled with broken tile, crushed stone, slag cinders or sand mixed with mortar.
18. Dense hard-burned clay or shale tile.
19. Medium-burned clay tile.
20. Not less than $^5/_8$" thickness of 1:3 sanded gypsum plaster.
21. Units of not less than 30% solid material.
22. Units of not less than 40% solid material.
23. Units of not less than 50% solid material.
24. Units of not less than 45% solid material.
25. Units of not less than 60% solid material.
26. All tiles laid in portland cement-lime mortar.
27. Blocks laid in 1:3 sanded gypsum mortar voids in blocks not to exceed 30%.
28. Units of expanded slag or pumice aggregates.
29. Units of crushed limestone, blast furnace slag, cinders and expanded clay or shale.
30. Units of calcareous sand and gravel. Coarse aggregate, 60% or more calcite and dolomite.
31. Units of siliceous sand and gravel. 90% or more quartz, chert, or flint.
32. Unit at least 49% solid.
33. Unit at least 62% solid.
34. Unit at least 65% solid.
35. Unit at least 73% solid.
36. Ratings based on one unit and one cell in wall thickness.
37. Minimum of $^1/_2$" — 1:3 sanded gypsum plaster.

38. Non-load bearing.
39. See Clay Tile Partition Design Construction drawings, p. 48.



Designs of tiles used in fire-test partitions.



The four types of construction used in fire-test partitions.

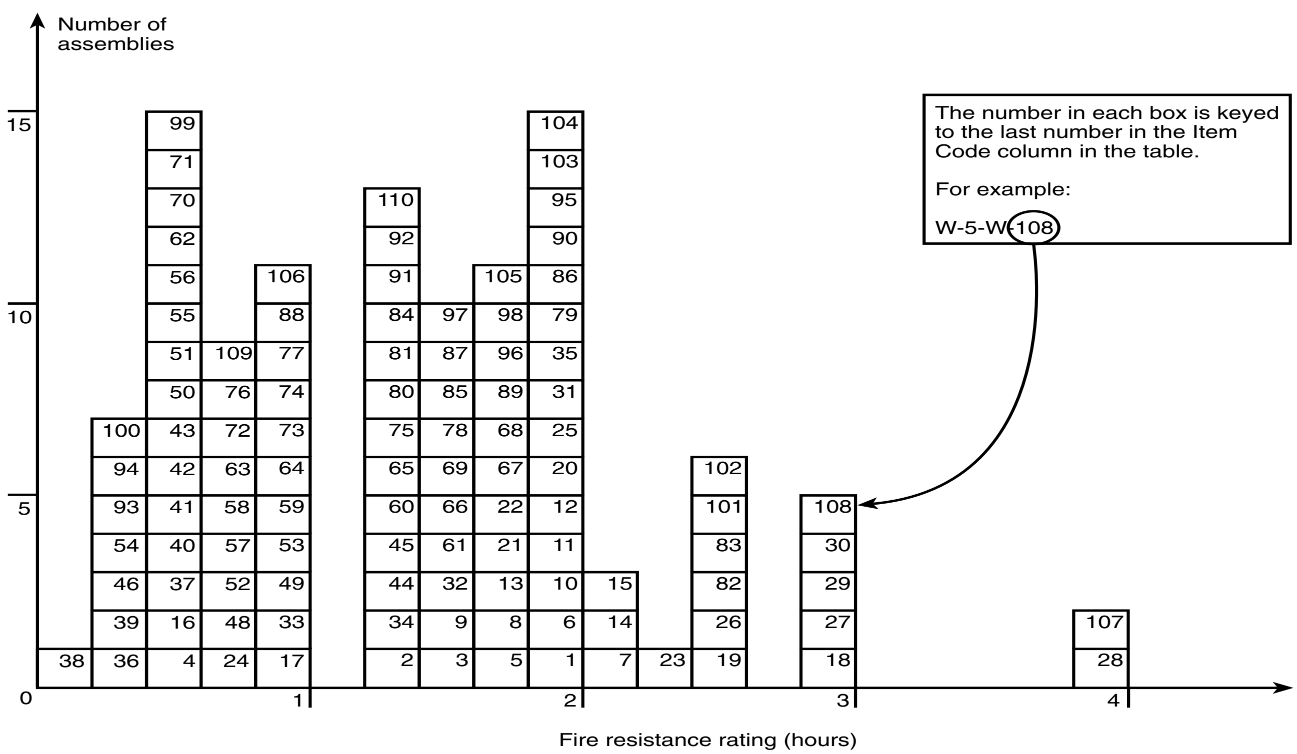


Figure 1.1.2 Walls—Masonry 4” to less than 6” thick

Table 1.1.2 Masonry Walls
4" (100 mm) to less than 6" (150 mm) thick

Item Code	Thickness	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
W-4-M-1	4"	Solid 3" thick, gypsum blocks laid in 1:3 sanded gypsum mortar; facings: $^1/_2$" of 1:3 sanded gypsum plaster (both sides)	n/a	2 hr		1		1	2
W-4-M-2	4"	Solid clay or shale brick	n/a	1 hr 15 min		1		1,2	$1^1/_4$
W-4-M-3	4"	Concrete; no facings	n/a	1 hr 30 min		1		1	$1^1/_2$
W-4-M-4	4"	Clay tile; Illinois surface clay; single cell thick; no face plaster; construction "C"; design "B"	n/a	25 min			2	3 – 7, 36	$^1/_3$
W-4-M-5	4"	Solid sand-lime brick	n/a	1 hr 45 min		1		1	$1^3/_4$
W-4-M-6	4"	Solid wall; 3" thick block; $^1/_2$" plaster each side; $17^3/_4$" × $8^3/_4$" × 3" "breeze blocks"; portland cement/sand mortar	n/a	1 hr 52 min			7	2	$1^3/_4$
W-4-M-7	4"	Concrete (4020 PSI); reinforcement: vertical $^3/_8$"; horizontal $^1/_4$ "; 6" × 6" grid	n/a	2 hr 10 min			7	2	2
W-4-M-8	4"	Concrete wall (4340 PSI crush); reinforcement: $^1/_4$" diameter rebar on 8" centers (vertical and horizontal)	n/a	1 hr 40 min			7	2	$1^2/_3$
W-4-M-9	$4^3/_{16}$"	$^{43}/_{16}$" × $^{25}/_8$" cellular fletton brick (1873 PSI) with $^1/_2$" sand mortar; bricks are U-shaped yielding hollow cover (approx. 2" × 4") in final (cross-section) configuration	n/a	1 hr 25 min			7	2	$1^1/_3$
W-4-M-10	$4^1/_4$"	$4^1/_4$" × $2^1/_2$" fletton (1831 PSI) brick in $^1/_2$" sand mortar	n/a	1 hr 53 min			7	2	$1^3/_4$
W-4-M-11	$4^1/_4$"	$4^1/_4$" × $2^1/_2$" London stock (683 PSI) brick; $^1/_2$" grout	n/a	1 hr 52 min			7	2	$1^3/_4$
W-4-M-12	$4^1/_2$"	$4^1/_4$" × $2^1/_2$" Leicester red, wire-cut brick (4465 PSI) in $^1/_2$" sand mortar	n/a	1 hr 56 min			7	6	$1^3/_4$
W-4-M-13	$4^1/_4$"	$4^1/_4$" × $2^1/_2$" stairfoot brick (7527 PSI) $^1/_2$" sand mortar	n/a	1 hr 37 min			7	2	$1^1/_2$
W-4-M-14	$4^1/_4$"	$4^1/_4$" × $2^1/_2$" sand-lime brick (2603 PSI) $^1/_2$" sand mortar	n/a	2 hr 6 min			7	2	2
W-4-M-15	$4^1/_4$"	$4^1/_4$" × $2^1/_2$" concrete brick (2527 PSI) $^1/_2$" sand mortar	n/a	2 hr 10 min			7	2	2
W-4-M-16	$4^1/_2$"	4" thick clay tile; Ohio fire clay; single cell thick; no plaster exposed face; $^1/_2$" 1:2 gypsum back face; construction "S"; design "F"	n/a	31 min			2	3–6, 36	$^1/_2$
W-4-M-17	$4^1/_2$"	4" thick clay tile; Ohio fire clay; single cell thick; plaster exposed face: $^1/_2$"; 1:2 sanded gypsum; back face: none; design "F"; construction "S"	80 PSI	50 min			2	3–5,8, 36	$^3/_4$
W-4-M-18	$4^1/_2$"	Core: solid sand-lime brick; $^1/_2$" sanded gypsum plaster facings on both sides	80 PSI	3 hr		1		1,11	3
W-4-M-19	$4^1/_2$"	Core: solid sand-lime brick; $^1/_2$" sanded gypsum plaster facings on both sides	80 PSI	2 hr 30 min		1		1,11	$2^1/_2$
W-4-M-20	$4^1/_2$"	Core: concrete brick $^1/_2$" of 1:3 sanded gypsum plaster facings on both sides	80 PSI	2 hr		1		1,11	2
W-4-M-21	$4^1/_2$"	Core: solid clay or shale bricks; $^1/_2$" thick, 1:3 sanded gypsum plaster facings on fire sides	80 PSI	1 hr 45 min		1		1,2, 11	$1^3/_4$
W-4-M-22	$4^3/_4$"	4" thick clay tile; Ohio fire clay; single cell thick; cells filled with cement and broken tile concrete; plaster on exposed face: none on unexposed face$^3/_4$" 1:3 sanded gypsum; construction "E"; design "G"	n/a	1 hr 48 min			2	2,3–5, 9, 36	$1^3/_4$

Table 1.1.2 Masonry Walls
4" (100 mm) to less than 6" (150 mm) thick continued

			Performance		Reference Number				
Item Code	Thickness	Construction Details	Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92	Notes	Rec Hours
W-4-M-23	$4^3/_4$"	4" thick clay tile; Ohio fire clay; single cell thick; cells filled with cement and broken tile concrete; no plaster exposed face; $^3/_4$" neat gypsum plaster on unexposed face; design "G," construction "F"	n/a	2 hr. 14 min			2	2,3–5, 9, 36	2
W-5-M-24	5"	3" × 13" airspace; 1" thick metal reinforced concrete facings on both sides; faces connected with wood splines	2,250 lb/ft.	45 min		1		1	$^3/_4$
W-5-M-25	5"	Core: 3" thick void filled with "nodulated" mineral wool weighing 10 lbs/ft^3; 1" thick metal reinforced concrete facings on both sides	2,250 lb/ft.	2 hr		1		1	2
W-5-M-26	5"	Core: solid clay or shale brick; $^1/_2$" thick, 1:3 sanded gypsum plaster facings on both sides	40 PSI	2 hr 30 min		1		1,2,11	$2^1/_2$
W-5-M-27	5"	Core: solid 4" thick gypsum blocks, laid in 1:3 sanded gypsum mortar; $^1/_2$" of 1:3 sanded gypsum plaster facings on both sides	n/a	3 hr		1		1	3
W-5-M-28	5"	Core: 4" thick hollow gypsum blocks with 30% voids; blocks laid in 1:3 sanded gypsum mortar; no facings	n/a	4 hr		1		1	4
W-5-M-29	5"	Core: concrete brick; $^1/_2$" of 1:3 sanded gypsum plaster facings on both sides	160 PSI	3 hr		1		1	3
W-5-M-30	$5^1/_4$"	4" thick clay tile; Illinois surface clay; double cell thick; plaster — $^5/_8$" thick sanded gypsum 1:3 both faces; design "P"; construction "S"	n/a	2 hr 53 min			2	2–5,9, 36	$2^3/_4$
W-5-M-31	$5^1/_4$"	4" thick clay tile; New Jersey fire clay; double cell thick; plaster — $^5/_8$" sanded gypsum 1:3 both faces; design "D"; construction "S"	n/a	1 hr 52 min			2	2-5,9, 36	$1^3/_4$
W-5-M-32	$5^1/_4$"	4" thick clay tile; New Jersey fire clay; single cell thick; $^5/_8$" plaster on both sides: 1:3 sanded gypsum; design "D"; construction CS"	n/a	1 hr 34 min			2	2–5,9, 36	$1^1/_2$
W-5-M-33	$5^1/_4$"	4" thick clay tile; New Jersey fire clay; single cell thick; face plaster — $^5/_8$" both sides; 1:3 sanded gypsum; construction "S"; design "B"	n/a	50 min			2	3–5,8, 36	$^3/_4$
W-5-M-34	$5^1/_4$"	4" thick clay tile; Ohio fire clay; single cell thick; face plaster — $^5/_8$" both sides; 1:3 sanded gypsum; construction "A"; design "B"	n/a	1 hr 19 min			2	2–5,9, 36	$1^1/_4$
W-5-M-35	$5^1/_4$"	4" thick clay tile; Illinois surface clay; single cell thick; face plaster — $^5/_8$" both sides; 1:3 sanded gypsum; construction "S"; design "B"	n/a	1 hr 59 min			2	2–5,10, 36	$1^3/_4$
W-4-M-36	4"	Core: structural clay tile; see notes 12, 16, 21; no facings	n/a	15 min		1		3,4,24	$^1/_4$
W-4-M-37	4"	Core: structural clay tile; see notes 12, 17, 21; no facings	n/a	25 min		1		3,4,24	$^1/_3$
W-4-M-38	4"	Core: structural clay tile; see notes 12, 16, 20; no facings	n/a	10 min		1		3,4,24	$^1/_6$
W-4-M-39	4"	Core: structural clay tile; see notes 12, 17, 20; no facings	n/a	20 min		1		3,4,24	$^1/_3$
W-4-M-40	4"	Core: structural clay tile; see notes 13, 16, 23; no facings	n/a	30 min		1		3,4,24	$^1/_2$
W-4-M-41	4"	Core: structural clay tile; see notes 13, 17, 23; no facings	n/a	35 min		1		3,4,24	$^1/_2$
W-4-M-42	4"	Core: structural clay tile; see notes 13, 16, 21; no facings	n/a	25 min		1		3,4,24	$^1/_3$
W-4-M-43	4"	Core: structural clay tile; see notes 13, 17, 21; no facings	n/a	30 min		1		3,4,24	$^1/_2$
W-4-M-44	4"	Core: structural clay tile; see notes 15, 16, 20; no facings	n/a	1 hr 15 min		1		3,4,24	$1^1/_4$
W-4-M-45	4"	Core: structural clay tile; see notes 15, 17, 20; no facings	n/a	1 hr 15 min		1		3,4,24	$1^1/_4$

Table 1.1.2 Masonry Walls
4" (100 mm) to less than 6" (150 mm) thick continued

			Performance		Reference Number				
Item Code	Thickness	Construction Details	Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92	Notes	Rec Hours
W-4-M-46	4"	Core: structural clay tile; see notes 14, 16, 22; no facings	n/a	20 min		1		3,4,24	$^1/_3$
W-4-M-47	4"	Core: structural clay tile; see notes 14, 17, 22; no facings	n/a	25 min		1		3,4,24	$^1/_3$
W-4-M-48	$4^1/_4$"	Core: structural clay tile; see notes 12, 16, 21; facings on both sides; see note 18	n/a	45 min		1		3,4,24	$^3/_4$
W-4-M-49	$4^1/_4$"	Core: structural clay tile; see notes 12, 17, 21; facings on both sides; see note 18	n/a	1 hr		1		3,4,24	1
W-4-M-50	$4^5/_8$"	Core: structural clay tile; see notes 12, 16, 21; facings on unexposed side only; see note 18	n/a	25 min		1		3,4,24	$^1/_3$
W-4-M-51	$4^5/_8$"	Core: structural clay tile; see notes 12, 17, 21; facings on unexposed side only; see note 18	n/a	30 min		1		3,4,24	$^1/_2$
W-4-M-52	$4^5/_8$"	Core: structural clay tile; see notes 12, 16, 21; facings on exposed side only; see note 18	n/a	45 min		1		3,4,24	$^3/_4$
W-4-M-53	$4^5/_8$"	Core: structural clay tile; see notes 12, 17, 21; facings on fire side only; see note 18	n/a	1 hr		1		3,4,24	1
W-4-M-54	$4^5/_8$"	Core: structural clay tile; see notes 12, 16, 20; facings on unexposed side; see note 18	n/a	20 min		1		3,4,24	$^1/_3$
W-4-M-55	$4^5/_8$"	Core: structural clay tile; see notes 12, 17, 20; facings on unexposed side; see note 18	n/a	25 min		1		3,4,24	$^1/_3$
W-4-M-56	$4^5/_8$"	Core: structural clay tile; see notes 12, 16, 20; facings on fire side only; see note 18	n/a	30 min		1		3,4,24	$^1/_2$
W-4-M-57	$4^5/_8$"	Core: structural clay tile; see notes 12, 17, 20; facings on fire side only; see note 18	n/a	45 min		1		3,4,24	$^3/_4$
W-4-M-58	$4^5/_8$"	Core: structural clay tile; see notes 13, 16, 23; facings on unexposed side only; see note 18	n/a	40 min		1		3,4,24	$^2/_3$
W-4-M-59	$4^5/_8$"	Core: structural clay tile; see notes 13, 17, 23; facing on unexposed side only; see note 18	n/a	1 hr		1		3,4,24	1
W-4-M-60	$4^5/_8$"	Core: structural clay tile; see notes 13, 16, 23; facing on fire side only; see note 18	n/a	1 hr 15 min		1		3,4,24	$1^1/_4$
W-4-M-61	$4^5/_8$"	Core: structural clay tile; see notes 13, 17, 23; facing on fire side only; see note 18	n/a	1 hr 30 min		1		3,4,24	$1^1/_2$
W-4-M-62	$4^5/_8$"	Core: structural clay tile; see notes 13, 16, 21; facing on unexposed side only; see note 18	n/a	35 min		1		3,4,24	$^1/_2$
W-4-M-63	$4^5/_8$"	Core: structural clay tile; see notes 13, 17, 21; facings on unexposed face only; see note 18	n/a	45 min		1		3,4,24	$^3/_4$
W-4-M-64	$4^5/_8$"	Core: structural clay tile; see notes 13, 16, 23; facing on exposed face only; see note 18	n/a	1 hr		1		3,4,24	1
W-4-M-65	$4^5/_8$"	Core: structural clay tile; see notes 13, 17, 21; facing on exposed side only; see note 18	n/a	1 hr 15 min		1		3,4,24	$1^1/_4$
W-4-M-66	$4^5/_8$"	Core: structural clay tile; see notes 15, 17, 20; facings on unexposed side only; see note 18	n/a	1 hr 30 min		1		3,4,24	$1^1/_2$
W-4-M-67	$4^5/_8$"	Core: structural clay tile; see notes 15, 16, 20; facings on exposed side only; see note 18	n/a	1 hr 45 min		1		3,4,24	$1^3/_4$
W-4-M-68	$4^5/_8$"	Core: structural clay tile; see notes 15, 17, 20; facings on exposed side only; see note 18	n/a	1 hr 45 min		1		3,4,24	$1^3/_4$
W-4-M-69	$4^5/_8$"	Core: structural clay tile; see notes 15, 16, 20; facings on unexposed side only; see note 18	n/a	1 hr 30 min		1		3,4,24	$1^1/_2$
W-4-M-70	$4^5/_8$"	Core: structural clay tile; see notes 14, 16, 22; facings on unexposed side only; see note 18	n/a	30 min		1		3,4,24	$^1/_2$
W-4-M-71	$4^5/_8$"	Core: structural clay tile; see notes 14, 17, 22; facings on unexposed side only; see note 18	n/a	35 min		1		3,4,24	$^1/_2$
W-4-M-72	$4^5/_8$"	Core: structural clay tile; see notes 14, 16, 22; facings on fire side of wall only; see note 18	n/a	45 min		1		3,4,24	$^3/_4$
W-4-M-73	$4^5/_8$"	Core: structural clay tile; see notes 14, 17, 22; facings on fire side of wall only; see note 18	n/a	1 hr		1		3,4,24	1
W-5-M-74	$5^1/_4$"	Core: structural clay tile; see notes 12, 16, 21; facings on both sides; see note 18	n/a	1 hr		1		3,4,24	1

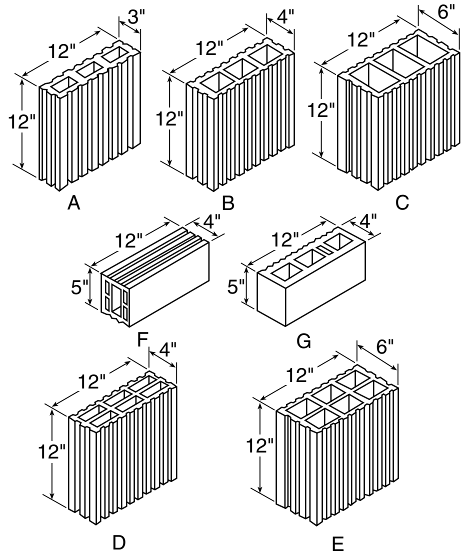
Table 1.1.2 Masonry Walls
4" (100 mm) to less than 6" (150 mm) thick continued

Item Code	Thickness	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
W-5-M-75	5 1/4"	Core: structural clay tile; see notes 12, 17, 21; facings on both sides; see note 18	n/a	1 hr 15 min		1		3,4,24	1 1/4
W-5-M-76	5 1/4"	Core: structural clay tile; see notes 12, 16, 20; facings on both sides; see note 18	n/a	45 min		1		3,4,24	3/4
W-5-M-77	5 1/4"	Core: structural clay tile; see notes 12, 17, 20; facings on both sides; see note 18	n/a	1 hr		1		3,4,24	1
W-5-M-78	5 1/4"	Core: structural clay tile; see notes 13, 16, 23; facings on both sides of wall; see note 18	n/a	1 hr 30 min		1		3,4,24	1 1/2
W-5-M-79	5 1/4"	Core: structural clay tile; see notes 13, 17, 23; facings on both sides of wall; see note 18	n/a	2 hr		1		3,4,24	2
W-5-M-80	5 1/4"	Core: structural clay tile; see notes 13, 16, 21; facings on both sides of wall; see note 18	n/a	1 hr 15 min		1		3,4,24	1 1/4
W-5-M-81	5 1/4"	Core: structural clay tile; see notes 13, 16, 21; facing on both sides of wall; see note 18	n/a	1 hr 30 min		1		3,4,24	1 1/2
W-5-M-82	5 1/4"	Core: structural clay tile; see notes 15, 16, 20; facings on both sides; see note 18	n/a	2 hr 30 min		1		3,4,24	2 1/2
W-5-M-83	5 1/4"	Core: structural clay tile; see notes 15, 17, 20; facings on both sides; see note 18	n/a	2 hr 30 min		1		3,4,24	2 1/2
W-5-M-84	5 1/4"	Core: structural clay tile; see notes 14, 16, 22; facings on both sides of wall; see note 18	n/a	1 hr 15 min		1		3,4,24	1 1/4
W-5-M-85	5 1/4"	Core: structural clay tile; see notes 14, 17, 22; facings on both sides of wall; see note 18	n/a	1 hr 30 min		1		3,4,24	1 1/2
W-4-86	4"	Core: 3" thick gypsum blocks 70% solid; see note 26; facings on both sides per note 25	n/a	2 hr		1			2
W-4-M-87	4"	Core: hollow concrete units; see notes 27, 34, 35; no facings	n/a	1 hr 30 min		1			1 1/2
W-4-M-88	4"	Core: hollow concrete units; see notes 28, 33, 35; no facings	n/a	1 hr		1			1
W-4-M-89	4"	Core: hollow concrete units; see notes 28, 34, 35; facings on both sides per note 25	n/a	1 hr 45 min		1			1 3/4
W-4-M-90	4"	Core: hollow concrete units; see notes 27, 34, 35; facings on both sides per note 25	n/a	2 hr		1			2
W-4-M-91	4"	Core: hollow concrete units; see notes 27, 32, 35; no facings	n/a	1 hr 15 min		1			1 1/4
W-4-M-92	4"	Core: hollow concrete units; see notes 28, 34, 35; no facings	n/a	1 hr 15 min		1			1 1/4
W-4-M-93	4"	Core: hollow concrete units; see notes 29, 32, 35; no facings	n/a	20 min		1			1/3
W-4-M-94	4"	Core: hollow concrete units; see notes 30, 34, 35; no facings	n/a	15 min		1			1/4
W-4-M-95	4 1/2"	Core: hollow concrete units; see notes 27, 34, 35; facing on one side only; see note 25	n/a	2 hr		1			2
W-4-M-96	4 1/2"	Core: hollow concrete units; see notes 27, 32, 35; facing on one side only; see note 25	n/a	1 hr 45 min		1			1 3/4
W-4-M-97	4 1/2"	Core: hollow concrete units; see notes 28, 33, 35; facing on one side per note 25	n/a	1 hr 30 min		1			1 1/2
W-4-M-98	4 1/2"	Core: hollow concrete units; see notes 28, 34, 35; facing on one side only per note 25	n/a	1 hr 45 min		1			1 3/4
W-4-M-99	4 1/2"	Core: hollow concrete units; see notes 29, 32, 35; facing on one side per note 25	n/a	30 min		1			1/2
W-4-M-100	4 1/2"	Core: hollow concrete units; see notes 30, 34, 35; facing on one side per note 25	n/a	20 min		1			1/3
W-5-M-101	5"	Core: hollow concrete units; see notes 27, 34, 35; facings on both sides; see note 25	n/a	2 hr 30 min		1			2 1/2
W-5-M-102	5"	Core: hollow concrete units; see notes 27, 32, 35; facings on both sides per note 25	n/a	2 hr 30 min		1			2 1/2
W-5-M-103	5"	Core: hollow concrete units; see notes 28, 33, 35; facings on both sides per note 25	n/a	2 hr		1			2

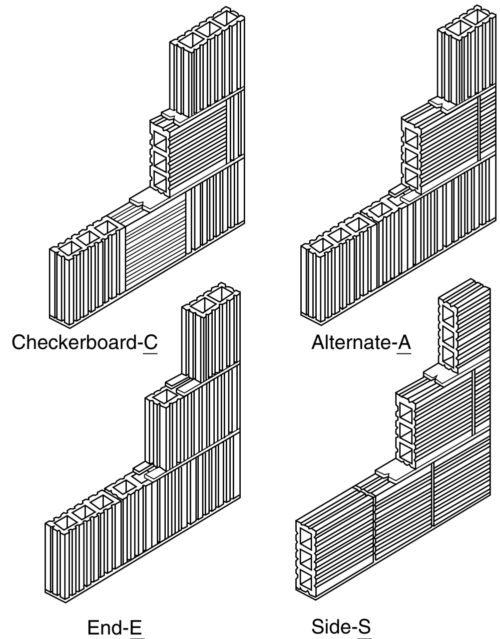
Table 1.1.2 Masonry Walls
4" (100 mm) to less than 6" (150 mm) thick continued

Item Code	Thickness	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
W-5-M-104	5"	Core: hollow concrete units; see notes 28, 31, 35; facings on both sides per note 25	n/a	2 hr		1			2
W-5-M-105	5"	Core: hollow concrete units; see notes 29, 32, 35; facings on both sides per note 25	n/a	1 hr 45 min		1			$1^3/_4$
W-5-M-106	5"	Core: hollow concrete units; see notes 30, 34, 35; facings on both sides per note 25	n/a	1 hr		1			1
W-5-M-107	5"	Core: 5" thick solid gypsum blocks; see note 26; no facings	n/a	4 hr		1			4
W-5-M-108	5"	Core: 4" thick hollow gypsum blocks; see note 26; facings on both sides per note 25	n/a	3 hr		1			3
W-5-M-109	4"	Concrete with 4" × 4" No. 6 welded wire mesh at wall center	100 PSI	45 min			43	2	$^3/_4$
W-5-M-110	4"	Concrete with 4" × 4" No. 6 welded wire mesh at wall center	n/a	1 hr 15 min			43	2	$1^1/_4$

NOTES: Table 1.1.2
1. Tested at NBS under ASA Spec. No. A 2-1934.
2. Failure mode — maximum temperature rise.
3. Tested at NBS under ASA Spec. No. 42-1934 (ASTM C-19-53) except that hose stream testing where carried out was run on test specimens exposed for full test duration, not for a reduced period as is contemporarily done.
4. For clay tile walls, unless the source of the clay can be positively identified, it is suggested that the most pessimistic hour rating for the fire endurance of a clay tile partition of that thickness be followed. Identified sources of clay showing longer fire endurance can lead to longer time recommendations.
5. See appendix of original report for construction and design details for clay tile walls.
6. Failure mode — flame thru or crack formation showing flames.
7. Hole formed at 25 minimum; partition collapsed at 42 minimum on removal from furnace.
8. Failure mode — collapse.
9. Hose stream — pass.
10. Hose stream hole formed in specimen.
11. Load — 80 PSI for gross wall cross-sectioned area.
12. One cell in wall thickness.
13. Two cells in wall thickness.
14. Double cells plus one cell in wall thickness.
15. One cell in wall thickness, cells filled with broken tile, crushed stone, slag, cinders, or sand mixed with mortar.
16. Dense hard-burned clay or shale tile.
17. Medium-burned clay tile.
18. Not less than $^5/_8$" thickness of 1:3 sanded gypsum plaster.
19. Units of not less than 30% solid material.
20. Units of not less than 40% solid material.
21. Units of not less than 50% solid material.
22. Units of not less than 45% solid material.
23. Units of not less than 60% solid material.
24. All tiles laid in portland cement-lime mortar.
25. Minimum $^1/_2$" — 1:3 sanded gypsum plaster.
26. Laid in 1:3 sanded gypsum mortar. Voids in hollow units not to exceed 30%.
27. Units of expanded slag or pumice aggregate.
28. Units of crushed limestone, blast furnace slag, cinders, and expanded clay or shale.
29. Units of calcareous sand and gravel. Coarse aggregate, 60% or more calcite and dolomite.
30. Units of siliceous sand and gravel. 90% or more quartz, chert, or flint.
31. Unit at least 49% solid.
32. Unit at least 62% solid.
33. Unit at least 65% solid.
34. Unit at least 73% solid.
35. Ratings based on one unit and one cell in wall thickness.
36. See Clay Tile Partition Design Construction drawings, p. 54.



Designs of tiles used in fire-test partitions.



The four types of construction used in fire-test partitions.

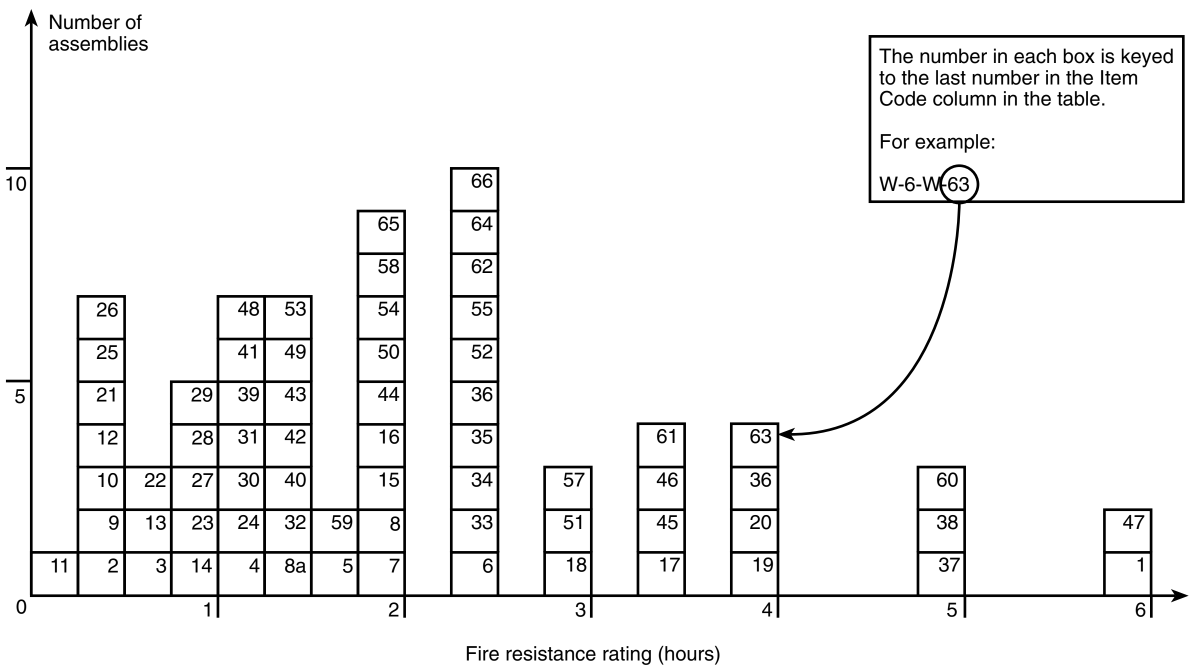


Figure 1.1.3 Walls—Masonry 6" to less than 8" thick

Table 1.1.3 Masonry Walls
6" to less than 8" thick (150 mm)/(200 mm)

Item Code	Thickness	Construction Details	Performance Load	Performance Time	Reference Number Pre-BMS-92	Reference Number BMS-92	Reference Number Post-BMS-92	Notes	Rec Hours
W-6-M-1	6"	Core: 5" thick, solid gypsum blocks laid in 1:3 sanded gypsum mortar; $^{1}/_{2}$" of 1:3 sanded gypsum plaster facings on both sides	n/a	6 hr		1			6
W-6-M-2	6"	6" clay tile; Ohio fire clay; single cell thick; plaster — none; design "C"; construction "A"	n/a	17 min			2	1,3,4,6, 55	$^{1}/_{4}$
W-6-M-3	6"	6" clay tile; Illinois surface clay; double cell thick; no plaster; design "E"; construction "S"	n/a	45 min			2	1-4,7, 55	$^{3}/_{4}$
W-6-M-4	6"	6" clay tile; New Jersey fire clay; double cell thick; no plaster; design "E"; construction "S"	n/a	1 hr 1 min			2	1-4,8, 55	1
W-7-M-5	7$^{1}/_{4}$"	6" clay tile; Illinois surface clay; double cell thick; plaster: $^{5}/_{8}$" — 1:3 sanded gypsum both faces; design "E"; construction "A"	n/a	1 hr 41 min			2	1-4, 55	1$^{2}/_{3}$
W-7-M-6	7$^{1}/_{4}$"	6" clay tile; New Jersey fire clay; Double cell thick; plaster: $^{5}/_{8}$" — 1:3 sanded gypsum both faces; design "E"; construction "S"	n/a	2 hr 23 min			2	1-4,9, 55	2$^{1}/_{3}$
W-7-M-7	7$^{1}/_{4}$"	6" clay tile; Ohio fire clay; single cell thick; plaster: $^{5}/_{8}$" sanded gypsum; 1:3 both faces; design "C"; construction "A"	n/a	1 hr 54 min			2	1-4,9, 55	2$^{3}/_{4}$
W-7-M-8	7$^{1}/_{4}$"	6" clay tile; Illinois surface clay; single cell thick; plaster: $^{5}/_{8}$" sanded gypsum 1:3 both faces; design "C"; construction "S"	n/a	2 hr			2	1,3,4, 9,10, 55	2
W-7-M-8a	7$^{1}/_{4}$"	6" clay tile; Illinois surface clay; single cell thick; plaster: $^{5}/_{8}$" sanded gypsum 1:3 both faces; design "C"; construction "E"	n/a	1 hr 23 min			2	1-4,9, 10,55	1$^{1}/_{4}$
W-6-M-9	6"	Core: structural clay tile; see notes 12, 16, 20; no facings	n/a	20 min		1		3,5,25	$^{1}/_{3}$
W-6-M-10	6"	Core: structural clay tile; see notes 12, 17, 20; no facings	n/a	25 min		1		3,5,24	$^{1}/_{3}$
W-6-M-11	6"	Core: structural clay tile; see notes 12, 16, 19; no facings	n/a	15 min		1		3,5,24	$^{1}/_{4}$
W-6-M-12	6"	Core: structural clay tile; see notes 12, 17, 19; no facings	n/a	20 min		1		3,5,24	$^{1}/_{3}$
W-6-M-13	6"	Core: structural clay tile; see notes 13, 16, 22; no facings	n/a	45 min		1		3,5,24	$^{3}/_{4}$
W-6-M-14	6"	Core: structural clay tile; see notes 13, 17, 22; no facings	n/a	1 hr		1		3,5,24	1
W-6-M-15	6"	Core: structural clay tile; see notes 15, 17, 19; no facings	n/a	2 hr		1		3,5,24	2
W-6-M-16	6"	Core: structural clay tile; see notes 15, 16, 19; no facings	n/a	2 hr		1		3,5,24	2
W-6-M-17	6"	Cored concrete masonry; see notes 12, 34, 26, 38, 41; no facings	80 PSI	3 hr 30 min		1		5,25	3$^{1}/_{2}$
W-6-M-18	6"	Cored concrete masonry; see notes 12, 33, 36, 38, 41; no facings	80 PSI	3 hr		1		5,25	3
W-6-M-19	6$^{1}/_{2}$"	Cored concrete masonry; see notes 12, 34, 36, 38, 41; facings: see note 35 for side 1	80 PSI	4 hr		1		5,25	4
W-6-M-20	6$^{1}/_{2}$"	Cored concrete masonry; see notes 12, 33, 36, 38, 41; facings: see note 35 for side 1	80 PSI	4 hr		1		5,25	4
W-6-M-21	6$^{5}/_{8}$"	Core: structural clay tile; see notes 12, 16, 20; facing: unexposed face only; see note 18	n/a	30 min		1		3,5,24	$^{1}/_{2}$
W-6-M-22	6$^{5}/_{8}$"	Core: structural clay tile; see notes 12, 17, 20; facing: unexposed face only; see note 18	n/a	40 min		1		3,5,24	$^{2}/_{3}$
W-6-M-23	6$^{5}/_{8}$"	Core: structural clay tile; see notes 12, 16, 20; facing: exposed face only; see note 18	n/a	1 hr		1		3,5,24	1
W-6-M-24	6$^{5}/_{8}$"	Core: structural clay tile; see notes 12, 17, 20; facing: exposed face only; see note 18	n/a	1 hr 5 min		1		3,5,24	1
W-6-M-25	6$^{5}/_{8}$"	Core: structural clay tile; see notes 12, 16, 19; facing: unexposed side only; see note 18	n/a	25 min		1		3,5,24	$^{1}/_{3}$
W-6-M-26	6$^{5}/_{8}$"	Core: structural clay tile; see notes 12, 7, 19; facings: on unexposed side only; see note 18	n/a	30 min		1		3,5,24	$^{1}/_{2}$
W-6-M-27	6$^{5}/_{8}$"	Core: structural clay tile; see notes 12, 16, 19; facings: on exposed side only; see note 18	n/a	1 hr		1		3,5,24	1
W-6-M-28	6$^{5}/_{8}$"	Core: structural clay tile; see notes 12, 17, 19; facings: on fire side only; see note 18	n/a	1 hr		1		3,5,24	1

Table 1.1.3 Masonry Walls
6" to less than 8" thick (150 mm)/(200 mm)

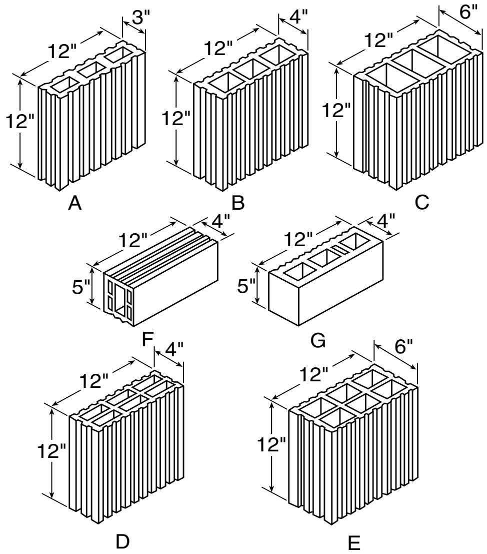
Item Code	Thickness	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
W-6-M-29	$6^5/_8$"	Core: structural clay tile; see notes 13, 16, 22; facings: on unexposed side only; see note 18	n/a	1 hr		1		3,5,24	1
W-6-M-30	$6^5/_8$"	Core: structural clay tile; see notes 13, 17, 22; facings: on unexposed side only; see note 18	n/a	1 hr 15 min		1		3,5,24	$1^1/_4$
W-6-M-31	$6^5/_8$"	Core: structural clay tile; see notes 13, 16, 22; facings: on fire side only; see note 18	n/a	1 hr 15 min		1		3,5,24	$1^1/_4$
W-6-M-32	$6^5/_8$"	Core: structural clay tile; see notes 13, 17, 22; facing: on fire side only; see note 18	n/a	1 hr 30 min		1		3,5,24	$1^1/_2$
W-6-M-33	$6^5/_8$"	Core: structural clay tile; see notes 15, 16, 19; facings: on unexposed side only; see note 18	n/a	2 hr 30 min		1		3,5,24	$2^1/_2$
W-6-M-34	$6^5/_8$"	Core: structural clay tile; see notes 15, 17, 19; facings: on unexposed side only; see note 18	n/a	2 hr 30 min		1		3,5,24	$2^1/_2$
W-6-M-35	$6^5/_8$"	Core: structural clay tile; see notes 15, 16, 19; facings: on fire side only; see note 18	n/a	2 hr 30 min		1		3,5,24	$2^1/_2$
W-6-M-36	$6^5/_8$"	Core: structural clay tile; see notes 15, 17, 19; facings: on fire side only; see note 18	n/a	2 hr 30 min		1		3,5,24	$2^1/_2$
W-7-M-37	7"	Cored concrete masonry; see notes 12, 34, 36, 38, 41; see note 35 for facings on both sides	80 PSI	5 hr		1		5,25	5
W-7-M-38	7"	Cored concrete masonry; see notes 12, 33, 36, 38, 41; see note 35 for facings	80 PSI	5 hr		1		5,25	5
W-7-M-39	$7^1/_4$"	Core: structural clay tile; see notes 12, 16, 20; see note 18 for facings on both sides	n/a	1 hr 15 min		1		3,5,24	$1^1/_4$
W-7-M-40	$7^1/_4$"	Core: structural clay tile; see notes 12, 17, 20; see note 18 for facings on both sides	n/a	1 hr 30 min		1		3,5,24	$1^1/_2$
W-7-M-41	$7^1/_4$"	Core: structural clay tile; see notes 12, 16, 19; see note 18 for facings on both sides	n/a	1 hr 15 min		1		3,5,24	$1^1/_4$
W-7-M-42	$7^1/_4$"	Core: structural clay tile; see notes 12, 17, 19; see note 18 for facings on both sides	n/a	1 hr 30 min		1		3,5,24	$1^1/_2$
W-7-M-43	$7^1/_4$"	Core: structural clay tile; see notes 13, 16, 22; facing: on both sides of wall; see note 18	n/a	1 hr 30 min		1		3,5,24	$1^1/_2$
W-7-M-44	$7^1/_4$"	Core: structural clay tile; see notes 13, 17, 22; facings: on both sides of wall; see note 18	n/a	2 hr		1		3,5,24	2
W-7-M-45	$7^1/_4$"	Core: structural clay tile; see notes 15, 16, 19; facings: both sides; see note 18	n/a	3 hr 30 min		1		3,5,24	$3^1/_2$
W-7-M-46	$7^1/_4$"	Core: structural clay tile; see notes 15, 17, 19; facings: both sides; see note 18	n/a	3 hr 30 min		1		3,5,24	$3^1/_2$
W-6-M-47	6"	Core: 5" thick solid gypsum blocks; see note 45; facings: both sides per note 35	n/a	6 hr		1			6
W-6-M-48	6"	Core: hollow concrete units; see notes 46, 50, 54; no facings	n/a	1 hr 15 min		1			$1^1/_4$
W-6-M-49	6"	Core: hollow concrete units; see notes 46, 50, 54; no facings	n/a	1 hr 30 min		1			$1^1/_2$
W-6-M-50	6"	Core: hollow concrete units; see notes 41, 46, 54; no facings	n/a	2 hr		1			2
W-6-M-51	6"	Core: hollow concrete units; see notes 46, 53, 54; no facings	n/a	3 hr		1			3
W-6-M-52	6"	Core: hollow concrete units; see notes 47, 53, 54; no facings	n/a	2 hr 30 min		1			$2^1/_2$
W-6-M-53	6"	Core: hollow concrete units; see notes 47, 51, 54; no facings	n/a	1 hr 30 min		1			$1^1/_2$
W-6-M-54	$6^1/_2$"	Core: hollow concrete units; see notes 46, 50, 54; facing: one side only per note 35	n/a	2 hr		1			2
W-6-M-55	$6^1/_2$"	Core: hollow concrete units; see notes 4, 51, 54; facings: one side per note 35	n/a	2 hr 30 min		1			$2^1/_2$
W-6-M-56	$6^1/_2$"	Core: hollow concrete units; see notes 46, 53, 54; facings: one side per note 35	n/a	4 hr		1			4
W-6-M-57	$6^1/_2$"	Core: hollow concrete units; see notes 47, 53, 54; facings: one side per note 35	n/a	3 hr		1			3

Table 1.1.3 Masonry Walls
6" to less than 8" thick (150 mm)/(200 mm)

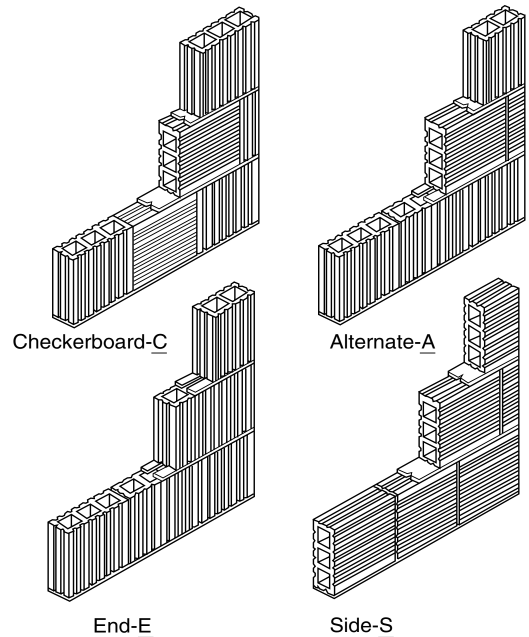
Item Code	Thickness	Construction Details	Performance: Load	Performance: Time	Reference Number: Pre-BMS-92	Reference Number: BMS-92	Reference Number: Post-BMS-92	Notes	Rec Hours
W-6-M-58	$6^1/_2$"	Core: hollow concrete units; see notes 47, 51, 54; facings: one side per note 35	n/a	2 hr		1			2
W-6-M-59	$6^1/_2$"	Core: hollow concrete units; see notes 47, 50, 54; facings: one side per note 35	n/a	1 hr 45 min		1			$1^3/_4$
W-7-M-60	7"	Core: hollow concrete units; see notes 46, 53, 54; facings: both sides per note 35	n/a	5 hr		1			5
W-7-M-61	7"	Core: hollow concrete units; see notes 46, 51, 54; facings: both sides per note 35	n/a	3 hr 30 min		1			$3^1/_2$
W-7-M-62	7"	Core: hollow concrete units; see notes 46, 50, 54; facings: both sides per note 35	n/a	2 hr 30 min		1			$2^1/_2$
W-7-M-63	7"	Core: hollow concrete units; see notes 47, 53, 54; facings: both sides per note 35	n/a	4 hr		1			4
W-7-M-64	7"	Core: hollow concrete units; see notes 47, 51, 54; facings: both sides per note 35	n/a	2 hr 30 min		1			$2^1/_2$
W-7-M-65	7"	Core: hollow concrete units; see notes 47, 50, 54; facings: both sides per note 35	n/a	2 hr		1			2
W-6-M-66	6"	Concrete wall with 4" × 4" No. 6 wire fabric (welded) near wall center for reinforcement	300 PSI	2 hr 30 min			43	2	$2^1/_2$

NOTES: Table 1.1.3
1. Tested at NBS under ASA Spec. No. 42-1934 (ASTM C-19-53) except that hose stream testing where carried out was run on test specimens exposed for full test duration, not for a reduced period as is contemporarily done.
2. Failure by thermal criteria — maximum temperature rise.
3. For clay tile walls, unless the source or density of the clay can be positively identified or determined, it is suggested that the lowest hourly rating for the fire endurance of a clay tile partition of that thickness be followed. Identified sources of clay showing longer fire endurance can lead to longer time recommendations.
4. See note 55 for construction and design details for clay tile walls.
5. Tested at NBS under ASA Spec. No. A2-1934.
6. Failure mode — collapse.
7. Collapsed on removal from furnace @ 1 hour 9 minutes.
8. Hose stream — failed.
9. Hose stream — passed.
10. No end point met in test.
11. Wall collapsed at 1 hour 28 minutes.
12. One cell in wall thickness.
13. Two cells in wall thickness.
14. Double shells plus one cell in wall thickness.
15. One cell in wall thickness, cells filled with broken tile, crushed stone, slag, cinders, or sand mixed with mortar.
16. Dense hard-burned clay or shale tile.
17. Medium-burned clay tile.
18. Not less than $^5/_8$" thickness of 1:3 sanded gypsum plaster.
19. Units of not less than 30% solid material.
20. Units of not less than 40% solid material.
21. Units of not less than 50% solid material.
22. Units of not less than 45% solid material.
23. Units of not less than 60% solid material.
24. All tiles laid in portland cement-lime mortar.
25. Load — 80 PSI for gross cross-sectional area of wall.
26. Three cells in wall thickness.
27. Minimum % of solid material in concrete units: 52.
28. Minimum % of solid material in concrete units: 54.
29. Minimum % of solid material in concrete units: 55.
30. Minimum % of solid material in concrete units: 57.
31. Minimum % of solid material in concrete units: 62.
32. Minimum % of solid material in concrete units: 65.
33. Minimum % of solid material in concrete units: 70.
34. Minimum % of solid material in concrete units: 76.
35. Not less than $^1/_2$" of 1:3 sanded gypsum plaster.
36. Noncombustible or no members framed into wall.
37. Combustible members framed into wall.
38. One unit in wall thickness.
39. Two units in wall thickness.
40. Three units in wall thickness.

41. Concrete units made with expanded slag or pumice aggregates.
42. Concrete units made with expanded burned clay or shale, crushed limestone, air cooled slag, or cinders.
43. Concrete units made with calcareous sand and gravel. Coarse aggregate, 60% or more calcite and dolomite.
44. Concrete units made with siliceous sand and gravel. 90% or more quartz, chert, or flint.
45. Laid in 1:3 sanded gypsum mortar.
46. Units of expanded slag or pumice aggregate.
47. Units of crushed limestone, blast furnace slag, cinders, and expanded clay or shale.
48. Units of calcareous sand and gravel. Coarse aggregate,
60% or more calcite and dolomite.
49. Units of siliceous sand and gravel. 90% or more quartz, chert, or flint.
50. Unit minimum 49% solid.
51. Unit minimum 62% solid.
52. Unit minimum 65% solid.
53. Unit minimum 73% solid.
54. Ratings based on 1 unit and 1 cell in wall section.
55. See Clay Tile Partition Design Construction drawings,
p.58.



Designs of tiles used in fire-test partitions.



The four types of construction used in fire-test partitions.

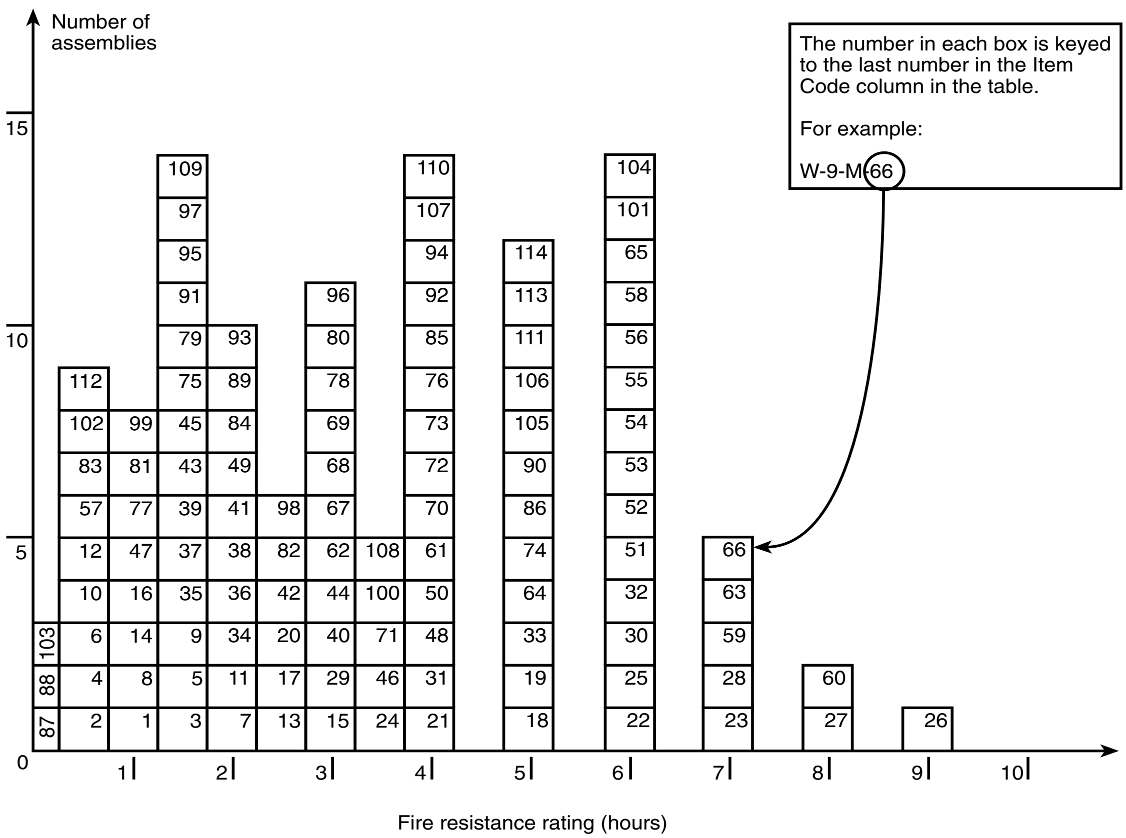


Figure 1.1.4 Walls—Masonry 8” to less than 10” thick

Table 1.1.4 Walls — Masonry
8" (200 mm) to less than 10" (250 mm) thick

Item Code	Thickness	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
W-8-M-1	8"	Core: clay or shale structural tile; units in wall thickness: 1; cells in wall thickness: 2; minimum % solids in units: 40	80 PSI	1 hr 15 min		1		1,20	1 1/4
W-8-M-2	8"	Core: clay or shale structural tile; units in wall thickness: 1; cell in wall thickness: 2; minimum % solids in units: 40; facings: none; result for wall with combustible members framed into interior	80 PSI	45 min		1		1,20	3/4
W-8-M-3	8"	Core: clay or shale structural tile; units in wall thickness: 1; cells in wall thickness: 2; minimum % solids in units: 43	80 PSI	1 hr 30 min		1		1,20	1 1/2
W-8-M-4	8"	Core: clay or shale structural tile; units in wall thickness: 1; cells in wall thickness: 2; minimum % solids in units: 43; no facings; combustible members framed into wall	80 PSI	45 min		1		1,20	3/4
W-8-M-5	8"	Core: clay or shale structural tile; no facings	See notes	1 hr 30 min		1		1,2,5, 10,18, 20,21	1 1/2
W-8-M-6	8"	Core: clay or shale structural tile; no facings	See notes	45 min		1		1,2,5,10, 19-21	3/4
W-8-M-7	8"	Core: clay or shale structural tile; no facings	See notes	2 hr		1		1,2,5, 13,18, 20,21	2
W-8-M-8	8"	Core: clay or shale structural tile; no facings	See notes	1 hr 15 min		1		1,2,5, 13,19, 20,21	1 1/4
W-8-M-9	8"	Core: clay or shale structural tile; no facings	See notes	1 hr 45 min		1		1,2,6,9, 18,20,21	1 3/4
W-8-M-10	8"	Core: clay or shale structural tile; no facings	See notes	45 min		1		1,2,6,9, 19,20,21	3/4
W-8-M-11	8"	Core: clay or shale structural tile; no facings	See notes	2 hr		1		1,2,6, 10,18, 20,21	2
W-8-M-12	8"	Core: clay or shale structural tile; no facings	See notes	45 min		1		1,2,6, 10,19, 20,21	3/4
W-8-M-13	8"	Core: clay or shale structural tile; no facings	See notes	2 hr 30 min		1		1,3,6, 12,18, 20,21	2 1/2
W-8-M-14	8"	Core: clay or shale structural tile; no facings	See notes	1 hr		1		1,2,6, 12,19, 20,21	1
W-8-M-15	8"	Core: clay or shale structural tile; no facings	See notes	3 hr		1		1,2,6, 16,18, 20,21	3
W-8-M-16	8"	Core: clay or shale structural tile; no facings	See notes	1 hr 15 min		1		1,2,6, 16,19, 20,21	1 1/4
W-8-M-17	8"	Units in wall thickness: 1; cells in wall thickness: 1; minimum % solids: 70; cored clay or shale brick; no facings	See notes	2 hr 30 min		1		1,44	2 1/2
W-8-M-18	8"	Cored clay or shale bricks; units in wall thickness: 2; cells in wall thickness: 2; minimum % solids, 87; no facings	See notes	5 hr		1		1,45	5
W-8-M-19	8"	Core: solid clay or shale brick; no facings	See notes	5 hr		1		1,22,45	5
W-8-M-20	8"	Core: hollow rolok of clay or shale	See notes	2 hr 30 min		1		1,22,45	2 1/2
W-8-M-21	8"	Core: hollow rolok bak of clay or shale; no facings	See notes	4 hr		1		1,45	4

Table 1.1.4 Walls — Masonry
8" (200 mm) to less than 10" (250 mm) thick

			Performance		Reference Number				
Item Code	**Thickness**	**Construction Details**	**Load**	**Time**	**Pre-BMS-92**	**BMS-92**	**Post-BMS-92**	**Notes**	**Rec Hours**
W-8-M-22	8"	Core: concrete brick; no facings	See notes	6 hr		1		1,45	6
W-8-M-23	8"	Core: sand-lime brick; no facings	See notes	7 hr		1		1,45	7
W-8-M-24	8"	Core: 4"; 40% solid clay or shale structural tile; 1 side 4" brick facing	See notes	3 hr 30 min		1		1,20	$3^{1}/_{2}$
W-8-M-25	8"	Concrete wall (3220 PSI); reinforcing vertical rods 1" from each face and 1" diameter; horizontal rod $^{3}/_{8}$" diameter	22,200 lb/ft	6 hr			7		6
W-8-M-26	8"	Core: sand-lime brick; $^{1}/_{2}$" of 1:3 sanded gypsum plaster facing on one side	See notes	9 hr		1		1,45	9
W-8-M-27	$8^{1}/_{2}$"	Core: sand-lime brick; $^{1}/_{2}$" of 1:3 sanded gypsum plaster facing on one side	See notes	8 hr		1		1,45	8
W-8-M-28	$8^{1}/_{2}$"	Core: concrete; $^{1}/_{2}$" of 1:3 sanded gypsum plaster facing on one side	See notes	7 hr		1		1,45	7
W-8-M-29	$8^{1}/_{2}$"	Core: hollow rolok of clay or shale; $^{1}/_{2}$" of 1:3 sanded gypsum plaster facing on one side	See notes	3 hr		1		1,45	3
W-8-M-30	$8^{1}/_{2}$"	Core: solid clay or shale brick; $^{1}/_{2}$" thick, 1:3 sanded gypsum plaster facing on one side	See notes	6 hr		1		1,22,45	6
W-8-M-31	$8^{1}/_{2}$"	Core: cored clay or shale brick; units in wall thickness: 1; cells in wall thickness: 1; minimum % solids: 70; $^{1}/_{2}$" of 1:3 sanded gypsum plaster facing on both sides	See notes	4 hr		1		1,44	4
W-8-M-32	$8^{1}/_{2}$"	Core: cored clay or shale brick; units in wall thickness: 2; cells in wall thickness: 2; minimum % solids: 87; $^{1}/_{2}$" of 1:3 sanded gypsum plaster facing on one side	See notes	6 hr		1		1,45	6
W-8-M-33	$8^{1}/_{2}$"	Hollow rolok bak of clay or shale core; $^{1}/_{2}$" of 1:3 sanded gypsum plaster facing on one side	See notes	5 hr		1		1,45	5
W-8-M-34	$8^{1}/_{2}$"	Core: clay or shale structural tile; units in wall thickness: 1; cells in wall thickness: 2; minimum % solids in units: 40; $^{5}/_{8}$" of 1:3 sanded gypsum plaster facing on one side	See notes	2 hr		1		1,20,21	2
W-8-M-35	$8^{5}/_{8}$"	Core: clay or shale structural tile; units in wall thickness: 1; cells in wall thickness: 2; minimum % solids in units: 40; exposed face: $^{5}/_{8}$" of 1:3 sanded gypsum plaster	See notes	1 hr 30 min		1		1,20,21	$1^{1}/_{2}$
W-8-M-36	$8^{5}/_{8}$"	Core: clay or shale structural tile; units in wall thickness: 1; cells in wall thickness: 2; minimum % solids in units: 43; $^{5}/_{8}$" of 1:3 sanded gypsum plaster facing on one side	See notes	2 hr		1		1,20,21	2
W-8-M-37	$8^{5}/_{8}$"	Core: clay or shale structural tile; units in wall thickness: 1; cells in wall thickness: 2; minimum % solids in units: 43; $^{5}/_{8}$" of 1:3 sanded gypsum plaster on the exposed face only	See notes	1 hr 30 min				1,20,21	$1^{1}/_{2}$
W-8-M-38	$8^{5}/_{8}$"	Core: clay or shale structural tile; see note 17 for facing side 1	See notes	2 hr		1		1,2,5, 10,18, 20,21	2
W-8-M-39	$8^{5}/_{8}$"	Core: clay or shale structural tile; facings: on exposed side only; see note 17	See notes	1 hr 30 min		1		1,2,5, 10,19, 20,21	$1^{1}/_{2}$
W-8-M-40	$8^{5}/_{8}$"	Core: clay or shale structural tile; facings on exposed side only; see note 17	See notes	3 hr		1		1,2,5,13 18,20,21	3
W-8-M-41	$8^{5}/_{8}$"	Core: clay or shale structural tile; facings on exposed side only; see note 17	See notes	2 hr		1		1,2,5, 13,19, 20,21	2

Table 1.1.4 Walls — Masonry
8" (200 mm) to less than 10" (250 mm) thick

Item Code	Thickness	Construction Details	Performance: Load	Performance: Time	Reference Number: Pre-BMS-92	Reference Number: BMS-92	Reference Number: Post-BMS-92	Notes	Rec Hours
W-8-M-42	$8^5/_8$"	Core: clay or shale structural tile; facings on side 1; see note 17	See notes	2 hr 30 min		1		1,2,6,9, 18,20, 21	$2^1/_2$
W-8-M-43	$8^5/_8$"	Core: clay or shale structural tile; facings on exposed side per note 17	See notes	1 hr 30 min		1		1,2,6,9, 19,20,21	$1^1/_2$
W-8-M-44	$8^5/_8$"	Core: clay or shale structural tile; facings: side 1: see note 17; side 2: none	See notes	3 hr		1		1,2,6, 10,18, 20,21	3
W-8-M-45	$8^5/_8$"	Core: clay or shale structural tile; facings on fire side only; see note 17	See notes	1 hr 30 min		1		1,2,6, 10,19, 20,21	$1^1/_2$
W-8-M-46	$8^5/_8$"	Core: clay or shale structural tile; facings: side 1: see note 17; side 2: none	See notes	3 hr 30 min		1		1,2,6, 12,18, 20,21	$3^1/_2$
W-8-M-47	$8^5/_8$"	Core: clay or shale structural tile; facings exposed side only; see note 17	See notes	1 hr 45 min		1		1,2,6, 12,19, 20,21	$1^3/_4$
W-8-M-48	$8^5/_8$"	Core: clay or shale structural tile; facings: side 1: see note 17; side 2: none	See notes	4 hr		1		1,2,6, 16,18, 20,21	4
W-8-M-49	$8^5/_8$"	Core: clay or shale structural tile; facings: fire side only; see note 17	See notes	2 hr		1		1,2,6, 16,19, 20,21	2
W-8-M-50	$8^5/_8$"	Core: 4"; 40% solid clay or shale structural tile; 4" brick plus $^5/_8$" of 1:3 sanded gypsum plaster facing on one side	See notes	4 hr		1		1,20	4
W-8-M-51	$8^3/_4$"	$8^3/_4$" × $2^1/_2$" and 4" × $2^1/_2$" cellular fletton (1873 PSI) single and triple cell hollow bricks set in $^1/_2$" sand mortar in alt. courses	3.6 ton/ft	6 hr			7	23,29	6
W-8-M-52	$8^3/_4$"	$8^3/_4$" thick cement brick (2527 PSI) with P.C. and sand mortar	3.6 ton/ft	6 hr			7	23,24	6
W-8-M-53	$8^3/_4$"	$8^3/_4$" × $2^1/_2$" fletton brick (1831 PSI) in $^1/_2$" sand mortar	3.6 ton/ft	6 hr			7	23,24	6
W-8-M-54	$8^3/_4$"	$8^3/_4$" × $2^1/_2$" London stock brick (683 PSI) in $^1/_2$" P.C. and sand mortar	7.2 ton/ft	6 hr			7	23,24	6
W-9-M-55	9"	9" × $2^1/_2$" Leicester red wire cut brick (4465 PSI) in $^1/_2$" P.C. and sand mortar	6.0 ton/ft	6 hr			7	23,24	6
W-9-M-56	9"	9" × 3" sand-lime brick (2603 PSI) in $^1/_2$" in P.C. sand mortar	3.6 ton/ft	6 hr			7	23,24	6
W-9-M-57	9"	2 layers 27/8 fletton brick (1910 PSI) with $3^1/_4$" air space; cement and sand mortar	1.5 ton/ft	32 min			7	23,25	$^1/_3$
W-9-M-58	9"	9" × 3" stairfoot brick (7527 PSI) in $^1/_2$" sand-cement mortar	7.2 ton/ft	6 hr			7	23,24	6
W-9-M-59	9"	Core: solid clay or shale bricks; $^1/_2$" thick; 1:3 sanded gypsum plaster facing on both sides	See notes	7 hr		1		1,45,22	7
W-9-M-60	9"	Core: concrete brick; $^1/_2$" of 1:3 sanded gypsum plaster facings on both sides	See notes	8 hr		1		1,45	8
W-9-M-61	9"	Core: hollow rolok of clay or shale; $^1/_2$" of 1:3 sanded gypsum plaster facings on both sides	See notes	4 hr		1		1,45	4
W-9-M-62	9"	Cored clay or shale brick; units in wall thickness: 1; cells in wall thickness: 1; minimum % solids: 70; $^1/_2$" of 1:3 sanded gypsum plaster facing on one side	See notes	3 hr		1		1,44	3
W-9-M-63	9"	Cored clay or shale bricks; units in wall thickness: 2; cells in wall thickness: 2; minimum % solids: 87; $^1/_2$" of 1:3 sanded gypsum plaster facing on both sides	See notes	7 hr		1		1,45	7

Table 1.1.4 Walls — Masonry
8" (200 mm) to less than 10" (250 mm) thick

Item Code	Thickness	Construction Details	Performance Load	Performance Time	Reference Number Pre-BMS-92	Reference Number BMS-92	Reference Number Post-BMS-92	Notes	Rec Hours
W-9-M-64	9-10"	Core: cavity wall of clay or shale brick; no facings	See notes	5 hr		1		1,45	5
W-9-M-65	9-10"	Core: cavity construction of clay or shale brick; $^1/_2$" of 1:3 sanded gypsum plaster facing on one side	See notes	6 hr		1		1,45	6
W-9-M-66	9-10"	Core: cavity construction of clay or shale brick; $^1/_2$" of 1:3 sanded gypsum plaster facing on both sides	See notes	7 hr		1		1,45	7
W-9-M-67	$9^1/_4$"	Core: clay or shale structural tile; units in wall thickness: 1; cells in wall thickness: 2; minimum % solids in units: 40; $^5/_8$" of 1:3 sanded gypsum plaster facing on both sides	See notes	3 hr		1		1,20, 21	3
W-9-M-68	$9^1/_4$"	Core: clay or shale structural tile; units in wall thickness: 1; cells in wall thickness: 2; minimum % solids in units: 43; $^5/_8$" of 1:3 sanded gypsum plaster facings on both sides	See notes	3 hr		1		1,20, 21	3
W-9-M-69	$9^1/_4$"	Core: clay or shale structural tile; facings: side 1 and 2 see note 17	See notes	3 hr		1		1,2,5, 10,18, 20,21	3
W-9-M-70	$9^1/_4$"	Core: clay or shale structural tile; facings: side 1 and 2 see note 17	See notes	4 hr		1		1,2,5, 13,18, 20,21	4
W-9-M-71	$9^1/_4$"	Core: clay or shale structural tile; facings: side 1 and 2 see note 17	See notes	3 hr 30 min		1		1,2,6,9, 18,20, 21	3 $^1/_2$
W-9-M-72	$9^1/_4$"	Core: clay or shale structural tile; facings: side 1 and 2 see note 17	See notes	4 hr		1		1,2,6, 10,18, 20,21	4
W-9-M-73	$9^1/_4$"	Core: clay or shale structural tile; facings: side 1 and 2 see note 17	See notes	4 hr		1		1,2,6, 12,18, 20,21	4
W-9-M-74	$9^1/_4$"	Core: clay or shale structural tile; facings: side 1 and 2 see note 17	See notes	5 hr		1		1,2,6, 16,18, 20,21	5
W-8-M-75	8"	Cored concrete masonry; see notes 2, 19, 26, 34, 40; no facings	80 PSI	1 hr 30 min		1		1,20	$1^1/_2$
W-8-M-76	8"	Cored concrete masonry; see notes 2, 18, 26, 34, 40; no facings	80 PSI	4 hr		1		1,20	4
W-8-M-77	8"	Cored concrete masonry; see notes 2, 19, 26, 31, 40; no facings	80 PSI	1 hr 15 min		1		1,20	$1^1/_4$
W-8-M-78	8"	Cored concrete masonry; see notes 2, 18, 26, 31, 40; no facings	80 PSI	3 hr		1		1,20	3
W-8-M-79	8"	Cored concrete masonry; see notes 2, 19, 26, 36, 41; no facings	80 PSI	1 hr 30 min		1		1,20	$1^1/_2$
W-8-M-80	8"	Cored concrete masonry; see notes 2, 18, 26, 36, 41; no facings	80 PSI	3 hr		1		1,20	3
W-8-M-81	8"	Cored concrete masonry; see notes 2, 19, 26, 34, 41; no facings	80 PSI	1 hr		1		1,20	1
W-8-M-82	8"	Cored concrete masonry; see notes 2, 18, 26, 34, 41; no facings	80 PSI	2 hr 30 min		1		1,20	$2^1/_2$
W-8-M-83	8"	Cored concrete masonry; see notes 2, 19, 26, 29, 41; no facings	80 PSI	45 min		1		1,20	$^3/_4$
W-8-M-84	8"	Cored concrete masonry; see notes 2, 18, 26, 29, 41; no facings	80 PSI	2 hr		1		1,20	2
W-8-M-85	$8^1/_2$"	Cored concrete masonry; see notes 3, 18, 26, 34, 41; facings: $2^1/_2$" brick	80 PSI	4 hr		1		1,20	4
W-8-M-86	8"	Cored concrete masonry; see notes 3, 18, 26, 34, 41; facings: $3^3/_4$" brick face	80 PSI	5 hr		1		1,20	5

Table 1.1.4 Walls — Masonry
8" (200 mm) to less than 10" (250 mm) thick

Item Code	Thickness	Construction Details	Performance: Load	Performance: Time	Reference Number: Pre-BMS-92	Reference Number: BMS-92	Reference Number: Post-BMS-92	Notes	Rec Hours
W-8-M-87	8"	Cored concrete masonry; see notes 2, 19, 26, 30, 43; no facings	80 PSI	12 min		1		1,20	$^1/_5$
W-8-M-88	8"	Cored concrete masonry; see notes 2, 18, 26, 30, 43; no facings	80PSI	12 min		1		1,20	$^1/_5$
W-8-M-89	$8^1/_2$"	Cored concrete masonry; see notes 2, 19, 26, 34, 40; facings: on fire side only; see note 38	80 PSI	2 hr		1		1,20	2
W-8-M-90	$8^1/_2$"	Cored concrete masonry; see notes 2, 18, 26, 34, 40; facings: see note 38 for side 1	80 PSI	5 hr		1		1,20	5
W-8-M-91	$8^1/_2$"	Cored concrete masonry; see notes 2, 19, 26, 31, 40; facings on fire side only; see note 38	80 PSI	1 hr 45 min		1		1,20	$1^3/_4$
W-8-M-92	$8^1/_2$"	Cored concrete masonry; see notes 2, 18, 26, 31, 40; facings on one side; see note 38	80 PSI	4 hr		1		1,20	4
W-8-M-93	$8^1/_2$"	Cored concrete masonry; see notes 2, 19, 26, 36, 41; facings on fire side only; see note 38	80 PSI	2 hr		1		1,20	2
W-8-M-94	$8^1/_2$"	Cored concrete masonry; see notes 2, 18, 26, 36, 41; facings on fire side only; see note 38	80 PSI	4 hr		1		1,20	4
W-8-M-95	$8^1/_2$"	Cored concrete masonry; see notes 2, 19, 26, 34, 41; facings on fire side only; see note 38	80 PSI	1 hr 30 min		1		1,20	$1^1/_2$
W-8-M-96	$8^1/_2$"	Cored concrete masonry; see notes 2, 18, 26, 34, 41; facings on one side; see note 38	80 PSI	3 hr		1		1,20	3
W-8-M-97	$8^1/_2$"	Cored concrete masonry; see notes 2, 19, 26, 29, 41; facings on fire side only; see note 38	80 PSI	1 hr 30 min		1		1,20	$1^1/_2$
W-8-M-98	$8^1/_2$"	Cored concrete masonry; see notes 2, 18, 26, 29, 41; facings on one side; see note 38	80 PSI	2 hr 30 min		1		1,20	$2^1/_2$
W-8-M-99	$8^1/_2$"	Cored concrete masonry; see notes 3, 19, 23, 27, 41; no facings	80 PSI	1 hr 15 min		1		1,20	$1^1/_4$
W-8-M-100	$8^1/_2$"	Cored concrete masonry; see notes 3, 18, 23, 27, 41; no facings	80 PSI	3 hr 30 min		1		1,20	$3^1/_2$
W-8-M-101	$8^1/_2$"	Cored concrete masonry; see notes 3, 18, 26, 34, 41; facings $3^3/_4$" brick face; one side only; see note 38	80 PSI	6 hr		1		1,20	6
W-8-M-102	$8^1/_2$"	Cored concrete masonry; see notes 2, 19, 26, 30, 43; facings on fire side only; see note 38	80 PSI	30 min		1		1,20	$^1/_2$
W-8-M-103	$8^1/_2$"	Cored concrete masonry; see notes 2, 18, 26, 30, 43; facings on one side only; see note 38	80 PSI	12 min		1		1,20	$^1/_5$
W-9-M-104	9"	Cored concrete masonry; see notes 2, 18, 26, 34, 40; facings on both sides; see note 38	80 PSI	6 hr		1		1,20	6
W-9-M-105	9"	Cored concrete masonry; see notes 2, 18, 26, 31, 40; facings on both sides; see note 38	80 PSI	5 hr		1		1,20	5
W-9-M-106	9"	Cored concrete masonry; see notes 2, 18, 26, 36, 41; facings on both sides of wall; see note 38	80 PSI	5 hr		1		1,20	5
W-9-M-107	9"	Cored concrete masonry; see notes 2, 18, 26, 34, 40; facings on both sides; see note 38.	80 PSI	4 hr		1		1,20	4
W-9-M-108	9"	Cored concrete masonry; see notes 2, 18, 26, 29, 41; facings on both sides; see note 38	80 PSI	3 hr 30 min		1		1,20	$3^1/_2$
W-9-M-109	9"	Cored concrete masonry; see notes 3, 19, 23, 27, 40; facing on fire side only; see note 38	80 PSI	1 hr 45 min		1		1,20	$1^3/_4$
W-9-M-110	9"	Cored concrete masonry; see notes 3, 18, 27, 23, 41; facings on one side only; see note 38	80 PSI	4 hr		1		1,20	4
W-9-M-111	9"	Cored concrete masonry; see notes 3, 18, 26, 34, 41; $2^1/_2$" brick face on one side only; see note 38	80 PSI	5 hr		1		1,20	5
W-8-M-112	9"	Cored concrete masonry; see notes 2, 18, 26, 30, 43; facings on both sides; see note 38	80 PSI	30 min		1		1,20	$^1/_2$
W-9-M-113	$9^1/_2$"	Cored concrete masonry; see notes 3, 18, 23, 27, 41; facings on both sides; see note 38	80 PSI	5 hr		1		1,20	5
W-8-M-114	8"		200 PSI	5hr			43	22	5

NOTES: Table 1.1.4
1. Tested at NBS under ASA Spec. No. 42-1934 (ASTM C-19-53).
2. One unit in wall thickness.
3. Two units in wall thickness.
4. Two or three units in wall thickness.
5. Two cells in wall thickness.
6. Three or four cells in wall thickness.
7. Four or five cells in wall thickness.
8. Five or six cells in wall thickness.
9. Minimum % of solid materials in units: 40%.
10. Minimum % of solid materials in units: 43%.
11. Minimum % of solid materials in units: 46%.
12. Minimum % of solid materials in units: 48%.
13. Minimum % of solid materials in units: 49%.
14. Minimum % of solid materials in units: 45%.
15. Minimum % of solid materials in units: 51%.
16. Minimum % of solid materials in units: 53%.
17. Not less than $^5/_8$" thickness of 1:3 sanded gypsum plaster.
18. Noncombustible or no members framed into wall.
19. Combustible members framed into wall.
20. Load: 80 PSI for gross cross sectional area of wall.
21. Portland cement — lime mortar.
22. Failure mode — thermal.
23. British test.
24. Passed all criteria.
25. Failed by sudden collapse with no preceding signs of impending failure.
26. One cell in wall thickness.
27. Two cells in wall thickness.
28. Three cells in wall thickness.
29. Minimum % of solid material in concrete units: 52.
30. Minimum % of solid material in concrete units: 54.
31. Minimum % of solid material in concrete units: 55.
32. Minimum % of solid material in concrete units: 57.
33. Minimum % of solid material in concrete units: 60.
34. Minimum % of solid material in concrete units: 62.
35. Minimum % of solid material in concrete units: 65.
36. Minimum % of solid material in concrete units: 70.
37. Minimum % of solid material in concrete units: 76.
38. Not less than $^1/_2$" of 1:3 sanded gypsum plaster.
39. Three units in wall thickness.
40. Concrete units made with expanded slag or pumice aggregates.
41. Concrete units made with expanded burned clay or shale, crushed limestone, air cooled slag, or cinders.
42. Concrete units made with calcareous sand and gravel. Coarse aggregate, 60% or more calcite and dolomite.
43. Concrete units made with siliceous sand and gravel. 90% or more quartz, chert, and dolomite.
44. Load: 120 PSI for gross cross-sectional area of wall.
45. Load: 160 PSI for gross cross-sectional area of wall.

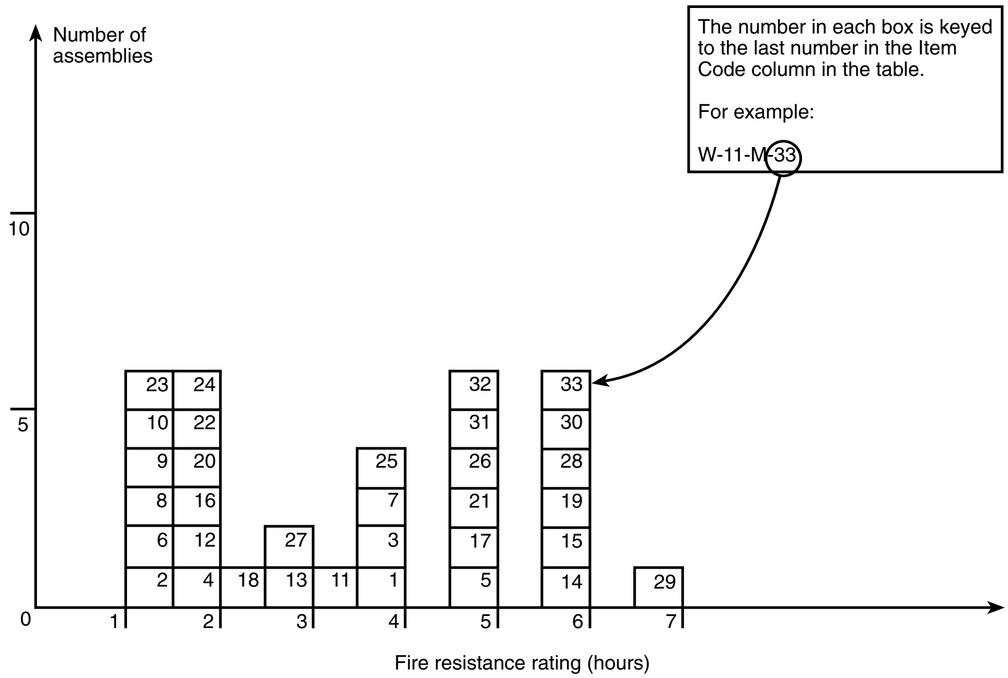


Figure 1-1.5 Walls — Masonry 10" (250 mm) to less than 12" (300 mm) thick

Table 1.1.5 Walls — Masonry
10" (250 mm) to less than 12" (300 mm) thick

			Performance		Reference Number				
Item Code	Thickness	Construction Details	Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92	Notes	Rec Hours
W-10-M-1	10"	Core: two, $3^3/_4$", 40% solid clay or shale structural tiles with 2" air space between; facings: $^3/_4$" portland cement plaster or stucco on both sides	80 PSI	4 hr		1		1,20	4
W-10-M-2	10"	Cored concrete masonry, 2" air cavity; see notes 3, 19, 27, 34, 40; facings: none	80 PSI	1 hr 30 min		1		1,20	$1^1/_2$
W-10-M-3	10"	Cored concrete masonry; see notes 3, 18, 27, 34, 40; facings: none	80 PSI	4 hr		1		1,20	4
W-10-M-4	10"	Cored concrete masonry; see notes 2, 19, 26, 33, 40; facings: none	80 PSI	2 hr		1		1,20	2
W-10-M-5	10"	Cored concrete masonry; see notes 2, 18, 26, 33, 40; no facings	80 PSI	5 hr		1		1,20	5
W-10-M-6	10"	Cored concrete masonry; see notes 2, 19, 26, 33, 41; no facings	80 PSI	1 hr 30 min		1		1,20	$1^1/_2$
W-10-M-7	10"	Cored concrete masonry; see notes 2, 18, 26, 33, 41; no facings	80 PSI	4 hr		1		1,20	4
W-10-M-8	10"	Cored concrete masonry (cavity type 2" air space) see notes 3, 19, 27, 34, 42; no facings	80 PSI	1 hr 15 min		1		1,20	$1^1/_4$
W-10-M-9	10"	Cored concrete masonry (cavity type 2" air space); see notes 3, 27, 34, 42; no facings	80 PSI	1 hr 15 min		1		1,20	$1^1/_4$
W-10-M-10	10"	Cored concrete masonry (cavity type 2" air space); see notes 3, 19, 27, 34, 41; no facings	80 PSI	1 hr 15 min		1		1,20	$1^1/_4$
W-10-M-11	10"	Cored concrete masonry (cavity type 2" air space); see notes 3, 18, 27, 34, 41; no facings	80 PSI	3 hr 30 min		1		1,20	$3^1/_2$
W-10-M-12	10"	9" thick concrete block ($11^3/_4" \times 9" \times 4^1/_4"$) with 2 - 2" thick voids included; $^3/_8$" P.C. plaster 1/8" neat gypsum	n/a	1 hr 53 min			7	23,44	$1^3/_4$

Table 1.1.5 Walls — Masonry
10" (250 mm) to less than 12" (300 mm) thick

Item Code	Thickness	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
W-10-M-13	10"	Hollow clay tile block wall — $8\frac{1}{2}$" block with 2 - 3" voids in each $8\frac{1}{2}$" section; $\frac{3}{4}$" gypsum plaster — each face	n/a	2 hr 42 min			7	23,25	$2\frac{1}{2}$
W-10-M-14	10"	2 layers $4\frac{1}{2}$" brick with $1\frac{1}{2}$" air space — no ties sand cement mortar (fletton brick - 1910 PSI)	n/a	6 hr			7	23,24	6
W-10-M-15	10"	2 layers $4\frac{1}{4}$" thick fletton brick — 1910 PSI brick; $1\frac{1}{2}$" air space; ties — 18" O.C. vertical; 3' O.C. - horizontal	n/a	6 hr			7	23,24	6
W-10-M-16	$10\frac{1}{2}$"	Cored concrete masonry; 2" air cavity; see notes 3, 19, 27, 34, 40; facings: fire side only; see note 38	80 PSI	2 hr		1		1,20	2
W-10-M-17	$10\frac{1}{2}$"	Cored concrete masonry; see notes 3, 18, 27, 34, 40; facings: only side one; see note 38	80 PSI	5 hr		1		1,20	5
W-10-M-18	$10\frac{1}{2}$"	Cored concrete masonry; see notes 2, 19, 26, 33, 40; facings on fire side only; see note 38	80 PSI	2 hr 30 min		1		1,20	$2\frac{1}{2}$
W-10-M-19	$10\frac{1}{2}$"	Cored concrete masonry; see notes 2, 18, 26, 33, 40; facings on one side; see note 38	80 PSI	6 hr		1		1,20	6
W-10-M-20	$10\frac{1}{2}$"	Cored concrete masonry; see notes 2, 19, 26, 33, 41; facings on fire side of wall only; see note 38	80 PSI	2 hr		1		1,20	2
W-10-M-21	$10\frac{1}{2}$"	Cored concrete masonry; see notes 2, 18, 26, 33, 41; facings on one side only; see note 38	80 PSI	5 hr		1		1,20	5
W-10-M-22	$10\frac{1}{2}$"	Cored concrete masonry (cavity type 2" air space); see notes 3, 19, 27, 34, 42; facing on fire side only; see note 38	80 PSI	1 hr 45 min		1		1,20	$1\frac{3}{4}$
W-10-M-23	$10\frac{1}{2}$"	Cored concrete masonry (cavity type 2" air space); see notes 3, 18, 27, 34, 42; facings on one side only; see note 38	80 PSI	1 hr 15 min		1		1,20	$1\frac{1}{4}$
W-10-M-24	$10\frac{1}{2}$"	Cored concrete masonry (cavity type 2" air space); see notes 3, 19, 27, 34, 41; facings on fire side only; see note 38	80 PSI	2 hr		1		1,20	2
W-10-M-25	$10\frac{1}{2}$"	Cored concrete masonry (cavity type 2" air space); see notes 3, 18, 27, 34, 41; facings on one side only; see note 38	80 PSI	4 hr		1		1,20	4
W-10-M-26	$10\frac{5}{8}$"	Core: 8", 40% solid tile plus 2" furring tile; $\frac{5}{8}$" sanded gypsum plaster between tile types; facings on both sides $\frac{3}{4}$" portland cement plaster or stucco	80 PSI	5 hr		1		1,20	5
W-10-M-27	$10\frac{5}{8}$"	Core: 8", 40% solid tile plus 2" furring tile; $\frac{5}{8}$" sanded gypsum plaster between tile types; facings on one side $\frac{3}{4}$" portland cement plaster or stucco	80 PSI	3 hr 30 min		1		1,20	$3\frac{1}{2}$
W-11-M-28	11"	Cored concrete masonry; see notes 3, 18, 27, 34, 40; facings on both sides; see note 38	80 PSI	6 hr		1		1,20	6
W-11-M-29	11"	Cored concrete masonry; see notes 2, 18, 26, 33, 40; facings on both sides; see note 38	80 PSI	7 hr		1		1,20	7
W-11-M-30	11"	Cored concrete masonry; see notes 2, 18, 26, 33, 41; facings on both sides of wall; see note 38	80 PSI	6 hr		1		1,20	6
W-11-M-31	11"	Cored concrete masonry (cavity type 2" air space); see notes 3, 18, 27, 34, 42; facings on both sides; see note 38	80 PSI	5 hr		1		1,20	5
W-11-M-32	11"	Cored concrete masonry (cavity type 2" air space); see notes 3, 18, 27, 34, 41; facings on both sides; see note 38	80 PSI	5 hr		1		1,20	5
W-11-M-33	11"	2 layers brick ($4\frac{1}{2}$" fletton 2428 PSI) 2" air space; galv. ties — 18" O.C. — horizontal; 3' O.C. — vertical	3 ton/ft	6 hr			7	23,24	6

NOTES: Table 1.1.5
1. Tested at NBS under ASA Spec. A2-1934.
2. One unit in wall thickness.
3. Two units in wall thickness.
4. Two or three units in wall thickness.

5. Two cells in wall thickness.
6. Three or four cells in wall thickness.
7. Four or five cells in wall thickness.
8. Five or six cells in wall thickness.
9. Minimum % of solid materials in units: 40%.
10. Minimum % of solid materials in units: 43%.
11. Minimum % of solid materials in units: 46%.
12. Minimum % of solid materials in units: 48%.
13. Minimum % of solid materials in units: 49%.
14. Minimum % of solid materials in units: 45%.
15. Minimum % of solid materials in units: 51%.
16. Minimum % of solid materials in units: 53%.
17. Not less than $^5/_8$" thickness of 1:3 sanded gypsum plaster.
18. Noncombustible or no members framed into wall.
19. Combustible members framed into wall.
20. Load: 80 PSI for gross cross-sectional area.
21. Portland cement — lime mortar.
22. Failure mode — thermal.
23. British test.
24. Passed all criteria.
25. Failed by sudden collapse with no preceding signs of impending failure.
26. One cell in wall thickness.
27. Two cells in wall thickness.
28. Three cells in wall thickness.
29. Minimum % of solid material in concrete units: 52%.
30. Minimum % of solid material in concrete units: 54%.
31. Minimum % of solid material in concrete units: 55%.
32. Minimum % of solid material in concrete units: 57%.
33. Minimum % of solid material in concrete units: 60%.
34. Minimum % of solid material in concrete units: 62%.
35. Minimum % of solid material in concrete units: 65%.
36. Minimum % of solid material in concrete units: 70%.
37. Minimum % of solid material in concrete units: 76%.
38. Not less than $^1/_2$" of 1:3 sanded gypsum plaster.
39. Three units in wall thickness.
40. Concrete units made with expanded slag or pumice aggregates.
41. Concrete units made with expanded burned clay or shale, crushed limestone, air cooled slag, or cinders.
42. Concrete units made with calcareous sand and gravel.
Coarse aggregate, 60% or more calcite and dolomite.

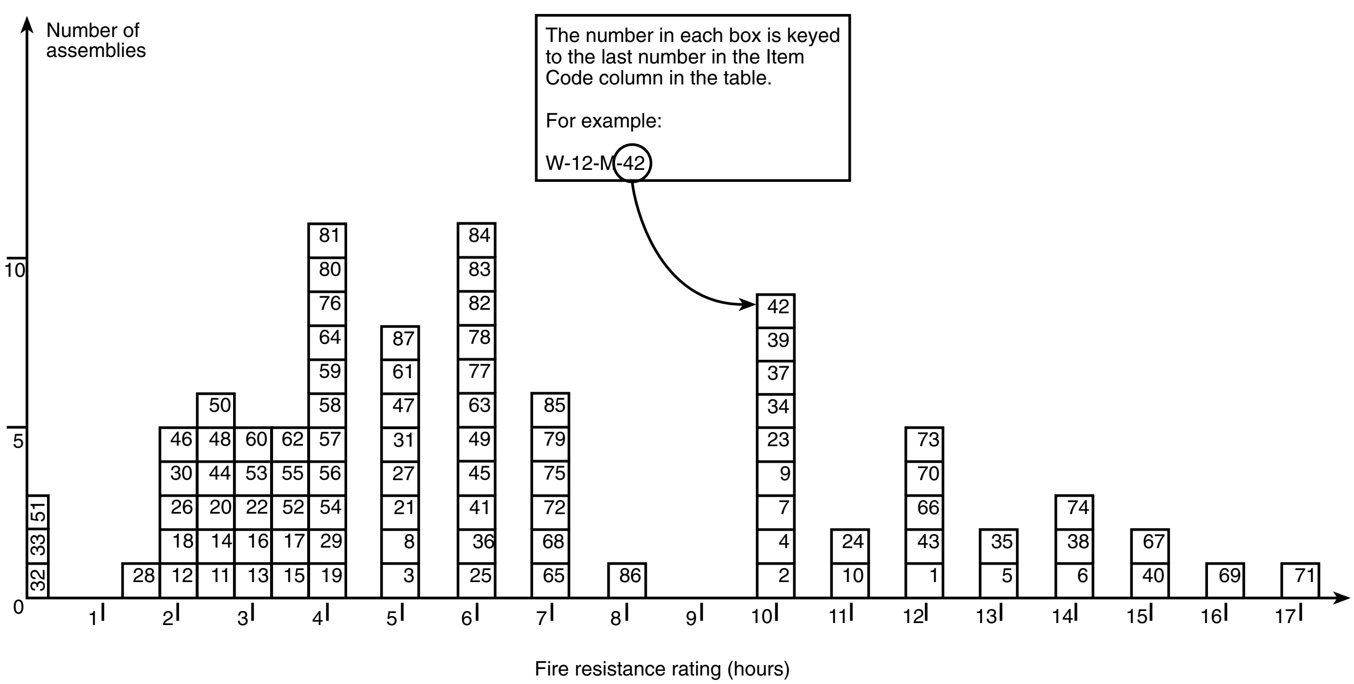


Figure 1.1.6 Walls—Masonry 12" to less than 14" thick

Table 1.1.6 Walls — Masonry
12" (300 mm) to less than 14" (350 mm) thick

Item Code	Thickness	Construction Details	Performance: Load	Performance: Time	Reference Number: Pre-BMS-92	Reference Number: BMS-92	Reference Number: Post-BMS-92	Notes	Rec Hours
W-12-M-1	12"	Core: Solid clay or shale brick; No facings	n/a	12 hr		1		1	12
W-12-M-2	12"	Core: Solid clay or shale brick; No facings	160 PSI	10 hr		1		1,44	10
W-12-M-3	12"	Core: Hollow rolok of clay or shale; No facings	160 PSI	5 hr		1		1,44	5
W-12-M-4	12"	Core: Hollow rolok bak of clay or shale; No facings	160 PSI	10 hr		1		1,44	10
W-12-M-5	12"	Core: concrete brick; No facings	160 PSI	13 hr		1		1,44	13
W-12-M-6	12"	Core: sand-lime brick; No facings	n/a	14 hr		1		1	14
W-12-M-7	12"	Core: sand-lime brick; No facings	160 PSI	10 hr		1		1,44	10
W-12-M-8	12"	Cored clay or shale bricks; units in wall thickness: 1; cells in wall thickness: 2; minimum % solids: 70; no facings	120 PSI	5 hr		1		1,45	5
W-12-M-9	12"	Cored clay or shale bricks; units in wall thickness: 3; cells in wall thickness: 3; minimum % solids: 87; no facings	160 PSI	10 hr		1		1,44	10
W-12-M-10	12"	Cored clay or shale bricks; units in wall thickness: 3; cells in wall thickness: 3; minimum % solids: 87; no facings	n/a	11 hr		1		1	11
W-12-M-11	12"	Core: clay or shale structural tile; see notes 2, 6, 9, 18; no facings	80 PSI	$2^1/_2$ hr		1		1,20	$2^1/_2$
W-12-M-12	12"	Core: clay or shale structural tile; see notes 2, 4, 9, 19; no facings	80 PSI	2 hr		1		1,20	2
W-12-M-13	12"	Core: clay or shale structural tile; see notes 2, 6, 14, 19; no facings	80 PSI	3 hr		1		1,20	3
W-12-M-14	12"	Core: clay or shale structural tile; see notes 2, 6, 14, 18; no facings	80 PSI	$2^1/_2$ hr		1		1,20	$2^1/_2$
W-12-M-15	12"	Core: clay or shale structural tile; see notes 2, 4, 13, 18; no facings	80 PSI	$3^1/_2$ hr		1		1,20	$3^1/_2$
W-12-M-16	12"	Core: clay or shale structural tile; see notes 2, 4, 13, 19; no facings	80 PSI	3 hr		1		1,20	3
W-12-M-17	12"	Core: clay or shale structural tile; see notes 3, 6, 9, 18; no facings	80 PSI	$3^1/_2$ hr		1		1,20	$3^1/_2$
W-12-M-18	12"	Core: clay or shale structural tile; see notes 3, 6, 9, 19; no facings	80 PSI	2 hr		1		1,20	2
W-12-M-19	12"	Core: clay or shale structural tile; see notes 3, 6, 14, 18; no facings	80 PSI	4 hr		1		1,20	4
W-12-M-20	12"	Core: clay or shale structural tile; see notes 3, 6, 14, 19; no facings	80 PSI	$2^1/_2$ hr		1		1,20	$2^1/_2$
W-12-M-21	12"	Core: clay or shale structural tile; see notes 3, 6, 16, 18; no facings	80 PSI	5 hr		1		1,20	5
W-12-M-22	12"	Core: clay or shale structural tile; See notes 3, 6, 16, 19; no facings	80 PSI	3 hr		1		1,20	3
W-12-M-23	12"	Core: 8", 70% solid clay or shale structural tile; 4" brick facing on one side	80 PSI	10 hr		1		1,20	10
W-12-M-24	12"	Core: 8", 70% solid clay or shale structural tile; 4" brick facing on one side	n/a	11 hr		1		1	11
W-12-M-25	12"	Core: 8", 40% solid clay or shale structural tile; 4" brick facing on one side	80 PSI	6 hr		1		1,20	6
W-12-M-26	12"	Cored concrete masonry; See notes 1, 9, 15, 16, 20; No facings	80 PSI	2 hr		1		1,20	2
W-12-M-27	12"	Cored concrete masonry; See notes 2, 18, 26, 34, 41; no facings	80 PSI	5 hr		1		1,20	5
W-12-M-28	12"	Cored concrete masonry; See notes 2, 19, 26, 31, 41; no facings	80 PSI	$1^1/_2$ hr		1		1,20	$1^1/_2$

Table 1.1.6 Walls — Masonry
12" (300 mm) to less than 14" (350 mm) thick

Item Code	Thickness	Construction Details	Performance: Load	Performance: Time	Reference Number: Pre-BMS-92	Reference Number: BMS-92	Reference Number: Post-BMS-92	Notes	Rec Hours
W-12-M-29	12"	Cored concrete masonry; See notes 2, 18, 26, 31, 41; no facings	80 PSI	4 hr		1		1,20	4
W-12-M-30	12"	Cored concrete masonry; See notes 3, 19, 27, 31, 43; no facings	80 PSI	2 hr		1		1,20	2
W-12-M-31	12"	Cored concrete masonry; See notes 3, 18, 27, 31, 43; no facings	80 PSI	5 hr		1		1,20	5
W-12-M-32	12"	Cored concrete masonry; See notes 2, 19, 26, 32, 43; no facings	80 PSI	25 min		1		1,20	$^1/_3$
W-12-M-33	12"	Cored concrete masonry; See notes 2, 18, 26, 32, 43; no facings	80 PSI	25 min		1		1,20	$^1/_3$
W-12-M-34	$12^1/_2$"	Core: solid clay or shale brick; $^1/_2$" of 1:3 sanded gypsum plaster facing on one side	160 PSI	10 hr		1		1,44	10
W-12-M-35	$12^1/_2$"	Core: solid clay or shale brick; $^1/_2$" of 1:3 sanded gypsum plaster facing on one side	n/a	13 hr		1		1	13
W-12-M-36	$12^1/_2$"	Core: Hollow rolok of clay or shale; $^1/_2$" of 1:3 sanded gypsum plaster facing on one side	160 PSI	6 hr		1		1,44	6
W-12-M-37	$12^1/_2$"	Core: Hollow rolok bak of clay or shale; $^1/_2$" of 1:3 sanded gypsum plaster facing on one side	160 PSI	10 hr		1		1,44	10
W-12-M-38	$12^1/_2$"	Core: concrete; $^1/_2$" of 1:3 sanded gypsum plaster facing on one side	160 PSI	14 hr		1		1,44	14
W-12-M-39	$12^1/_2$"	Core: sand-lime brick; $^1/_2$" of 1:3 sanded gypsum plaster facing on one side	160 PSI	10 hr		1		1,44	10
W-12-M-40	$12^1/_2$"	Core: sand-lime brick; $^1/_2$" of 1:3 sanded gypsum plaster facing on one side	n/a	15 hr		1		1	15
W-12-M-41	$12^1/_2$"	Units in wall thickness: 1; cells in wall thickness: 2; minimum % solids: 70; cored clay or shale brick; $^1/_2$" of 1:3 sanded gypsum plaster facing on one side	120 PSI	6 hr		1		1,45	6
W-12-M-42	$12^1/_2$"	Cored clay or shale bricks; units in wall thickness: 3; cells in wall thickness: 3; minimum % solids: 87; $^1/_2$" of 1:3 sanded gypsum plaster facings on one side	160 PSI	10 hr		1		1,44	10
W-12-M-43	$12^1/_2$"	Cored clay or shale bricks; units in wall thickness: 3; cells in wall thickness: 3; minimum % solids: 87; $^1/_2$" of 1:3 sanded gypsum plaster facing on one side	n/a	12 hr		1		1	12
W-12-M-44	$12^1/_2$"	Cored concrete masonry; See notes 2, 19, 26, 34, 41; facing on fire side only - See note 38	80 PSI	$2^1/_2$ hr		1		1,20	$2^1/_2$
W-12-M-45	$12^1/_2$"	Cored concrete masonry; See notes 2, 18, 26, 34, 39, 41; facing on one side only - See note 38	80 PSI	6 hr		1		1,20	6
W-12-M-46	$12^1/_2$"	Cored concrete masonry; See notes 2, 19, 26, 34, 41; facing on fire side only - See note 38	80 PSI	2 hr		1		1,20	2
W-12-M-47	$12^1/_2$"	Cored concrete masonry;See notes 2, 18, 26, 31, 41; facings one side of wall only - See note 38	80 PSI	5 hr		1		1,20	5
W-12-M-48	$12^1/_2$"	Cored concrete masonry; See notes 3, 19, 27, 31, 43; facing on fire side only - See note 38	80 PSI	$2^1/_2$ hr		1		1,20	$2^1/_2$
W-12-M-49	$12^1/_2$"	Cored concrete masonry; See notes 3, 18, 27, 31, 43; facing one side only - See note 38	80 PSI	6 hr		1		1,20	6
W-12-M-50	$12^1/_2$"	Cored concrete masonry; See notes 2, 19, 26, 32, 43; facing on fire side only - See note 38	80 PSI	$2^1/_2$ hr		1		1,20	$2^1/_2$
W-12-M-51	$12^1/_2$"	Cored concrete masonry; See notes 2, 18, 26, 32, 43; facing one side only - See note 38	80 PSI	25 min		1		1,20	$^1/_3$
W-12-M-52	$12^5/_8$"	Clay or shale structural tile; See notes 2, 6, 9, 18; facing: side 1 - See note 17; side 2 none	80 PSI	$3^1/_2$ hr		1		1,20	$3^1/_2$
W-12-M-53	$12^5/_8$"	Clay or shale structural tile; See notes 2, 6, 9, 19; facing on fire side only - See note 17	80 PSI	3 hr		1		1,20	3
W-12-M-54	$12^5/_8$"	Clay or shale structural tile; See notes 2, 6, 14, 19; facing: side 1 - See note 17; side 2 - none	80 PSI	4 hr		1		1,20	4
W-12-M-55	$12^5/_8$"	Clay or shale structural tile; See notes 2, 6, 14, 18; facings on exposed side only - See note 17	80 PSI	$3^1/_2$ hr		1		1,20	$3^1/_2$

Table 1.1.6 Walls — Masonry
12" (300 mm) to less than 14" (350 mm) thick

Item Code	Thickness	Construction Details	Performance Load	Performance Time	Reference Number Pre-BMS-92	Reference Number BMS-92	Reference Number Post-BMS-92	Notes	Rec Hours
W-12-M-56	$12^5/_8$"	Clay or shale structural tile; See notes 2, 4, 13, 18; facings: side 1 - See note 17; side 2 - none	80 PSI	4 hr		1		1,20	4
W-12-M-57	$12^5/_8$"	Clay or shale structural tile; See notes 1, 4, 13, 19; facings on fire side only; See note 17	80 PSI	4 hr		1		1,20	4
W-12-M-58	$12^5/_8$"	Clay or shale structural tile; See notes 3, 6, 9, 18; facings: side 1 - See note 17; side 2 - none	80 PSI	4 hr		1		1,20	4
W-12-M-59	$12^5/_8$"	Clay or shale structural tile; See notes 3, 6, 9, 19; facings on fire side only - See note 17	80 PSI	3 hr		1		1,20	3
W-12-M-60	$12^5/_8$"	Clay or shale structural tile; See notes 3, 6, 14, 18; facings: side 1 - See note 17; side 2 - none	80 PSI	5 hr		1		1,20	5
W-12-M-61	$12^5/_8$"	Clay or shale structural tile; See notes 3, 6, 14, 19; facings: fire side only; See note 17	80 PSI	3 hr 30 min		1		1,20	$3^1/_2$
W-12-M-62	$12^5/_8$	Clay or shale structural tile; See notes 3, 6, 16, 18; Facings: Side 1 - See note 17; side 2 - none	80 PSI	6 hr		1		1,20	6
W-12-M-63	$12^5/_8$"	Clay or shale structural tile; See notes 3, 6, 16, 19; Facing fire side only; See note 17	80 PSI	4 hr		1		1,20	4
W-12-M-64	$12^5/_8$"	Core: 8", 40% solid clay or shale structural tile; Facings 4" brick plus $^5/_8$" of 1:3 sanded gypsum plaster on one side	80 PSI	7 hr		1		1,20	7
W-13-M-65	13"	Core:solid clay or shale brick; $^1/_2$" of 1:3 sanded gypsum plaster facing on both sides	160 PSI	12 hr		1		1,44	12
W-13-M-66	13"	Core: solid clay or shale brick; $^1/_2$" of 1:3 sanded gypsum plaster facing on both sides	n/a	15 hr		1		1,20	15
W-13-M-67	13"	Core: solid clay or shale brick; $^1/_2$" of 1:3 sanded gypsum plaster facings on both sides	n/a	15 hr		1		1	15
W-13-M-68	13"	Core: Hollow rolok of clay or shale; $^1/_2$" of 1:3 sanded gypsum plaster facings on both sides	80 PSI	7 hr		1		1,20	7
W-13-M-69	13"	Core: concrete brick; $^1/_2$" of 1:3 sanded gypsum plaster facings on both sides	160 PSI	16 hr		1		1,44	16
W-13-M-70	13"	Core: sand-lime brick; $^1/_2$" of 1:3 sanded gypsum plaster facings on both sides	160 PSI	12 hr		1		1,44	12
W-13-M-71	13"	Core: sand-lime brick; $^1/_2$" of 1:3 sanded gypsum plaster facings on both sides	n/a	17 hr		1		1	17
W-13-M-72	13"	Cored clay or shale bricks; units in wall thickness: 1; cells in wall thickness: 2; minimum % solids: 70; $^1/_2$" of 1:3 sanded gypsum plaster facings on both sides	120 PSI	7 hr		1		1,45	7
W-13-M-73	13"	Cored clay or shale bricks; units in wall thickness: 3; cells in wall thickness: 3; minimum % solids: 87; $^1/_2$" of 1:3 sanded gypsum plaster facings on both sides	160 PSI	12 hr		1		1,44	12
W-13-M-74	13"	Cored clay or shale bricks; units in wall thickness: 3; cells in wall thickness: 2; minimum % solids: 87; $^1/_2$" of 1:3 sanded gypsum plaster facings on both sides	n/a	14 hr		1		1	14
W-13-M-75	13"	Cored concrete masonry; See notes 18, 23, 28, 39, 41; no facings	80 PSI	7 hr		1		1,20	7
W-13-M-76	13"	Cored concrete masonry; See notes 19, 23, 28, 39, 41; no facings	80 PSI	4 hr		1		1,20	4
W-13-M-77	13"	Cored concrete masonry; See notes 3, 18, 27, 31, 43; facings on both sides; See note 38	80 PSI	6 hr		1		1,20	6
W-13-M-78	13"	Cored concrete masonry; See notes 2, 18, 26, 31, 41; facings on both sides; See note 38	80 PSI	6 hr		1		1,20	6
W-13-M-79	13"	Cored concrete masonry; See notes 2, 18, 26, 34, 41; facings on both sides of wall; See note 38	80 PSI	7 hr		1		1,20	7
W-13-M-80	$13^1/_4$"	Core: clay or shale structural tile: See notes 2, 6, 9, 18; facings: See note 17 for both sides	80 PSI	4 hr		1		1,20	4
W-13-M-81	$13^1/_4$"	Core: clay or shale structural tile; See notes 2, 6, 14, 19; facings: See note 17 for both sides	80 PSI	4 hr		1		1,20	4

Table 1.1.6 Walls — Masonry
12" (300 mm) to less than 14" (350 mm) thick

Item Code	Thickness	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
W-13-M-82	13 1/4"	Core: clay or shale structural tile; See notes 2, 4, 13, 18; facings: See note 17 for both sides	80 PSI	6 hr		1		1,20	6
W-13-M-83	13 1/4"	Core: clay or shale structural tile; See notes 3, 6, 9, 18; facings: See note 17 for both sides	80 PSI	6 hr		1		1,20	6
W-13-M-84	13 1/4"	Core: clay or shale structural tile; See notes 3, 6, 14, 18; facings: See note 17 for both sides	80 PSI	6 hr		1		1,20	6
W-13-M-85	13 1/4"	Core: clay or shale structural tile; See notes 3, 6, 16, 18; facings: See note 17 for both sides	80 PSI	7 hr		1		1,20	7
W-13-M-86	13 1/2"	Cored concrete masonry; See notes 18, 23, 28, 39, 41; facing on one side only; See note 38	80 PSI	8 hr		1		1,20	8
W-13-M-87	13 1/2"	Cored concrete masonry; See notes 19, 23, 28, 39, 41; facing on fire side only; See note 38	80 PSI	5 hr		1		1,20	5

NOTES: Table 1.1.6
1. Tested at NBS under ASA Spec. A2-1934.
2. One unit in wall thickness.
3. Two units in wall thickness.
4. Two or three units in wall thickness.
5. Two cells in wall thickness.
6. Three or four cells in wall thickness.
7. Four or five cells in wall thickness.
8. Five or six cells in wall thickness.
9. Minimum % of solid materials in units: 40%.
10. Minimum % of solid materials in units: 43%.
11. Minimum % of solid materials in units: 46%.
12. Minimum % of solid materials in units: 48%.
13. Minimum % of solid materials in units: 49%.
14. Minimum % of solid materials in units: 45%.
15. Minimum % of solid materials in units: 51%.
16. Minimum % of solid materials in units: 53%.
17. Not less than 5/8 thickness of 1:3 sanded gypsum plaster.
18. Noncombustible or no members framed into wall.
19. Combustible members framed into wall.
20. Load: 80 PSI for gross area.
21. Portland cement — lime mortar.
22. Failure mode — thermal.
23. British test.
24. Passed all criteria.
25. Failed by sudden collapse with no preceding signs of impending failure.
26. One cell in wall thickness.
27. Two cells in wall thickness.
28. Three cells in wall thickness.
29. Minimum % of solid material in concrete units: 52%.
30. Minimum % of solid material in concrete units: 54%.
31. Minimum % of solid material in concrete units: 55%.
32. Minimum % of solid material in concrete units: 57%.
33. Minimum % of solid material in concrete units: 60%.
34. Minimum % of solid material in concrete units: 62%.
35. Minimum % of solid material in concrete units: 65%.
36. Minimum % of solid material in concrete units: 70%.
37. Minimum % of solid material in concrete units: 76%.
38. Not less than 1/2" of 1:3 sanded gypsum plaster.
39. Three units in wall thickness.
40. Concrete units made with expanded slag or pumice aggregates.
41. Concrete units made with expanded burned clay or shale, crushed limestone, air cooled slag, or cinders.
42. Concrete units made with calcareous sand and gravel. Coarse aggregate, 60% or more calcite and dolomite.
43. Concrete units made with siliceous sand and gravel. 90% or more quartz, chert, or flint.
44. Load: 160 PSI of gross wall cross-sectional area.
45. Load: 120 PSI of gross wall cross-sectional area.

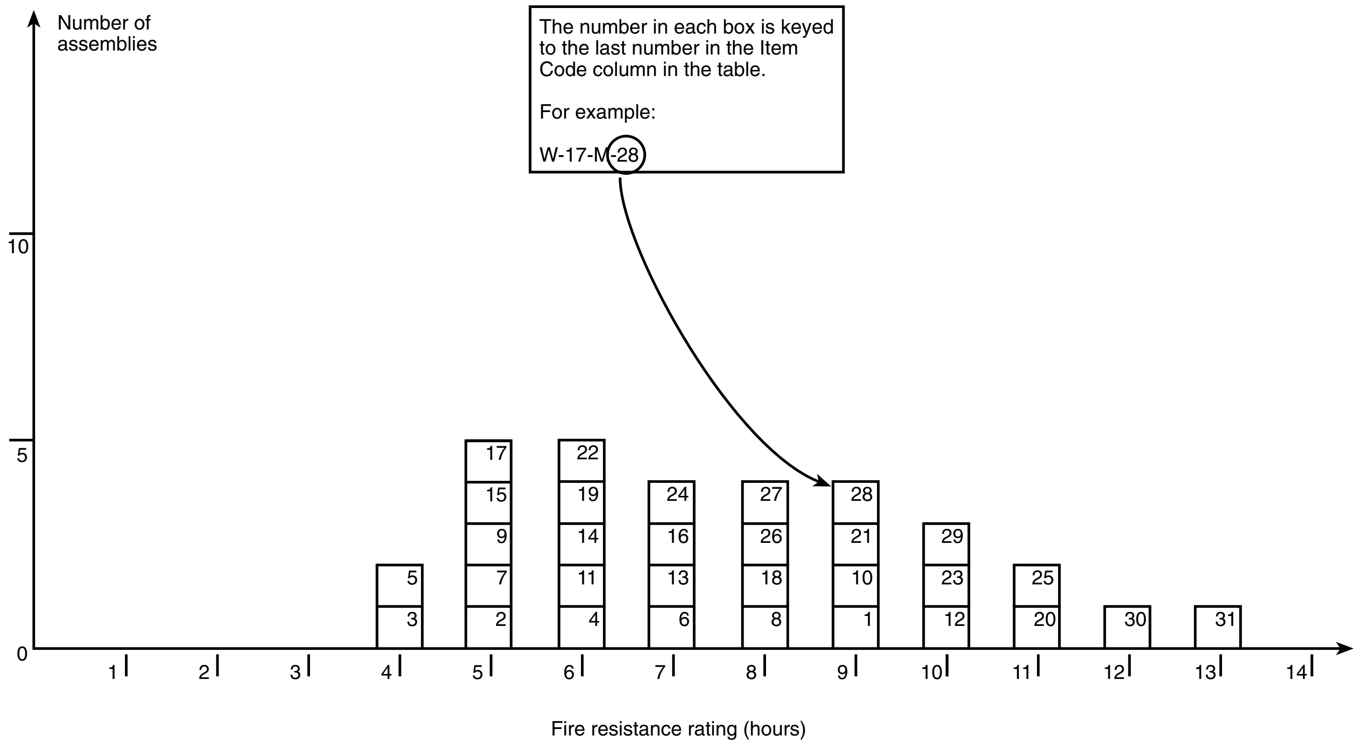


Figure 1.1.7 Walls—Masonry 14" or more thick

Table 1.1.7 Masonry Walls 14" (350 mm) or more thick

Item Code	Thickness	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
W-14-M-1	14"	Core: Cored concrete masonry; See notes 18, 28, 35, 39, 41; Facings: both sides, see note 38	80 PSI	9 hr		1		1,20	9
W-16-M-2	16"	Core: Clay or shale structural tile; See notes 4, 7, 9, 19; no facings	80 PSI	5 hr		1		1,20	5
W-16-M-3	16"	Core: Clay or shale structural tile; See notes 4, 7, 9, 19; No facings	80 PSI	4 hr		1		1,20	4
W-16-M-4	16"	Core: Clay or shale structural tile; See notes 4, 7, 10, 18; No facings	80 PSI	6 hr		1		1,20	6
W-16-M-5	16"	Core: Clay or shale structural tile; See notes 4, 7, 10, 19; No facings	80 PSI	4 hr		1		1,20	4
W-16-M-6	16"	Core: Clay or shale structural tile; See notes 4, 7, 11, 18; No facings	80 PSI	7 hr		1		1,20	7
W-16-M-7	16"	Core: Clay or shale structural tile; See notes 4, 7, 11, 19; No facings	80 PSI	5 hr		1		1,20	5
W-16-M-8	16"	Core: Clay or shale structural tile; See notes 4, 8, 13, 18; No facings	80 PSI	8 hr		1		1,20	8
W-16-M-9	16"	Core: Clay or shale structural tile; See notes 4, 8, 13, 19; No facings	80 PSI	5 hr		1		1,20	5
W-16-M-10	16"	Clay or shale structural tile core; See notes 4, 8, 15, 18; No Facings	80 PSI	9 hr		1		1,20	9
W-16-M-11	16"	Clay or shale structural tile core; See notes 3, 7, 14, 18; No facings	80 PSI	6 hr		1		1,20	6
W-16-M-12	16"	Clay or shale structural tile core; See notes 4, 8, 16, 18; No facings	80 PSI	10 hr		1		1,20	10
W-16-M-13	16"	Clay or shale structural tile core; See notes 4, 6, 16, 19; No facings	80 PSI	7 hr		1		1,20	7

Table 1.1.7 Masonry Walls 14" (350 mm) or more thick

Item Code	Thickness	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
W-16-M-14	16 5/8"	Clay or shale structural tile core; See notes 4, 7, 9, 18; Facings: Side 1 - See note 17; Side 2 - None	80 PSI	6 hr		1		1,20	6
W-16-M-15	16 5/8"	Clay or shale structural tile core; See notes 4, 7, 9, 19; Facings: Fire side only; See note 17	80 PSI	5 hr		1		1,20	5
W-16-M-16	16 5/8"	Clay or shale structural tile core; See notes 4, 7, 10, 18; Facings: Side 1 - See note 17; Side 2 - None	80 PSI	7 hr		1		1,20	7
W-16-M-17	16 5/8"	Clay or shale structural tile core; See notes 4, 7, 10, 19; Facings: Fire side only; See note 17	80 PSI	5 hr		1		1,20	5
W-16-M-18	16 5/8"	Clay or shale structural tile core; See notes 4, 7, 11, 18; Facings: Side 1 - See note 17; Side 2 - None	80 PSI	8 hr		1		1,20	8
W-16-M-19	16 5/8"	Clay or shale structural tile core; See notes 4, 7, 11, 19; Facings: Fire side only; See note 17	80 PSI	6 hr		1		1,20	6
W-16-M-20	16 5/8"	Clay or shale structural tile core; See notes 4, 8, 13, 18; Facings: Side 1 - See note 17; side 2 same as side 1	80 PSI	11 hr		1		1,20	11
W-16-M-21	16 5/8"	Clay or shale structural tile core; See notes 4, 8, 13, 18; Facings: Side 1 - See note 17; Side 2 - None	80 PSI	9 hr		1		1,20	9
W-16-M-22	16 5/8"	Clay or shale structural tile core; See notes 4, 8, 13, 19; Facings: Fire side only; See note 17	80 PSI	6 hr		1		1,20	6
W-16-M-23	16 5/8"	Clay or shale structural tile core; See notes 4, 8, 15, 18; Facings: Side 1 - See note 17; Side 2 - None	80 PSI	10 hr		1		1,20	10
W-16-M-24	16 5/8"	Clay or shale structural tile core; See notes 4, 8, 15, 19; Facings: Fire side only; See note 17	80 PSI	7 hr		1		1,20	7
W-16-M-25	16 5/8"	Clay or shale structural tile core; See notes 4, 6, 16, 18; Facings: Side 1 - See note 17; Side 2 - none	80 PSI	11 hr		1		1,20	11
W-16-M-26	16 5/8"	Clay or shale structural tile core; See notes 4, 6, 16, 19; Facings: Fire side only; See note 17	80 PSI	8 hr		1		1,20	8
W-17-M-27	17 1/4"	Clay or shale structural tile core; See notes 4, 7, 9, 18; Facings: Side 1 & 2 - See note 17	80 PSI	8 hr		1		1,20	8
W-17-M-28	17 1/4"	Clay or shale structural tile core; See notes 4, 7, 10, 18; Facings: Side 1 & 2 - See note 17	80 PSI	9 hr		1		1,20	9
W-17-M-29	17 1/4"	Clay or shale structural tile core; See notes 4, 7, 11, 18; Facings: Side 1 & 2 - See note 17	80 PSI	10 hr		1		1,20	10
W-17-M-30	17 1/4"	Clay or shale structural tile core; See notes 4, 8, 15, 18; Facings: Side 1 & 2 - See note 17	80 PSI	12 hr		1		1,20	12
W-17-M-31	17 1/4"	Clay or shale structural tile core; See notes 4, 6, 16, 18; Facings: Side 1 & 2 : See note 17	80 PSI	13 hr		1		1,20	13

NOTES: Table 1.1.7
1. Tested at NBS under ASA Spec. A2-1934.
2. One unit in wall thickness.
3. Two units in wall thickness.
4. Two or three units in wall thickness.
5. Two cells in wall thickness.
6. Three or four cells in wall thickness.
7. Four or five cells in wall thickness.
8. Five or six cells in wall thickness.
9. Minimum % of solid materials in units: 40%.
10. Minimum % of solid materials in units: 43%.
11. Minimum % of solid materials in units: 46%.
12. Minimum % of solid materials in units: 48%.
13. Minimum % of solid materials in units: 49%.
14. Minimum % of solid materials in units: 45%.
15. Minimum % of solid materials in units: 51%.
16. Minimum % of solid materials in units: 53%.
17. Not less than 5/8" thickness of 1:3 sanded gypsum plaster.
18. Noncombustible or no members framed into wall.
19. Combustible members framed into wall.
20. Load: 80 PSI for gross area.
21. Portland cement — lime mortar.
22. Failure mode — thermal.

23. British test.
24. Passed all criteria.
25. Failed by sudden collapse with no preceding signs of impending failure.
26. One cell in wall thickness.
27. Two cells in wall thickness.
28. Three cells in wall thickness.
29. Minimum % of solid material in concrete units: 52%.
30. Minimum % of solid material in concrete units: 54%.
31. Minimum % of solid material in concrete units: 55%.
32. Minimum % of solid material in concrete units: 57%.
33. Minimum % of solid material in concrete units: 60%.
34. Minimum % of solid material in concrete units: 62%.
35. Minimum % of solid material in concrete units: 65%.
36. Minimum % of solid material in concrete units: 70%.
37. Minimum % of solid material in concrete units: 76%.
38. Not less than $^1/_2$" of 1:3 sanded gypsum plaster.
39. Three units in wall thickness.
40. Concrete units made with expanded slag or pumice aggregates.
41. Concrete units made with expanded burned clay or shale, crushed limestone, air cooled slag or cinders.
42. Concrete units made with calcareous sand and gravel. Coarse aggregate, 60% or more calcite and dolomite.
43. Concrete units made with siliceous sand and gravel. 90% or more quartz, chert, or flint.

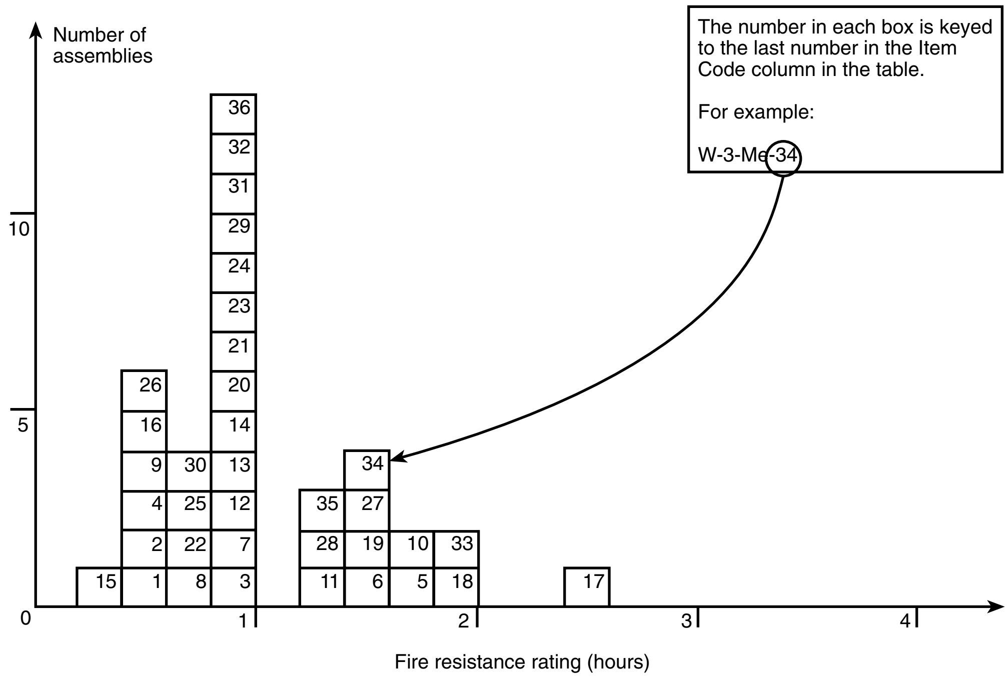


Figure 1.2.1 Walls—Metal Frame 0" to less than 4" thick

Table 1.2.1 Metal Frame Walls 0" (0 mm) to less than 4" (100 mm) thick

Item Code	Thickness	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
W-3-Me-1	3"	Core:Steel channels having 3 rows of 4" × $^1/_8$" staggered slots in web; Core filled with heat expanded vermiculite weighing 15 lb/ft^2 of wall area; Facings: Side 1 - 18 gauge steel, spot welded to core; Side 2 - Same as side 1	n/a	25 min		1			$^1/_3$
W-3-Me-2	3"	Core: Steel channels having 3 rows of 4" × $^1/_8$" staggered slots in web; Core filled with heat expanded vermiculite weighing 2 lb/ft^2 of wall area; facings: Side 1 and 2 - 18 gauge steel, spot welded to core	n/a	30 min		1			$^1/_2$
W-2-Me-3	2$^1/_2$"	Solid partition $^3/_8$" tension rods (vertical) 3' O.C. with metal lath; Scratch coat—cement/sand/lime plaster; float coats - cement/sand/lime plaster; finish coats - neat gypsum plaster	n/a	1 hr			7	1	1
W-2-Me-4	2"	Solid wall: steel channel per note 1, 2" thickness of 1:2, 1:3 portland cement on metal lath	n/a	30 min		1			$^1/_2$
W-2-Me-5	2"	Solid wall: steel channel per note 1, 2" thickness of neat gypsum plaster on metal lath	n/a	1 hr 45 min		1			1$^3/_4$
W-2-Me-6	2"	Solid wall: steel channel per note 1, 2" thickness of 1: $^1/_2$, 1: $^1/_2$ gypsum plaster on metal lath	n/a	1 hr 30 min		1			1$^1/_2$
W-2-Me-7	2"	Solid wall: steel channel per note 2, 2" thickness of 1:1, 1:1 gypsum plaster on metal lath	n/a	1 hr		1			1
W-2-Me-8	2"	Solid wall: steel channel per note 1, 2" thickness of 1:2, 1:2 gypsum plaster on metal lath	n/a	45 min		1			$^3/_4$
W-2-Me-9	2$^1/_4$"	Solid wall: steel channel per note 2, 2$^1/_4$" thickness of 1:2, 1:3 portland cement on metal lath	n/a	30 min		1			$^1/_2$
W-2-Me-10	2$^1/_4$"	Solid wall: steel channel per note 2, 2$^1/_4$" thickness of neat gypsum plaster on metal lath	n/a	2 hr		1			2
W-2-Me-11	2$^1/_4$"	Solid wall: steel channel per note 2, 2$^1/_4$" thickness of 1: $^1/_2$, 1: $^1/_2$ gypsum plaster on metal lath	n/a	1 hr 45 min		1			1$^3/_4$

Table 1.2.1 Metal Frame Walls 0" (0 mm) to less than 4" (100 mm) thick

Item Code	Thickness	Construction Details	Performance: Load	Performance: Time	Reference Number: Pre-BMS-92	Reference Number: BMS-92	Reference Number: Post-BMS-92	Notes	Rec Hours
W-2-Me-12	2 1/4"	Solid wall: steel channel per note 2, 2 1/4" thickness of 1:1, 1:1 gypsum plaster on metal lath	n/a	1 hr 15 min		1			1 1/4
W-2-Me-13	2 1/4"	Solid wall: steel channel per note 2, 2 1/4" thickness of 1:2, 1:2 gypsum plaster on metal lath	n/a	1 hr		1			1
W-2-Me-14	2 1/2"	Solid wall: steel channel per note 1, 2 1/2" thickness of 4.5:1:7, 4.5:1:7 portland cement, sawdust, and sand sprayed on wire mesh (See note 3 for wire mesh)	n/a	1 hr		1			1
W-2-Me-15	2 1/2"	Solid wall: steel channel per note 2, 2 1/2" thickness of 1:4, 1:4 portland cement spray on wire mesh (per note 3)	n/a	20 min		1			1/3
W-2-Me-16	2 1/2"	Solid wall: steel channel per note 2, 2 1/2" thickness of 1:2, 1:3 portland cement on metal lath	n/a	30 min		1			1/2
W-2-Me-17	2 1/2"	Solid wall: steel channel per note 2, 2 1/2" thickness of neat gypsum plaster on metal lath	n/a	2 hr 30 min		1			2 1/2
W-2-Me-18	2 1/2"	Solid wall: steel channel per note 2, 2 1/2" thickness of 1: 1/2, 1: 1/2 gypsum plaster on metal lath	n/a	2 hr		1			2
W-2-Me-19	2 1/2"	Solid wall: steel channel per note 2, 2 1/2" thickness of 1:1, 1:1 gypsum plaster on metal lath	n/a	1 hr 30 min		1			1 1/2
W-2-Me-20	2 1/2"	Solid wall: steel channel per note 2, 2 1/2" thickness of 1:2, 1:2 gypsum plaster on metal lath	n/a	1 hr		1			1
W-2-Me-21	2 1/2"	Solid wall: steel channel per note 2, 2 1/2" thickness of 1:2, 1:3 gypsum plaster on metal lath	n/a	1 hr		1			1
W-3-Me-22	3"	Core: steel channels per note 2, 1:2, 1:2 gypsum plaster on 3/4" soft asbestos lath, plaster thickness 2"	n/a	45 min		1			3/4
W-3-Me-23	3 1/2"	Solid wall: steel channel per note 2, 2 1/2" thickness of 1:2, 1:2 gypsum plaster on 3/4" asbestos lath	n/a	1 hr		1			1
W-3-Me-24	3 1/2"	Solid wall: steel channel per note 2, lath over and 1:2 1/2, 1:2 1/2 gypsum plaster on 1" magnesium oxysulfate wood fiberboard, plaster thickness 2 1/2"	n/a	1 hr		1			1
W-3-Me-25	3 1/2"	Core: steel studs, note 4; facings 3/4" thickness of 1:1/30:2, 1:1/30:3 portland cement and asbestos fiber plaster	n/a	45 min		1			3/4
W-3-Me-26	3 1/2"	Core: steel studs, note 4; facings: both sides 3/4" thickness of 1:2, 1:3 portland cement	n/a	30 min		1			1/2
W-3-Me-27	3 1/2"	Core: steel studs per note 4; facings: both sides 3/4" thickness of neat gypsum plaster	n/a	1 hr 30 min		1			1 1/2
W-3-Me-28	3 1/2"	Core: steel studs per note 4; facings: both sides 3/4" thickness of 1: 1/2, 1: 1/2 gypsum plaster	n/a	1 hr 15 min		1			1 1/4
W-3-Me-29	3 1/2"	Core: steel studs, note 4; facings: both sides 3/4" thickness of 1:2, 1:2 gypsum plaster	n/a	1 hr		1			1
W-3-Me-30	3 1/2"	Core: steel studs, note 4; facings: both sides 3/4" thickness of 1:2, 1:3 gypsum plaster	n/a	45 min		1			3/4
W-3-Me-31	3 3/4"	Core: steel studs, note 4; facings: both sides 7/8" thickness of 1:1/30:2,1:1/30:3 portland cement and asbestos fiber plaster	n/a	1 hr		1			1
W-3-Me-32	3 3/4"	Core: steel studs, note 4; facings: both sides 7/8" thickness of 1:2, 1:3 portland cement	n/a	45 min		1			3/4
W-3-Me-33	3 3/4"	Core: steel studs, note 4; facings: both sides 7/8" thickness of neat gypsum plaster	n/a	2 hr		1			2
W-3-Me-34	3 3/4"	Core: steel studs per note 4; facings: both sides 7/8" thickness of 1: 1/2, 1: 1/2 gypsum plaster	n/a	1 hr 30 min		1			1 1/2
W-3-Me-35	3 3/4"	Core: steel studs per note 4; facings: both sides 7/8" thickness of 1:2, 1:2 gypsum plaster	n/a	1 hr 15 min		1			1 1/4
W-3-Me-36	3 3/4"	Core: steel per note 4; facings: 7/8" thickness of 1:2, 1:3 gypsum plaster on both sides	n/a	1 hr		1			1

NOTES: Table 1.2.1
1. Failure mode — local temperature rise — back face.
2. 3/4" or 1" channel framing — hot-rolled or strip-steel channels.
3. Reinforcement is 4" square mesh of No. 6 wire welded at intersections (no channels).
4. Ratings are for any usual type of non-load-bearing metal framing providing 2" (or more) air space.

General Note:

The construction details of the wall assemblies are as complete as the source documentation will permit. Data on the method of attachment of facings and the gauge of steel studs was provided when known. The cross-sectional area of the steel stud can be computed, thereby permitting a reasoned estimate of actual loading conditions. For load-bearing assemblies, the maximum allowable stress for the steel studs has been provided in the table "Notes." More often, it is the thermal properties of the facing materials, rather than the specific gauge of the steel, that will determine the degree of fire resistance. This is particularly true for non-bearing wall assemblies.

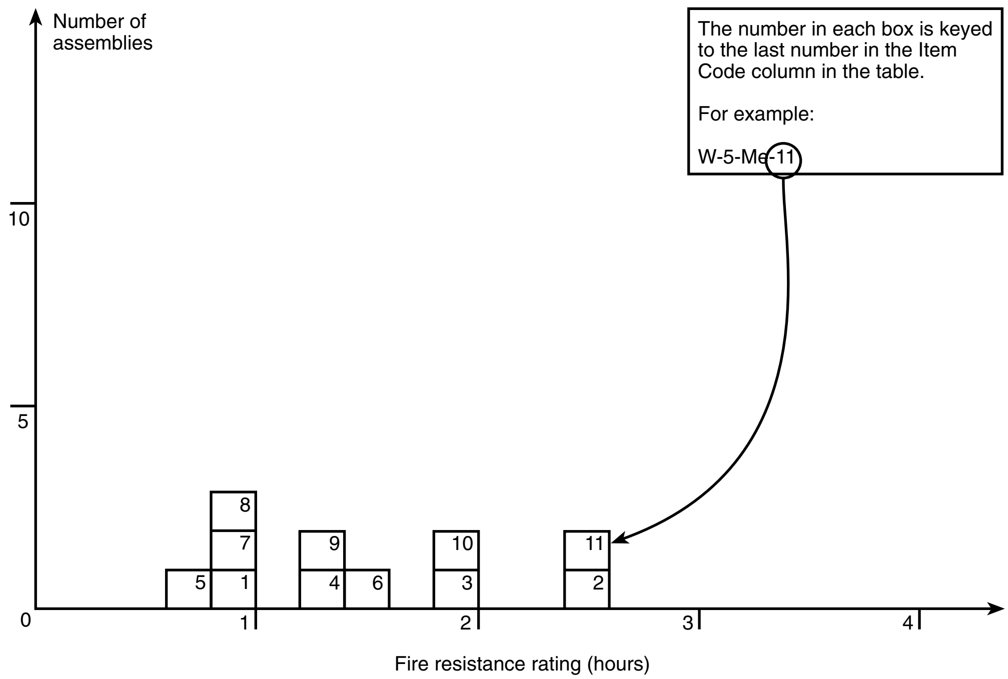


Figure 1.2.2 Walls—Metal Frame 4" to less than 6" thick

Table 1.2.2 Metal Frame Walls 4" (100 mm) to less than 6" (150 mm) thick

Item Code	Thickness	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
W-5-Me-1	5 1/2"	3" cavity with 16 ga. channel studs (3 1/2' O.C.) of 1/2" × 1/2" channel and 3" spacer; Metal lath on ribs with plaster (3 coats) 3/4" over face of lath; Plaster (each side) - scratch coat - cement/lime/sand with hair; float coat - cement/lime/sand; finish coat - neat gypsum	n/a	1 hr 11 min			7	1	1
W-4-Me-2	4"	Core: steel studs per note 2; Facings: both sides 1" thickness of neat gypsum plaster	n/a	2 1/2 hr		1			2 1/2
W-4-Me-3	4"	Core: steel studs per note 2; Facings: both sides 1" thickness of 1: 1/2, 1: 1/2 gypsum plaster	n/a	2 hr		1			2
W-4-Me-4	4"	Core: steel per note 2; Facings: both sides 1" thickness of 1:2, 1:3 gypsum plaster	n/a	1 1/4 hr		1			1 1/4
W-4-Me-5	4 1/2"	Core: lightweight steel stud 3" in depth; Facings: Both sides 3/4" thick sanded gypsum plaster, 1:2 scratch coat, 1:3 brown coat applied on metal lath	See note 4	45 min		1		5	3/4
W-4-Me-6	4 1/2"	Core: lightweight steel studs 3" in depth; Facings: both sides 3/4" thick neat gypsum plaster on metal lath	See note 4	1 hr 30 min		1		5	1 1/2

Table 1.2.2 Metal Frame Walls 4" (100 mm) to less than 6" (150 mm) thick

Item Code	Thickness	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
W-4-Me-7	$4^1/_2$"	Core: lightweight steel studs 3" in depth; Facings: both sides $^3/_4$" thick sanded gypsum plaster, 1:2 scratch and brown coats applied over metal lath	See note 4	1 hr		1		5	1
W-4-Me-8	$4^3/_4$"	Core: lightweight steel studs 3" in depth; Facings: both sides $^7/_8$" thick sanded gypsum plaster, 1:2 scratch, 1:3 brown, applied over metal lath	See note 4	1 hr		1		5	1
W-4-Me-9	$4^3/_4$"	Core: lightweight steel studs 3" in depth; Facings: both sides $^7/_8$" thick sanded gypsum plaster, 1:2 scratch and brown coats applied on metal lath	See note 4	1 hr 15 min		1		5	$1^1/_4$
W-5-Me-10	5"	Core: lightweight steel studs 3" in depth; Facings: both sides 1" thick neat gypsum plaster on metal lath	See note 4	2 hr		1		5	2
W-5-Me-11	5"	Core: lightweight steel studs 3" in depth; facings: both sides 1" thick neat gypsum plaster on metal lath	See note 4	2 hr 30 min		1		5,6	$2^1/_2$

NOTES: Table 1.2.2
1. Failure mode — local back face temperature rise.
2. Ratings are for any usual type of non-bearing metal framing providing a minimum 2" air space.
3. Facing materials secured to lightweight steel studs not less than 3" deep.
4. Rating based on loading to develop a maximum stress of 7270 PSI for net area of each stud.
5. Spacing of steel studs must be sufficient to develop adequate rigidity in the metal-lath or gypsum-plaster base.
6. As per note 4 but load/stud not to exceed 5120 PSI.

General Note:

The construction details of the wall assemblies are as complete as the source documentation will permit. Data on the method of attachment of facings and the gauge of steel studs was provided when known. The cross-sectional area of the steel stud can be computed, thereby permitting a reasoned estimate of actual loading conditions. For load-bearing assemblies, the maximum allowable stress for the steel studs has been provided in the table "Notes." More often, it is the thermal properties of the facing materials, rather than the specific gauge of the steel, that will determine the degree of fire resistance. This is particularly true for non-bearing wall assemblies.

Table 1.2.3 Metal Frame Walls 6" (150 mm) to less than 8" (200 mm) thick

Item Code	Thickness	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
W-6-Me-1	$6^5/_8$"	On one side of 1" magnesium oxysulfate wood fiber-board sheathing attached to steel studs (see notes 1 and 2), 1" air space, and 3 $^3/_4$" brick secured with metal ties to steel frame every fifth course; inside facing of $^7/_8$" 1:2 sanded gypsum plaster on metal lath secured directly to studs; plaster side exposed to fire	See note 2	$1^3/_4$ hr		1		1	$1^3/_4$
W-6-Me-2	$6^5/_8$"	On one side of 1" magnesium oxysulfate wood fiber-board sheathing attached to steel studs (Seeee notes 1 and 2), 1" air space, and 3 $^3/_4$" brick secured with metal ties to steel frame every fifth course; inside facing of $^7/_8$" 1:2 sanded gypsum plaster on metal lath secured directly to studs; brick face exposed to fire	See note 2	4 hr		1		1	4
W-6-Me-3	$6^5/_8$"	On one side of 1" magnesium oxysulfate wood fiber-board sheathing attached to steel studs (See notes 1 and 2), 1" air space, and 3 $^3/_4$" brick secured with metal ties to steel frame every fifth course; inside facing of $^7/_8$" vermiculite plaster on metal lath secured directly to studs; plaster side exposed to fire	See note 2	2 hr		1		1	2

NOTES: Table 1.2.3
1. Lightweight steel studs (minimum 3" deep) used. Stud spacing dependent on loading, but in each case, spacing is to be such that adequate rigidity is provided to the metal lath plaster base.
2. Load is such that stress developed in studs is not greater than 5120 PSI calculated from net stud area.

General Note:

The construction details of the wall assemblies are as complete as the source documentation will permit. Data on the method of attachment of facings and the gauge of steel studs was provided when known. The cross-sectional area of the steel stud can be computed, thereby permitting a reasoned estimate of actual loading conditions. For load-bearing assemblies, the maximum allowable stress for the steel studs has been provided in the table “Notes.” More often, it is the thermal properties of the facing materials, rather than the specific gauge of the steel, that will determine the degree of fire resistance. This is particularly true for non-bearing wall assemblies.

Table 1.2.4 Metal Frame Walls
8" (200 mm) to less than 10" (250 mm) thick

Item Code	Thickness	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
W-9-Me-1	9 1/16"	On one side of 1/2" wood fiberboard sheathing next to studs, 3/4" air space formed with 3/4" × 1 5/8" wood strips placed over the fiberboard and secured to the studs; paper backed wire lath nailed to strips 3 3/4" brick veneer held in place by filling a 3/4" space between the brick and paper backed lath with mortar; inside facing of 3/4" neat gypsum plaster on metal lath attached to 5/16" plywood strips secured to edges of steel studs; rated as combustible because of the sheathing; See notes 1 and 2; plaster exposed	See note 2	1 1/2 hr		1		1	1 1/2
W-9-Me-2	9 1/16"	Same as above with brick exposed	See note 2	4 hr		1		1	4
W-8-Me-3	8 1/2"	On one side of paper backed wire lath attached to studs and 3-3/4" brick veneer held in place by filling a 1" space between the brick and lath with mortar; inside facing of 1" paper-enclosed mineral wood blanket weighing .6 lb/ft^2 attached to studs, metal lath or paper backed wire lath laid over the blanket and attached to the studs, and 3/4" sanded gypsum plaster 1:2 for the scratch and 1:3 for the brown coat (See notes 1 and 2); plaster face exposed	See note 2	4 hr		1		1	4
W-8-Me-4	8 1/2"	Same as above with brick exposed	See note 2	5 hr		1		1	5

NOTES: Table 1.2.4
1. Lightweight steel studs ≥ 3" in depth. Stud spacing is dependent upon loading but in any case the spacing is to be such that adequate rigidity is provided to the metal-lath plaster base.
2. Load is such that stress developed in the steel studs is ≤ 5,120 psi calculated from net area of the stud.

General Note:

The construction details of the wall assemblies are as complete as the source documentation will permit. Data on the method of attachment of facings and the gauge of steel studs was provided when known. The cross-sectional area of the steel stud can be computed, thereby permitting a reasoned estimate of actual loading conditions. For load-bearing assemblies, the maximum allowable stress for the steel studs has been provided in the table “Notes.” More often, it is the thermal properties of the facing materials, rather than the specific gauge of the steel, that will determine the degree of fire resistance. This is particularly true for non-bearing wall assemblies.

Table 1.3.1 Wood Frame Walls
0" (0 mm) to less than 4" (100 mm) thick

Item Code	Thickness	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
W-3-W-1	3 3/4"	Solid wall - 2 1/4" Wood-Wool Slab Core; 3/4" gypsum plaster each side	n/a	2 hr			7	1,6	2
W-3-W-2	3 7/8"	2 × 4 stud wall, 3/16" thick cement asbestos board on both sides of wall	360 PSI net area	10 min		1		2-5	1/6
W-3-W-3	3 7/8"	Same as W-3-W-2 but stud cavities filled with 1 lb/ft^2 mineral wool batts	360 PSI net area	40 min		1		2-5	2/3

NOTES: Table 1.3.1

1. Achieved "Grade C" fire resistance (British).
2. Nominal 2 × 4 wood studs of No. 1 Common or better lumber set edgewise, 2 × 4 plates at top and bottom and blocking at mid-height of wall.
3. All horizontal joints in facing material backed by 2 × 4 blocking in wall.
4. Load = 360 PSI of net stud cross-sectional area.
5. Facings secured with 6 d casing nails. Nail holes predrilled and 0.02" - 0.03" smaller than nail diameter.
6. The wood-wool core is a pressed excelsior slab which possesses insulating properties similar to cellulosic insulation.

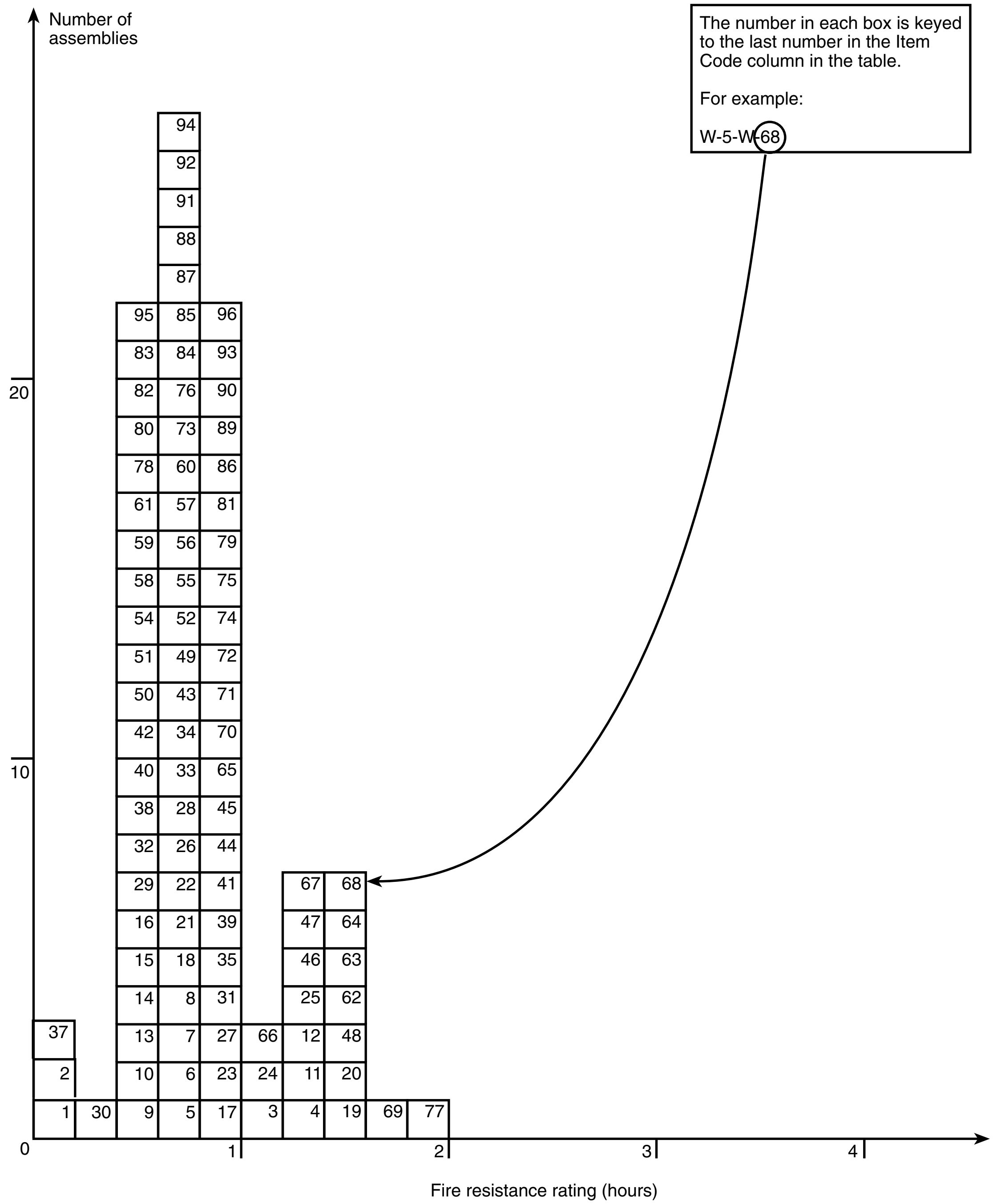


Figure 1.3.2 Wood Frame Walls 4" to less than 6" thick

Table 1.3.2 Wood Frame Walls 4" (100 mm) to less than 6" (150 mm) thick

Item Code	Thickness	Construction Details	Performance Load	Performance Time	Reference Number Pre-BMS-92	Reference Number BMS-92	Reference Number Post-BMS-92	Notes	Rec Hours
W-4-W-1	4"	2" × 4" stud wall; $^3/_{16}$" CAB; No insulation Design A	35 min	10 min			4	1-10	$^1/_6$
W-4-W-2	$4^1/_8$"	2" × 4" stud wall; $^3/_{16}$" CAB; No insulation Design A	38 min	9 min			4	1-10	$^1/_6$
W-4-W-3	$4^3/_4$"	2" × 4" stud wall; $^3/_{16}$" CAB and $^3/_8$" Gypsum board face (both sides); Design B	62 min	64 min			4	1-10	1
W-5-W-4	5"	2" × 4" stud wall; $^3/_{16}$" CAB and $^1/_2$" Gypsum board face (both sides); Design B	79 min	Greater than 90 min			4	1-10	1
W-4-W-5	$4^3/_4$"	2" × 4" stud wall; $^3/_{16}$" CAB and $^3/_8$" Gypsum board (both sides); Design B	45 min	45 min			4	1-12	–
W-5-W-6	5"	2" × 4" stud wall; $^3/_{16}$" CAB and $^1/_2$" Gypsum board face (both sides); Design B	45 min	45 min			4	1-10 12-13	–
W-4-W-7	4"	2" × 4" stud wall; $^3/_{16}$" CAB face; $3^1/_2$" Mineral Wool Insulation; Design C	40 min	42 min			4	1-10	$^2/_3$
W-4-W-8	4"	2" × 4" stud wall; $^3/_{16}$" CAB face; $3^1/_2$" Mineral Wool Insulation; Design C	46 min	46 min			4	1-10,43	$^2/_3$
W-4-W-9	4"	2" × 4" stud wall; $^3/_{16}$" CAB face; $3^1/_2$" Mineral Wool Insulation; Design C	30 min	30 min			4	1-10, 12-14	–
W-4-W-10	$4^1/_8$"	2" × 4" stud wall; $^3/_{16}$" CAB face; $3^1/_2$" Mineral Wool Insulation; Design		30 min			4	1-8, 12,14	–
W-4-W-11	$4^3/_4$"	2" × 4" stud wall; $^3/_{16}$" CAB face; $^3/_8$" Gypsum strips over studs; 5 $^1/_2$" Mineral Wool Insulation; Design D	79 min	79 min			4	1-10	1
W-4-W-12	$4^3/_4$"	2" × 4" stud wall; $^3/_{16}$" CAB face; $^3/_8$" Gypsum strips @ stud edges; $7^1/_2$" Mineral Wool Insulation; Design D	82 min	82 min			4	1-10	1
W-4-W-13	$4^3/_4$"	2" × 4" stud wall; $^3/_{16}$" CAB face; $^3/_8$" Gypsum board strips over studs; $5^1/_2$" Mineral Wool Insulation; Design D	30 min	30 min			4	1-12	–
W-4-W-14	$4^3/_4$"	2" × 4" stud wall; $^3/_{16}$" CAB face; $^3/_8$" Gypsum board strips over studs; 7" mineral mool insulation; Design D	30 min	30 min			4	1-12	–
W-5-W-15	$5^1/_2$"	2" × 4" stud wall; Exposed face - CAB shingles over 1" × 6"; Unexposed face - $^1/_8$" CAB sheet; $^7/_{16}$" fiberboard (wood); Design E	34 min	–			4	1-10	$^1/_2$
W-5-W-16	$5^1/_2$"	2" × 4" stud wall; Exposed face - $^1/_8$" CAB sheet; $^7/_{16}$" fiberboard; Unexposed face - CAB shingles over 1" × 6"; Design E	32 min	33 min			4	1-10	$^1/_2$
W-5-W-17	$5^1/_2$"	2" × 4" stud wall; Exposed face - CAB shingles over 1" × 6"; Unexposed face - $^1/_8$" CAB sheet; Gypsum @ stud edges; $3^1/_2$" Mineral Wool Insulation; Design F	51 min				4	1-10	$^3/_4$
W-5-W-18	$5^1/_2$"	2" × 4" stud wall; Exposed face - $^1/_8$" CAB sheet; Gypsum board @ stud edges; Unexposed face - CAB shingles over 1" × 6"; $3^1/_2$" Mineral Wool Insulation; Design F	42 min				4	1-10	$^2/_3$
W-5-W-19	$5^5/_8$"	2" × 4" stud wall; Exposed face - CAB shingles over 1" × 6"; Unexposed face - $^1/_8$" CAB sheet, Gypsum board @ Stud edges; $5^1/_2$" Mineral Wool Insulation; Design G	74 min	85 min			4	1-10	1
W-5-W-20	$5^5/_8$"	2" × 4" stud wall; Unexposed face - CAB shingles over 1" × 6"; Exposed face - $^1/_8$" CAB sheet, Gypsum board @ $^3/_{16}$" Stud edges; $^7/_{16}$" fiberboard; $5^1/_2$" Mineral Wool Insulation; Design G	79 min	85 min			4	1-10	$1^1/_4$
W-5-W-21	$5^5/_8$"	2" × 4" stud wall; Exposed face - CAB shingles 1" × 6" sheathing; Unexposed face - CAB sheet, Gypsum board @ Stud edges; $5^1/_2$" Mineral Wool Insulation; Design G	38 min	38 min			4	1-10, 12-14	–

Table 1.3.2 Wood Frame Walls 4" (100 mm) to less than 6" (150 mm) thick

Item Code	Thickness	Construction Details	Performance Load	Performance Time	Reference Number Pre-BMS-92	Reference Number BMS-92	Reference Number Post-BMS-92	Notes	Rec Hours
W-5-W-22	$5\frac{5}{8}$"	2" × 4" stud wall; Exposed face - CAB sheet, Gypsum board @ Stud edges; Unexposed face - CAB shingles 1" × 6" sheathing; $5\frac{1}{2}$" Mineral Wood Insulation; Design G	38 min	38 min			4	1-12	–
W-6-W-23	6"	2" × 4" Stud wall; 16" O.C.; $\frac{1}{2}$" Gypsum board each side; $\frac{1}{2}$" gypsum plaster each side	n/a	60 min			7	15	1
W-6-W-24	6"	2" × 4" Stud wall; 16" O.C.; $\frac{1}{2}$"Gypsum board each side; $\frac{1}{2}$" gypsum plaster each side	n/a	68 min			7	16	1
W-6-W-25	$6\frac{7}{8}$"	2" × 4" Stud wall; 18" O.C.; $\frac{3}{4}$" Gypsum plank each side; $\frac{3}{16}$" gypsum plaster each side	n/a	80 min			7	15	$1\frac{1}{3}$
W-5-W-26	$5\frac{1}{8}$"	2" × 4" Stud wall; 16" O.C.; $\frac{3}{8}$" Gypsum board each side; $\frac{3}{16}$" gypsum plaster each side	n/a	37 min			7	15	$\frac{1}{2}$
W-5-W-27	$5\frac{3}{4}$"	2" × 4" Stud wall; 16" O.C.; $\frac{3}{8}$" Gypsum lath each side; $\frac{1}{2}$" gypsum plaster each side	n/a	52 min			7	15	$\frac{3}{4}$
W-5-W-28	5"	2" × 4" Stud wall; 16" O.C.; $\frac{1}{2}$" Gypsum board each side	n/a	37 min			7	16	$\frac{1}{2}$
W-5-W-29	5"	2" × 4" Stud wall; $\frac{1}{2}$" fiberboard both sides 14% M.C. with F.R. paint @ 35 gm/ft^2	n/a	28 min			7	15	$\frac{1}{3}$
W-4-W-30	$4\frac{3}{4}$"	2" × 4" Stud wall; fire side - $\frac{1}{4}$" (wood) fiberboard; back face - $\frac{1}{2}$" CAB; 16" O.C.	n/a	17 min			7	15,16	$\frac{1}{4}$
W-5-W-31	$5\frac{1}{8}$"	2" × 4" Stud wall; 16" O.C.; $\frac{1}{2}$" fiberboard insulation with $\frac{1}{32}$" asbestos (both sides of each board)	n/a	50 min			7	16	$\frac{3}{4}$
W-4-W-32	$4\frac{1}{4}$"	2" × 4" Stud wall; $\frac{3}{8}$" thick gypsum wallboard on both faces; insulated cavities	note 23	25 min		1		17,18, 23	$\frac{1}{3}$
W-4-W-33	$4\frac{1}{2}$"	2" × 4" Stud wall; $\frac{1}{2}$" thick gypsum wallboard on both faces	note 17	40 min		1		17,23	$\frac{2}{3}$
W-4-W-34	$4\frac{1}{2}$"	2" × 4" Stud wall; $\frac{1}{2}$" thick gypsum wallboard on both faces; insulated cavities	note 17	45 min		1		17,18, 23	$\frac{3}{4}$
W-4-W-35	$4\frac{1}{2}$"	2" × 4" Stud wall; $\frac{1}{2}$" thick gypsum wallboard on both faces; insulated cavities	n/a	1 hr		1		17,18, 24	1
W-4-W-36	$4\frac{1}{2}$"	2" × 4" Stud wall; $\frac{1}{2}$" thick, 1.1 lb/ft^2 wood fiberboard sheathing on both faces	note 23	15 min		1		17,23	$\frac{1}{4}$
W-4-W-37	$4\frac{1}{2}$"	2" × 4" Stud wall; $\frac{1}{2}$" thick, 0.7 lb/ft^2 wood fiberboard sheathing on both faces	note 23	10 min		1		17,23	$\frac{1}{6}$
W-4-W-38	$4\frac{1}{2}$"	2" × 4" Stud wall; $\frac{1}{2}$" thick, "flameproofed," 1.6 lb/ft^2 wood fiberboard sheathing on both faces	note 23	30 min		1		17,23	$\frac{1}{2}$
W-4-W-39	$4\frac{1}{2}$"	2" × 4" Stud wall; $\frac{1}{2}$" thick gypsum wallboard on both faces; insulated cavities	note 23	1 hr		1		17,18, 23	1
W-4-W-40	$4\frac{1}{2}$"	2" × 4" Stud wall; $\frac{1}{2}$" thick, 1:2, 1:3 gypsum plaster on wood lath on both faces	note 23	30 min		1		17,21, 23	$\frac{1}{2}$
W-4-W-41	$4\frac{1}{2}$"	2" × 4" Stud wall; $\frac{1}{2}$" thick, 1:2, 1:3 gypsum plaster on wood lath on both faces; insulated cavities	note 23	1 hr		1		17,18, 21,23	1
W-4-W-42	$4\frac{1}{2}$"	2" × 4" Stud wall; $\frac{1}{2}$" thick, 1:5, 1:7.5 lime plaster on wood lath on both wall faces	note 23	30 min		1		17,21, 23	$\frac{1}{2}$
W-4-W-43	$4\frac{1}{2}$"	2" × 4" Stud wall; $\frac{1}{2}$" thick, 1:5, 1:7.5 lime plaster on wood lath on both faces, insulated cavities	note 23	45 min		1		17,18, 21,23	$\frac{3}{4}$
W-4-W-44	$4\frac{5}{8}$"	2" × 4" Stud wall; $\frac{3}{16}$" thick cement-asbestos over $\frac{3}{8}$" thick gypsum board on both faces	note 23	1 hr		1		25,26, 23,27	1
W-4-W-45	$4\frac{5}{8}$"	2" × 4" Stud wall; studs faced with 4" wide strips of $\frac{3}{8}$" thick gypsum board; $\frac{3}{16}$" thick cement-asbestos board on both faces; insulated cavities	note 23	1 hr		1		23,25, 28,27	1
W-4-W-46	$4\frac{5}{8}$"	Same as W-4-W-45 but non-load bearing	n/a	$1\frac{1}{4}$ hr		1		24,28	$1\frac{1}{4}$

Table 1.3.2 Wood Frame Walls 4" (100 mm) to less than 6" (150 mm) thick

Item Code	Thickness	Construction Details	Performance: Load	Performance: Time	Reference Number: Pre-BMS-92	Reference Number: BMS-92	Reference Number: Post-BMS-92	Notes	Rec Hours
W-4-W-47	4 7/8"	2" × 4" Stud wall; 3/16" thick cement-asbestos board over 1/2" thick gypsum sheathing on both faces	note 23	1 1/4 hr		1		23,25, 27,26	1 1/4
W-4-W-48	4 7/8"	Same as W-4-W-47 but non-load bearing	n/a	1 1/2 hr		1		24,27	1 1/2
W-5-W-49	5"	2" × 4" Stud wall; exterior face: 3/4" wood sheathing, asbestos felt 14 lb/100 ft^2 and 5/32" cement-asbestos shingles; interior face 4" wide strips of 3/8" gypsu m board over studs; wall faced with 3/16" thick cement-asbestos board	note 23	40 min		1		18,23, 25,26, 29	2/3
W-5-W-50	5"	2" × 4" Stud wall; exterior face as per W-5-W-49; interior face: 9/16" composite board consisting of 7/16" thick wood fiber board faced with 1/8" thick cement-asbestos board; exterior side exposed to fire	note 23	30 min		1		23,25, 26,30	1/2
W-5-W-51	5"	Same as W-5-W-50 but interior side exposed to fire	note 23	30 min		1		23,25, 26	1/2
W-5-W-52	5"	Same as W-5-W-49 but exterior side exposed to fire	note 23	45 min		1		18,23, 25,26	3/4
W-5-W-53	5"	2" × 4" Stud wall; 3/4" thick T&G wood boards on both sides	note 23	20 min		1		17,23	1/3
W-5-W-54	5"	Same as W-5-W-53 but with insulated cavities	note 23	35 min		1		17,18, 23	1/2
W-5-W-55	5"	2" × 4" Stud wall; 3/4" thick T&G wood boards on both sides with 30 lb/100 ft^2 asbestos, paper between studs and boards	note 23	45 min		1		17,23	3/4
W-5-W-56	5"	2" × 4" Stud wall; 1/2" thick, 1:2, 1:3 gypsum plaster on metal lath on both sides of wall	note 23	45 min		1		17,21, 23	3/4
W-5-W-57	5"	2" × 4" Stud wall; 3/4" thick 2:1:8, 2:1:12 lime and Keene's cement plaster on metal lath, both sides of wall	note 23	45 min		1		17,21, 23	3/4
W-5-W-58	5"	2" × 4" Stud wall; 3/4" thick 2:1:8, 2:1:10 lime portland cement plaster over metal lath on both sides of wall	note 23	30 min		1		17,21, 23	1/2
W-5-W-59	5"	2" × 4" Stud wall; 3/4" thick 1:5, 1:7.5 lime plaster on metal lath on both sides of wall	note 23	30 min		1		17,21, 23	1/2
W-5-W-60	5"	2" × 4" Stud wall; 3/4" thick, 1:1/30:2, 1:1/30:3 portland cement, asbestos fiber plaster on metal lath on both sides of wall	note 23	45 min		1		17,21, 23	3/4
W-5-W-61	5"	2" × 4" Stud wall; 3/4" thick 1:2, 1:3 portland cement plaster on metal lath on both sides of wall	note 23	30 min		1		17,21, 23	1/2
W-5-W-62	5"	2" × 4" Stud wall; 3/4" thick neat plaster on metal lath on both sides of wall	n/a	1 hr 30 min		1		17,22, 24	1 1/2
W-5-W-63	5"	2" × 4" Stud wall; 3/4" thick neat gypsum plaster on metal lath on both sides of wall	note 23	1 hr 30 min		1		17,21, 23	1 1/2
W-5-W-64	5"	2" × 4" Stud wall; 3/4" thick 1:2, 1:2 gypsum plaster on metal lath on both sides of wall, insulated cavities	note 23	1 hr 30 min		1		17,18, 21,23	1 1/2
W-5-W-65	5"	2" × 4" Stud wall, same as W-5-W-64 but wall cavities not insulated	note 23	1 hr		1		17,21, 23	1
W-5-W-66	5"	2" × 4" Stud wall; 3/4" thick 1:2, 1:3 gypsum plaster on metal lath on both sides of wall, insulated cavities	note 23	1 hr 15 min		1		17,18, 21,23	1 1/4
W-5-W-67	5 1/16"	Same as W-5-W-49 except cavity insulation of 1 3/4 lb/ft^2 mineral wool bats; rating applies when either wall side exposed to fire	note 23	1 hr 15 min		1		23,26, 25	1 1/4
W-5-W-68	5 1/4"	2" × 4" Stud wall; 7/8" thick 1:2, 1:3 gypsum plaster on metal lath on both sides of wall, insulated cavities	note 23	1 hr 30 min		1		17,18, 21,23	1 1/2
W-5-W-69	5 1/4"	2" × 4" Stud wall; 7/8" thick neat gypsum plaster applied on metal lath, on both sides of wall	n/a	1 hr 45 min		1		17,22, 24	1 3/4

Table 1.3.2 Wood Frame Walls 4" (100 mm) to less than 6" (150 mm) thick

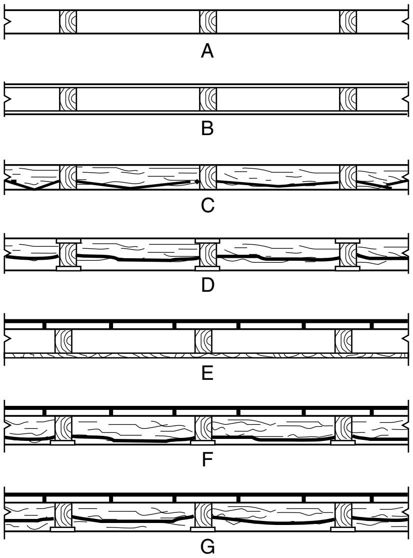
Item Code	Thickness	Construction Details	Performance: Load	Performance: Time	Reference Number: Pre-BMS-92	Reference Number: BMS-92	Reference Number: Post-BMS-92	Notes	Rec Hours
W-5-W-70	5 1/4"	2" × 4" Stud wall; 1/2" thick neat gypsum plaster on 3/8" plain gypsum lath, both sides of wall	note 23	1 hr		1		17,22, 23	1
W-5-W-71	5 1/4"	2" × 4" Stud wall; 1/2" thick, 1:2, 1:2 gypsum plaster on 3/8" thick plain gypsum lath with 1 3/4" × 1 3/4" metal lath pads nailed 8" O.C. vertically, 16" O.C. horizontally, both sides of wall	note 23	1 hr		1		17,21, 23	1
W-5-W-72	5 1/4"	2" × 4" Stud wall; 1/2" thick 1:2, 1:2 gypsum plaster on 3/8" perforated gypsum lath, one 3/4" diameter hole or larger per 16" sq. in. of lath surface, both sides of wall	note 23	1 hr		1		17,21, 23	1
W-5-W-73	5 1/4"	2" × 4" Stud wall; 1/2" thick 1:2, 1:2 gypsum plaster on 3/8" gypsum lath (plain, indented or perforated) both sides of wall	note 23	45 min		1		17,21, 23	3/4
W-5-W-74	5 1/4"	2" × 4" Stud wall; 7/8" thick 1:2, 1:3 gypsum plaster over metal lath on both sides of wall	note 23	1 hr		1		17,21, 23	1
W-5-W-75	5 1/4"	2" × 4" Stud wall; 7/8" thick 1:1/30:2, 1:1/30:3 portland cement, asbestos plaster applied over metal lath on both sides of wall	note 23	1 hr		1		17,21, 23	1
W-5-W-76	5 1/4"	2" × 4" Stud wall; 7/8" thick 1:2, 1:3 portland cement plaster over metal lath on both sides of wall	note 23	45 min		1		17,21, 23	3/4
W-5-W-77	5 1/2"	2" × 4" Stud wall; 1" thick neat gypsum plaster over metal lath on both sides of wall, non-load bearing	n/a	2 hr		1		17,22, 24	2
W-5-W-78	5 1/2"	2" × 4" Stud wall; 1/2" thick 1:2, 1:2 gypsum plaster on 1/2" thick, 0.7 lb/ft² wood fiberboard both sides of wall	note 23	35 min		1		17,21, 23	1/2
W-4-W-79	4 3/4"	2" × 4" wood stud wall; 1/2" thick 1:2, 1:2 gypsum plaster over wood lath on both sides of wall; mineral wool insulation	n/a	1 hr			43	21,31, 35,38	1
W-4-W-80	4 3/4"	Same as W-4-W-79 but uninsulated	n/a	35 min			43	21,31, 35	1/2
W-4-W-81	4 3/4"	2" × 4" wood stud wall; 1/2" thick 3:1:8, 3:1:12 lime, Keene's cement, sand plaster over wood lath both sides of wall; mineral wool insulation	n/a	1 hr			43	21,31, 35,40	1
W-4-W-82	4 3/4"	2" × 4" wood stud wall; 1/2" thick 1:6 1/4, 1:6 1/4 lime Keene's cement plaster over wood lath both sides of wall; mineral wool insulation	n/a	30 min			43	21,31, 35,40	1/2
W-4-W-83	4 3/4"	2" × 4" wood stud wall; 1/2" thick 1:5, 1:7.5 lime plaster over wood lath on both sides of wall	n/a	30 min			43	21,31, 35	1/2
W-5-W-84	5 1/8"	2" × 4" wood stud wall; 11/16" thick 1:5, 1:7.5 lime plaster over wood lath on both sides of wall; mineral wool insulation	n/a	45 min			43	21,31, 35,39	1/2
W-5-W-85	5 1/4"	2" × 4" wood stud wall; 3/4" thick 1:5, 1:7 lime plaster over wood lath on both sides of wall; mineral wool insulation	n/a	40 min			43	21,31, 35,40	2/3
W-5-W-86	5 1/4"	2" × 4" wood stud wall; 1/2" thick 2:1:12 lime, Keene's cement and sand scratch cost, 1/2" thick 2:1:18 lime, Keene's cement, sand brown coat over wood lath on both sides of wall; mineral wool insulation	n/a	1 hr			43	21,31, 35,40	1
W-5-W-87	5 1/4"	2" × 4" wood stud wall; 1/2" thick 1:2, 1:2 gypsum plaster over 3/8" thick plaster board on both sides of wall	n/a	45 min			43	21,31	3/4
W-5-W-88	5 1/4"	2" × 4" wood stud wall; 1/2" thick 1:2, 1:2 gypsum plaster over 3/8" thick gypsum lath on both sides of wall	n/a	45 min			43	21,31	3/4
W-5-W-89	5 1/4"	2" × 4" wood stud wall; 1/2" thick 1:2, 1:2 gypsum plaster over 3/8" gypsum lath, on both sides of wall	n/a	1 hr			43	21,31, 33	1
W-5-W-90	5 1/4"	2" × 4" wood stud wall; 1/2" thick neat plaster over 3/8" thick gypsum lath, on both sides of wall	n/a	1 hr			43	21,22, 31	1

Table 1.3.2 Wood Frame Walls 4" (100 mm) to less than 6" (150 mm) thick

Item Code	Thickness	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
W-5-W-91	5 1/4"	2" × 4" wood stud wall; 1/2" thick 1:2, 1:2 gypsum plaster over 3/8" thick indented gypsum lath, on both sides of wall	n/a	45 min			43	21,31	3/4
W-5-W-92	5 1/4"	2" × 4" wood stud wall; 1/2" thick 1:2, 1:2 gypsum plaster over perforated gypsum lath, 3/8" thick on both wall faces	n/a	45 min			43	21,31, 34	3/4
W-5-W-93	5 1/4"	2" × 4" wood stud wall; 1/2" thick 1:2, 1:2 gypsum plaster over 3/8" thick perforated gypsum lath on both sides of wall	n/a	1 hr			43	21,31	1
W-5-W-94	5 1/4"	2" × 4" wood stud wall; 1/2" thick 1:2, 1:2 gypsum plaster over perforated gypsum lath 3/8" thick over both sides of wall	n/a	45 min			43	21,31, 34	3/4
W-5-W-95	5 1/4"	2" × 4" wood stud wall; 1/2" thick 1:2, 1:2 gypsum plaster over 1/2" thick wood fiberboard plaster base on both sides of wall	n/a	35 min			43	21,31, 36	1/2
W-5-W-96	5 3/4"	2" × 4" wood stud wall; 1/2" thick 1:2, 1:2 gypsum plaster over 7/8" thick flameproofed wood fiberboard, on both sides of wall	n/a	1 hr			43	21,31, 37	1

NOTES: Table 1.3.2

1. All specimens 8' or 8'8" × 10'4" — i.e., 1/2 of furnace size. See note 42 for design cross section.
2. Specimens tested in tandem (two per exposure).
3. Test per ASA No. A-2-1934 except where unloaded. Also, panels were of "half" size of furnace opening. Time value signifies a thermal failure time.
4. 2 × 4 studs - 16" O.C.; where 10'4", blocking @ 2'4" height.
5. Facing 4' × 8' - cement-asbestos board sheets - 3/16" thick.
6. Sheathing (diagonal) - 25/32" × 5 1/2" - 1" × 6" pine.
7. Facing shingles - 24" × 12" × 5/32" where used.
8. Asbestos felt — asphalt set between sheathing and shingles.
9. Load — 30,500 lbs or 360 PSI/stud where load was tested.
10. Walls were tested beyond achievement of first test end point. A load bearing time in excess of performance time indicates that although thermal criteria were exceeded load bearing ability continued.
11. Wall was rated for 1 hr combustible use in original source.
12. Hose stream test specimen. See table entry of similar design above for recommended rating.
13. Rated 1 1/4 hr load bearing. Rated 1 1/2 hr non-load bearing.
14. Failed hose stream.
15. Test terminated due to flame penetration.
16. Test terminated — local back face temperature rise.
17. Nominal 2 × 4 wood studs of No. 1 common or better lumber set edgewise. 2 × 4 plates at top and bottom and blocking at mid-height of wall.
18. Cavity insulation consists of rock wool bats 1.0 lb/ft^2 of filled cavity area.
19. Cavity insulation consists of glass-wool bats 0.6 lb/ft^2 of filled cavity area.
20. Cavity insulation consists of blown-in forck wool 2.0 lb/ft^2 of filled cavity area.
21. Mix proportions for plastered walls as follows: first ratio indicates scratch coat mix, weight of dry plaster to dry sand; second ratio indicates brown coat mix.
22. “Neat” plaster is taken to mean unsanded wood-fiber gypsum plaster.
23. Load = 360 PSI of net stud cross-sectional area.
24. Rated as non-load bearing.
25. Nominal 2 × 4 studs per note 17, spaced at 16" on center.
26. Horizontal joints in facing material supported by 2 × 4 blocking within wall.
27. Facings secured with 6 d casing nails. Nail holes predrilled and were 0.02" – 0.03" smaller than nail diameter.
28. Cavity insulation consists of mineral wool bats weighing 2 lb/ft^2 of filled cavity area.
29. Interior wall face exposed to fire.
30. Exterior wall face exposed to fire.
31. Nominal 2 × 4 studs of yellow pine or Douglas fir spaced 16" on center in a single row.
32. Studs as in note 31 except double row, with studs in rows staggered.
33. Six roofing nails with metal-lath pads around heads to each 16" × 48" lath.
34. Areas of holes less than 2 3/4% of area of lath.
35. Wood laths were nailed with either 3 d or 4 d nails, one nail to each bearing, and the end joining broken every 7th course.
36. 1/2" thick fiberboard plaster base nailed with 3 d or 4 d common wire nails spaced 4" – 6" on center.
37. 7/8" thick fiberboard plaster base nailed with 5 d common wire nails spaced 4" – 6" on center.
38. Mineral wool bats 1.05-1.25 lb/ft^2 with waterproofed-paper backing.
39. Blown-in mineral wool insulation, 2.2 lb/ft^2.
40. Mineral wool bats, 1.4 lb/ft^2 with waterproofed-paper backing.
41. Mineral wool bats, 0.9 lb/ft^2.
42. See wall design diagram, below.



43. Duplicate specimen of W-4-W-7, tested simultaneously with W-4-W-7 in 18 ft. test furnace.

Table 1.3.3 Wood Frame Walls 6"(150 mm) to less than 8" (200 mm) thick

Item Code	Thickness	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
W-6-W-1	6 1/4"	2" × 4" Stud Wall, 1/2" thick, 1:2, 1:2 gypsum plaster on 7/8" Flameproofed wood fiberboard weighing 2.8 lb/ft² - both sides of wall	note 3	1 hr		1		1-3	1
W-6-W-2	6 1/2"	2" × 4" Stud Wall, 1/2" thick, 1:3, 1:3 gypsum plaster on 1" thick magnesium oxysulfate wood fiberboard - both sides of wall	note 3	45 min		1		1-3	3/4
W-7-W-3	7 1/4"	Double row of 2 × 4 studs, 1/2" thick 1:2, 1:2 gypsum plaster applied over 3/8" thick perforated gypsum lath on both sides of wall; Mineral wool insulation	n/a	1 hr			43	2,4,5	1
W-7-W-4	7 1/2"	Double row of 2 × 4 studs, 5/8" thick 1:2, 1:2 gypsum plaster applied over 3/8" thick perforated gypsum lath overlaid with 2" × 2", 16 gauge wire fabric, on both sides of wall	n/a	1 hr 15 min			43	2,4	1 1/4

Notes:
1. Nominal 2 × 4 wood studs of No. 1 common or better lumber set edgewise. 2 × 4 plates at top and bottom and blocking at mid-height of wall.
2. Mix proportions for plastered walls as follows: first ratio indicates scratch coat mix, weight of dry plaster to dry sand; second ratio indicates brown coat mix.
3. Load = 360 PSI of net stud cross-sectional area.
4. Nominal 2 × 4 studs of yellow pine or Douglas fir spaced 16" in a double row, with studs in rows staggered.
5. Mineral wool bats, 0.19 lb/ft².

Table 1.4.1 Walls — Miscellaneous Materials 0" (0 mm) to less than 4" (100 mm) thick

Item Code	Thickness	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
W-3-Mi-1	$3^7/_8$"	Glass brick wall (bricks $5^3/_4" \times 5^3/_4" \times 3^7/_8"$) $^1/_4$" mortar bed - cement/lime/sand; mounted in brick (9") wall with mastic and $^1/_2$" asbestos rope	n/a	1 hr			7	1,2	1
W-3-Mi-2	3"	Core: 2" magnesium oxysulfate wood-fiber blocks laid in portland cement lime mortar; Facings on both sides; see Note 3	n/a	1 hr		1		3	1
W-3-Mi-3	$3^7/_8$"	Core: $8" \times 4^7/_8"$ glass blocks 3 $^7/_8$" thick weighing 4 lbs. each. Laid in portland cement lime mortar, horizontal mortar joints reinforced with metal lath	n/a	$^1/_4$ hr		1			$^1/_4$

NOTES: Table 1.4.1
1. No failure reached at 1 hour.
2. These glass blocks are assumed to be solid based on other test data available for similar but hollow units that show significantly reduced fire endurance.
3. Minimum of $^1/_2$" of 1:3 sanded gypsum plaster required to develop this rating.

Table 1.4.2 Walls — Miscellaneous Materials 4" (100 mm) to less than 6" (150 mm) thick

Item Code	Thickness	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
W-4-Mi-1	4"	Core: 3" magnesium oxysulfate wood-fiber blocks laid in portland cement mortar; Facings: both sides per note 1	n/a	2 hr		1			2

NOTES: Table 1.4.2
1. $^1/_2$" sanded gypsum plaster. Voids in hollow blocks to be not more than 30%.

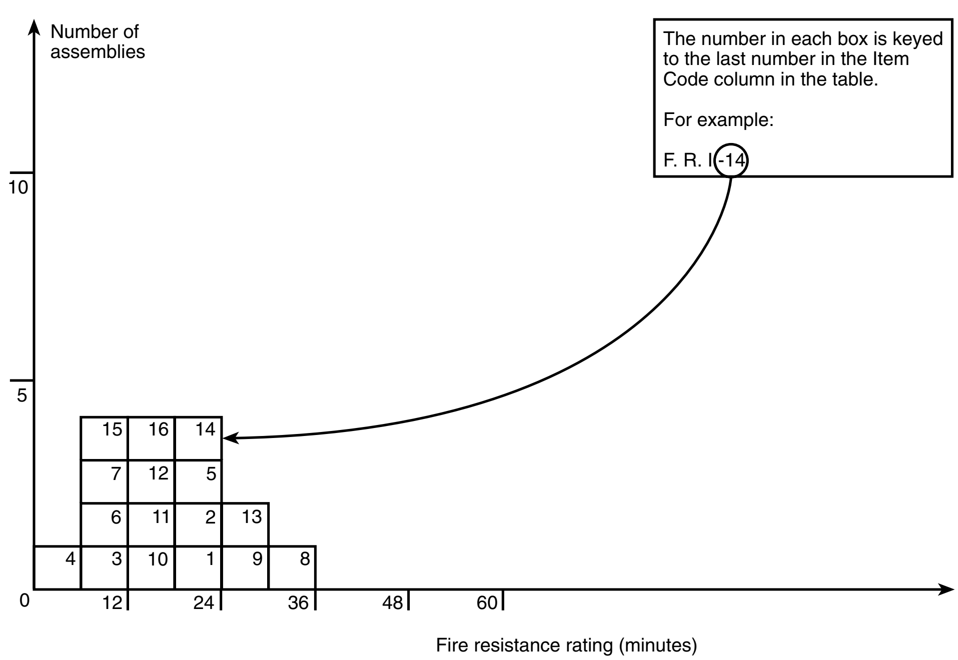


Figure 1.5.1 Finish Ratings—Inorganic Materials

Table 1.5.1 Finish Ratings — Inorganic Materials

Item Code	Thickness	Construction Details	Performance Finish Rating	Reference Number Pre-BMS-92	BMS-92	Post-BMS-92	Notes	Rec F.R. (min.)
FR-I-1	9/16"	3/8" gypsum wallboard faced with 3/16" cement asbestos board	20 min		1		1,2	15
FR-I-2	11/16"	1/2" gypsum sheathing faced with 3/16" cement asbestos board	20 min		1		1,2	20
FR-I-3	3/16"	3/16" cement asbestos board over uninsulated cavity	10 min		1		1,2	5
FR-I-4	3/16"	3/16" cement asbestos board over insulated cavities	5 min		1		1,2	5
FR-I-5	3/4"	3/4" thick 1:2, 1:3 gypsum plaster over paper backed metal lath	20 min		1		1-3	20
FR-I-6	3/4"	3/4" thick portland cement plaster on metal lath	10 min		1		1,2	10
FR-I-7	3/4"	3/4" thick, 1:5, 1:75 lime plaster on metal lath	10 min		1		1,2	10
FR-I-8	1"	1" thick neat gypsum plaster on metal lath	35 min		1		1,2,4	35
FR-I-9	3/4"	3/4" thick neat gypsum plaster on metal lath	30 min		1		1,2,4	30
FR-I-10	3/4"	3/4" thick 1:2, 1:2 gypsum plaster on metal lath	15 min		1		1-3	15
FR-I-11	1/2"	Same as F.R.-I-7, except 1/2" thick on wood lath	15 min		1		1-3	15
FR-I-12	1/2"	1/2" thick, 1:2, 1:3 gypsum plaster on wood lath	15 min		1		1-3	15
FR-I-13	7/8"	1/2" thick, 1:2, 1:2 gypsum plaster on 3/8" perforated gypsum lath	30 min		1		1-3	30
FR-I-14	7/8"	1/2" thick, 1:2, 1:2 gypsum plaster on 3/8" thick plain or indented gypsum plaster	20 min		1		1-3	20
FR-I-15	3/8"	3/8" gypsum wallboard	10 min		1		1,2	10
FR-I-16	1/2"	1/2" gypsum wallboard	15 min		1		1,2	15

NOTES: Table 1.5.1
1. The finish rating is the time required to obtain an average temperature rise of 250°F, or a single point rise of 325°F, at the interface between the material being rated and the substrate being protected.
2. Tested in accordance with the *Standard Specifications for Fire Tests of Building Construction and Materials*, ASA A2.
3. Mix proportions for plaster as follows: first ratio, dry weight of plaster to dry weight of sand for scratch coat; second ratio, plaster: sand for brown coat.
4. Neat plaster means unsanded wood-fiber gypsum plaster.

General Note:
The finish rating of modern building materials can be found in the current literature.

Table 1.5.2 Finish Rating — Organic Materials

Item Code	Thickness	Construction Details	Performance Finish Rating	Reference Number Pre-BMS-92	BMS-92	Post-BMS-92	Notes	Rec F.R. (min.)
FR-0-1	9/16"	7/16" wood fiber board faced with 1/8" cement asbestos board	15 min		1		1,2	15
FR-0-2	29/32"	3/4" wood sheathing, asbestos felt weighing 14 lb/100 ft^2 and 5/32" cement asbestos shingles	20 min		1		1,2	20
FR-0-3	1 1/2"	1" thick magnesium oxysulfate wood fiberboard faced with 1:3, 1:3 gypsum plaster, 1/2" thick	20 min		1		1-3	20
FR-0-4	1/2"	1/2" thick wood fiberboard	5 min		1		1,2	5
FR-0-5	1/2"	1/2" thick flameproofed wood fiberboard	10 min		1		1,2	10
FR-0-6	1"	1/2" thick wood fiberboard faced with 1/2" thick 1:2, 1:2 gypsum plaster	15 min		1		1-3	15
FR-0-7	1 3/8"	7/8" thick flameproofed wood fiberboard faced with 1/2" thick 1:2, 1:2 gypsum plaster	30 min		1		1-3	30
FR-0-8	1 1/4"	1 1/4" thick plywood	30 min			35		30

NOTES: Table 1.5.2
1. The finish rating is the time required to obtain an average temperature rise of 250°F, or a single point rise of 325°F, at the interface between the material being rated and the substrate being protected.
2. Tested in accordance with the *Standard Specifications for Fire Tests of Building Construction and Materials*, ASA A2.
3. Plaster ratios as follows: first ratio is for scratch coat, weight of dry plaster: weight of dry sand; second ratio is for the brown coat.

General Note:
The finish rating of thinner materials, particularly thinner woods, have not been listed because the possible effects of shrinkage, warpage, and aging cannot be predicted.

Section II—Columns

Table 2.1.1 Reinforced Concrete Columns
Minimum Dimension 0" (0 mm) to less than 6" (150 mm)

Item Code	Minimum Dimension	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
C-6-RC-1	6"	6" × 6" Square Columns; Gravel Aggregate Concrete (4030 PSI); Reinforcement - Vertical 4 $^7/_8$" rebars; Horizontal - $^5/_{16}$" Ties @ 6" Pitch; Cover 1"	34.7 tons	62 min			7	1,2	1
C-6-RC-2	6"	6" × 6" Square Columns; Gravel Aggregate Concrete (4200 Psi); Reinforcement - Vertical 4 $^1/_2$" rebars; Horizontal - $^5/_{16}$" Ties @ 6" Pitch; Cover - 1"	21 tons	69 min			7	1,2	1

NOTES: Table 2.1.1
1. Collapse
2. British test.

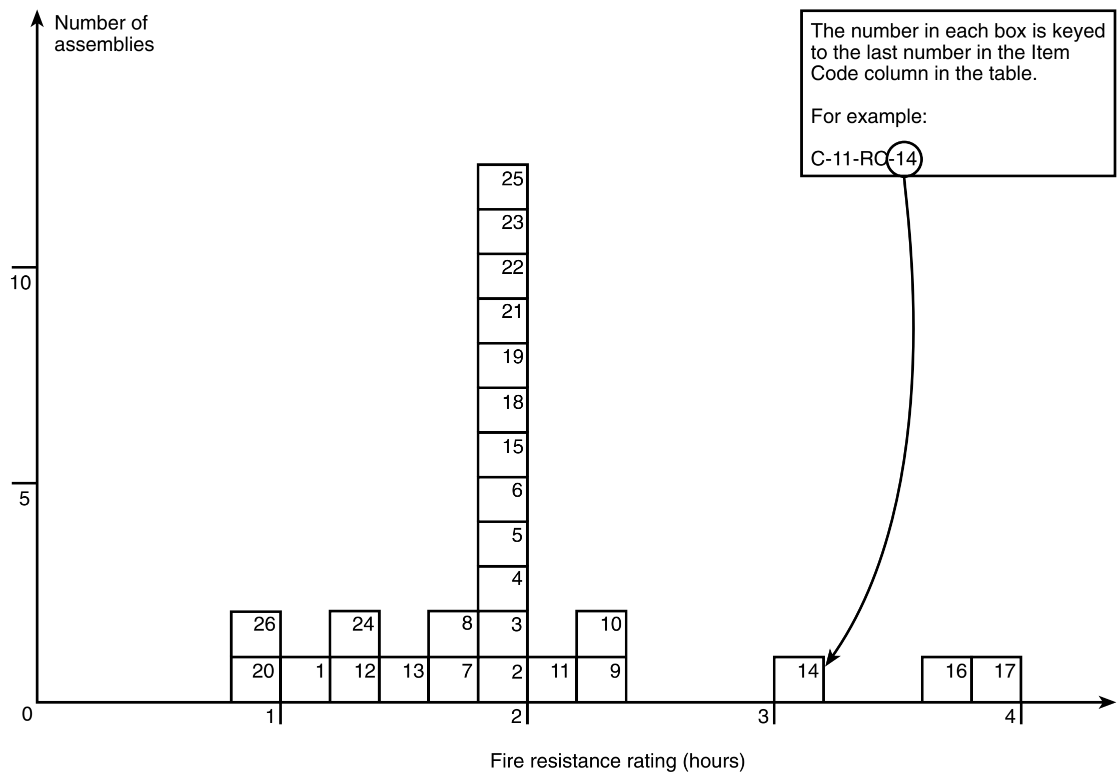


Figure 2.1.2 Reinforced Concrete Columns Minimum Dimension 10" to less than 12"

Table 2.1.2 Reinforced Concrete Columns Minimum Dimension 10" (250 mm) to less than 12" (300 mm)

Item Code	Minimum Dimension	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
C-10-RC-1	10"	10" Square Columns; Aggregate Concrete (4260 Psi); Reinforcement: Vertical 4-1 $^1/_4$" rebars; Horizontal $^3/_8$" Ties @ 6" Pitch; Cover 1 $^1/_4$"	92.2 tons	1 hr 2 min			7	1	1
C-10-RC-2	10"	10" Square Columns; Aggregate Concrete (2325 Psi); Reinforcement: Vertical 4-$^1/_2$" rebars; Horizontal $^5/_{16}$" Ties @ 6" Pitch; Cover 1"	46.7 tons	1 hr 52 min			7	1	1$^3/_4$
C-10-RC-3	10"	10" Square Columns; Aggregate Concrete (5370 Psi); Reinforcement: Vertical 4-$^1/_2$" rebars; Horizontal $^5/_{16}$" Ties @ 6" Pitch; Cover 1"	46.5 tons	2 hr			7	2,3, 11	2
C-10-RC-4	10"	10" Square Columns; Aggregate Concrete (5206 Psi); Reinforcement: Vertical 4-$^1/_2$" rebars; Horizontal $^5/_{16}$" Ties @ 6" Pitch; Cover 1"	46.5 tons	2 hr			7	2,7	2
C-10-RC-5	10"	10" Square Columns; Aggregate Concrete (5674 Psi); Reinforcement: Vertical 4-$^1/_2$" rebars; Horizontal $^5/_{16}$" Ties @ 6" Pitch; Cover 1"	46.7 tons	2 hr			7	1	2
C-10-RC-6	10"	10" Square Columns; Aggregate Concrete (5150 Psi); Reinforcement: Vertical 4-1 $^1/_2$" rebars; Horizontal $^5/_{16}$" Ties @ 6" Pitch; Cover 1"	66 tons	1 hr 43 min			7	1	1$^3/_4$
C-10-RC-7	10"	10" Square Columns; Aggregate Concrete (5580 Psi); Reinforcement: Vertical 4-$^1/_2$" rebars; Horizontal $^5/_{16}$" Ties @ 6" Pitch; 1" Cover	62.5 tons	1 hr 38 min			7	1	1 $^1/_2$
C-10-RC-8	10"	10" Square Columns; Aggregate Concrete (4080 Psi); Reinforcement: Vertical 4-$^1/_8$" rebars; Horizontal $^5/_{16}$" Ties @ 6" Pitch; 1 $^1/_2$" Cover	72.8 tons	1 hr 48 min			7	1	1$^3/_4$
C-10-RC-9	10"	10" Square Columns; Aggregate Concrete (2510 Psi); Reinforcement: Vertical 4- $^1/_2$" rebars; Horizontal $^5/_{16}$" Ties @ 6" Pitch; Cover 1"	72.8 tons	1 hr 48 min			7	1	2$^1/_4$
C-10-RC-10	10"	10" Square Columns; Aggregate Concrete (2170 Psi); Reinforcement: Vertical 4- $^1/_2$" rebars; Horizontal $^5/_{16}$" Ties @ 6" Pitch; Cover 1"	45 tons	2 hr 14 min			7	1	2$^1/_4$
C-10-RC-11	10"	10" Square Columns; Gravel Aggregate Concrete (4015 Psi); Reinforcement: Vertical 4- $^1/_2$" rebars; Horizontal $^5/_{16}$" Ties @ 6" Pitch; Cover 1"	46.5 tons	2 hr 6 min			7	1	2
C-11-RC-12	11"	11" Square Columns; Gravel Aggregate Concrete (4150 Psi); Reinforcement: Vertical 4- 1 $^1/_4$" rebars; Horizontal $^3/_8$" Ties @ 7 $^1/_2$" Pitch; Cover 1 $^1/_2$"	61 tons	1 hr 23 min			7	1	1$^1/_4$
C-11-RC-13	11"	11" Square Columns; Gravel Aggregate Concrete (4380 Psi); Reinforcement-vertical 4- 1 $^1/_4$" rebars; Horizontal $^3/_8$" Ties @ 7 $^1/_2$" Pitch; Cover 1 $^1/_2$"	61 tons	1 hr 26 min			7	1	1$^1/_4$
C-11-RC-14	11"	11" Square Columns; Gravel Aggregate Concrete (4140 Psi); Reinforcement: Vertical 4- 1 $^1/_4$" rebars; Horizontal $^3/_8$" Ties @ 7 $^1/_2$" Pitch; Steel Mesh Around Reinforcement; Cover 1 $^1/_2$"	61 tons	3 hr 9 min			7	1	3
C-11-RC-15	11"	11" Square Columns; Slag Aggregate Concrete (3690 Psi); Reinforcement: Vertical 4- 1 $^1/_4$" Rebar; Horizontal $^3/_8$" Ties @ 7 $^1/_2$" Pitch; Cover 1 $^1/_2$"	91 tons	2 hr			7	2-5	2
C-11-RC-16	11"	11" Square Columns; Limestone Aggregate Concrete (5230 Psi); Reinforcement: Vertical 4- 1 $^1/_4$" rebars; Horizontal $^3/_8$" Ties @ 7 $^1/_2$" Pitch; Cover 1 $^1/_2$"	91.5 tons	3 hr 41 min			7	1	3$^1/_2$
C-11-RC-17	11"	11" Square Columns; Limestone Aggregate Concrete (5530 Psi); Reinforcement: Vertical 4- 1 $^1/_4$" rebars; Horizontal $^3/_8$" Ties @ 7 $^1/_2$" Pitch; Cover 1 $^1/_2$"	91.5 tons	3 hr 47 min			7	1	3$^1/_2$
C-11-RC-18	11"	11" Square Columns; Limestone Aggregate Concrete (5280 Psi); Reinforcement: Vertical 4- 1 $^1/_4$" rebars; Horizontal $^3/_8$" Ties @ 7 $^1/_2$" Pitch; Cover 1 $^1/_2$"	91.5 tons	2 hr			7	2-4,6	2

Table 2.1.2 Reinforced Concrete Columns Minimum Dimension 10" (250 mm) to less than 12" (300 mm)

Item Code	Minimum Dimension	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
C-11-RC-19	11"	11" Square Columns; Limestone Aggregate Concrete (4180 Psi); Reinforcement: Vertical 4- 5/8" rebars; Horizontal 3/8" Ties @ 7" Pitch; Cover 1 1/2"	71.4 tons	2 hr			7	2,7	2
C-11-RC-20	11"	11" Square Columns; Gravel Concrete (4530 Psi); Reinforcement: Vertical 4- 5/8" rebars; Horizontal 3/8" Ties @ 7" Pitch; Cover 1 1/2" With 1/2" Plaster	58.8 tons	2 hr			7	2,3,9	1 1/4
C-11-RC-21	11"	11" Square Columns; Gravel Concrete (3520 Psi); Reinforcement: Vertical 4- 5/8" rebars; Horizontal 3/8" Ties @ 7" Pitch; Cover 1 1/2"	variable	1 hr 24 min			7	1, 8	2
C-11-RC-22	11"	11" Square Columns; Aggregate Concrete (3710 Psi); Reinforcement: Vertical 4- 5/8" rebars; Horizontal 3/8" Ties @ 7" Pitch; Cover 1 1/2"	58.8 tons	2 hr			7	2,3, 10	2
C-11-RC-23	11"	11" Square Columns; Aggregate Concrete (3190 Psi); Reinforcement: Vertical 4- 5/8" rebars; Horizontal 3/8" Ties @ 7" Pitch; Cover 1 1/2"	58.8 tons	2 hr			7	2,3, 10	2
C-11-RC-24	11"	11" Square Columns; Aggregate Concrete (4860 Psi); Reinforcement: Vertical 4- 5/8" rebars; Horizontal 3/8" Ties @ 7" Pitch; Cover 1 1/2"	86.1 tons	1 hr 20 min			7	1	1 1/3
C-11-RC-25	11"	11" Square Columns; Aggregate Concrete (4850 Psi); Reinforcement: Vertical 4- 5/8" rebars; Horizontal 3/8" Ties @ 7" Pitch; Cover 1 1/2"	58.8 tons	1 hr 59 min			7	1	1 3/4
C-11-RC-26	11"	11" Square Columns; Aggregate Concrete (3834 Psi); Reinforcement: Vertical 4- 5/8" rebars; Horizontal 5/16" Ties @ 4 1/2" Pitch; Cover 1 1/2"	71.4 tons	53 min			7	1	3/4

NOTES: Table 2.1.2
1. Failure mode — collapse.
2. Passed 2-hr fire exposure.
3. Passed hose stream test.
4. Reloaded effectively after 48 hours but collapsed at load in excess of original test load.
5. Failing load was 150 tons.
6. Failing load was 112 tons.
7. Failed during hose stream test.
8. Range of load 58.8 tons (initial) to 92 tons (92 min.) to 60 tons (80 min.).
9. Collapsed at 44 tons in reload after 96 hours.
10. Withstood reload after 72 hours.
11. Collapsed on reload after 48 hours.

Table 2.1.3 Minimum Dimension 12" (300 mm) to less than 14" (350 mm)

Item Code	Minimum Dimension	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
C-12-RC-1	12"	12" Square Columns; Gravel Aggregate concrete (2647 Psi); Reinforcement: Vertical 4-5/8" rebars; Horizontal 5/16" ties @ 4 1/2" pitch; Cover 2"	78.2 tons	38 min		1	7	1	1/2
C-12-RC-2	12"	Reinforced Columns with 1 1/2" concrete outside of reinforced steel; gross diameter or side of column 12"; Group I, Column A		6 hr		1		2,3	6
C-12-RC-3	12"	Description as per C-12-RC-2; Group I, Column B		4 hr		1		2,3	4
C-12-RC-4	12"	Description as per C-12-RC-2; Group II, Column A		4 hr		1		2,3	4
C-12-RC-5	12"	Description as per C-12-RC-2; Group II, Column B		2 hr 30 min		1		2,3	2 1/2
C-12-RC-6	12"	Description as per C-12-RC-2; Group III, Column A		6 hr		1		2,3	3
C-12-RC-7	12"	Description as per C-12-RC-2; Group III, Column B		2 hr		1		2,3	2

Table 2.1.3 Minimum Dimension 12" (300 mm) to less than 14" (350 mm)

Item Code	Minimum Dimension	Construction Details	Performance: Load	Performance: Time	Reference Number: Pre-BMS-92	Reference Number: BMS-92	Reference Number: Post-BMS-92	Notes	Rec Hours
C-12-RC-8	12"	Description as per C-12-RC-2; Group IV, Column A		2 hr		1		2,3	2
C-12-RC-9	12"	Description as per C-12-RC-2; Group IV, Column B		1 hr 30 min		1		2,3	1 1/2

NOTES: Table 2.1.3
1. Failure mode — unspecified structural.
2. Group I — includes concrete having calcareous aggregate containing a combined total of not more than 10 percent of quartz, chert, and flint for the coarse aggregate.
Group II — includes concrete having trap-rock aggregate applied without metal ties and also concrete having cinder, sandstone, or granite aggregate, if held in place with wire mesh or expanded metal having not larger than 4-in. mesh, weighing not less than 1.7 lb/yd^2, placed not more than 1 in. from the surface of the concrete.
Group III — includes concrete having cinder, sandstone, or granite aggregate tied with No. 5 gauge steel wire, wound spirally over the column section on a pitch of 8 in., or equivalent ties, and concrete having siliceous aggregates containing a combined total of 60 percent or more of quartz, chert, and flint, if held in place with wire mesh or expanded metal having not larger than 4-in. mesh, weighing not less than 1.7 lb/yd^2 placed not more than 1 in. from the surface of the concrete.
Group IV — includes concrete having siliceous aggregates containing a combined total of 60 percent or more of quartz, chert, and flint, and tied with No. 5 gauge steel wire wound spirally over the column section on a pitch of 8 in., or equivalent ties.
3. Groupings of aggregates and ties are the same as for structural steel columns protected solidly with concrete, the ties to be placed over the vertical reinforcing bars and the mesh, where required, to be placed within 1 in. from the surface of the column.
Column A — working loads are assumed as carried by the area of the column inside of the lines circumscribing the reinforcing steel.
Column B — working loads are assumed as carried by the gross area of the column.

Table 2.1.4 Reinforced Concrete Columns
Minimum Dimension 14" (350 mm) to less than 16" (400 mm)

Item Code	Minimum Dimension	Construction Details	Performance: Load	Performance: Time	Reference Number: Pre-BMS-92	Reference Number: BMS-92	Reference Number: Post-BMS-92	Notes	Rec Hours
C-14-RC-1	14"	14" Square Columns; Gravel aggregate concrete (4295 PSI); Reinforcement: Vertical 4-3/4" rebars; Horizontal 1/4" ties @ 9" pitch; Cover 1 1/2"	86 tons	1 hr 22 min			7	1	1 1/4
C-14-RC-2	14"	Reinforced columns with 1 1/2" concrete outside reinforcing steel; gross diameter or side of column 14"; Group I, Column A		7 hr		1		2,3	7
C-14-RC-3	14"	Description as per C-14-RC-2; Group II, Column B		5 hr		1		2,3	5
C-14-RC-4	14"	Description as per C-14-RC-2; Group III, Column A		5 hr		1		2,3	5
C-14-RC-5	14"	Description as per C-14-RC-2; Group IV, Column B		3 hr 30 min		1		2,3	3 1/2
C-14-RC-6	14"	Description as per C-14-RC-2; Group III, Column A		4 hr		1		2,3	4
C-14-RC-7	14"	Description as per C-14-RC-2; Group III, Column B		2 hr 30 min		1		2,3	2 1/2
C-14-RC-8	14"	Description as per C-14-RC-2; Group IV, Column A		2 hr 30 min		1		2,3	2 1/2
C-14-RC-9	14"	Description as per C-14-RC-2; Group IV, Column B		1 hr 30 min		1		2,3	1 1/2

NOTES: Table 2.1.4
1. Failure mode — main rebars buckled between links at various points.
2. Group I — includes concrete having calcareous aggregate containing a combined total of not more than 10 percent of quartz, chert, and flint for the coarse aggregate.
Group II — includes concrete having trap-rock aggregate applied without metal ties and also concrete having cinder, sandstone, or granite aggregate, if held in place with wire mesh or expanded metal having not larger than 4-in. mesh, weighing not less than 1.7 lb/yd^2, placed not more than 1 in. from the surface of the concrete.
Group III — includes concrete having cinder, sandstone, or granite aggregate tied with No. 5 gauge steel wire, wound spirally over the column section on a pitch of 8 in., or equivalent ties, and concrete having siliceous aggregates containing a combined total of 60 percent or more of quartz, chert, and flint, if held in place with wire mesh or expanded metal having not larger than 4-in. mesh, weighing not less than 1.7 lb/yd^2 placed not more than 1 in. from the surface of the concrete.
Group IV — includes concrete having siliceous aggregates containing a combined total of 60 percent or more of quartz, chert, and flint, and tied with No. 5 gauge steel wire wound spirally over the column section on a pitch of 8 in., or equivalent ties.
3. Groupings of aggregates and ties are the same as for structural steel columns protected solidly with concrete, the ties to be placed over the vertical reinforcing bars and the mesh, where required, to be placed within 1 in. from the surface of the column.
Column A — working loads are assumed as carried by the area of the column inside of the lines circumscribing the reinforcing steel.

Column B — working loads are assumed as carried by the gross area of the column.

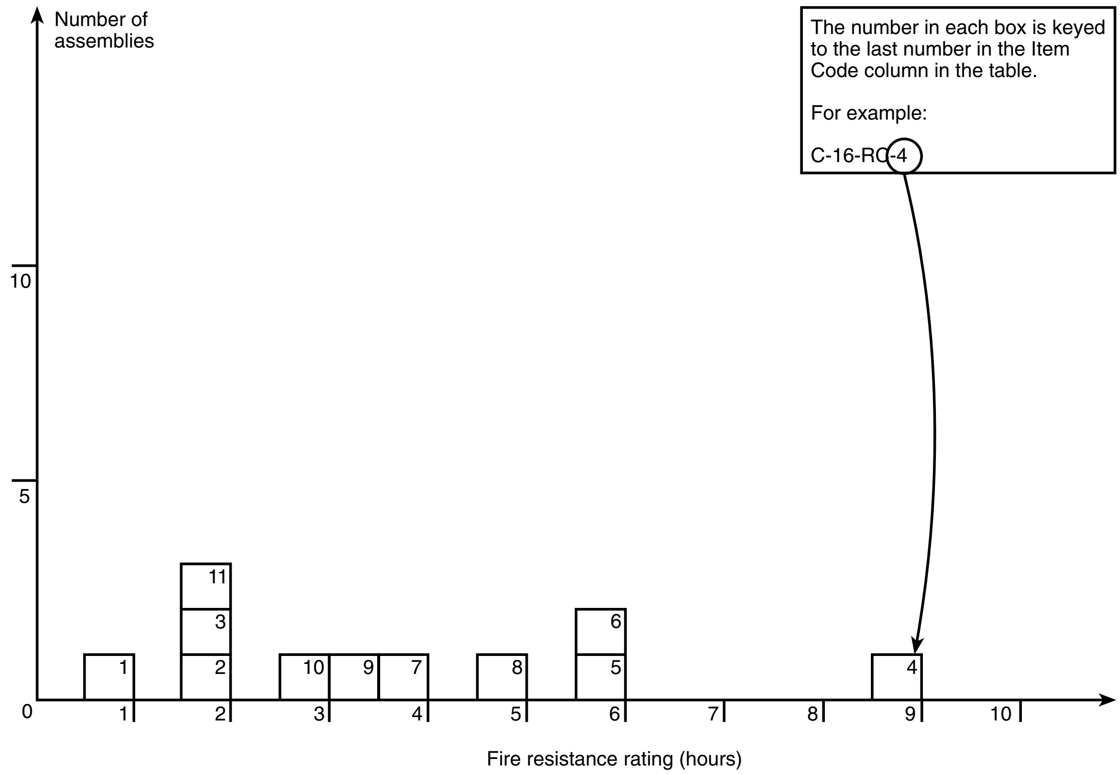


Figure 2.1.5 Reinforced Concrete Columns Minimum Dimension 16” to less than 18”

Table 2.1.5 Reinforced Concrete Columns Minimum Dimension 16" (400 mm) to less than 18" (450 mm)

Item Code	Minimum Dimension	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
C-16-RC-1	16"	16" Square Columns; Gravel aggregate concrete (4550 PSI); Reinforcement: Vertical 8-1 $^3/_8$" rebars; Horizontal $^5/_{16}$" ties @ 6" pitch linking center rebars of each face forming a smaller square in column cross section	237 tons	1 hr			7	1-3	1
C-16-RC-2	16"	16" Square Columns; Gravel aggregate concrete (3360 PSI): Reinforcement: Vertical 8- 1 $^3/_8$" rebars; Horizontal $^5/_{16}$" ties @ 6" pitch; Cover 1 $^3/_8$"	210	2 hr			7	2,4-6	2
C-16-RC-3	16"	16" Square Columns; Gravel aggregate concrete (3980 PSI); Reinforcement: Vertical 4- $^7/_8$" rebars; Horizontal $^3/_8$" ties @ 6" pitch; Cover 1"	123.5 tons	2 hr			7	2,4,7	2
C-16-RC-4	16"	Reinforced concrete columns with 1 $^1/_2$" concrete outside reinforcing steel; gross diameter or side of column: 16"; Group I, Column A		9 hr		1		8,9	9
C-16-RC-5	16"	Description as per C-16-RC-4; Group I, Column B		6 hr		1		8,9	6
C-16-RC-6	16"	Description as per C-16-RC-4; Group II, Column A		6 hr		1		8,9	6
C-16-RC-7	16"	Description as per C-16-RC-4; Group II, Column B		4 hr		1		8,9	4
C-16-RC-8	16"	Description as per C-16-RC-4; Group III, Column A		5 hr		1		8,9	5
C-16-RC-9	16"	Description as per C-16-RC-4; Group III, Column B		3 hr 30 min		1		8,9	3 $^1/_2$
C-16-RC-10	16"	Description as per C-16-RC-4; Group IV, Column A		3 hr		1		8,9	3
C-16-RC-11	16"	Description as per C-16-RC-4; Group IV, Column B		2 hr		1		8,9	2

NOTES: Table 2.1.5

1. Column passed 1-hr fire test.
2. Column passed hose stream test.
3. No reload specified.
4. Column passed 2-hr fire test.
5. Column reloaded successfully after 24 hours.
6. Reinforcing details same as C-16-RC-1.
7. Column passed reload after 72 hours.
8. Group I — includes concrete having calcareous aggregate containing a combined total of not more than 10 percent of quartz, chert, and flint for the coarse aggregate.

Group II — includes concrete having trap-rock aggregate applied without metal ties and also concrete having cinder, sandstone, or granite aggregate, if held in place with wire mesh or expanded metal having not larger than 4-in. mesh, weighing not less than 1.7 lb/yd^2, placed not more than 1 in. from the surface of the concrete.

Group III — includes concrete having cinder, sandstone, or granite aggregate tied with No. 5 gauge steel wire, wound spirally over the column section on a pitch of 8 in., or equivalent ties, and concrete having siliceous aggregates containing a combined total of 60 percent or more of quartz, chert, and flint, if held in place with wire mesh or expanded metal having not larger than 4-in. mesh, weighing not less than 1.7 lb/yd^2 placed not more than 1 in. from the surface of the concrete.

Group IV — includes concrete having siliceous aggregates containing a combined total of 60 percent or more of quartz, chert, and flint, and tied with No. 5 gauge steel wire wound spirally over the column section on a pitch of 8 in., or equivalent ties.

9. Groupings of aggregates and ties are the same as for structural steel columns protected solidly with concrete, the ties to be placed over the vertical reinforcing bars and the mesh, where required, to be placed within 1 in. from the surface of the column.

Column A — working loads are assumed as carried by the area of the column inside of the lines circumscribing the reinforcing steel.

Column B — working loads are assumed as carried by the gross area of the column.

Table 2.1.6 Reinforced Concrete Columns
Minimum Dimension 18" (450 mm) to less than 20" (500 mm)

			Performance		Reference Number				
Item Code	**Minimum Dimension**	**Construction Details**	**Load**	**Time**	**Pre-BMS-92**	**BMS-92**	**Post-BMS-92**	**Notes**	**Rec Hours**
C-18-RC-1	18"	Reinforced concrete columns with 1 1/2" concrete outside reinforcing steel; gross diameter or side of column: 18"; Group I, Column A		11 hr		1		1,2	11
C-18-RC-2	18"	Description as per C-18-RC-1; Group I, Column B		8 hr		1		1,2	8
C-18-RC-3	18"	Description as per C-18-RC-1; Group II, Column A		7 hr		1		1,2	7
C-18-RC-4	18"	Description as per C-18-RC-1; Group II, Column B		5 hr		1		1,2	5
C-18-RC-5	18"	Description as per C-18-RC-1; Group III, Column A		6 hr		1		1,2	6
C-18-RC-6	18"	Description as per C-18-RC-1; Group III, Column B		4 hr		1		1,2	4
C-18-RC-7	18"	Description as per C-18-RC-1; Group IV, Column A		3 hr 30 min		1		1,2	3 1/2
C-16-RC-8	18"	Description as per C-18-RC-1; Group IV, Column B		2 hr 30 min		1		1,2	2 1/2

NOTES: Table 2.1.6

1. Group I — includes concrete having calcareous aggregate containing a combined total of not more than 10 percent of quartz, chert, and flint for the coarse aggregate.

Group II — includes concrete having trap-rock aggregate applied without metal ties and also concrete having cinder, sandstone, or granite aggregate, if held in place with wire mesh or expanded metal having not larger than 4-in. mesh, weighing not less than 1.7 lb/yd^2 placed not more than 1 in. from the surface of the concrete.

Group III — includes concrete having cinder, sandstone, or granite aggregate tied with No. 5 gauge steel wire, wound spirally over the column section on a pitch of 8 in., or equivalent ties, and concrete having siliceous aggregates containing a combined total of 60 percent or more of quartz, chert, and flint, if held in place with wire mesh or expanded metal having not larger than 4-in. mesh, weighing not less than 1.7 lb/yd^2 placed not more than 1 in. from the surface of the concrete.

Group IV — includes concrete having siliceous aggregates containing a combined total of 60 percent or more of quartz, chert, and flint, and tied with No. 5 gauge steel wire wound spirally over the column section on a pitch of 8 in., or equivalent ties.

2. Groupings of aggregates and ties are the same as for structural steel columns protected solidly with concrete, the ties to be placed over the vertical reinforcing bars and the mesh, where required, to be placed within 1 in. from the surface of the column.

Column A — working loads are assumed as carried by the area of the column inside of the lines circumscribing the reinforcing steel.

Column B — working loads are assumed as carried by the gross area of the column.

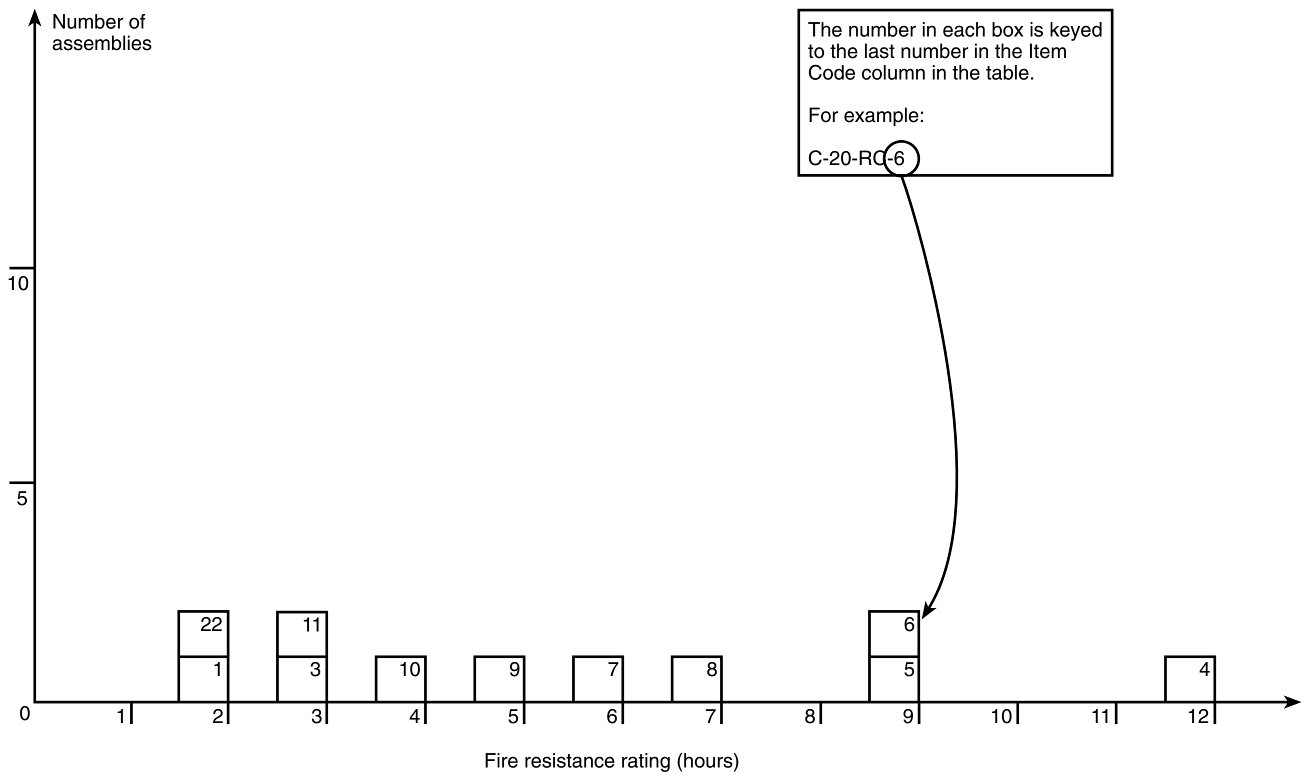


Figure 2.1.7 Reinforced Concrete Columns Minimum Dimension 20” to less than 22”

Table 2.1.7 Reinforced Concrete Columns
Minimum Dimension 20" (500 mm) to less than 22" (550 mm)

Item Code	Minimum Dimension	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
C-20-RC-1	20"	20" Square Columns; Gravel aggregate concrete (6690 PSI); Reinforcement: Vertical 4-1 $^3/_4$" rebars; Horizontal $^3/_8$" wire @ 6" pitch; Cover 1 $^3/_4$"	367 tons	2 hr			7	1-3	2
C-20-RC-2	20"	20" Square Columns; Gravel aggregate concrete (4330 PSI); Reinforcement: Vertical 4- 1 $^3/_4$" rebars; Horizontal $^3/_8$" ties @ 6" pitch; Cover 1 $^3/_4$"	327 tons	2 hr			7	1,2,4	2
C-20-RC-3	20 $^1/_4$"	20 $^1/_4$" Square Columns; Gravel aggregate concrete (4230 PSI); Reinforcement: Vertical 4- 1 $^1/_8$" rebar; Horizontal $^3/_8$" wire @ 5" pitch; Cover 1 $^1/_8$"	199 tons	2 hr 56 min			7	5	2 $^3/_4$
C-20-RC-4	20"	Reinforced concrete columns with 1 $^1/_2$" concrete outside of reinforcing steel; gross diameter or side of column: 20"; group i, column a		12 hr		1		6,7	12
C-20-RC-5	20"	Description as per C-20-RC-4; Group I, Column B		9 hr		1		6,7	9
C-20-RC-6	20"	Description as per C-20-RC-4; Group II, Column A		9 hr		1		6,7	9
C-20-RC-7	20"	Description as per C-20-RC-4; Group II, Column B		6 hr		1		6,7	6
C-20-RC-8	20"	Description as per C-20-RC-4; Group III, Column A		7 hr		1		6,7	7
C-20-RC-9	20"	Description as per C-20-RC-4; Group III, Column B		5 hr		1		6,7	5
C-20-RC-10	20"	Description as per C-20-RC-4; Group IV, Column A		4 hr		1		6,7	4
C-20-RC-11	20"	Description as per C-20-RC-4; Group IV, Column B		3 hr		1		6,7	3

NOTES: Table 2.1.7
1. Passed 2-hr fire test.
2. Passed hose stream test.
3. Failed during reload at 300 tons.

4. Passed reload after 72 hours.
5. Failure mode — collapse.
6. Group I — includes concrete having calcareous aggregate containing a combined total of not more than 10 percent of quartz, chert, and flint for the coarse aggregate.

Group II — includes concrete having trap-rock aggregate applied without metal ties and also concrete having cinder, sandstone, or granite aggregate, if held in place with wire mesh or expanded metal having not larger than 4-in. mesh, weighing not less than 1.7 lb/yd^2, placed not more than 1 in. from the surface of the concrete.

Group III — includes concrete having cinder, sandstone, or granite aggregate tied with No. 5 gauge steel wire, wound spirally over the column section on a pitch of 8 in., or equivalent ties, and concrete having siliceous aggregates containing a combined total of 60 percent or more of quartz, chert, and flint, if held in place with wire mesh or expanded metal having not larger than 4-in. mesh, weighing not less than 1.7 lb/yd^2 placed not more than 1 in. from the surface of the concrete.

Group IV — includes concrete having siliceous aggregates containing a combined total of 60 percent or more of quartz, chert, and flint, and tied with No. 5 gauge steel wire wound spirally over the column section on a pitch of 8 in., or equivalent ties.

7. Groupings of aggregates and ties are the same as for structural steel columns protected solidly with concrete, the ties to be placed over the vertical reinforcing bars and the mesh, where required, to be placed within 1 in. from the surface of the column.

Column A — working loads are assumed as carried by the area of the column inside of the lines circumscribing the reinforcing steel.

Column B — working loads are assumed as carried by the gross area of the column.

Table 2.1.8 Hexagonal Reinforced
Minimum Dimension 12" (300 mm) to less than 14" (350 mm)

Item Code	Minimum Dimension	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
C-12-HRC-1	12"	12" Hexagonal Columns; Gravel aggregate concrete (4420 PSI); Vertical Reinforcement: 8 1/2" rebars; Horizontal Reinforcement: helical 5/16" winding @ 1 1/2" pitch; Cover 1/2"	88 tons	58 min			7	1	3/4
C-12-HRC-2	12"	12" Hexagonal Columns; Gravel aggregate concrete (3460 PSI); Vertical Reinforcement: 8- 1/2" rebars; Horizontal Reinforcement: 5/16" helical winding @ 1 1/2" pitch; Cover 1/2"	78.7 tons	1 hr			7	2	1

NOTES: Table 2.1.8
1. Failure mode — collapse.
2. Test stopped at 1 hour.

Table 2.1.9 Hexagonal Reinforced Concrete Columns
Minimum Dimension 14" (350 mm) to less than 16" (400 mm)

Item Code	Minimum Dimension	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
C-14-HRC-1	14"	14" Hexagonal Columns; Gravel aggregate concrete (4970 PSI); Vertical Reinforcement: 8 1/2" rebar; Horizontal reinforcement: 5/16" helical winding @ 2" pitch; Cover 1/2"	90 tons	2 hr			7	1-3	2

NOTES: Table 2.1.9
1. Withstood 2-hr fire test.
2. Withstood hose stream test.
3. Withstood reload after 48 hours.

Table 2.1.10 Hexagonal Reinforced Concrete Columns Diameter — 16" (400 mm) to less than 18" (450 mm)

Item Code	Minimum Dimension	Construction Details	Performance Load	Performance Time	Reference Number Pre-BMS-92	Reference Number BMS-92	Reference Number Post-BMS-92	Notes	Rec Hours
C-16-HRC-1	16"	16" Hexagonal Columns; Gravel concrete (6320 PSI); Vertical Reinforcement: 8 $5/8$" rebar; horizontal reinforcement: $5/16$" helical winding @ $3/4$" pitch; Cover $1/2$"	140 tons	1 hr 55 min			7	1	1 $3/4$
C-16-HRC-2	16"	16" Hexagonal Columns; Gravel aggregate concrete (5580 PSI); Vertical Reinforcement: 8 $5/8$" rebar; Horizontal reinforcement $5/16$" helical winding @ 1 $3/4$" pitch; Cover $1/2$"	124 tons	2 hr			7	2	2

NOTES: Table 2.1.10
1. Failure Mode — Collapse.
2. Failed on furnace removal.

Table 2.1.11 Hexagonal Reinforced Concrete Columns Diameter — 20" (500 mm) to less than 22" (550 mm)

Item Code	Minimum Dimension	Construction Details	Performance Load	Performance Time	Reference Number Pre-BMS-92	Reference Number BMS-92	Reference Number Post-BMS-92	Notes	Rec Hours
C-20-HRC-1	20"	20" Hexagonal Columns; Gravel Concrete (6080 PSI); Vertical Reinforcement: $3/4$" rebar; Horizontal Reinforcement: $5/16$" helical winding @ 1 $3/4$" pitch; Cover $1/2$"	211 tons	2 hr			7	1	2
C-20-HRC-2	20"	20" Hexagonal Columns; Gravel Concrete (5080 PSI); Vertical Reinforcement: $3/4$" rebar; Horizontal Reinforcement: $5/16$" wire @ 1 $3/4$" pitch; Cover $1/2$"	184 tons	2 hr 15 min			7	2,3,4	2 $1/4$

NOTES: Table 2.1.11
1. Column collapsed on furnace removal.
2. Passed 2 $1/4$-hr fire test.
3. Passed hose stream test.
4. Withstood reload after 48 hours.

Table 2.2 Round Cast Iron Columns

Item Code	Minimum Dimension	Construction Details	Performance Load	Performance Time	Reference Number Pre-BMS-92	Reference Number BMS-92	Reference Number Post-BMS-92	Notes	Rec Hours
C-7-CI-1	7" O.D.	Column: 0.6" min. thickness metal, unprotected	—	30 min		1			$1/2$
C-7-CI-2	7" O.D.	Column: 0.6" metal thickness concrete filled, outside unprotected	—	45 min		1			$3/4$
C-11-CI-3	11" O.D.	Column: 0.6" minimum metal thickness; Protection: 1 $1/2$" portland cement plaster on high ribbed metal lath, $1/2$" broken air space	—	3 hr		1			3
C-11-CI-4	11" O.D.	Column: 0.6" min. metal thickness; Protection: 2" concrete other than siliceous aggregate	—	2 hr 30 min		1			2 $1/2$
C-12-CI-5	12.5" O.D.	Column: 7" O.D., 0.6" min. metal thickness; Protection: 2" porous hollow tile, $3/4$" mortar between tile and column, outside wire ties	—	3 hr		1			3
C-7-CI-6	7.6" O.D.	Column: 7" I.D., $3/10$" min. thickness metal, concrete filled unprotected	—	30 min		1			$1/2$
C-8-CI-7	8.6" O.D.	Column: 8" I.D., $3/10$" min. thickness metal, concrete filled reinforced with 4- 3 $1/2$" × $3/8$" angles, in fill; unprotected outside	—	1 hr		1			1

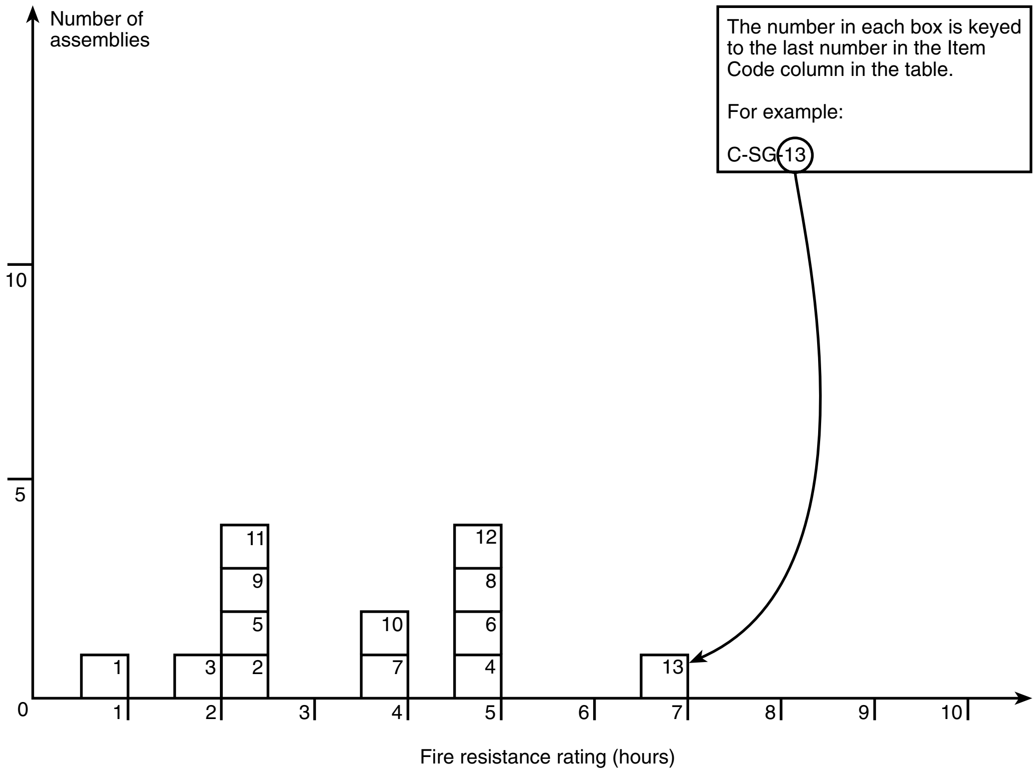


Figure 2.3 Steel Columns — Gypsum Encasements

Table 2.3 Steel Columns — Gypsum Encasements

Item Code	Minimum Area of Solid Material	Construction Details	Performance: Load	Performance: Time	Reference Number: Pre-BMS-92	Reference Number: BMS-92	Reference Number: Post-BMS-92	Notes	Rec Hours
C-SG-1	—	Steel protected with 3/4" 1:3 sanded gypsum or 1" 1:2 1/2 portland cement plaster on wire or lath; one layer	—	1 hr		1			1
C-SG-2	—	Same as C-SG-1; two layers	—	2 hr 30 min		1			2 1/2
C-SG-3	130 in.^{2}	2" solid blocks with wire mesh in horizontal joints, 1" mortar on flange, re-entrant space filled with block and mortar	—	2 hr		1			2
C-SG-4	150 in.^{2}	Same as C-130-SG-3 with 1/2" sanded gypsum plaster	—	5 hr		1			5
C-SG-5	130 in.^{2}	2" solid blocks with wire mesh in horizontal joints, 1" mortar on flange, re-entrant space filled with gypsum concrete	—	2 hr 30 min		1			2 1/2
C-SG-6	150 in.^{2}	Same as C-130-SG-5 with 1/2" sanded gypsum plaster	—	5 hr		1			5
C-SG-7	300 in.^{2}	4" solid blocks with wire mesh in horizontal joints, 1" mortar on flange, re-entrant space filled with block and mortar	—	4 hr		1			4
C-SG-8	300 in.^{2}	Same as C-300-SG-7 with re-entrant space filled with gypsum concrete	—	5 hr		1			5
C-SG-9	85 in.^{2}	2" solid blocks with cramps at horizontal joints, mortar on flange only at horizontal joints, re-entrant space not filled	—	2 hr 30 min		1			2 1/2
C-SG-10	105 in.^{2}	Same as C-85-SG-9 with 1/2" sanded gypsum plaster	—	4 hr		1			4
C-SG-11	95 in.^{2}	3" hollow blocks with cramps at horizontal joints, mortar on flange only at horizontal joints, re-entrant space not filled	—	2 hr 30 min		1			2 1/2

Table 2.3 Steel Columns — Gypsum Encasements

Item Code	Minimum Area of Solid Material	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
C-SG-12	120 in.^{2}	Same as C-95-SG-11 with $^1/_2$" sanded gypsum plaster	—	5 hr		1			5
C-SG-13	130 in.^{2}	2" neat fibered gypsum re-entrant space filled poured solid and reinforced with 4" × 4" wire mesh $^1/_2$" sanded gypsum plaster	—	7 hr		1			7

Table 2.4 Timber Columns Minimum Dimension

Item Code	Minimum Dimension	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
C-11-TC-1	11"	With unprotected steel plate cap		30 min		1		1,2	$^1/_2$
C-11-TC-2	11"	With unprotected cast iron cap and pintle		45 min		1		1,2	$^3/_4$
C-11-TC-3	11"	With concrete or protected steel or cast iron cap		1 hr 15 min		1		1,2	1$^1/_4$
C-11-TC-4	11"	With $^3/_8$" gypsum wallboard over column and over cast iron or steel cap		1 hr 15 min		1		1,2	1$^1/_4$
C-11-TC-5	11"	With 1" portland cement plaster on wire lath over column and over cast iron or steel cap; $^3/_4$" air space		2 hr		1		1,2	2

NOTES: Table 2.4
1. Minimum Area: 120 in.^{2}
2. Type of wood: Long leaf pine or Douglas fir.

Table 2.5.1.1 Steel Columns — Concrete Encasements Minimum Dimension less than 6" (150 mm)

Item Code	Minimum Dimension	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
C-5-SC-1	5"	5" × 6" outer dimensions; 4" × 3" × 10 lb - H Beam; Protection: Gravel Concrete (4900 PSI) 6" × 4" - 13 SWG mesh	12 tons	1 hr 29 min			7	1	1$^1/_4$

NOTES: Table 2.5.1.1
1. Failure mode — collapse.

Table 2.5.1.2 Steel Columns — Concrete Encasements 6" (150 mm) to less than 8" (200 mm) thick

Item Code	Minimum Dimension	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
C-7-SC-1	7"	7" × 8" Column; 4" × 3" × 10" H Beam; Protection: Brick-filled concrete (6220 PSI); 6" × 4" mesh - 13 SWG; mesh 1" below column surface	12 tons	2 hr 46 min			7	1	3
C-7-SC-2	7"	7" × 8" Column; 4" × 3" × 10 lb H Beam; Protection: Gravel concrete (5140 PSI); 6" × 4" 13 SWG; mesh 1" below surface	12 tons	3 hr 1 min			7	1	2$^3/_4$
C-7-SC-3	7"	7" × 8" Column; 4" × 3" × 10 lb H Beam; Protection: Concrete (4540 PSI); 6" × 4" 13 SWG; mesh 1" below column surface	12 tons	3 hr 9 min			7	1	3
C-7-SC-4	7"	7" × 8" Column; 4" × 3" × 10 lb H Beam; Protection: Gravel concrete (5520 PSI); 4" × 4" mesh; 16 SWG	12 tons	2 hr 50 min			7	1	2$^3/_4$

NOTES: Table 2.5.1.2
1. Failure mode — collapse.

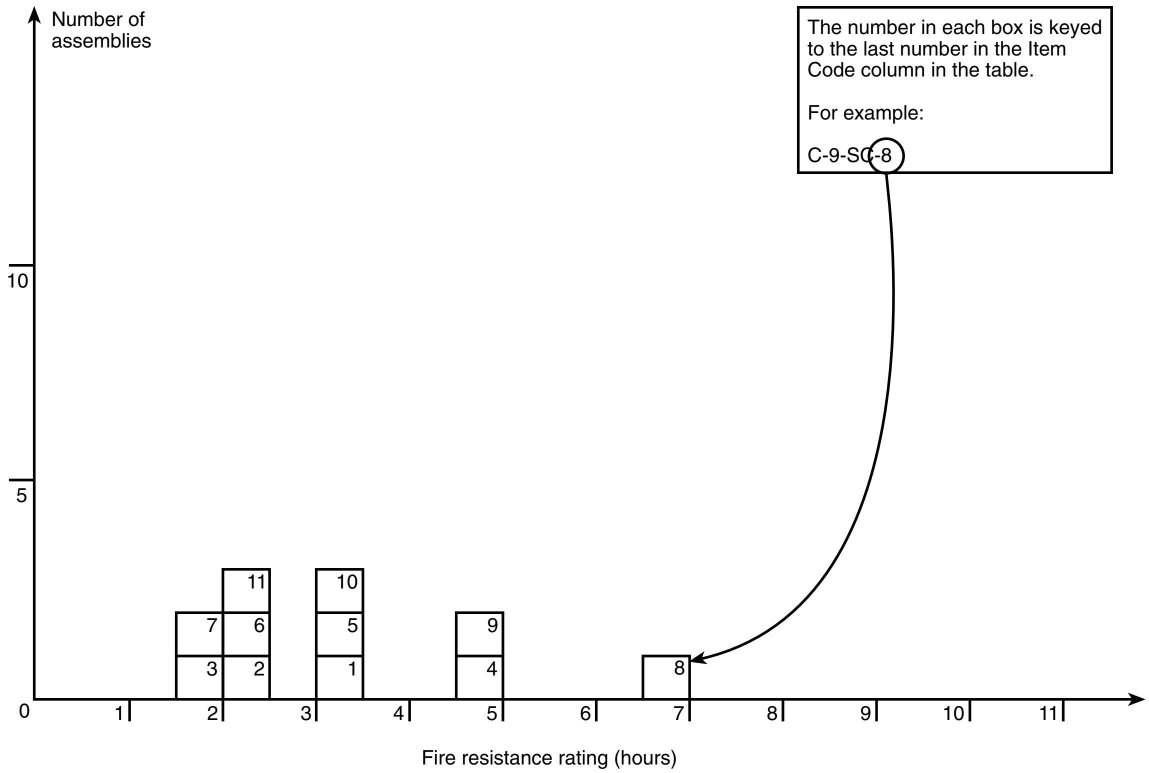


Figure 2.5.1.3 Steel Columns—Concrete Encasements Minimum Dimension 8” to less than 10”

Table 2.5.1.3 Steel Columns — Concrete Encasements Minimum Dimension 8" (200 mm) to less than 10" (250 mm)

Item Code	Minimum Dimension	Construction details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
C-8-SC-1	8 1/2"	8 1/2" × 10" Column; 6" × 4 1/2" × 20 lb H Beam; Protection: Gravel Concrete (5140 PSI) 6" × 4" 13 SWG mesh	39 tons	3 hr 8 min			7	1	3
C-8-SC-2	8"	8" × 10" Column; 8" × 6" × 35 lb I Beam; Protection: Gravel concrete (4240 PSI) 4" × 6" mesh; 13 SWG with 1/2" cover	90 tons	2 hr 1 min			7	1	2
C-8-SC-3	8"	8" × 10" Concrete encased column; 8" × 6" × 35 lb H beam; protection: aggregate concrete (3750 PSI) with 4" mesh; 16 SWG reinforcing 1/2" below column surface	90 tons	1 hr 58 min			7	1	1 3/4
C-8-SC-4	8"	6" × 6" Steel Column with 2" outside protection; Group I	—	5 hr		1		2	5
C-8-SC-5	8"	6" × 6" Steel Column with 2" outside protection; Group II	—	3 hr 30 min		1		2	3 1/2
C-8-SC-6	8"	6" × 6" Steel Column with 2" outside protection; Group III	—	2 hr 30 min		1		2	2 1/2
C-8-SC-7	8"	6" × 6" Steel Column with 2" outside protection; Group IV	—	1 hr 45 min		1		2	1 3/4
C-9-SC-8	9"	6" × 6" Steel Column with 3" outside protection; Group I	—	7 hr		1		2	7
C-9-SC-9	9"	6" × 6" Steel Column with 3" outside protection; Group II	—	5 hr		1		2	5

Table 2.5.1.3 Steel Columns — Concrete Encasements
Minimum Dimension 8" (200 mm) to less than 10" (250 mm)

Item Code	Minimum Dimension	Construction details	Performance: Load	Performance: Time	Reference Number: Pre-BMS-92	Reference Number: BMS-92	Reference Number: Post-BMS-92	Notes	Rec Hours
C-9-SC-10	9"	6" × 6" Steel Column with 3" outside protection; Group III	—	30 hr 30 min		1		2	3 1/2
C-9-SC-11	9"	6" × 6" Steel Column with 3" outside protection; Group IV	—	2 hr 30 min		1		2	2 1/2

NOTES: Table 2.5.1.3
1. Failure mode — collapse.
2. Group I — includes concrete having calcareous aggregate containing a combined total of not more than 10 percent of quartz, chert, and flint for the coarse aggregate.

Group II — includes concrete having trap-rock aggregate applied without metal ties and also concrete having cinder, sandstone, or granite aggregate, if held in place with wire mesh or expanded metal having not larger than 4-in. mesh, weighing not less than 1.7 lb/yd^2, placed not more than 1 in. from the surface of the concrete.

Group III — includes concrete having cinder, sandstone, or granite aggregate tied with No. 5 gauge steel wire, wound spirally over the column section on a pitch of 8 in., or equivalent ties, and concrete having siliceous aggregates containing a combined total of 60 percent or more of quartz, chert, and flint, if held in place with wire mesh or expanded metal having not larger than 4-in. mesh, weighing not less than 1.7 lb/yd^2 placed not more than 1 in. from the surface of the concrete.

Group IV — includes concrete having siliceous aggregates containing a combined total of 60 percent or more of quartz, chert, and flint, and tied with No. 5 gauge steel wire wound spirally over the column section on a pitch of 8 in., or equivalent ties.

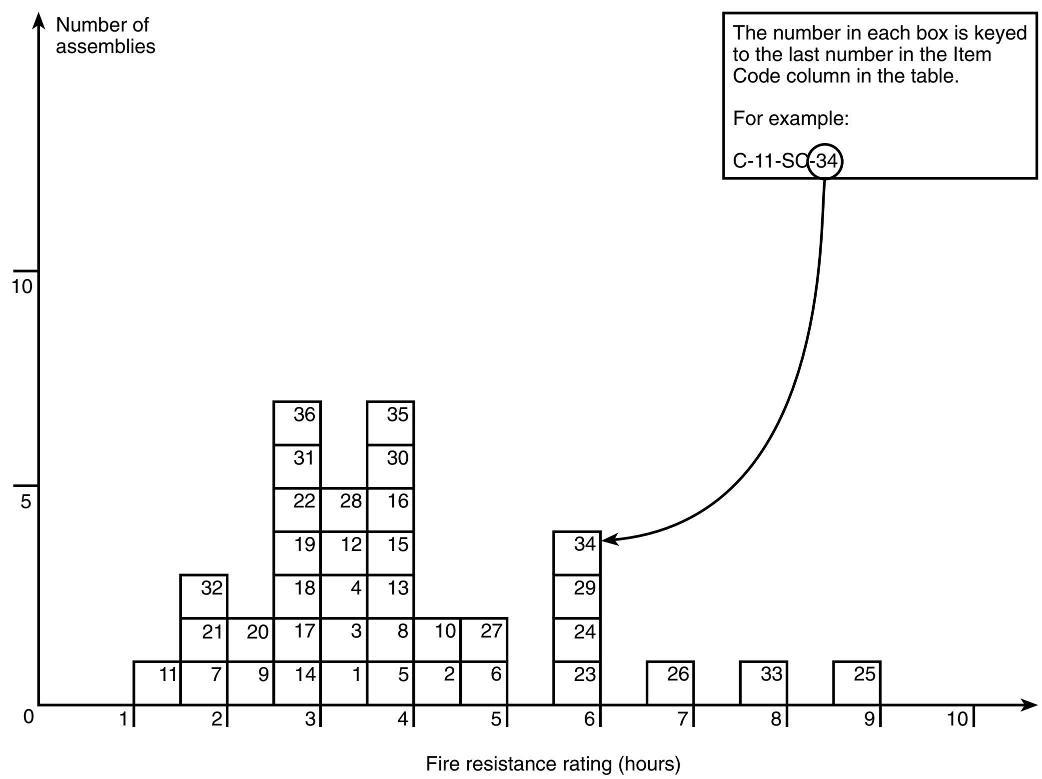


Figure 2.5.1.4 Steel Columns—Concrete Encasements Minimum Dimension 10” to less than 12”

Table 2.5.1.4 Steel Columns — Concrete Encasements
Minimum Dimension 10" (250 mm) to less than 12" (300 mm)

Item Code	Minimum Dimension	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
C-10-SC-1	10"	10" × 12" concrete encased steel column; 8" × 6" × 35 lb H beam; protection: Gravel aggregate concrete (3640 PSI); Mesh 6" × 4"; 13 SWG, 1" below column surface	90 tons	3 hr 7 min			7	1,2	3
C-10-SC-2	10"	Column: 10" × 16"; 8" × 6" × 35 lb "H" beam; Protection: clay brick concrete (3630 PSI); 6" × 4" mesh; 13 SWG, mesh 1" below column surface	90 tons	4 hr 6 min			7	2	4
C-10-SC-3	10"	Column: 10" × 12"; 8" × 6" × 35 lb "H" beam; Protection: concrete of crushed stone and sand (3930 PSI) 6" × 4" - 13 SWG mesh; 1" below column surface	90 tons	3 hr 17 min			7	2	$3^1/_4$
C-10-SC-4	10"	Column: 10" × 12"; 8" × 6" × 35 lb "H" beam; Protection: Concrete of crushed basalt and sand (4350 PSI) 6" × 4" - 13 SWG mesh; 1" below column surface	90 tons	3 hr 2 min			7	2	$3^1/_3$
C-10-SC-5	10"	Column: 10" × 12"; 8" × 6" × 35 lb "H" beam; Protection: concrete gravel aggregate (5570 PSI) 6" × 4" mesh; 13 SWG	90 tons	3 hr 39 min			7	2	$3^1/_2$
C-10-SC-6	10"	Column: 10" × 16"; 8" × 6" × 35 lb "I" beam; Protection: gravel concrete (4950 PSI) 6" × 4" - 13 SWG; 1" below column surface	90 tons	4 hr 32 min			7	2	$4\,^1/_2$
C-10-SC-7	10"	10" × 12" concrete encased steel column; 8" × 6" × 35 lb "H" beam; Protection: aggregate concrete (1370 PSI) with 6" × 4" mesh; 13 SWG reinforcing 1" below column surface	90 tons	2 hr			7	3,4	2
C-10-SC-8	10"	10" × 12" concrete encased steel column; 8" × 6" × 35 lb "H" column; Protection: aggregate concrete (4000 PSI) with 13 SWG iron wire loosely wound around column @ 6" pitch about 2" beneath column surface	86 tons	3 hr 36 min			7	2	$3^1/_2$
C-10-SC-9	10"	10" × 12" concrete encased steel column; 8" × 6" × 35 lb "H" beam; Protection: aggregate concrete (3290 PSI); 2" cover minimum	86 tons	2 hr 8 min			7	2	2
C-10-SC-10	10"	10" × 14" concrete encased column; 8" × 6" × 35 lb "H" column; Protection: crushed brick-filled concrete (5310 PSI); with 6" × 4" mesh; 13 SWG reinforcement 1" beneath column surface	90 tons	4 hr 28 min			7	2	$4^1/_3$
C-10-SC-11	10"	10" × 12" concrete encased column; 8" × 6" × 35 lb "H" beam; Protection: aggregate concrete (342 PSI) with 6" × 4" mesh; 13 SWG reinforcements 1" below surface	90 tons	1 hr 2 min			7	2	1
C-10-SC-12	10"	10" × 12" concrete encased steel column; 8" × 6" × 35 lb "H" beam; Protection: aggregate concrete (4480 PSI) 4-$^3/_8$" vertical rebars @ H beam edges with $^3/_{16}$" spacers @ beam surface @ 3' pitch and $^3/_{16}$binders @ 10" pitch; 2" concrete cover	90 tons	3 hr 2 min			7	2	3
C-10-SC-13	10"	10" × 12" concrete encased steel column; 8" × 6" × 35 lb "H" beams Protection: aggregate concrete (5070 PSI) with 6" × 4" mesh; 13 SWG reinforcing @ 6" beam sides wrapped and held by wire ties across (open) 8" beam face; reinforcements wrapped in 6" × 4" mesh; 13 SWG throughout with $^1/_2$" cover to column surface	90 tons	3 hr 59 min			7	2	$3^3/_4$
C-10-SC-14	10"	10" × 12" concrete encased steel column; 8" × 6" × 35 lb "H" column; Protection: aggregate concrete (4410 PSI) 6" × 4" mesh; 13 SWG reinforcement 1 $^1/_4$" below column surface; $^1/_2$" lime-cement plaster with $^3/_8$" gypsum plaster finish	90 tons	2 hr 50 min			7	2	$2^3/_4$
C-10-SC-15	10"	10" × 12" concrete encased steel column; 8" × 6" × 35 lb "H" beam; Protection: crushed clay brick-filled concrete (4260 PSI) with 6" × 4" mesh; 13 SWG reinforcing 1" below column surface	90 tons	3 hr 54 min			7	2	$3^3/_4$

Table 2.5.1.4 Steel Columns — Concrete Encasements
Minimum Dimension 10" (250 mm) to less than 12" (300 mm)

Item Code	Minimum Dimension	Construction Details	Performance Load	Performance Time	Reference Number Pre-BMS-92	Reference Number BMS-92	Reference Number Post-BMS-92	Notes	Rec Hours
C-10-SC-16	10"	10" × 12" concrete encased steel columns; 8" × 6" × 35 lb "H" beam; Protection: limestone aggregate concrete (4350 PSI) 6" × 4" mesh; 13 SWG reinforcing 1" below column surface	90 tons	3 hr 54 min			7	2	3 3/4
C-10-SC-17	10"	10" × 12" concrete encased steel column; 8" × 6" × 35 lb "H" beam; Protection: limestone aggregate concrete (5300 PSI) with 6" × 4"; 13 SWG wire mesh 1" below column surface	90 tons	3 hr			7	4,5	3
C-10-SC-18	10"	10" × 12" concrete encased steel column; 8" × 6" × 35 lb "H" beam; Protection: limestone aggregate concrete (4800 PSI) with 6" × 4"; 13 SWG mesh reinforcement 1" below surface	90 tons	3 hr			7	4,5	3
C-10-SC-19	10"	10" × 14" concrete encased steel column; 12" × 8" × 65 lb "H" beam; Protection: aggregate concrete (3900 PSI) 4" mesh; 16 SWG reinforcing 1/2" below column surface	118 tons	2 hr 42 min			7	2	2
C-10-SC-20	10"	10" × 14" concrete encased steel column; 12" × 8" × 65 lb "H" beam; Protection: aggregate concrete (4930 PSI); 4" mesh; 16 SWG reinforcing 1/2" below column surface	177 tons	2 hr 8 min			7	2	2
C-10-SC-21	10 3/8"	10 3/8" × 12 3/8" concrete encased steel column; 8" × 6" × 35 lb "H" beam; Protection: aggregate concrete (835 PSI) with 6" × 4" mesh; 13 SWG reinforcing 1 3/16" below column surface; 3/16" gypsum plaster finish	90 tons	2 hr			7	3,4	2
C-11-SC-22	11"	11" × 13" concrete encased steel column; 8" × 6" × 35 lb "H" beam; Protection: "open texture" brick-filled concrete (890 PSI) with 6" × 4" mesh; 13 SWG reinforcing 1 1/2" below column surface; 3/8" lime cement plaster; 1/8" gypsum plaster finish	90 tons	3 hr			7	6,7	3
C-11-SC-23	11"	11" × 12" column; 4" × 3" × 10 lb "H" beam; gravel concrete (4550 PSI); 6" × 4" - 13 SWG mesh reinforcing; 1" below column surface	12 tons	6 hr			7	7,8	6
C-11-SC-24	11"	11" × 12" column; 4" × 3" × 10 lb "H" beam; Protection: gravel aggregate concrete (3830 PSI) with 4" × 4" mesh; 16 SWG; 1" below column surface	16 tons	5 hr 32 min			7	2	5 1/2
C-10-SC-25	10"	6" × 6" steel column with 4" outside protection; Group I	—	9 hr		1		9	9
C-10-SC-26	10"	Description as per C-1-SC-25; Group II	—	7 hr		1		9	7
C-10-SC-27	10"	Description as per C-1-SC-25; Group III	—	5 hr		1		9	5
C-10-SC-28	10"	Description as per C-1-SC-25; Group IV	—	3 hr 30 min		1		9	3 1/2
C-10-SC-29	10"	8" × 8" steel column with 2" outside protection; Group I	—	6 hr		1		9	6
C-10-SC-30	10"	Description as per C-10-SC-29; Group II	—	4 hr		1		9	4
C-10-SC-31	10"	Description as per C-10-SC-29; Group III	—	3 hr		1		9	3
C-10-SC-32	10"	Description as per C-10-SC-29; Group IV	—	2 hr		1		9	2
C-11-SC-33	11"	8" × 8" steel column with 3" outside protection; Group I	—	8 hr		1		9	8
C-11-SC-34	11"	Description as per C-11-SC-33; Group II	—	6 hr		1		9	6
C-11-SC-35	11"	Description as per C-11-SC-33; Group III	—	4 hr		1		9	4
C-11-SC-36	11"	Description as per C-11-SC-33; Group IV	—	3 hr		1		9	3

NOTES: Table 2.5.1.4

1. Tested under total restraint load to prevent expansion — minimum load 90 tons.
2. Failure mode — collapse.
3. Passed 2-hr fire test (Grade "C" — British).
4. Passed hose stream test.
5. Column tested and passed 3-hr grade fire resistance (British).
6. Column passed 3-hr fire test.

7. Column collapsed during hose stream test.
8. Column passed 6-hr fire test.
9. Group I — includes concrete having calcareous aggregate containing a combined total of not more than 10 percent of quartz, chert, and flint for the coarse aggregate.

Group II — includes concrete having trap-rock aggregate applied without metal ties and also concrete having cinder, sandstone, or granite aggregate, if held in place with wire mesh or expanded metal having not larger than 4-in. mesh, weighing not less than 1.7 lb/yd^2, placed not more than 1 in. from the surface of the concrete.

Group III — includes concrete having cinder, sandstone, or granite aggregate tied with No. 5 gauge steel wire, wound spirally over the column section on a pitch of 8 in., or equivalent ties, and concrete having siliceous aggregates containing a combined total of 60 percent or more of quartz, chert, and flint, if held in place with wire mesh or expanded metal having not larger than 4-in. mesh, weighing not less than 1.7 lb/yd^2 placed not more than 1 in. from the surface of the concrete.

Group IV — includes concrete having siliceous aggregates containing a combined total of 60 percent or more of quartz, chert, and flint, and tied with No. 5 gauge steel wire wound spirally over the column section on a pitch of 8 in., or equivalent ties.

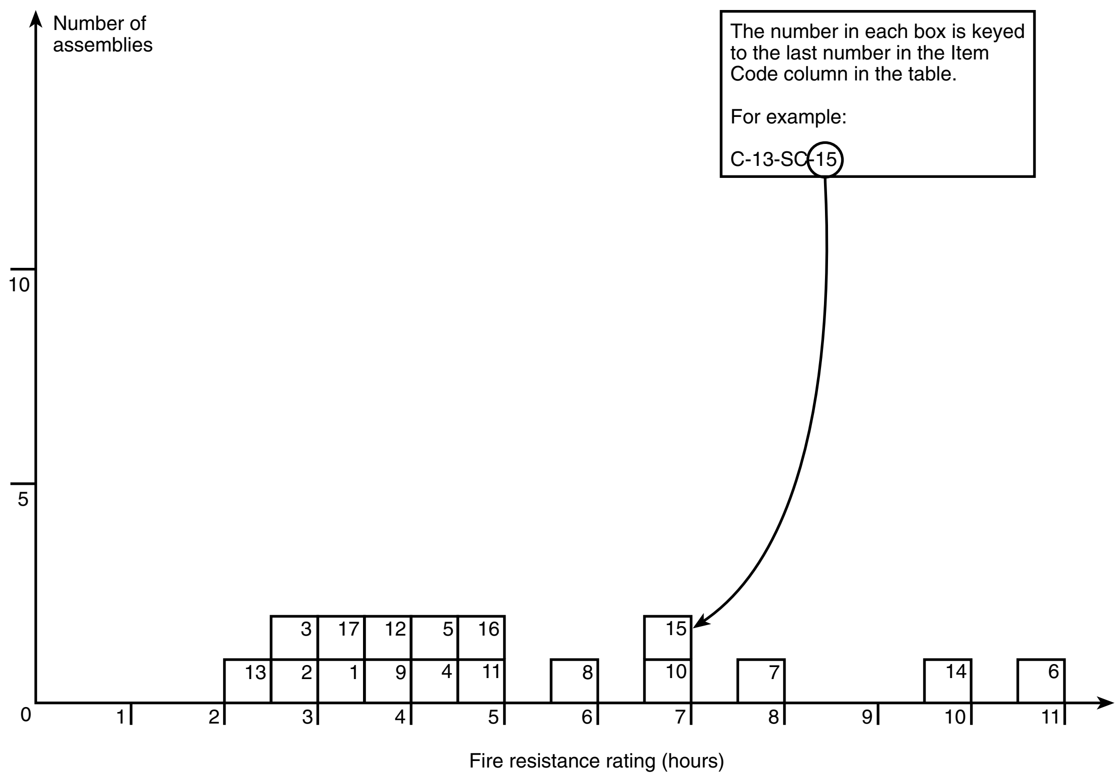


Figure 2.5.1.5 Steel Columns—Concrete Encasements Minimum Dimension 12" to less than 14"

Table 2.5.1.5 Steel Columns — Concrete Encasements
Minimum Dimension 12" (300 mm) to less than 14" (350 mm)

Item Code	Minimum Dimension	Construction Details	Performance Load	Performance Time	Reference Number Pre-BMS-92	Reference Number BMS-92	Reference Number Post-BMS-92	Notes	Rec Hours
C-12-SC-1	12"	12" × 14" Concrete encased steel column; 8" × 6" × 351b "H" beam; Protection: Aggregate concrete (4150 PSI) with 4" mesh; 16 SWG reinforcing 1" below column surface	120 tons	3 hr 24 min			7	1	3 1/3
C-12-SC-2	12"	12" × 16" Concrete encased column; 8" × 6" × 35 lb "H" beam; Protection: Aggregate concrete (4300 PSI) with 4" mesh; 16 SWG reinforcing 1" below surface	90 tons	24 hr 52 min			7	1	2 3/4
C-12-SC-3	12"	12" × 16" Concrete encased steel column; 12" × 8" × 65 lb "H" column; Protection: Gravel aggregate concrete (3550 PSI) with 4" mesh; 16 SWG reinforcement 1" below column surface	177 tons	2 hr 31 min			7	1	2 1/2
C-12-SC-4	12"	12" × 16" concrete encased column; 12" × 8" × 65 lb "H" beam; Protection: Aggregate concrete (3450 PSI) with 4" - 16 SWG mesh reinforcement 1" below column surface	118 tons	4 hr 4 min			7	1	4 1/3
C-12-SC-5	12 1/2"	12 1/2" × 14" column; 6" × 4 1/2" × 20 lb "H" beam; Protection: Gravel aggregate concrete (3750 PSI) with 4" × 4" mesh; 16 SWG reinforcing 1" below column surface	52 tons	4 hr 29 min			7	1	4 1/3
C-12-SC-6	12"	8" × 8" steel column; 2" outside protection; Group I	—	11 hr			1	2	11
C-12-SC-7	12"	Description as per C-12-SC-6; Group II	—	8 hr		1		2	8
C-12-SC-8	12"	Description as per C-12-SC-6; Group III	—	6 hr		1		2	6
C-12-SC-9	12"	Description as per C-12-SC-6; Group IV	—	4 hr		1		2	4
C-12-SC-10	12"	10" × 10" steel column with 2" outside protection; Group I	—	7 hr		1		2	7
C-12-SC-11	12"	Description as per C-12-SC-10; Group II	—	5 hr		1		2	5
C-12-SC-12	12"	Description as per C-12-SC-10; Group III	—	4 hr		1		2	4
C-12-SC-13	12"	Description as per C-12-SC-10; Group IV	—	2 hr 30 min		1		2	2 1/2
C-13-SC-14	13"	10" × 10" steel column with 3" outside protection; Group I	—	10 hr		1		2	10
C-13-SC-15	13"	Description as per C-13-SC-14; Group II	—	7 hr		1		2	7
C-13-SC-16	13"	Description as per C-13-SC-14; Group III	—	5 hr		1		2	5
C-13-SC-17	13"	Description as per C-13-SC-14; Group IV	—	3 hr 30 min		1		2	3 1/2

NOTES: Table 2.5.1.5
1. Failure mode — collapse.
2. Group I — includes concrete having calcareous aggregate containing a combined total of not more than 10 percent of quartz, chert, and flint for the coarse aggregate.

Group II — includes concrete having trap-rack aggregate applied without metal ties and also concrete having cinder, sandstone, or granite aggregate, if held in place with wire mesh or expanded metal having not larger than 4-in. mesh, weighing not less than 1.7 lb/yd^2, placed not more than 1 in. from the surface of the concrete.

Group III — includes concrete having cinder, sandstone, or granite aggregate tied with No. 5 gauge steel wire, wound spirally over the column section on a pitch of 8 in., or equivalent ties, and concrete having siliceous aggregates containing a combined total of 60 percent or more of quartz, chert, and flint, if held in place with wire mesh or expanded metal having not larger than 4-in. mesh, weighing not less than 1.7 lb/yd^2 placed not more than 1 in. from the surface of the concrete.

Group IV — includes concrete having siliceous aggregates containing a combined total of 60 percent or more of quartz, chert, and flint, and tied with No. 5 gauge steel wire wound spirally over the column section on a pitch of 8 in., or equivalent ties.

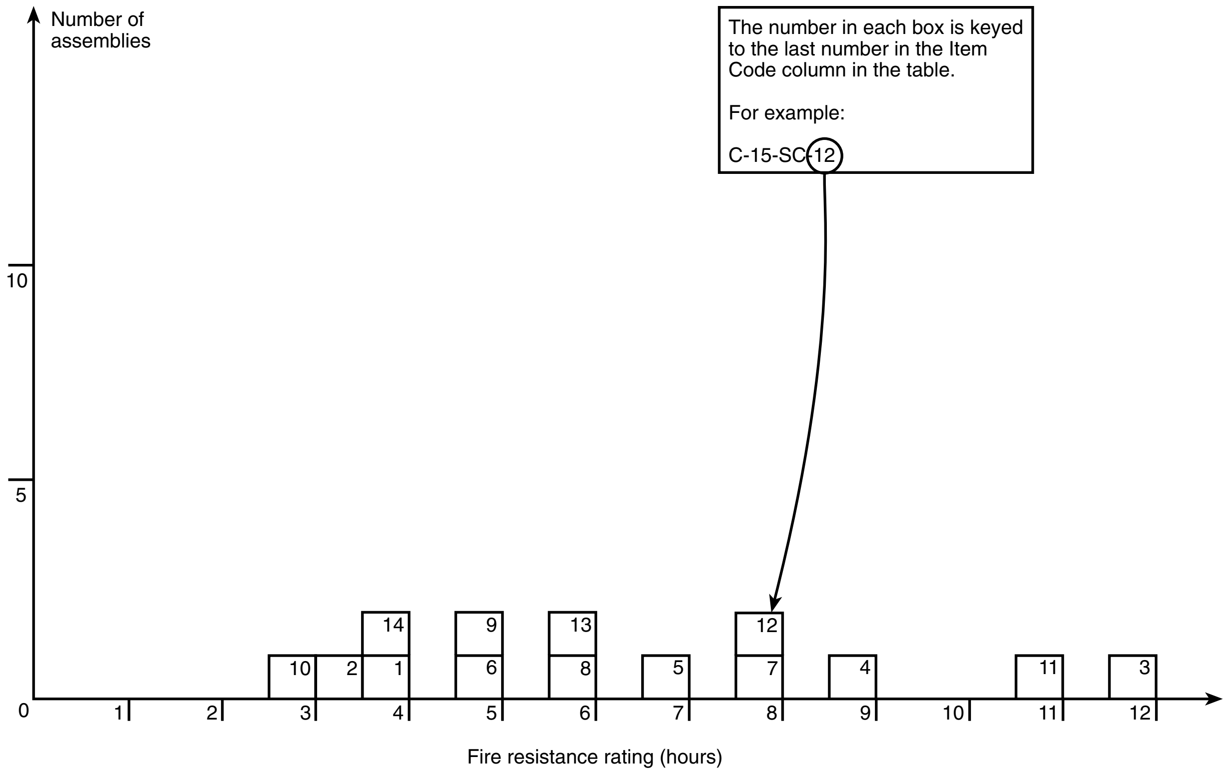


Figure 2.5.1.6 Steel Columns—Concrete Encasements Minimum Dimension 14” to less than 16”

Table 2.5.1.6 Steel Columns — Concrete Encasements Minimum Dimension 14" (250 mm) to less than 16" (40 mm)

Item Code	Minimum Dimension	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
C-14-SC-1	14"	14" × 16" Concrete encased steel column; 8" × 6" × 35 lb "H" column; Protection: Aggregate concrete (4240 PSI) with 4" mesh 16 SWG reinforcing 1" below column surface	90 tons	3 hr 40 min			7	1	3
C-14-SC-2	14"	14" × 18" Concrete encased steel column; 12" × 8" × 65 lb "H" Beam; Protection: Gravel aggregate concrete (4000 PSI) with 4" 16 SWG wire mesh reinforcement 1" below column surface	177 tons	3 hr 20 min			7	1	3
C-14-SC-3	14"	10" × 10" steel column with 4" outside protection; Group I	—	12 hr		1		2	12
C-14-SC-4	14"	Description as per C-14-SC-3; Group II	—	9 hr		1		2	9
C-14-SC-5	14"	Description as per C-14-SC-3; Group III	—	7 hr		1		2	7
C-14-SC-6	14"	Description as per C-14-SC-3; Group IV	—	5 hr		1		2	5
C-14-SC-7	14"	12" × 12" steel column with 2" outside protection; Group I	—	8 hr		1		2	8
C-14-SC-8	14"	Description as per C-14-SC-7; Group II	—	6 hr		1		2	6
C-14-SC-9	14"	Description as per C-14-SC-7; Group III	—	5 hr		1		2	5
C-14-SC-10	14"	Description as per C-14-SC-7; Group IV	—	3 hr		1		2	3
C-15-SC-11	15"	12" × 12" steel column with 3" outside protection; Group I	—	11 hr		1		2	11
C-15-SC-12	15"	Description as per C-15-SC-11; Group II	—	8 hr		1		2	8
C-15-SC-13	15"	Description as per C-15-SC-11; Group III	—	6 hr		1		2	6
C-15-SC-14	15"	Description as per C-15-SC-11; Group IV	—	4 hr		1		2	4

NOTES: Table 2.5.1.6
1. Collapse.

2. Group I — includes concrete having calcareous aggregate containing a combined total of not more than 10 percent of quartz, chert, and flint for the coarse aggregate.
Group II — includes concrete having trap-rock aggregate applied without metal ties and also concrete having cinder, sandstone, or granite aggregate, if held in place with wire mesh or expanded metal having not larger than 4-in. mesh, weighing not less than 1.7 lb/yd^2, placed not more than 1 in. from the surface of the concrete.
Group III — includes concrete having cinder, sandstone, or granite aggregate tied with No. 5 gauge steel wire, wound spirally over the column section on a pitch of 8 in., or equivalent ties, and concrete having siliceous aggregates containing a combined total of 60 percent or more of quartz, chert, and flint, if held in place with wire mesh or expanded metal having not larger than 4-in. mesh, weighing not less than 1.7 lb/yd^2 placed not more than 1 in. from the surface of the concrete.
Group IV — includes concrete having siliceous aggregates containing a combined total of 60 percent or more of quartz, chert, and flint, and tied with No. 5 gauge steel wire wound spirally over the column section on a pitch of 8 in. or equivalent ties.

Table 2.5.1.7 Steel Columns — Concrete Encasements
Minimum Dimension 16" to less than 18"

Item Code	Minimum Dimension	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
C-16-SC-1	16"	12" × 12" steel column with 4” outside protection: Group 1.	—	14 hr.		1		1	14
C-16-SC-2	16"	Description as per C-16-SC-1; Group II.	—	10 hr.		1		1	10
C-16-SC-3	16"	Description as per C-16-SC-1; Group III.	—	8 hr		1		1	8
C-16-SC-4	16"	Description as per C-16-SC-1; Group IV	—	5 hr		1		1	5

NOTES: Table 2.5.1.7
1. Collapse.
2. Group I — includes concrete having calcareous aggregate containing a combined total of not more than 10 percent of quartz, chert, and flint for the coarse aggregate.
Group II — includes concrete having trap-rock aggregate applied without metal ties and also concrete having cinder, sandstone, or granite aggregate, if held in place with wire mesh or expanded metal having not larger than 4-in. mesh, weighing not less than 1.7 lb/yd^2, placed not more than 1 in. from the surface of the concrete.
Group III — includes concrete having cinder, sandstone, or granite aggregate tied with No. 5 gauge steel wire, wound spirally over the column section on a pitch of 8 in., or equivalent ties, and concrete having siliceous aggregates containing a combined total of 60 percent or more of quartz, chert, and flint, if held in place with wire mesh or expanded metal having not larger than 4-in. mesh, weighing not less than 1.7 lb/yd^2 placed not more than 1 in. from the surface of the concrete.
Group IV — includes concrete having siliceous aggregates containing a combined total of 60 percent or more of quartz, chert, and flint, and tied with No. 5 gauge steel wire wound spirally over the column section on a pitch of 8 in. or equivalent ties.

Table 2.5.2.1 Steel Columns — Brick and Block Encasements
Minimum Dimension 10" (250 mm) to less than 12" (300 mm)

Item Code	Minimum Dimension	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
C-10-SB-1	10 1/2"	10 1/2" × 13" Brick-encased steel columns; 8" × 6" × 35 lb "H" Beam; Protection: Fill of broken brick and mortar; 2" brick on edge, joints broken in alt. courses; Cement-sand grout; 13 SWG wire reinforcement in every third horizontal joint	90 tons	3 hr 6 min			7	1	3
C-10-SB-2	10 1/2"	10 1/2" × 13" brick-encased steel columns; 8" × 6" × 35 lb "H" beam; Protection: 2" brick, joints broken in alt. courses; Cement-sand grout; 13 SWG iron wire reinforcement in alternate horizontal joints	90 tons	2 hr			7	2-4	2
C-10-SB-3	10"	10" × 12" block-encased columns; 8" × 6" × 35 lb "H" beam; Protection: 2" foamed slag concrete blocks; 13 SWG wire at each horizontal joint; mortar at each joint	90 tons	2 hr			7	5	2
C-10-SB-4	10 1/2"	10 1/2" × 12" block-encased steel columns; 8" × 6" × 35 lb "H" beam; Protection: Gravel aggregate concrete fill (unconsolidated) 2" thick hollow clay tiles with mortar at edges	86 tons	56 min			7	1	3/4
C-10-SB-5	10 1/2"	10 1/2" × 12" block-encased steel columns; 8" × 6" × 35 lb "H" beam; Protection: 2" hollow clay tiles with mortar at edges	86 tons	22 min			7	1	1/4