NFPA 909
Standard for the Protection of Cultural Resources, Including Museums, Libraries, Places of Worship, and Historic Properties

1997 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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NFPA 909

Standard for the

Protection of Cultural Resources Including Museums, Libraries, Places of Worship, and Historic Properties

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This edition of NFPA 909, *Standard for the Protection of Cultural Resources Including Museums, Libraries, Places of Worship, and Historic Properties,* was prepared by the Technical Committee on Cultural Resources and acted on by the National Fire Protection Association, Inc., at its Annual Meeting held May 19-22, 1997, in Los Angeles, CA. It was issued by the Standards Council on July 24, 1997, with an effective date of August 15, 1997, and supersedes all previous editions.

This edition of NFPA 909 was approved as an American National Standard on August 15, 1997.

Origin and Development of NFPA 909

Since the first NFPA document was issued on this subject in 1948 ("Protecting our Heritage"), the Technical Committee on Cultural Resources has developed a series of recommended practices to govern these specialized buildings and sites. Five separate documents governing libraries, museums, places of worship, historic structures, and historic sites existed in 1996.

In each case, the documents were written as recommended practices or guides. There were a number of reasons why the documents were developed and maintained as such. One reason had to do with the delicate nature of the facilities and sites. Unlike commercial buildings, "new" historic structures are not constructed. In other words, all of the historic structures are existing, making retrofit of many common fire protection systems impractical to install in some cases. In addition, retrofit of fire alarm systems or sprinkler systems can be cost-prohibitive for a smaller, historically significant structure. Unfortunately, many of the readily available solutions to correct fire protection problems in other types of existing facilities might not be practical in the case of older, historic buildings.

A number of philosophical issues center on the methods used to protect cultural resource facilities. One main item deals with a structured fire prevention program that is carried out by the facility operator. The span of these protection schemes must account for structures ranging from a single-family dwelling to public libraries to public museums.

In lieu of continuing with four separate documents, each one containing similar pieces of information, the committee started a project approximately two years ago to provide a single source document to cover all culturally significant buildings and sites. At the same time, it was decided to write the document using mandatory language and develop a standard. The catalyst for doing this has been related to a number of catastrophic fires in the last 10 years, including the Central Los Angeles Library fire and the Windsor Castle fire.

The result of this project is this document, NFPA 909, *Standard for the Protection of Cultural Resources Including Museums, Libraries, Places of Worship, and Historic Properties.*

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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®.*

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in membership may have occurred. A key to classifications is found at the back of this document.

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.

Contents

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NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Appendix A.

Information on referenced publications can be found in Chpater 11 and Appendix N.

FOREWORD

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

This document is divided into two basic parts — the body, which is located in the front of the document, and the appendices in the back.

This standard has been structured to provide requirements that are mandatory, and uses the term "shall" when describing an action. The appendix contains recommendations that are not mandatory and uses terms such as "could," "should," or "might." An appendix item should not be considered unimportant; on the contrary, many appendix items are explanations of mandatory requirements and should be taken into consideration.

This standard has been structured to provide each cultural structure or site (i.e., museum, library, historic structure, and place of worship) with its specific sets of requirements (Chapters 8 through 10). The reader must also refer to Chapters 1 through 7, which apply to all the types of structures.

Chapter 1 General

1-1 Scope. This standard shall apply to culturally significant structures and their contents. Such structures include, but are not limited to, buildings that store or display museum or library collections, historic buildings, and places of worship. It also includes spaces within other buildings used for such culturally significant purposes.

1-1.1 New Cultural Property Occupancies. The requirements of this standard shall apply to the following:

(a) New buildings or portions thereof used as a cultural property occupancy

(b) Additions made to a cultural property occupancy

(c) Alterations, modernizations, or renovations of existing occupancies

(d) Existing buildings or portions thereof upon change of occupancy to a cultural property occupancy

1-1.2 Existing Cultural Property Occupancies. The requirements of this standard shall apply to existing buildings or portions thereof currently occupied as cultural property occupancies.

Exception: An existing building housing a cultural property occupancy established prior to the effective date of this standard shall be permitted to be approved for continued use if it conforms to or is made to conform to the provisions of this standard to the extent that, in the opinion of the authority having jurisdiction, reasonable life safety against the hazards of fire, explosion, and panic is provided and maintained.

1-2 Purpose.

1-2.1 This standard shall prescribe minimum requirements for the protection of cultural properties and their contents from fire through a comprehensive fire protection program.

1-2.2 Because of the special nature of cultural properties, this standard shall supplement existing codes and standards to apply specifically to buildings or portions of buildings devoted to such use.

1-3 Life Safety. The requirements of NFPA *101®, Life Safety Code®,* shall apply to both new and existing cultural properties. The authority having jurisdiction shall be permitted to consider alternative arrangements, provided the alternative arrangements offer equivalent or greater protection.

1-4 Alternative Methods.

1-4.1 Nothing in this document shall be intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety to those prescribed by this document, providing that the following conditions are met:

(a) Technical documentation is submitted to the authority having jurisdiction to demonstrate equivalency

(b) The system, method, or device is approved for the intended purpose

1-4.2 Cultural properties or portions of such structures that do not strictly comply with this standard shall be considered to be in compliance if it can be shown that equivalent protection has been provided or that no specific hazard will be created or continued through noncompliance.

1-4.3 It is intended that a designer capable of applying more complete and rigorous analysis to special or unusual problems shall have latitude in the development of the applicable design. In such cases, the designer shall be responsible for demonstrating the validity of the approach. This standard shall not do away with the need for competent engineering judgment and shall not be intended to be used as a design handbook.

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.

Arson. The deliberate setting of fires with a criminal intent.

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 hoist way, 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.

Book Stack. The area of a library in which most of the books are shelved.

Code.* A standard that is an extensive compilation of provisions covering broad subject matter or that is suitable for adoption into law independently of other codes and standards.

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

Collections Storage Room. An enclosure providing a safe and secure environment for collections including vaults but not bookstacks.

Compact Storage Module. An assembly of shelving sections mounted on carriages with the arrangement of carriages on tracks so as to provide one moving aisle serving multiple carriages between fixed end ranges. *(See Figure C-3(b).)*

Compact Storage System. A storage installation composed of multiple compact storage modules. *[See Figure C-6(a).]*

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 or damaged parts in an effort to recreate the original appearance of a damaged work of art.

Cultural Properties. Buildings, structures or sites, or portions thereof, that are culturally significant, or that house culturally significant collections. Such properties include, but are not limited to, museums, libraries, historic structures, and places of worship.

Early Warning. A signal provided by a detection system, such as one using smoke or flame detectors, that detects fire in its earliest stages of development so as to enhance the opportunity of building occupants for escape and commencement of suppression.

Fire Alarm System. A system or portion of a combination system consisting of components and circuits arranged to monitor and annunciate the status of fire alarm or supervisory signal initiating devices and to initiate appropriate response to those signals.

Fire Barrier Wall. A wall, other than a fire wall, having a fire resistance rating.

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 Load. The weight of combustibles in a fire area [ft^2 (m^2)] or on a floor in buildings and structures, including either contents or building parts, or both.

Fire Protection System. Any fire alarm device or system, or fire extinguishing device or system, or their combination, which is designed to detect, control, or extinguish a fire.

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 Tests of Fire Endurance of Building Construction and Materials.*

Fire Resistive. Refers to properties or designs to resist the effects of any fire to which a material or structure can be expected to be subjected.

Fire Retardant. A treatment that reduces the flame spread and smoke-developed rating of a wall, partition, column, ceiling, fabric or other material and that complies with NFPA 703, *Standard for Fire Retardant Impregnated Wood and Fire Retardant Coatings for Building Materials.*

Fire Safety Manager. The authorized person, formally and officially appointed or designated by the governing body or responsible party of a cultural resource facility or institution, who is charged with the duties and responsibilities of providing and ensuring fire protection for that facility or institution. In smaller organizations this role shall be permitted to be combined with that of another position or appointment. In larger institutions, the person's responsibilities shall be permitted to include supervision of other fire protection staff. The authorized person shall be permitted to be an employee of the cultural resource facility or institution who has certification, education, training, and/or experience with generally accepted fire protection practices. Alternatively, cultural resource facilities or institutions shall be permitted to designate appropriate outside persons such as consulting fire protection engineers, fire service personnel, insurance company loss control representatives, local code officials, or other individuals with similar fire protection credentials.

Fire Stop. A fire-resistant material, barrier, or construction installed in concealed spaces or between structural elements of a building to retard the spread of fire through walls, ceilings, floors, and related building components.

Hazardous Areas.* Areas of structures or buildings posing a degree of hazard greater than normal to the general occupancy of the building or structure.

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 Site. A place, often with associated structures, having historic significance.

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.

Hot Work. Operations including cutting, welding, Thermit welding, brazing, soldering, grinding, thermal spraying, thawing pipe, torch-applied roofing, or any other similar situation.

Impairment. A shutdown of fire protection equipment or systems or portion thereof. The two types of impairments are as follows:

(a) *Emergency.* A condition where fire protection systems or equipment or a portion thereof is out of order due to an unexpected occurrence, such as a ruptured sprinkler pipe, or device or component failure.

(b) *Preplanned.* A condition where a fire protection system or equipment or a portion thereof is out of service due to work that has been planned in advance, such as revisions to the water supply or sprinkler system piping.

Initiating Device. A system component that originates transmission of a change of state of condition, such as a smoke detector, manual fire alarm box, supervisory switch, and so forth.

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Library.* A place in which books and other media are kept for reading, reference or lending.

Library, Secondary Storage Facility. Warehouse facilities, established to house lesser-used books and other materials in rack storage.

Listed.* Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets identified standards or has been tested and found suitable for a specified purpose.

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.

Multitier Book Stack. A system of back-to-back metal (steel or wrought iron) bracket shelving stacked by being bolted together into multiple levels or tiers at approximately 7-ft (2.1336-m) intervals to form a book stack with walkways for each tier suspended from the posts or columns supporting the bracket shelving sections in each range. The system is usually erected inside a structural shell housing the book stack. Typically there is a vertical opening (space gap or "deck slit") between the walkway and the ranges at each tier from the bottom tier to the top tier. *[See Figure A-9-5.2(a) and A-9-5.2(b).]*

Museum.* Any building or place where cultural, scientific, or artistic items of intrinsic cultural value and interest are kept or exhibited to the public.

Noncombustible. A material that, in the form in which it is used and under the conditions anticipated, does not ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat. Materials that are reported as passing ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C,* shall be considered noncombustible materials.

Notification Appliance. A fire alarm system component such as a bell, horn, speaker, strobe, printer, and so forth, that provides an audible or visible output, or both.

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 shall be permitted to occupy a building or portion thereof at any one time.

Place of Worship. Any building that functions primarily as a group meeting place for the practice of religion. This includes, but is not limited to, churches, synagogues, cathedrals, temples, and meeting halls.

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 vegetative cover of the site.

Private. Intended for or limited to the use of some particular person(s) or group.

Protected Premises. The physical location protected by a fire alarm system, fire suppression system, or both.

Protection. The act or process of applying measures designed to affect the physical condition of a building, structure, or object 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.

Protective Systems, Equipment, or Apparatus. Automatic sprinklers, standpipes, carbon dioxide systems, clean agent systems, automatic covers, and other devices used for extinguishing fires.

Public. Of, pertaining to, or affecting a population or a community as a whole; open to all persons.

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 re-establishing 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.

Self-Closing Device. A mechanism that ensures that a door or other closure, when opened, will return to the closed position.

Separation. See Fire Barrier Wall.

Shall. Indicates a mandatory requirement.

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.

Smoke Detector. A device that detects visible or invisible airborne particles of combustion.

Special Events. Functions, such as receptions, dinners, private viewings, and so forth, held at the cultural resource property for specific groups (e.g., members, boards, outside organizations).

Sprinkler System. For fire protection purposes, an integrated system of underground and overhead piping designed in accordance with fire protection engineering standards. The installation includes one or more automatic water supplies. The portion of the sprinkler system above ground is a network of specially sized or hydraulically designed piping installed in a building, structure, or area, generally overhead, and to which sprinklers are attached in a systematic pattern. The valve controlling each system riser is located in the system riser or its supply piping. Each sprinkler system riser includes a device for actuating an alarm when the system is in operation. The system is usually activated by heat from a fire and discharges water over the fire area.

Standard. A document, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and which is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions shall be located in an appendix, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

Utilities. As used in this standard, utilities include all electrical power services; communication and security services; electrical control circuits; HVAC distribution and control circuits; undampered HVAC duct systems; water, steam, waste water, and drain pipes and services; fire suppression systems including water-based and non-water-based; oil and piped hydraulic and pneumatic systems.

Vertical Opening. An opening through a floor, ceiling, or roof.

Zone. A defined area within the protected premises. A zone can define an area from which a signal can be received, an area to which a signal can be sent, or an area in which a form of control can be executed.

1-6* Collections Storage.

1-6.1 Introduction. This section shall apply to building areas used for collection storage.

1-6.2 Life Safety.

(a) Emergency lighting shall be provided for safe egress, and shall comply with the requirements of NFPA *101, Life Safety Code.*

(b) Fire alarm notification appliances shall be provided in every collection storage room.

1-6.3* Fire Prevention.

(a) Smoking shall be prohibited in all collection storage rooms.

(b) Electrical distribution power panels shall not be installed in collection storage rooms.

(c) Only noncombustible storage cabinets shall be used in collection storage rooms. Padding, dust covers, humidity buffering materials, and other serious fire-loading materials shall be noncombustible or treated with an approved fire-retardant coating.

(d) Utilities other than those supporting fire suppression, fire detection, and security systems shall not pass through collection storage spaces.

Exception: Utilities that directly serve such spaces shall be permitted in the space.

(e) Controls for utilities serving the collection storage space shall be located outside the space so that access to the controls does not require entry into the collections storage space.

(f) Controls for utilities serving collection storage spaces shall be designed to allow isolation of storage space utilities in an emergency.

(g) Fixed space heaters installed in collection storage rooms shall be listed, and the installation shall be approved by the authority having jurisdiction. Portable space heaters shall not be permitted.

1-6.4* Fire Protection. One-hour fire separation shall be provided between adjoining spaces and collection storage rooms.

(a) Automatic smoke detection shall be provided in every storage room.

(b) An approved automatic fire-suppression system shall be provided in collection storage areas greater than 500 ft^2 (46.25 m^2).

Exception: Where only noncombustible collections (e.g., bronze sculptures, ceramics, minerals) including packing or crating materials, cabinets, shelves, and so forth are present, or where all collections are stored inside approved noncombustible cabinets.

1-6.5* Smoke Control. Approved systems shall be provided to prevent smoke and soot from entering collection storage areas.

1-6.6 Wet Collections.

1-6.6.1 Storage of collections preserved in combustible or flammable solutions shall comply with the requirements of NFPA 30, *Flammable and Combustible Liquids Code.*

1-6.6.2 Containers used for storing specimens in combustible or flammable liquids shall have tight-sealing lids that minimize evaporation loss or spillage of contents should the container tip over.

1-6.6.3 Only approved containers shall be used in dispensing (topping off) operations.

1-6.6.4 Carts used to transport storage containers shall be sturdy and designed to carry their loads close to the ground.

1-6.6.5 Shelving. Shelving units used to hold wet collections shall meet the following requirements:

(a) Designed to support the loads placed on them

(b) Tied together or anchored securely to prevent an earthquake or other event from toppling one or more shelves

(c) Constructed with raised lips and barriers across all open shelves to prevent containers from falling off the shelf

(d) Anchored and braced in storage areas that are subject to earthquakes

(e) * Designed such that anchors and bracing provide shelving with strength equal to or greater than the building structure

1-6.7* Storage of Records. Museum and archival records shall be stored and protected in accordance with NFPA 232, *Standard for the Protection of Records.*

1-6.8* Compact Storage.

(a) Where compact storage is installed in an existing storage area, the existing automatic fire detection and fire suppression systems shall be modified as required to accommodate the fire loading.

(b) Fire protection systems for collection storage areas where compact storage systems are used shall be designed to confine fire growth to the area of fire origin.

1-6.9 Electronic Media. Concealed spaces, combustible electric cable insulation, and storage of paper and records associated with electronic data processing equipment shall comply with the requirements of NFPA 75, *Standard for the Protection of Electronic Computer/Data Processing Equipment.*

1-6.10 Cellulose Nitrate Film. Storage facilities for cellulose nitrate film shall comply with the requirements of NFPA 40, *Standard for the Storage and Handling of Cellulose Nitrate Motion Picture Film.*

1-7 Special Events. Plans for special events shall be reviewed and approved by the fire safety manager.

1-7.1 Occupant Loading.

(a) The event coordinator shall ensure that the number of occupants admitted to the building is monitored and controlled so that the occupant load does not exceed the licensed limit.

(b) Orderly circulation of guests shall be maintained when special events are planned for large groups.

1-7.2 Egress.

(a) Exits, access to exits, and all other evacuation capabilities shall be maintained.

(b) Tables, plants, stages, or other temporary fixtures shall not visually or physically obstruct an exit, exit sign, or exit access. Such temporary features shall not reduce the width of an exit passage.

(c) Prior to a performance or event, attendees and participants shall be notified of how fire alarms are annunciated (i.e., audibly, visually, by voice communication, or a combination of these methods), locations of exit routes and exits, and how to safely evacuate the area.

(d) Key staff (e.g., event coordinators, volunteers, and so forth) shall be familiar with exit routes and shall ensure that exits are obvious, operable, and not blocked or restricted in any way.

(e) Upon activation of the fire alarm, occupants shall be evacuated from the building according to the egress plan.

1-7.3 Cooking Equipment.

(a) Cooking and food warming shall be performed in existing kitchen facilities, or electric warming devices shall be used only in a closely supervised location.

(b) A portable fire extinguisher, listed for the purpose, shall be located within 10 ft (3 m) of any cooking, warming, or related operation and shall be properly identified.

1-7.4 Smoking. Smoking shall be prohibited except as provided in Section 3-5.

1-7.5 Fireworks. Demonstrations of fireworks shall be held outside the building or structure and shall conform to NFPA 1123, *Code for Fireworks Display.*

1-7.6 Combustibles.

(a) Tents and canopies shall be noncombustible or certified as having been treated with an approved fire-retardant coating.

(b) Draperies, bunting textiles, wood, and miscellaneous support and decorative materials used inside the building shall be noncombustible or treated with an approved fire-retardant coating.

1-7.7 Electrical Equipment.

(a) Electrical appliances and equipment, including temporary installations, shall be listed and wiring shall comply with NFPA 70, *National Electrical Code®.*

(b) Exposed electrical wiring and extension cords shall not be placed across travel or exit routes.

(c) A licensed or registered electrician shall verify that electrical circuits do not exceed their rated capacity.

Chapter 2 Fire Emergency Planning

2-1 Fundamental Requirements.

2-1.1 Responsibility.

2-1.1.1 Fire emergency planning responsibilities include the following:

(a) The facility's governing body or those responsible for the institution shall establish and maintain plans and programs to protect against the disastrous effects of fire.

(b) In carrying out this responsibility, a fire risk assessment shall be conducted.

(See Appendix B, Fire Risk Assessment in Heritage Premises, for guidance in conducting this assessment.)

2-1.1.2* The facility's governing body or those responsible for the institution shall appoint a fire safety manager who is responsible for the protection of the site from fire. The fire safety manager's duties include (but are not limited to) the following: life safety systems, fire prevention, fire inspections, periodic property surveys, proper operation of fire protection equipment such as fire detection and fire suppression equipment, and portable fire extinguishers. Other duties shall include plans review for fire safety of new construction, renovations, or installation of displays or exhibits.

2-2 Planning for Fire Protection.

2-2.1 Fire Safety Goals. Fire safety goals or objectives shall be adopted that reflect the level of loss and interruption of service to the client community that those responsible for the cultural property are willing to accept as a result of a fire.

2-2.2 Fire Hazard Analysis.

(a) A thorough survey shall be made to determine existing and potential fire hazards.

(b) * Fire hazards shall be evaluated and classified for their severity and the difficulty and cost of abating them.

The survey shall include the following:

1. Identification of the cultural properties and special hazards and the creation of an action plan to minimize, eliminate, or protect against each of those hazards

2. Identification of those fire risks and means-of-egress problems that can be created by special events, and the creation of an internal process and action plan to minimize or eliminate those potential threats for each event

3. Recognition that public visitation can increase during special events, celebrations, and special exhibitions, and the creation of provisions for identifying and taking immediate action to prevent numbers of visitors from exceeding building and means-of-egress capabilities

4. Recognition that temporary or special exhibitions can create special fire protection risks and means-of-egress problems and compromise existing fire protection systems, and the creation of an action plan for preventing such problems and implementing immediate corrective actions if problems arise later

2-2.3* Fire Protection Plan.

(a) *Format of Plan.* A fire protection plan shall be developed for systematic achievement of fire safety goals and updated annually.

This shall include a yearly comprehensive facility inspection procedure with a documentation and corrective action process to ensure that all problems and hazards identified during the inspection are documented and corrected as soon as possible. *(See Appendices B, D, and E for additional information.)*

(b) *Fire Safety Log.* The fire safety manager shall be responsible for maintaining a permanent, current file of the cultural resource facility's or institution's fire protection program. As a minimum, permanent records documenting the following shall be kept:

1. Training of staff and volunteers, including fire evacuation drills and use of portable fire extinguishers

2. Testing, inspection, and maintenance reports for all fire safety equipment and systems, including records of actions taken to correct deficiencies

3. "As-built" plans, specifications, wiring and layout diagrams, and acceptance test reports for all fire protection systems (e.g., fire detection and alarm systems, automatic fire suppression systems)

4. The facility's fire protection plan

5. The facility's emergency plan

6. Inspection reports by local code enforcement officials, the authority having jurisdiction, local fire service officials, and insurance loss control representatives, including records of actions taken to correct deficiencies identified during each inspection

7. Fire protection systems actuation and alarm reports complete with the cause of the alarm or activation, response, and corrective action(s) taken

8. Full reports, including cause, extent of damage, response and recovery of *all* fire incidents

(c) **Arson.* Cultural properties shall implement precautions to prevent arson.

(d) *Locking Devices.*

1. Where security measures include use of delayed exit locking systems, the provisions of NFPA *101, Life Safety Code*, Section 5-2, Means of Egress Components, shall apply.

2. Delayed exit locking devices shall be tested quarterly, and a permanent written record of the test and the results shall be kept.

2-3 Planning for Response.

2-3.1* The governing body and the fire safety manager shall develop and implement an emergency management plan. There shall be an annual exercise to ensure that management and staff can implement and work with the plan and incorporate lessons learned from the exercise into an updated plan.

(a) The plan shall include provisions for notifying the fire department of the type and location of the emergency and directing them to the site once they arrive.

(b) Emergency telephone numbers shall be posted on or adjacent to all telephones.

2-3.2 An emergency evacuation plan shall be prepared in cooperation with the local fire department and other applicable authorities and updated annually.

This shall include the following:

(a) Fire safety precautions for special events and celebrations when normal operational conditions are substantially changed

(b) Fire safety precautions to make necessary adjustments for temporary and special exhibits

(c) Modification of staff training and drills to adjust for circumstances and larger visitation that can be created by special events and exhibits

(d) Provisions to notify the local fire service of special events expected to require adjustments to the emergency evacuation plan

2-3.3 Fire exit drills required by NFPA *101, Life Safety Code*, shall be conducted at regular intervals, but no less than twice per year.

2-4 Salvage Plan. A salvage plan shall be prepared in cooperation with the fire department, appropriate building staff, police, and insurance representatives. This plan shall be updated annually and shall include the following:

(a) Procedures to identify and prioritize collections and other valuable materials in accordance with the facility's policy

(b) A list of salvage equipment suppliers (e.g., pumps, freezing equipment, storage facilities, and so forth) and tradespeople

(c) A current list of disaster recovery specialists for damaged fine arts, collections, and archives, such as conservators from museums, archives, and other cultural properties willing to lend mutual aid assistance

(d) A list of people assigned to assist with salvage operations, including staff to deal with the press, fire authorities, police, and authorities that can restrict entry following a fire of suspicious origin

(e) Measures to maintain up-to-date copies of important documents in a secure, off-site location. Examples of such records include but are not limited to the following: collections inventories (e.g., accession, catalog, conservation, and loan documents along with copies of donation and gift forms), historical records (including baptismal and wedding records), essential business and insurance records, and building plans and systems documentation (e.g., drawings, specifications, and operating manuals).

(f) Procedures to identify and handle hazardous materials, such as asbestos or PCPs, that can cause a health hazard or contaminate the structure or contents after a fire. This shall include impoundment of fire-fighting water where it poses a hazard to the environment.

2-5 Training.

2-5.1 The facility's governing board and its fire safety manager shall ensure that all staff, including volunteers and interns, receive periodic and regular training pertinent to their assigned responsibilities involving the following:

(a) The facility's fire protection plan

(b) The facility's emergency evacuation plan

(c) The facility's salvage plan

(d) The facility's fire protection and detection systems including the proper use of portable fire extinguishes

This training shall be reinforced by annual drills.

2-5.2 Training shall include emergency evacuation of mobility-impaired individuals.

2-5.3 Employees and others with a role in the salvage plan shall receive additional training in the activities necessary to fulfill this role. Training shall be reinforced by annual drills.

2-5.4 A permanent record shall be maintained of all fire and salvage training.

Chapter 3 Fire Prevention

3-1* Introduction. This chapter shall outline the minimum criteria necessary to implement a comprehensive fire prevention program.

3-2 Decorations.

3-2.1* Decorative materials used for special events, occasions, and holidays shall be noncombustible or shall be treated with an approved fire-retardant coating.

3-2.2 Decorations treated with an approved fire-retardant coating shall be kept a minimum of 36 in. (0.90 m) from ignition sources, such as light fixtures, radiators, electric heaters, and so forth.

3-3* Fire Spread Control. Interior doors shall be kept closed when the building is not occupied.

Exception: Where doors are required to remain open for interior ventilation and air movement concerns are critical to the conservation of historic building fabric, collections, or both, and where the interior doors are themselves part of the historic fabric, careful and professional analysis shall be performed and documented and alternative methods to control fire spread shall be implemented.

3-4* Housekeeping.

3-4.1 Stairwells, corridors, doorways, and any other portions of the means of egress for a building shall be free of combustibles, trash containers, and other materials.

3-4.2 Attic spaces shall be kept clean, free of combustibles, and locked.

3-4.3* Electrical rooms, mechanical rooms, and telephone closets shall be kept free of combustibles and locked. Stacks, exhaust ducts, and filters shall be cleaned as frequently as necessary to prevent the buildup of combustible dusts and fibers.

3-4.4 Rags, clothing, and waste material contaminated with oils, such as animal or vegetable oils, paints, thinners, wax, furniture polish, and other liquids or compounds that could cause spontaneous heating shall be kept isolated from other combustibles and in metal containers with tight-fitting metal lids.

3-4.5 Properly ventilated metal lockers shall be provided for storage of highly combustible supplies and workers' clothing contaminated with combustible or flammable liquids.

3-4.6 Combustible packing materials, such as shredded paper, styrofoam "peanuts," plastic, and excelsior, shall be stored in metal containers with self-closing covers. Areas where packing materials cannot be protected using these methods, such as dedicated crating and packing areas, shall be enclosed in 1-hr fire resistive construction or shall be equipped with sprinklers.

3-4.7 Trash shall be collected and disposed of at the end of each work day and more often if necessary.

3-4.8 Dumpsters used for bulk collection of trash or recyclable paper shall be constructed of metal with metal or plastic covers. Dumpsters and other large trash containers inside buildings, shall be stored as follows:

(a) In trash rooms having both automatic sprinklers and a 1-hr fire resistance rating

(b) In loading dock areas, separated from the rest of the building with a 2-hr fire resistance rating or 1-hr fire resistance rating and protected with automatic sprinklers

3-4.9 Trash containers, dumpsters, and other central waste-disposal units, any of which are stored outside, shall be kept at a minimum distance of 15 ft (4.6 m) from all parts of a building's exterior, including but not limited to windows, doors, roof eaves, and utility controls.

3-5 Smoking.

3-5.1 Smoking shall be prohibited inside buildings except in designated areas that meet the following requirements:

(a) Smoking areas shall be clearly and publicly identified.

(b) Smoking areas shall be provided with suitable ashtrays and other receptacles for the proper disposal of smoking materials.

(c) Smoking areas shall be physically separated from the rest of the building with a minimum 1-hr fire resistance rating for walls, ceilings, and floors.

(d) A properly mounted, rated, fully charged and operable portable fire extinguisher shall be located at each designated area.

3-5.2 Smoking shall not be permitted in the following areas:

(a) Exhibition areas or galleries

(b) Collections or any other types of storage areas

(c) Any type of workshop

(d) Laboratories

(e) Library reading rooms

(f) Library book stacks

(g) Assembly areas such as classrooms, auditoriums, and theaters

(h) Rest rooms

(i) Mechanical rooms

(j) Receiving areas or stock rooms

(k) Projection rooms

3-6 Hot Work. Hot work shall not be permitted unless there is no other viable alternative.

3-6.1 Hot Work Permit. A hot work permit shall be issued by the fire safety manager or designee to authorize work with any open flame devices used in soldering, brazing, cutting, and welding.

3-6.2 Permit Requirements. The hot work permit shall prescribe measures to protect the collections and ensure life safety, and shall include the following requirements as a minimum:

(a) A person trained in the use of fire extinguishers shall be stationed in the vicinity of the hot work operation for the duration of the work and for 60 minutes thereafter with frequent monitoring during the following 3 hours

(b) All combustibles within 35 ft (11 m) of the work site shall be relocated or be covered with noncombustible or fire-retardant coated tarpaulins or otherwise shielded with metal or noncombustible guards or curtains.

3-7 Open Flames.

3-7.1 Approval. Use of open flames and flame-producing devices, such as candles, oil lamps, fireplaces, forges, kilns, glassblowers, cook stoves, and so forth, shall be approved by the authority having jurisdiction.

3-7.2 Precautions. The following precautions shall be taken to control open flame and flame-producing devices:

(a) All employees working around open flame or flame-producing devices shall be trained in the proper use and operation of the device and in emergency response procedures

(b) Open flames and flame-producing devices shall be monitored constantly by a trained person

(c) A fire extinguisher, listed for the purpose, shall be located within 30 ft (9.15 m) of the area where open flames or flame-producing devices are in use

(d) Candles shall be kept a minimum of 4 ft (1.22 m) from combustible window treatments and wall or ceiling hangings

(e) Fireplaces shall be covered with a fire screen when not used for cooking or similar demonstrations

(f) Open flames within 100 ft (31 m) of the building shall not be left unattended

(g) The use of open flames either inside or outside the building shall be extinguished prior to shut-down of the facility to ensure that the flame is completely extinguished.

3-7.3 Chimneys.

(a) Chimneys serving active fireplaces or stoves shall be in accordance with NFPA 211, *Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances.*

(b) Chimneys serving active fireplaces or stoves shall be lined, provided with a spark arrestor, and maintained in good working order.

(c) Chimneys serving active fireplaces or stoves shall be inspected and cleaned annually.

Chapter 4* New Construction, Alterations, and Renovations

4-1* Fire Protection Systems.

4-1.1 Requirement. Fire protection systems shall be incorporated in all new construction in accordance with the facility's or institution's fire protection program and plan.

4-1.2 Design. Fire protection systems shall be designed to meet the facility's needs based on the fire protection objectives and on the fire risk assessment required by Chapter 2. See NFPA 550, *Guide to the Fire Safety Concepts Tree,* for a method to determine fire protection objectives.

4-1.3* Fire Detection and Alarm Systems.

4-1.3.1 Fire detection and alarm systems shall be designed and installed in accordance with the requirements of NFPA 72, *National Fire Alarm Code.*

(a) Smoke detectors shall be installed in every area and space where ambient conditions permit.

(b) Where ambient conditions will adversely affect the performance, reliability, and normal operation of smoke detectors, other forms of detection technology, such as heat detection, shall be used.

Exception: Heat detectors are not required in areas protected with an automatic sprinkler system installed in accordance with NFPA 13, Standard for the Installation of Sprinkler Systems.

4-1.3.2 Alarm Notification. When activated, the fire detection and alarm systems shall signal an alarm in accordance with the fire evacuation plan. Notification appliances shall be listed for the purpose and shall be installed as required by NFPA 72, *National Fire Alarm Code.*

(a) Storage areas and other remotely located spaces shall have at least one notification appliance installed in the space.

(b) High-noise areas, such as exhibit fabrication areas, shall have both a visible and an audible signal appliance.

4-1.3.3 Alarm Monitoring.

(a) Fire detection and alarm systems and automatic fire suppression systems shall transmit alarm condition signals to an approved monitoring facility.

(b) The monitoring facility and the communications method used for alarm signal transmission shall comply with the requirements of NFPA 72, *National Fire Alarm Code.*

4-1.4* Automatic Fire Suppression Systems. Automatic fire suppression systems, where required, shall be designed and installed in accordance with the appropriate NFPA standard.

4-1.5* Standpipe and Hose Systems. Standpipe and hose systems, where required, shall be designed and installed in accordance with the requirements of NFPA 14, *Standard for the Installation of Standpipe and Hose Systems.*

4-1.6 Provisions shall be made for controlled rapid egress of water during fire-fighting operations.

4-1.7* Portable Fire Extinguishers. Portable fire extinguishers shall be selected, installed, and maintained in accordance with the provisions of NFPA 10, *Standard for Portable Fire Extinguishers.*

4-2 Roof Coverings.

(a) Unlisted combustible roof coverings shall be treated with an approved fire-retardant coating.

(b) The facility shall maintain a record of the treatment to include certificate of approval of retardant, application method, and retreatment schedule.

(c) Fire-retardant coated roof coverings shall be retreated in accordance with the manufacturer's specifications.

4-3 Emergency Power. Emergency generators, where required, shall be installed and shall comply with the requirements of NFPA 70, *National Electrical Code,* and NFPA 110, *Standard for Emergency and Standby Power Systems.*

(a) Emergency generators shall have sufficient capacity to support critical fire safety functions and fire suppression systems, where required.

(b) Emergency generators that support other functions considered essential (e.g., temperature and humidity control to a particular storage vault, essential data processing equipment, critical research projects, and so forth) shall have sufficient capacity to support all functions with no degradation of fire safety system support.

4-4 Hazardous Areas. Hazardous areas (e.g., wet specimen storage rooms, workshops, display shops, conservation laboratories, paint rooms, restaurant kitchens, rooms containing central heating equipment such as boilers and furnaces, and so forth) shall be separated from other areas by a fire separation rated for a minimum of 1-hr fire resistance rating.

4-5 Interior Finishes. Interior finishes shall be selected to prevent flames from spreading rapidly or generating dangerous amounts of smoke and toxic products of combustion. Interior finish materials shall comply with the requirements of NFPA *101, Life Safety Code.*

4-6 Lightning Protection. A lightning protection system, where required, shall be designed, installed, and maintained in accordance with NFPA 780, *Standard for the Installation of Lightning Protection Systems.*

4-7 Location. Cultural properties located within or attached to a building or structure classified *Industrial, Storage,* or *High Hazard,* as defined in NFPA *101, Life Safety Code,* shall be separated by walls or partitions and floor or floor-ceiling assemblies having a fire resistance rating of no less than 2 hours.

4-8* Protection Against Exposure Fires. An exposed wall shall be protected to prevent heat, flames, or smoke from a nearby fire from being transmitted through it.

4-9 Protection from Wildfires.

(a) The governing body or party responsible for cultural resource properties located in areas that are wooded, surrounded by fire-prone vegetation, or heavy brush shall incorporate the requirements of NFPA 299, *Standard for Protection of Life and Property from Wildfire,* into the facility's or institution's fire protection program and plan.

(b) * Reduction of fuel loading in the landscape surrounding and owned by the cultural resource property shall be implemented in accordance with the requirements of NFPA 299, *Standard for Protection of Life and Property from Wildfire.*

(c) Where the landscape is historic and either a contributing element to the property's historic designation, or designated itself, the governing body or responsible party shall obtain a professional historic landscape architect evaluation and recommendation for reducing fire loading that can threaten either the cultural resource or the historic landscape. Such evaluation shall be performed to include the requirements of NFPA 299, *Standard for Protection of Life and Property from Wildfire.* The resulting recommendations of the evaluation shall be included in the facility's or institution's fire protection program and plan.

(d) Access roads shall be maintained and kept fully accessible at all times for fire service vehicles.

4-10* Security Measures.

(a) Measures to protect against the risk of arson, theft, burglary, and so forth shall not impede emergency evacuation.

(b) When the risk analysis required in Chapter 2 indicates that arson is a foreseeable hazard, the overall fire protection plan shall include security measures to prevent unauthorized entry into the protected premises.

4-11 Windowless Buildings.

(a) Windowless buildings shall be provided with knockout panels to allow fire department access to the building.

(b) An automatic fire suppression system shall be installed in accordance with the applicable NFPA standard(s).

(c) * Approved heat and smoke venting shall be installed.

(d) Provisions shall be made for removal of accumulated water from fire-fighting operations.

4-12 Alterations and Renovation.

4-12.1 Existing Fire Protection Systems. The design and layout of existing fire detection and suppression systems shall be evaluated to ensure that their operation will not be compromised.

4-12.2 Fire Spread Control.

(a) New openings in fire-rated assemblies, such as for doorways and duct penetrations, shall have self-closing or automatic fire doors and automatic fire dampers having fire resistance ratings in accordance with NFPA 80, *Standard for Fire Doors and Windows.*

(b) Penetrations in fire-rated assemblies around wiring, pipes, ducts, and so forth, shall be sealed with approved materials to maintain the integrity of the fire-rated assembly.

(c) New elevator shafts, dumbwaiters, stairways, and other vertical openings through the structure shall be constructed to prevent the spread of fire, smoke, and heat from one level to another.

(d) New doors in fire-rated assemblies that are required to be kept in the open position for any reason shall be equipped with approved door-holding devices controlled by a listed smoke detector.

Chapter 5 Fire Precautions During Alterations and Renovations

5-1 Fire Protection Systems.

(a) Alterations or renovations of fire protection systems shall comply with the provisions of the appropriate NFPA standard and shall be approved by the authority having jurisdiction.

(b) The fire department shall be notified and a fire watch posted *(see Section 5-7)* when any fire protection system is out of service for more than 8 hours *(see Section 6-2)*.

5-2 Precautions.

5-2.1* Contracts. All construction, alteration, or renovation contracts shall specify methods and responsibility for controlling fire hazards.

5-2.2 Supervision. Responsibility for enforcement of the terms of the contract relating to fire hazards shall be assigned, and authority shall be given to stop work pending correction of hazards. The responsible local authorities, such as fire and building code enforcement departments, shall be consulted.

5-2.3 Separation of Construction Areas. Each construction area shall be separated by partitions that will resist the spread of fire to other parts of the building.

(a) Tarpaulins or plastic sheeting, if used, shall be treated with an approved fire-retardant coating.

(b) Required exits and normal guard routes shall be maintained or supplementary routes provided.

(c) Fire extinguishers, listed for the purpose, shall be readily available.

5-2.4 Ignition Sources.

(a) Hot work operations shall comply with Section 3-6.

(b) Portable heating appliances shall comply with 5-4.2.

(c) On-site recharging of gas cylinders shall be prohibited.

(d) Temporary lighting and wiring shall comply with the requirements of NFPA 70, *National Electrical Code*.

(e) Smoking shall be prohibited or restricted to designated areas or to specified times. *(See 5-4.8.)*

5-2.5 Housekeeping. Housekeeping shall comply with 5-4.9.

5-2.6 Flammable and Combustible Liquids. Paint thinners, solvents, and other flammable and combustible liquids shall be limited to no more than a one-day supply.

(a) Flammable liquids kept on-site shall be stored in approved safety cabinets and containers. The provisions of NFPA 30, *Flammable and Combustible Liquids Code*, on limits of storage of flammable and combustible liquids inside buildings shall apply.

(b) Quantities of flammable and combustible liquids in excess of those necessary to complete a day's work shall be stored at least 50 ft (15.2 m) away from the main construction project.

(c) Gasoline-powered engines, such as those used in compressors and hoists, shall not be permitted inside the building.

5-2.7 Fire Protection Systems.

5-2.7.1 Fire Detection Systems. Fire detection systems shall be in accordance with 5-5.2.

5-2.7.2 Fire Suppression Systems.

(a) Automatic fire suppression systems shall be kept in proper working order during the project to the extent consistent with the nature of the construction.

(b) Disconnected or shut off standpipes or fire suppression systems shall be restored to service as soon as it is practical. *(See Section 6-2.)*

(c) Regular inspections of standpipe and sprinkler valves shall be conducted and recorded.

(d) Fire hydrants, sprinklers, standpipe and sprinkler fire department connections, and hose outlet valves shall not be obstructed by building materials, debris, or shrubbery, and shall be maintained in accordance with NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*.

5-2.8 Electrical Systems. Installations and modifications to electrical systems shall be made by licensed or registered electricians in conformity with NFPA 70, *National Electrical Code*.

5-3 Temporary Construction and Equipment.

5-3.1 Construction Offices and Sheds.

(a) Temporary offices, trailers, sheds, and other temporary facilities for the storage of tools and materials, where located closely together or located within the building, on the sidewalk bridging, or less than 35 ft (10 m) of the building, shall be of Type II noncombustible construction as defined by NFPA 220, *Standard on Types of Building Construction*.

(b) Temporary offices, trailers, sheds, and other temporary facilities of combustible construction shall be located at least 35 ft (10 m) from the main building and from each other.

(c) Heating devices used in construction offices and sheds shall be listed for the purpose.

(d) * Ample clearance shall be provided around stoves and heaters and all chimney and vent connectors to prevent ignition of adjacent combustible materials.

(e) Structures, equipment, and materials shall not impede egress of occupants or workers from the building or hinder access by fire apparatus to the building and hydrants.

5-3.2 Construction Equipment and Materials.

5-3.2.1 Equipment.

(a) Internal combustion engine-powered air equipment (e.g., compressors, hoists, derricks, pumps, and so forth) shall be placed so the exhausts discharge away from combustible materials.

(b) A minimum clearance of 6 in. (152 mm) shall be maintained between equipment exhaust piping and combustible materials.

(c) Service areas and fuel for construction equipment shall not be located inside the building.

5-3.2.2* Materials.

(a) * Flammable and combustible liquids shall comply with 5-2.6(b).

(b) Combustible construction components stored inside the building shall be limited to the minimum required to complete a day's project.

(c) Where steel construction is present, combustible storage shall not be placed in areas where specified fire-resistive coatings have not been applied.

(d) Storage of highly combustible materials (e.g., foam, plastic, rubber products, and so forth) shall not be permitted inside the building.

(e) Storage of construction materials shall not impede egress from buildings or access of fire apparatus to hydrants or to the building.

5-4 Construction Processes and Hazards.

5-4.1 Cutting and Welding Operations. Cutting and welding operations shall comply with the requirements of NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes.*

5-4.1.1 The person designated to be in charge of fire protection shall issue a hot work permit daily for cutting and welding operations as required by Section 3-6.

5-4.1.2* At the close of the workday the person responsible for fire protection on the site shall inspect areas where welding and cutting operations have occurred for hot metal or smoldering combustible materials.

5-4.1.3 Flammable gas cylinders used in the welding or cutting process shall be protected from vehicle damage and high temperatures.

5-4.2 Temporary Heating Equipment.

(a) Temporary heating equipment shall be listed for the purpose and used and installed in accordance with the listing.

(b) Temporary heating equipment shall comply with 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.*

(c) Temporary heating devices shall be used on a stable surface in a protected location where they will not be overturned.

(d) Portable equipment using oil or liquefied petroleum gas as fuel shall be removed to a safe location and allowed to cool prior to refueling.

(e) * A portable fire extinguisher, listed for the purpose, shall be located within 30 ft (9.1 m) of all portable heating devices.

(f) Chimney or vent connectors from direct-fired heaters, where required, shall be maintained at least 18 in. (457 mm) from combustible materials.

(g) Temporary heating equipment shall be attended and maintained by trained personnel.

5-4.3 Flammable and Combustible Liquids. The use and storage of flammable and combustible liquids shall be carefully controlled and monitored. *(See 5-2.6.)*

5-4.4 Roofing.

5-4.4.1 Asphalt and Tar Kettles.

(a) Asphalt and tar kettles used in roofing or other operations shall be located on the ground outside the building or on a noncombustible roof.

(b) Kettles in operation shall be continuously supervised by a trained person.

(c) Kettles shall be equipped with a metal cover to smother flames in the event of fire.

(d) * Fire extinguishers, listed for the purpose, shall be located within 30 ft (9.1 m) of such operations.

5-4.4.2 Liquefied Petroleum Gas (LPG).

(a) Cylinders or containers used for fueling tar kettles shall be protected against tampering and vandalism.

(b) When possible, cylinders and containers shall be placed in a secured area for protection against tampering.

(c) Cylinders or containers that cannot be secured in a protected area shall have the dome covers locked and secured, or the valve handle shall be removed or secured in the "off" position.

(d) Storage of LPG cylinders on rooftops shall not be permitted.

5-4.4.3 Used roofing mops shall not be stored inside the building.

5-4.5 Plumbing. Plumbing work involving open flames shall be conducted only under the supervision of the person in charge of fire protection and shall require a daily hot work permit. The provisions of 5-4.1 shall apply.

5-4.6 Demolition Work.

(a) Gas supplies shall be shut off at a point outside the affected area and shall be capped.

(b) Electrical service shall be reduced or eliminated in the affected area.

(c) Hot work shall not be permitted in combustible buildings except as outlined in 5-4.1.

(d) Fire walls, fire doors, cutoffs, and other fire separation assemblies shall be maintained in good repair where possible.

5-4.7 Other Hazardous Operations. Operations that introduce fire hazards shall be reviewed to determine if other, safer methods are available.

(a) Paint stripping operations involving open flames shall not be permitted.

(b) Floor sander dust accumulation bags shall be emptied into closed metal containers outside of the building before the close of the day.

5-4.8 Smoking.

5-4.8.1 Smoking shall be prohibited inside any building or building space or area under construction, renovation, or repair.

5-4.8.2 The governing body or responsible party for the institution or property shall designate a smoking area outside of the work area where contractors and workers are permitted to smoke.

(a) If located outside, this designated smoking area shall be clearly and publicly identified. It shall also be located a sufficient distance away from all combustible and flammable materials or liquids to prevent a fire from starting. Receptacles for spent smoking materials shall be provided in the designated smoking area. A properly mounted, rated, fully charged, and operable portable fire extinguisher shall be located at each designated smoking area.

(b) If located inside the cultural resource building, the smoking area shall fully comply with all of the requirements of Section 3-5 of this standard.

5-4.9 Housekeeping.

(a) The accumulation of debris or rubbish shall not be permitted inside construction areas or close to a source of ignition.

(b) Debris and rubbish shall be removed daily from the site and shall not be burned in the vicinity.

(c) Contractors shall provide ample receptacles for rubbish, papers, and so forth.

(d) A chute employed for the removal of debris shall be erected on the outside of the building.

(e) Burning waste materials on the premises shall not be permitted.

5-4.10 Electrical.

(a) Electrical wiring and equipment for light, heat, or power shall be installed in compliance with the requirements of NFPA 70, *National Electrical Code.*

(b) Temporary lighting, bulbs, and fixtures shall be installed so they do not come in contact with combustible materials.

(c) Circuit breakers for circuits that are not in use shall be shut off.

(d) Temporary wiring shall be removed immediately upon elimination of the need for which the wiring was installed.

5-4.11 Environmental Conditions. Openings in structures susceptible to damage from high winds that could cause skewing and misalignment of the structure, disruption of water supplies, or delivery systems for fire protection shall have secure, temporary coverings.

5-5 Fire Protection.

5-5.1 Fire Barriers.

(a) Fire walls and exit stairways required for the completed building shall be given construction priority.

(b) Fire doors with approved closing devices and hardware shall be installed as soon as practical and before combustible materials are introduced.

(c) Fire doors shall not be obstructed from closing.

5-5.2 Fire Detection Systems.

(a) Existing fire detection and alarm systems shall be maintained in proper working order during the project to the extent consistent with the nature of the construction.

(b) Smoke detectors within the construction area shall be removed or shall be protected from dust, dirt, and extreme temperatures during construction.

(c) Smoke detectors in temporary detection systems inside the construction area that are covered to keep out dust and dirt while work is in progress shall be uncovered at the end of each work day.

(d) After final construction cleanup by all trades, all smoke detectors shall be cleaned or replaced in accordance with NFPA 72, *National Fire Alarm Code.*

(e) Reacceptance testing in accordance with NFPA 72, *National Fire Alarm Code,* shall be performed after any adjustment, modification, or repair to any system wiring or component.

5-6 Fire Suppression.

5-6.1* Access.

(a) A suitable location at the site shall be designated as a control area and shall provide floor plans, utility control plans, emergency contact telephone numbers, labeled keys, and appropriate material safety data sheets. Where security is of concern, a lock box shall be provided for this information.

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

(c) Free access from the street to fire hydrants and to outside connections for standpipes, sprinklers, or other fire extinguishing equipment, whether permanent or temporary, shall be provided and maintained at all times.

(d) Protective pedestrian walkways shall be constructed so as not to impede access to hydrants, fire department connections, or fire extinguishing equipment.

(e) During construction operations, free access to permanent, temporary, or portable fire extinguishing equipment and systems shall be maintained.

(f) At least one stairway shall be provided in usable condition at all times in multistory buildings.

5-6.2* Water Supply. Water for fire suppression shall be available throughout all phases of construction.

5-6.3 Standpipes.

(a) New standpipes that are required or exist in buildings being altered shall be maintained in accordance with the progress of building activity such that they are always ready for fire department use.

(b) Hose and nozzles shall be provided and made ready for use as soon as either the temporary or permanent water supply is available.

5-6.4 Automatic Fire Suppression Systems.

(a) Where automatic fire suppression systems are provided, the installation shall be placed in service and monitored as soon as it is practical.

(b) Where fire suppression systems existed prior to the rehabilitation project, the system shall be kept in service as long as possible during the rehabilitation work.

(c) Where fire suppression systems must be taken out of service for modification, the local fire department shall be notified and the system shall be returned to service as soon as possible.

5-6.5 Portable Fire Extinguishers.

(a) Portable fire extinguishers, listed for the purpose, shall be located, mounted, and maintained in accordance with NFPA 10, *Standard for Portable Fire Extinguishers.*

(b) At least one approved portable fire extinguisher shall be readily accessible on each floor near each usable stairway.

5-7* Security.

(a) * Where assigned, security officers shall receive daily updates on the status of fire protection equipment and emergency procedures.

(b) Access to construction areas shall be limited to personnel authorized by the owner or contractor.

5-8 Emergency Communication.

(a) A telephone, or equivalent method of summoning the fire service, shall be provided and readily available.

(b) The telephone number of the fire service shall be prominently posted on or immediately adjacent to each telephone.

(c) Written instructions shall be posted on how to notify the local fire service of a fire and on actions for security officers or other staff to take after notifying the fire service.

Chapter 6 Inspection, Testing, and Maintenance

6-1* Purpose. This chapter shall establish the critical role of routine inspection, testing, and maintenance in cultural resource facilities and institutions.

6-2 Fire Protection Systems.

6-2.1 Requirement. All fire protection systems shall be tested, inspected, and maintained in full compliance with the manufacturer's recommendations and the requirements of NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems,* for water-based fire protection systems; NFPA 72, *National Fire Alarm Code,* for fire detection and alarm systems; the appropriate NFPA standard for automatic fire suppression systems; and any other applicable NFPA standard for fire protection systems.

6-2.2 Responsibility. The responsibility for properly maintaining fire protection systems shall be that of the governing body or responsible party of the cultural resource property. By means of periodic inspections, tests, and maintenance, the equipment shall be shown to be in good operating condition, or any defects or impairments shall be revealed and corrected. Inspection, testing, and maintenance shall be implemented in accordance with procedures meeting or exceeding those established in the appropriate standard for the type of fire protection system and in accordance with the manufacturer's instructions. These tasks shall be performed by personnel who have developed competence through training and experience.

6-2.3 Inspection. Inspection and periodic testing determine what, if any, maintenance actions are required to maintain the operability of fire protection systems. Applicable NFPA standards establish minimum inspection and testing frequencies, responsibilities, test routines, and reporting procedures for each type of system.

6-2.4 Testing. All fire protection systems shall be tested to verify that they function as intended. Test results shall be compared with those of the original acceptance test (if available) and with the most recent test results. Records shall be retained for the next test and for one year thereafter.

6-2.5 Maintenance. Maintenance shall be performed to keep all fire protection systems operable or to make necessary repairs. As-built system installation drawings, original acceptance test records, and device or equipment manufacturer's maintenance bulletins shall be retained by the fire safety manager to assist in the proper care of all fire protection equipment and systems and components.

6-3 Impairments to Fire Protection Systems.

6-3.1 General. When an emergency or a pre-planned impairment takes any fire protection system out of operational service, adequate measures shall be taken during the impairment to ensure that increased risks are minimized and the duration of the impairment is limited.

6-3.2 Preplanned Impairments. All preplanned impairments shall be authorized in advance of work by the fire safety manager. Before authorization is given, the fire safety manager shall be responsible for verifying that written procedures for impairments are followed. *(See 6-3.3.)*

6-3.3 Procedure. A written procedure shall be established and implemented by the fire safety manager to control any emergency or preplanned impairment. This procedure shall include, as a minimum, the following:

(a) Identification and tagging of all impaired equipment and systems

(b) Notification of personnel or organizations to be notified (e.g., authority having jurisdiction, local fire service, insurance carrier, central station of alarm company monitoring impaired systems, and supervisory staff in areas of the facility affected by the impairment)

(c) Statement of additional measures deemed necessary (e.g., setting up a fire watch) for the duration of the system impairment

(d) Actions and notifications to be taken when all impaired equipment and systems are restored to operational service [e.g., notifying the same personnel and organizations as in 6-3.3(b) above]

(e) Prior to a preplanned impairment, assemblage of all necessary parts, tools, materials, and labor at the impairment site before removing the system or equipment from service

(f) The expedition of all repair work

6-3.4 Restoring Systems to Service. When all impaired systems are restored to normal working order, the impairment coordinator shall verify that the following procedures have been implemented:

(a) Any necessary inspections and tests shall have been conducted to verify that affected systems and equipment are operational. Inspection and testing requirements shall be as required by the appropriate NFPA standard for the fire protection system or equipment involved.

(b) Those individuals listed in 6-3.3(b) shall be notified that protection has been restored.

(c) Impairment tags shall have been removed.

6-4 Heating and Cooking Equipment.

(a) Heating and air conditioning systems and cooking appliances shall be maintained in accordance with the manufacturer's specifications and the applicable NFPA standards.

(b) Heaters and ductwork, including hoods and ducts for ranges, shall be kept free of flammable and combustible deposits.

6-5 Chimneys. Chimneys for active stoves or fireplaces shall be inspected and cleaned annually in accordance with NFPA 211, *Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances.*

6-6* Electrical Systems. Electrical systems shall be maintained on a periodic basis.

6-7 Fire Barrier. The integrity of fire barriers shall be maintained in accordance with NFPA 221, *Standard for Fire Walls and Fire Barrier Walls.*

6-8 Fire-Retardant-Treated Materials. Applied coatings and treatments shall be maintained in accordance with NFPA 703, *Standard for Fire Retardant Impregnated Wood and Fire Retardant Coatings for Building Materials.*

6-9 Fire Extinguishers. Portable fire extinguishers shall be maintained in accordance with NFPA 10, *Standard for Portable Fire Extinguishers.*

Chapter 7 Historic Structures and Sites

7-1* Introduction. Two important goals of historic preservation shall be to provide adequate fire protection to all historic buildings while protecting those elements, spaces, and features that make them historically or architecturally significant.

A building survey shall be conducted to identify significant historic elements, spaces, and features; code deficiencies; and existing fire and life safety hazards and to establish restoration and preservation objectives. The building survey shall provide the basis for all fire protection and preservation planning decisions. It shall be conducted by a qualified professional experienced in fire protection and the preservation of architecturally significant structures.

7-1.2 Identification of Historic Elements, Spaces, and Features.

7-1.2.1 Exterior. The building survey shall identify those character-defining features and finishes that make the exterior of the building and grounds significant. Character-defining features can include sheathing or facade materials, roofing materials, chimneys, skylights, cornices, windows and doors, and extensions such as porches, railings, and other attached building components.

7-1.2.2 Construction. The building survey shall determine primary and secondary significance of all character-defining features and facades. Required exterior modifications or additions shall be located on the least-visible and significant elevation in order to keep the impact to a minimum.

7-1.2.3 Adjacent Structures. The building survey shall address the significant structure and all adjacent (contributing) structures that make up the historic setting of the property. Fire protection shall be afforded those contributing structures that can include buildings, sheds, vehicles, and displays.

7-1.2.4 Site Elements. The building survey shall identify those significant character-defining features of the property. Fire safety improvements shall minimize impact to significant landscape elements such as vegetation, roads and driveways, walking paths, fencing, and exterior use.

7-1.2.5 Interior. The building survey shall identify all significant interior spaces, floor plan organization, and character-defining features and finishes in the building, including those original to the building and changes to originals that have acquired significance in their own right. Character defining features and finishes may include; distinctive architectural details, 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.

7-1.2.6* Construction Features. The building survey shall determine primary and secondary significance of all character-defining facades, spaces, features, and finishes. Required interior modifications or additions shall be located in secondary spaces in a manner that minimizes visual impact and damage to historic materials.

7-1.2.7* Floor Plans. The building survey shall include review of floor plans to establish important characteristics of the building type, style, period, or historic function. Floor plans might be an important characteristic of the building type, style, period of construction, or historic function.

7-1.2.8* Significant Spaces. The building survey shall review significant spaces to establish rooms or other interior locations that are typical of the building type or style or are associated with specific persons or events.

7-1.2.9* Historic Documentation. The governing body and designated manager shall have a demonstrated knowledge and understanding of the significance of the historic structure. Each design professional shall be aware of the significance of the historic structure prior to beginning the design exercises for modification or installation of fire protection systems. All tradespeople shall be thoroughly briefed on the significance and importance of the structure, spaces, or unique character-defining features prior to the beginning of work.

7-1.2.10* Code, Standard, and Regulation Compliance. The building survey of existing conditions shall 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.

The authority having jurisdiction shall be encouraged to allow alternative methods that offer equivalent or greater protection while preserving the character-defining spaces, features, and finishes of the historic structure in accordance with the *Secretary of Interior's Standards for Rehabilitation and Guidelines for Rehabilitating Historic Buildings.*

7-1.3* Fire Hazards and Safety Deficiencies. The building survey shall identify conditions that could contribute to the start or spread of a fire, or to the endangerment of people or property by fire.

7-1.4* Fire Spread. The building shall be evaluated to determine potential paths of fire spread that could be inherent to its architectural design.

7-1.5 Means of Egress. The building survey shall identify egress system deficiencies such as insufficient numbers of exits, undersized exit capacity, inadequate exit fire resistance, dead-end corridors, excessive travel distances, and unenclosed stairs.

7-2 Planning.

7-2.1* Developing a Fire Safety Plan. Elements of a fire safety plan shall be selected to control or mitigate identified fire hazards appropriate to the objectives of historic preservation and fire safety in accordance with Chapter 2 of this document.

7-2.2 Management Involvement. Management shall be involved in fire safety planning to ensure successful program implementation. Management shall consider the following steps to ensure the fire safety of the historic property:

(a) Fully evaluate the existing conditions of the building.

(b) Educate and train appropriate personnel in the importance and implementation of a fire prevention program.

(c) Provide or have available trained, properly equipped salvage operations.

(d) Institute management and operation practices that minimize the causes of fire.

(e) Incorporate appropriate fire protection measures to limit any damage if fire occurs. Appropriate measures can include structural compartmentation, automatic detection and alarm, and fixed fire suppression systems.

7-2.3* Fire Prevention. Care shall be exercised to provide for the abatement of fire hazards.

7-2.4* Education and Training. Staff members shall be instructed to identify obvious fire hazards and report them to a designated individual.

7-2.5 Operations and Maintenance. The building shall be used, occupied, and maintained in a manner stressing fire safety. All building systems shall be properly maintained to minimize fire risks.

7-2.6 Enforcement. The responsibility for enforcement of fire prevention issues shall be clearly defined.

7-3 Preservation and Renovation.

7-3.1* Objectives. 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. Achieving this objective necessitates an understanding of historic preservation and fire protection concepts.

7-3.2 Historic Preservation. Historic buildings shall be treated with the sensitivity prescribed by conventional historic preservation criteria and standards, such as the *Secretary of the Interior's Standards for Rehabilitation and Guidelines for Rehabilitating Historic Buildings,* or other nationally recognized documents.

7-3.3 Preservation Authority Review. Projects shall be discussed with the appropriate preservation authorities as early as possible in the planning stages.

7-3.4* Code Enforcement. Proposed rehabilitation projects shall be discussed with the appropriate building and fire code officials as early as possible in the planning stages to establish code or safety conflicts.

7-3.5 Design. To reduce the possibility of fire, existing safety standards such as NFPA, Secretary of Interior's, and industry standards shall be consulted during the design of electrical, mechanical, and similar systems.

7-3.6* Management Responsibility. Management shall have active participation and direction of the fire protection effort throughout the preservation and renovation process.

7-3.7* Elimination or Control of Fire and Life Safety Hazards. The planning process for the preservation of an historic structure shall include provisions to control fire 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 Section 7-1)* shall be ranked by priority to help identify the most undesirable conditions.

7-3.7.1 Where a specific hazard is an essential part of the historic building fabric of the building, the threat to the building shall be controlled by providing special protection for the hazard.

7-3.8* Limiting Combustibility.

7-3.8.1 Construction Materials. Careful consideration shall 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 others not exposed to the public.

7-3.8.2 Interior Finish Materials. Choice of new interior finishes and fire-resistive treatments of historic fabrics shall be given consideration to minimize fire hazards.

7-3.8.3 Furnishings and Contents. Noncombustible materials shall be used as much as possible for furnishings and other contents of the building. Where intended occupancy of the building introduces combustible contents for which there are no substitutes, the building's fire loading shall be considered when fire suppression systems are designed or modified.

7-3.9 Compartmentation.

7-3.9.1 Horizontal Fire and Smoke Barriers. The planning for the preservation of an historic structure shall take into consideration the use of fire-rated walls and doors to subdivide building areas and to segregate specific hazards such as boilers, furnaces, or storage areas from the remainder of the building. These fire-rated barriers shall be designed to resist the passage of smoke and to confine the effects of fire where possible. Such designs often can be incorporated while maintaining the historic fabric of the building.

7-3.9.2 Vertical Enclosures. Provisions shall 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, shall be provided.

7-3.9.3 Fire Stops. Fire stops shall be provided in concealed spaces to prevent the spread of fire within walls and between rafters and floor joists. Filling concealed spaces with inert materials, such as mineral wool insulation or other similar fire-resistive materials, can further retard the spread of fire. 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.

7-3.10 Structural Protection. The existing structural fire resistance shall be determined. For older structures, the U.S. Department of Housing and Urban Development has developed the *Guideline on Fire Ratings of Archaic Materials and Assemblies* to identify approximate fire resistance qualities of older construction methods.

7-3.11 Detection and Alarm. Consideration shall be given to provide a separate fire detection system that can identify a fire condition from smoke, critical temperature rise, or infrared or ultraviolet radiation from the fire. The detection device that offers the fastest response with respect to the type of occupancy shall be a primary consideration.

7-3.11.1 Detection and alarm systems shall sound an alarm within the structure and shall transmit a signal to an alarm monitoring service or to a local fire department. Subsequent to an alarm, the fire department shall be contacted immediately to verify that the alarm was received.

7-3.11.2 Specific detectors shall be appropriate for the anticipated fire hazard.

7-3.12 Fire Extinguishment. An essential element in any fire safety plan is consideration of the means available to suppress a fire once it has begun. Management shall make critical decisions as to the type of fire suppression capability that will be provided in the building.

7-3.12.1* Automatic fire extinguishing systems shall be installed carefully to avoid damage to building fabric and to minimize aesthetic impact on architectural and historic features of the building.

7-3.12.2 Portable fire extinguishers are important items of fire protection equipment and shall be installed in accordance with NFPA 10, *Standard for Portable Fire Extinguishers.*

7-3.12.3 Where standpipes and hose lines are required or installed to provide reliable and effective hose streams in the shortest time possible, they shall be installed in accordance with NFPA 14, *Standard for the Installation of Standpipe and Hose Systems.*

Chapter 8 Museums and Museum Collections

8-1* General. The requirements of Chapters 1 through 7 shall apply to all museum buildings.

8-1.1 This chapter applies to buildings or spaces within buildings that store or display museum collections, and to historic buildings exhibited or used as museums.

8-1.2 This chapter prescribes minimum requirements for the protection of museums and museum collections from fire through a comprehensive museum fire protection program.

8-1.2.1 Because of the special nature of museums, this chapter supplements existing codes and standards to apply specifically to buildings or portions of buildings devoted to museum use.

8-2 Planning.

8-2.1 Fundamental Requirements.

8-2.1.1* Responsibility. The museum's governing body and its director or chief executive officer shall be responsible for ensuring that adequate protection is provided against fire and its disastrous effects in accordance with Chapter 2.

8-2.2 Emergency Evacuation Plan. The museum's governing board and its fire safety manager shall develop an emergency evacuation plan for the museum in accordance with the requirements of Section 2-3.

8-2.3 Fire Protection Plan. The museum's governing board and its fire safety manager shall develop a fire protection plan for the museum in accordance with the requirements of Section 2-2.2.

8-2.4 Salvage Plan. The museum's governing board and its fire safety manager shall develop a salvage plan for the museum in accordance with the requirements of Section 2-4 of this document.

8-2.5 Training. In accordance with the requirements of Section 2-5 of this document, the museum's governing board and its fire safety manager shall ensure that the museum's staff, including volunteers and interns, receive periodic and regular training in all aspects of the following:

(a) The museum's fire protection plan

(b) The museum's emergency evacuation plan

(c) The museum's salvage plan

(d) The museum's fire protection systems, including the proper use of portable extinguishers

8-3 Basic Fire Prevention.

8-3.1* Smoking. Smoking shall be prohibited except as permitted by Section 3-5.

8-3.2 Decorations. Decorative materials used for special occasions and holidays shall be used in accordance with Section 3-2.

8-3.3 Open Flames. Open flame demonstrations shall be in accordance with Section 3-7.

8-3.4* Housekeeping. The museum's governing board and its fire safety manager shall ensure a high standard of housekeeping and maintenance throughout the museum's building(s). All provisions of Chapter 3 shall be implemented and the following shall be included:

(a) Collections shipping and receiving areas shall be kept clear of accumulated combustible packing and crating materials. Discarded packing materials shall be properly disposed of in accordance with 3-4.6.

(b) Conservation laboratories and studios, collections restoration, cleaning, and treatment areas, and exhibit construction and fabrication areas are high-fire-risk areas. Safety precautions shall be in place to minimize and control fire hazards.

8-4 New Construction.

8-4.1 Museum Support Areas. Museum support areas shall be designed in accordance with Chapter 4.

8-4.2 Collection Storage Rooms. Collection storage rooms shall be in compliance with Section 1-6.

8-4.3 Compact Storage. Rooms housing compact storage systems shall comply with the following requirements:

(a) An automatic fire suppression system shall be required for compact shelving where museum or archival materials are stored

(b) The design shall recognize the special nature of the hazard from a fire that originates in a compact mobile storage unit when fuel loads are invariably large and fire growth is significantly different from other kinds of book storage.

(c) The automatic fire suppression system and the compact storage system shall be designed to limit fire damage in accordance with the museum's fire safety objectives (e.g., confine fire growth to the compact storage module of origin or the shelving range of origin). Significant factors to consider include the number and size of the storage modules, the separation provided between the modules (end-to-end and back-to-back), and the type of materials being stored.

8-5 Alterations and Renovations. Alterations, additions, and renovations shall comply with Section 4-12.

8-6* Exhibit Design and Construction.

8-6.1 The museum's fire safety manager shall thoroughly review exhibit installation plans to ensure compliance with the museum's fire protection plan and to further ensure that the proposed exhibit will not in any way compromise or adversely affect the following:

(a) Life safety systems, equipment, and measures in the exhibit, the exhibition area, and the museum building

(b) Means of egress in the exhibit, the exhibition area, and the museum building

(c) Exiting from the exhibit, the exhibition area, and the museum building

(d) Fire protection systems (including detection, alarms, and automatic suppression) in the exhibit, the exhibition area, and the museum building

(e) Fire safety in the exhibit, the exhibition area, and the museum building

(f) Emergency lighting systems in the exhibit, the exhibition area, and the museum building. Special lighting effects in the exhibit and exhibition area shall not reduce illumination below the minimum level for safe egress, or create any fire hazard.

8-6.2 The fire safety manager shall be kept fully informed and involved at every stage, including preliminary planning design, fabrication, and installation for each and every exhibit mounted or installed.

8-6.3 Exhibit Materials. Exhibits shall be fabricated and constructed using materials that are either noncombustible or treated with a fire-retardant coating. Treated foam board, fire-retardant-treated wood, textiles, and similar materials decrease fuel load created by exhibit construction.

(a) Materials that are not inherently fire resistant shall be treated with an approved fire-retardant coating.

Exception: Exhibit construction or backing materials placed in direct physical contact with or immediate proximity to collection objects need not be fire retardant coated if such fire-retardant coating will harm the collection object(s) involved. This exception shall apply only on an object-by-object-type basis and shall not be used as a total exemption from the use of fire-resistant or noncombustible materials in an exhibit.

(b) Those exhibit construction or backing materials that are treated with a chemical fire-retardant coating shall be periodically retreated with an approved fire-retardant coating in accordance with the manufacturer's specifications.

(c) The museum's fire safety manager shall maintain records of all chemical fire-retardant treatments. These records shall include the certificate of approval for each fire-retardant coating used, application method, and retreatment schedule.

(d) Combustible materials that cannot be made fire retardant shall be located so as to minimize potential hazards.

8-6.4 Portable extinguishers appropriate for the hazard shall be located as required in NFPA 10, *Standard for Portable Fire Extinguishers.*

8-6.5 All electrical wiring and work installed for an exhibit shall conform to the provisions of NFPA 70, *National Electrical Code.*

8-6.6 Temporary walls and exhibit components, such as cases and dioramas, shall not interfere with the operation of any fire protection system. Automatic fire suppression systems shall be appropriately redesigned or modified to account for increased fuel loads.

8-6.7 Orderly circulation of visitors shall be maintained when special exhibits are expected to draw large crowds. Lines or crowds waiting to enter the exhibit area or the museum shall not obstruct exits or access to exits. Evacuation capabilities must be maintained also.

8-7 Hazardous Areas.

8-7.1 Hazardous areas shall be separated from other areas with a minimum 1-hr fire-rated construction and shall have an automatic fire suppression system.

8-7.2 Paint spraying and spray booths shall be used in conformity with NFPA 33, *Standard for Spray Application Using Flammable or Combustible Materials.*

8-7.3 Flammable and combustible liquids (e.g., paints, pesticides, and so forth) shall be stored in accordance with NFPA 30, *Flammable and Combustible Liquids Code.*

8-7.4 Fumigation. Flammable or combustible pesticides used to rid collection objects of insect or mold infestations shall be handled and used in accordance with the provisions of NFPA 30, *Flammable and Combustible Liquids Code.*

8-8 Special Facilities.

8-8.1 Public Areas.

8-8.1.1 Drapes, curtains, props, and so forth shall be noncombustible, or shall be treated with an approved fire-retardant coating.

(a) The museum's fire safety manager shall maintain records of all chemical fire-retardant treatments. These records shall include the certificate of approval for each fire-retardant coating used, application method, and retreatment schedule.

(b) Combustible drapes, curtains, props, and so forth shall be retreated with an approved fire-retardant coating in accordance with the manufacturer's recommendations.

8-8.1.2 Auditorium tiered space structures on which people are permitted to sit shall be of noncombustible construction.

8-8.1.3 Carpet on vertical surfaces shall have a Class A rating, and shall comply with the requirements of NFPA *101, Life Safety Code.*

8-8.2 Laboratories and Studios. Laboratories and studios shall be in compliance with NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals,* and NFPA *101, Life Safety Code.*

8-8.2.1 Listed safety containers shall be provided for the storage and use of flammable and combustible liquids.

(a) Flammable or combustible liquids shall be stored and used in accordance with NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals.*

(b) No more than a one-day supply shall be kept outside of an approved storage cabinet or room in the building.

(c) Cabinets or rooms for the storage or dispensing of flammable liquids shall comply with the requirements of NFPA 30, *Flammable and Combustible Liquids Code.*

(d) Lighting fixtures, motors, and switches required to be of an explosionproof or intrinsically safe type shall be installed in accordance with NFPA 70, *National Electrical Code.*

8-8.2.2 Museum laboratories and studios shall be protected by an automatic fire suppression system.

8-8.2.3 Hot plates and other heat-producing appliances shall be listed for their application.

(a) Such devices shall be maintained in a safe operating condition.

(b) Pilot lights at the wall switches or on the appliances shall be provided to readily and visually indicate if the appliance is energized.

8-8.2.4 Waste receptacles shall be self-closing metal containers.

8-8.3 Wet Collections. Wet collections shall be stored and handled in accordance with 1-6.6.

8-9* Storage of Records. Museum records shall be stored and protected in accordance with NFPA 232, *Standard for the Protection of Records.*

8-10 Collection Storage Rooms. Collection storage rooms shall be in compliance with Section 1-6.

Chapter 9 Libraries and Library Collections

9-1* General. The provisions of Chapters 1 through 7 shall apply to all library buildings.

9-1.1 This chapter shall apply to buildings or spaces within buildings that provide storage for library collections available to the general public or community served by the library, including historic buildings that have library collections and reading rooms serving the public.

Exception: Privately owned libraries not open to the public.

9-1.2* The purpose of this chapter shall be to establish minimum requirements for fire prevention, fire protection, and fire loss contingency planning for the fire safety of the library's buildings, its collections, and for the life safety of those persons who visit libraries or work in them.

9-1.2.1 Because of the combination of public assembly occupancy in reading rooms with heavy fuel loads associated with storage occupancies, this chapter shall modify and supplement existing codes and standards to apply specifically to buildings or portions of buildings devoted to library use.

9-2 Planning.

9-2.1 Responsibility. The library's governing body and its director or chief executive officer shall be responsible for ensuring that adequate protection is provided against fire and its disastrous effects in accordance with Chapter 2.

9-2.2 Fire Protection Plan. The library's governing board and its fire safety manager shall develop a fire protection plan for the library in accordance with the requirements of Section 2-2.

9-2.3 Emergency Evacuation Plan. The library's governing board and its fire safety manager shall develop an emergency evacuation plan for the library in accordance with the requirements of Section 2-3.

9-2.4 Salvage Plan. The library's governing board and its fire safety manager shall develop a salvage plan for the library in accordance with the requirements of Section 2-4 of this document. *(See Appendix I for additional information.)*

9-2.5 Training. Training in emergency procedures shall be conducted in accordance with the requirements of Section 2-5 of this document.

9-3 Locking Devices. It is common for library security measures to funnel all occupants through a few exits that can be closely monitored. Where such measures are used in conjunction with delayed opening locking devices, locking arrangements shall comply with Section 2-2.3(d) of this standard and NFPA *101, Life Safety Code,* Section 5-2.

9-4 Collections Storage. Collections storage rooms shall comply with Section 1-6.

9-5* Book Stacks.

9-5.1 General. Fuel loads in library book stacks can range from 30 to more than 100 lb/ft^2 (146 to more than 488 kg/m^2) with potential fire durations of more than eight hours, numbers more comparable to warehouse occupancies than to business occupancies.

9-5.2* Multitier Book Stacks. Where multitier book stacks are used, the following requirements shall apply:

(a) An automatic fire detection system designed and installed in accordance with NFPA 72, *National Fire Alarm Code,* shall be installed in the book stacks.

(b) An automatic fire suppression system designed and installed in accordance with the appropriate NFPA standard shall be installed in the book stacks.

(c) Smoke barriers shall be installed in all vertical openings between tiers or decks.

9-5.3 Compact Storage.

(a) * An automatic fire suppression system shall be required for compact storage where library or archival materials are stored.

(b) The design shall recognize the special nature of the hazard from a fire that originates in a compact mobile storage unit when fuel loads are invariably large and fire growth is significantly different from other kinds of book storage.

(c) The automatic fire suppression system and the compact storage system shall be designed to limit fire damage in accordance with the library's fire safety objectives (e.g., confine fire growth to the compact storage module of origin or the shelving range of origin). Significant factors to consider include the number and size of the storage modules, the separation provided between the modules (end-to-end and back-to-back), and the type of materials being stored.

9-5.4 Secondary Storage Facilities. Some large libraries have established "secondary storage facilities," which are environmentally controlled warehouses using rack storage to heights of more than 30 ft (9.3 m). When rack storage methods are employed, automatic sprinkler systems shall be designed and installed in accordance with NFPA 231C, *Standard for Rack Storage of Materials.*

9-5.5 Single Tier Book Stacks.

9-5.5.1 An automatic fire detection system designed and installed in accordance with NFPA 72, *National Fire Alarm Code,* shall be installed in single-tier book stacks.

9-5.5.2 Where specified to achieve fire safety goals by the fire protection plan required by Chapter 2, an automatic fire suppression system designed and installed in accordance with the appropriate NFPA standard shall be installed in the book stacks.

9-5.6 Space Heaters.

(a) Only listed fixed space heaters shall be installed in bookstacks.

(b) Portable space heaters are not permitted in book stacks.

9-5.7 Smoking. Smoking shall be prohibited except as permitted by Section 3-5.

9-5.8* Utilities Serving Book Stack Space. Utilities other than those supporting fire suppression, detection, and security systems shall not pass through book stack spaces.

(a) Electrical distribution power panels shall not be installed in book stacks.

(b) Controls for utilities serving book stack space shall be located outside the space so that access to the controls does not require entry into the book stack.

(c) Controls for utilities serving book stack space shall be designed to allow isolation of book stack utilities in an emergency.

Exception: Utilities that directly serve book stack spaces shall be permitted in the space.

9-6 Fire Prevention.

9-6.1 Furniture, Drapes, and Curtains.

(a) Furniture, drapes, and curtains shall be noncombustible or treated with an approved fire-retardant coating.

(b) The library shall maintain records to show the fire-retardant coating used, application date, and retreatment schedule.

(c) Combustible drapes, curtains, props, and so forth shall be retreated with an approved fire-retardant coating in accordance with the manufacturer's recommendations.

9-6.2 Ignition Control.

9-6.2.1 Space Heaters. Only listed fixed space heaters shall be installed in book stacks. Portable space heaters are not permitted in book stacks.

9-6.2.2 Hot Work. All work with open flame devices used in soldering, brazing, cutting, and welding shall only be used as permitted by Section 3-6.

9-6.3 Housekeeping. Housekeeping shall be maintained as required by Section 3-4.

Exception: Storage on shelves from floor to ceiling shall be permitted in retrofit installation of sprinkler systems in multitier book stacks when designed in accordance with the special design requirements for this occupancy established by NFPA 13, Standard for the Installation of Sprinkler Systems.

9-6.4 Decorations. Decorative materials used for special occasions and holidays shall be used in accordance with Section 3-2.

9-7 Prevention of Arson.

9-7.1* General. The library shall take steps to prevent arson.

9-7.2 Book Returns. Book returns shall be constructed to prevent the spread of fire and smoke from the return into the rest of the library, or the book return shall be located in an outside receiving bin away from the exterior walls of the library building.

9-8 Hazardous Operations and Areas. Hazardous operations and areas (including library support areas) shall be designed in accordance with Chapter 4 and maintained in accordance with Chapter 6.

9-8.1 Fumigation. Flammable or combustible pesticides used to rid collection objects of insect or mold infestations shall be handled and used in accordance with the provisions of NFPA 30, *Flammable and Combustible Liquids Code.*

9-8.2* Cellulose Nitrate Motion Picture Film. Cellulose nitrate motion picture film shall only be projected, stored, handled, or processed for conversion to safety film as specified by NFPA 40, *Standard for the Storage and Handling of Cellulose Nitrate Motion Picture Film.*

9-8.3 Print Shops and Binderies. Low-flash-point inks, blanket wash solutions, and adhesives shall be used and stored in accordance with NFPA 30, *Flammable and Combustible Liquids Code.*

9-8.4* Book Restoration Laboratories.

9-8.4.1 Book restoration laboratories shall be in compliance with NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals.*

9-8.4.2 Listed safety containers shall be provided for the storage and use of flammable and combustible liquids.

(a) Flammable or combustible liquids shall be stored and used in accordance with NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals.*

(b) No more than a one-day supply shall be kept outside of an approved storage cabinet or room in the building.

(c) Cabinets or rooms for the storage or dispensing of flammable liquids shall comply with the requirements of NFPA 30, *Flammable and Combustible Liquids Code.*

(d) Lighting fixtures, motors, and switches required to be of an explosionproof or intrinsically safe type shall be installed in accordance with NFPA 70, *National Electrical Code.*

9-8.4.3 Hot plates and other appliances shall be listed for their application.

(a) Such devices shall be maintained in a safe operating condition.

(b) Pilot lights at the wall switches or on the appliances shall be provided to readily and visually indicate if the appliance is energized.

9-8.4.4 Self-closing metal waste receptacles shall be strategically placed in ample numbers.

9-8.4.5 Library laboratories shall be protected by an automatic fire suppression system.

9-9 Exhibit Design and Construction.

9-9.1 The layout of exhibits shall not infringe on exits or other fire safety features of the building.

9-9.2 Lighting adequate for egress shall be maintained in the area, night and day. Special lighting effects shall not reduce illumination below the minimum level for safe egress.

9-9.3 Fire-retardant-coated or noncombustible materials shall be used in the construction and support of the exhibit when applicable and subject to approval by the authority having jurisdiction. Fire-retardant-coated wood, foam boards, textiles, and other materials shall be used to decrease the fuel load.

(a) Materials that are not inherently fire resistant shall be treated with an approved fire-retardant coating.

Exception: Exhibit construction or backing materials placed in direct physical contact with or immediate proximity to collection objects need not be fire retardant coated if such fire-retardant coating will harm the collection object(s) involved. This exception shall apply only on an object-by-object-type basis and shall not be used as a total exemption from the use of fire-resistant or noncombustible materials in an exhibit.

(b) Combustible materials shall be periodically retreated with an approved fire-retardant coating in accordance with the manufacturer's specifications.

(c) The library shall maintain records of the treatment to include certificate of approval of retardant, application method, and retreatment schedule.

(d) Combustible materials that cannot be made fire retardant shall be located to minimize the hazard if they become ignited.

9-9.4 Portable extinguishers appropriate for the hazard shall be located as required in NFPA 10, *Standard for Portable Fire Extinguishers.*

9-9.5 Electrical work shall conform to the provisions of NFPA 70, *National Electrical Code.*

9-9.6 Temporary walls and exhibits, such as dioramas, shall not interfere with the operation of any fire protection system. Automatic fire suppression systems shall be appropriately redesigned or modified to account for increased fuel loads.

9-9.7 Orderly circulation of visitors shall be maintained when special exhibits are expected to draw large crowds. Lines or crowds waiting to enter the exhibit area or the library shall not obstruct exits or access to exits. Evacuation capabilities must also be maintained.

9-9.8 Design Review/Approval. Plans for exhibits shall be reviewed and approved by the fire safety manager prior to construction/installation. The fire safety manager shall be kept fully informed and involved at every stage, including preliminary planning, design, fabrication, and installation for each and every exhibit mounted or installed.

9-9.9 Temporary Floor Structures in Galleries, and so forth. The floor structure of galleries, rooms, or alcoves that are converted into temporary auditoriums or viewing rooms by constructing tier steps covered with carpeting on which visitors can be seated shall be of fire-resistive construction.

9-9.10 Carpet Used as Wall Covering. Carpet extending up wall surfaces for acoustic or aesthetic reasons shall be listed for the use, and shall comply with the requirements of NFPA *101, Life Safety Code.*

9-10* Storage of Records. Library records shall be stored and protected in accordance with NFPA 232, *Standard for the Protection of Records.*

Chapter 10 Places of Worship

10-1* Introduction. The requirements of Chapters 1 through 7 apply to buildings used as places of worship.

10-1.1 This chapter shall apply specifically to buildings, parts of buildings, or enclosed structures that function primarily as a place of worship. Protection of areas within or associated with a place of worship that function primarily as a museum (display or storage area for artifacts) and areas functioning primarily as libraries or book/document storage are addressed elsewhere in this standard.

10-1.2 This chapter shall prescribe minimum requirements for the protection of places of worship and their contents from fire. Because of the special nature of places of worship, this chapter modifies and supplements existing codes and standards to apply specifically to buildings or portions of buildings with this function.

10-2 Planning.

10-2.1 Fundamental Requirements.

10-2.1.1 Responsibility. The governing body of the place of worship, as well as its leadership, shall be responsible for ensuring that adequate fire protection programs are maintained in accordance with Chapter 2.

10-2.2 Emergency Plan. Following the risk assessment, an emergency plan shall be developed for the worship facility, including provision for emergency evacuation, fire department notification, and salvage of critical records and valuable artifacts in accordance with Section 2-3.

(a) In developing the emergency evacuation plan, special attention shall be given to evacuation of the elderly and small children, who might need additional assistance. Planning shall specifically address evacuation of occupancies such as Sunday schools, nurseries, and senior citizens meeting areas where the ratio of trained staff to individuals needing special assistance is low.

(b) The plan shall include provisions for notifying the fire department and directing them to the location of the fire once they arrive at the site.

(c) Emergency telephone numbers shall be posted on, or adjacent to, all telephones.

10-2.3 Training.

(a) All staff and employees of the place of worship, as well as nursery attendants, instructors, and other key volunteers, shall be trained in the provisions of the emergency evacuation plan and fire department notification.

(b) This training shall include emergency evacuation of mobility-impaired individuals and children.

10-3 Basic Fire Prevention.

10-3.1 Decorations.

(a) Decorative materials used for special occasions and holidays shall be noncombustible or shall be treated with a listed and approved fire-retardant coating.

(b) Decorations shall be kept a minimum of 4 ft (1.2 m) from ignition sources, including candles, censures, light fixtures, radiators, and electric heaters.

10-3.2 Housekeeping. Storage areas often present a serious fire hazard. Good housekeeping practices shall be maintained for all places of worship.

(a) Concealed spaces in the attic, basement, organ pipe runs, steeples, and beneath stairs and raised altar areas shall be kept free from accumulations of combustible materials.

(b) Flammable liquids such as paints, varnishes, cleaning solvents, and floor polishes shall be stored inside an approved flammable liquids storage cabinet, and quantities of these materials stored inside the building shall be kept to a minimum.

(c) Approved, self-closing trash cans shall be used to house oil rags. Trash disposal shall be performed regularly.

(d) Power lawn mowers, snow blowers, and other gas-powered implements shall not be stored within the structure.

10-4 New Construction.

10-4.1 Location. A place of worship located within or attached to a building or structure classified as *Industrial, Storage, or High Hazard,* as defined in NFPA *101, Life Safety Code,* shall be separated by walls or partitions, floor, and ceiling assemblies having a fire-resistance rating of not less than two hours.

10-4.2* Fire Suppression Systems. Fire suppression systems shall be incorporated in all new construction in accordance with the facility's or institution's fire protection program and plan.

10-4.3* Fire Alarm Systems. A fire alarm system shall be provided for all places of worship. Those systems shall be installed in accordance with NFPA 72, *National Fire Alarm Code,* and NFPA *101, Life Safety Code.*

10-4.3.1 Areas used for schools *(see 10-8.2)* or homeless shelters *(see 10-8.3)* shall be protected with an automatic smoke detection system.

10-4.3.2 All fire alarm systems shall automatically notify the fire department in accordance with NFPA 72, *National Fire Alarm Code.*

10-5 Candles and Censers. The use of all open flame devices shall be in compliance with NFPA *101, Life Safety Code.*

10-5.1 All lit candles shall be maintained a minimum of 4 ft (1.2 m) from combustible draperies and hangings.

10-5.2 All fixed candles shall be properly supported to prevent them from tipping over.

10-5.3 Following the extinguishment of all candles and incense fires, an individual shall remain on the premises for 30 minutes to guard against potential reignition.

10-5.4 Incense fires in censers shall be extinguished after use and before the censers are stored.

10-6 Historical Records and Artifacts. Historical records such as marriage, birth, and baptismal certificates, as well as valuable artifacts and relics of special significance, shall be identified, and planning shall include their removal, salvage, or both. Valuable record storage shall be protected in accordance with NFPA 232, *Standard for the Protection of Records.*

10-7 Draperies and Decorations.

10-7.1 All combustible draperies and decorations shall be treated with a fire-retardant compound.

Exception: Religious and historically significant fabrics that can be damaged by such treatments shall be permitted to be excluded from such treatments.

10-7.2 Treated fabrics are flammable to some degree and shall be placed so as to maintain a minimum separation of 36 in. (.9 m) from ignition sources such as light fixtures, radiators, and electric heaters. Where candles are used, such materials shall be a minimum of 4 ft (1.2 m) from the open flame.

10-8 Special Facilities.

10-8.1 Kitchens. Cleanliness is essential for all kitchen areas.

10-8.1.1 The installation of grease ducts and range hoods shall allow for proper maintenance and cleaning in accordance with NFPA 96, *Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations.*

10-8.1.2 An approved, automatic fire extinguishing system shall be installed over commercial grade cooking equipment in accordance with NFPA 96, *Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations.*

10-8.1.3 Range hoods, stoves, ducts, and filters shall be cleaned on a regular basis, using nonflammable cleaners.

10-8.2 Schools. Preschool or nursery school facilities located in a place of worship shall comply with NFPA *101, Life Safety Code.* The governing body shall consult the local authority having jurisdiction prior to the place of worship starting a school in its building.

10-8.3 Homeless Shelters. If a place of worship contains sleeping rooms for the homeless, this occupancy shall require additional protection as described in NFPA *101, Life Safety Code.* The governing body shall consult the local authority having jurisdiction prior to the addition of a sleeping room occupancy to a place of worship.

10-8.4 Sanctuaries, Auditoriums, and Gymnasiums. Sanctuaries, auditoriums, and gymnasiums shall comply with NFPA *101, Life Safety Code.* Special precautions shall be taken to minimize risks associated with combustible stage props, temporary lighting, and other special hazards introduced in conjunction with plays, festivals, tournaments, and similar productions.

10-8.5 Libraries. Libraries shall be in accordance with Chapter 9.

10-8.6 Artifacts and Museum/Exhibit Areas. Museum areas, including artifact and exhibit areas, shall be in accordance with Chapter 8.

Chapter 11 Referenced Publications

11-1 The following documents or portions thereof are referenced within this standard as mandatory requirements and shall be considered part of the requirements of this standard. The edition indicated for each referenced mandatory document is the current edition as of the date of the NFPA issuance of this standard. Some of these mandatory documents might also be referenced in this standard for specific informational purposes and, therefore, are also listed in Appendix N.

11-1.1 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 13, *Standard for the Installation of Sprinkler Systems,* 1996 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems,* 1996 edition.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems,* 1995 edition.

NFPA 30, *Flammable and Combustible Liquids Code,* 1996 edition.

NFPA 31, *Standard for the Installation of Oil-Burning Equipment,* 1997 edition.

NFPA 33, *Standard for Spray Application Using Flammable or Combustible Materials,* 1995 edition.

NFPA 40, *Standard for the Storage and Handling of Cellulose Nitrate Motion Picture Film,* 1997 edition.

NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals,* 1996 edition.

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

NFPA 54, *National Fuel Gas Code,* 1996 edition.

NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases,* 1995 edition.

NFPA 70, *National Electrical Code,* 1996 edition.

NFPA 72, *National Fire Alarm Code,* 1996 edition.

NFPA 75, *Standard for the Protection of Electronic Computer/Data Processing Equipment,* 1995 edition.

NFPA 96, *Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations,* 1994 edition.

NFPA *101, Life Safety Code,* 1997 edition.

NFPA 110, *Standard for Emergency and Standby Power Systems,* 1996 edition.

NFPA 211, *Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances,* 1996 edition.

NFPA 220, *Standard on Types of Building Construction,* 1995 edition.

NFPA 221, *Standard for Fire Walls and Fire Barrier Walls,* 1997 edition.

NFPA 231C, *Standard for Rack Storage of Materials,* 1995 edition.

NFPA 232, *Standard for the Protection of Records,* 1995 edition.

NFPA 232A, *Guide for Fire Protection for Archives and Records Centers,* 1995 edition.

NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials,* 1995 edition.

NFPA 299, *Standard for Protection of Life and Property from Wildfire,* 1997 edition.

NFPA 550, *Guide to the Fire Safety Concepts Tree,* 1995 edition.

NFPA 703, *Standard for Fire Retardant Impregnated Wood and Fire Retardant Coatings for Building Materials,* 1995 edition.

NFPA 780, *Standard for the Installation of Lightning Protection Systems,* 1995 edition.

NFPA 1123, *Code for Fireworks Display,* 1995 edition.

11-1.2 ASTM Publication. American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C,* 1994.

11-1.3 U.S. Government Publications. Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

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.

Appendix A Explanatory Material

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

A-1-5 Approved. 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 that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-5 Authority Having Jurisdiction. 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.

A-1-5 Code. The decision to designate a standard as a "code" is based on such factors as the size and scope of the document, its intended use and form of adoption, and whether it contains substantial enforcement and administrative provisions.

A-1-5 Hazardous Areas. Examples include: storage or use of combustibles or flammables; toxic, noxious, or corrosive materials; or use of heat-producing appliances.

A-1-5 Library. The term library covers an extremely wide range of situations; a library can be a small special or valuable collection in a private home or other building, or it can be a separate section in a building used for many purposes. It also can be a multimillion-dollar complex of buildings the purpose of which is to provide not only storage for books, but also study and reading areas, catalog rooms, work rooms, binderies, art collections, shops, and places of public assembly. However, all libraries have one characteristic in common: ample fuel in the form of books and other library materials (which may include compact discs, microforms, magnetic tapes, phonograph records, and motion picture films – cellulose nitrate as well as “safety” film) that can burn and contribute to a serious fire.

A-1-5 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A-1-5 Museum. The American Association of Museums defines a museum as “an organized and permanent nonprofit institution, essentially educational or aesthetic in purpose, with professional staff, which owns and utilizes tangible objects, cares for them, and exhibits them to the public on some regular schedule.”

A-1-6 Cultural institutions are using more plastic-based storage containers than ever before. Plastic is used for film storage, magazine dividers, storage boxes and bins, clothing bags, and various covers. Staff members need to realize that the presence of plastic-based materials can increase the risk of direct and indirect damage to the building and contents and collections of a cultural institution. Most plastic, when burned, produces thick, acrid, black products of combustion (smoke). As plastic burns, it degrades to its original petrochemical form, resulting in fire conditions similar to combustible liquid spill fires. Smoke from burning plastic can be very damaging, both in the area of fire origin and throughout a facility. Past experience has demonstrated that plastic covers and bags have a tendency to attract smoke particles to clothing and other fabrics. Staff should also consider the impact that plastic will have on the design of the fire protection systems protecting an area in a facility. Significant quantities of plastic will usually require higher levels of fire protection than is required with similar quantities of ordinary combustibles (e.g., paper, wood, cardboard, textiles). Thorough fire protection planning and design suggests that consideration should be given as to how smoke from a fire will be removed from the facility. Depending on the design, size, and compartmentalization of a facility, smoke removal can be easily accomplished by the local fire department using portable fans. Larger facilities, with few openings or windows to the outside, should consider ventilation system designs that will enable manually operated exhaust settings to ventilate smoke from the areas without direct openings to the outside. In cases such as these, fire departments might not be able to properly evacuate smoke in a timely fashion with the equipment typically available.

A-1-6.3 The primary goal of this section is to separate the fuel from the ignition sources and other sources that bring risk, for example, through the need for maintenance, into these areas.

A-1-6.4 Proper clearance should be maintained between fire protection system nozzles and stored material.

A-1-6.5 Smoke control systems should comply with the requirements of NFPA 92A, *Recommended Practice for Smoke-Control Systems,* NFPA 92B, *Guide for Smoke Management Systems in Malls, Atria, and Large Areas,* and NFPA 204, *Guide for Smoke and Heat Venting.*

A-1-6.6.5(e) Seismic protection design typically includes a combination of the following:

(a) *Rack Design.* Shelving constructed to provide the seismic strength requirements

(b) *Bottom Bracing.* Shelving secured to the floor with fasteners of adequate strength to resist the anticipated shear and tension forces

(c) *Top Bracing.* Sway bracing at the top of the racks to provide horizontal strength adequate to resist the expected seismic forces. In most cases bracing is tied to structural members of the building to provide a path for the horizontal forces.

A-1-6.7 NFPA 232A, *Guide for Fire Protection for Archives and Records Centers,* provides additional guidance for protecting facilities that have archives and records.

A-1-6.8 Compact storage systems present a severe fire challenge that requires engineering solutions specifically designed for each installation.

A-2-1.1.2 The fire safety manager can be an employee of the institution who has certification, education, training, and/or experience with generally accepted fire protection practices. Institutions can also utilize appropriate outside resources such as consulting engineers, fire department personnel, insurance company loss control representatives, code officials, or other individuals with similar credentials.

A-2-2.2(b) Competent application of systems analysis is a powerful tool in identifying cost-effective alternatives to achieve fire safety goals. For assistance see Appendix B, Fire Risk Assessment in Heritage Premises, and NFPA 550, *Guide to the Fire Safety Concepts Tree.*

A-2-2.3 The fire protection plan should address the following topics as appropriate to the circumstances of a particular building: compartmentation, structural analysis, alarm and communications ,menas of egress, smoke control, fire suppression,water supply, ignition prevention, and fuel control.

A-2-2.3(c) It is important to control the threat of arson. There are precautions that can minimize the likelihood of a serious fire. The most common fire setters are vandals, disgruntled patrons, and employees. They might break in at night or gain legitimate access during normal operating hours. *[See Table A-9-1(c).]*

(a) *General.* Experience indicates that if an unsuccessful fire arson has occurred, a repeat attempt is likely unless the fire setter is brought to justice. The cultural property then becomes a specific target, and extra precautions are warranted. These special precautions are itemized below as high-risk recommendations.

(b) *Security Recommendations.* Good security is the strongest deterrent to fire setters. Suggested elements of a sound security plan are as follows:

1. Reasonable surveillance (including use of electronic equipment) of all areas accessible to the public with spot checks at regular intervals. All nonpublic areas should have controlled access.

2. A background investigation for stability and character should be conducted to the extent legal restrictions allow on potential employees, security personnel, and others having free access to the entire facility.

3. All accessible openings, including doors, windows, vents, and so forth, should be properly secured. Fire exits should be arranged to prevent outside entry. Doors and windows should be checked to make sure locks are in good repair.

4. Exterior lighting is an effective and often underrated security measure against incendiarists and other miscreants. Where not provided by public utilities, lighting should be added at all concealed approaches to the facility.

5. A rigid closing procedure, including supervisory responsibility, should be established to ensure that all unauthorized people have left the building, that openings are secured, and that fire hazards, including ashtrays, trash receptacles, and so forth, are checked.

6. Book returns should be constructed to prevent the spread of fire and smoke from the return into the rest of the library. A better alternative could be to eliminate the inside book return and provide an outside receiving bin away from the exterior walls of the library building. Many fires have been set in book returns.

(c) *Recommendations for High-Risk Locations.* A higher level of precaution is essential when any of the following conditions exist:

1. High crime rate areas

2. Cultural properties associated with or connected to social or political causes

3. Locations having incurred an incendiary fire or threat of one

4. Seriously strained relations between employees and management. The following precautions should be used:

a. Provide security/watchman service during idle time or intrusion alarms connected to a reliable, constantly attended location.

b. Establish a cooperative liaison with police and fire departments.

c. Provide closed circuit television and monitors for remote areas of public access. The cameras provide a formidable psychological deterrent to fire setters and other wrongdoers.

d. Supplement outside lighting with a 7-ft (2.12-m) wire fence in areas of concealed access to the building.

A-2-3.1 The development of an emergency plan should be in accordance with NFPA 1600, *Recommended Practice for Disaster Management,* which provides guidance for managing the emergency condition to minimize loss of life, collections, and property, and to plan for recovery from the emergency situation.

A-3-1 Understanding, practicing, and enforcing the basic concepts and principles of fire prevention are some of the most important actions any cultural resource facility or institution can undertake. This chapter presents some of the basic precautions applicable to all types of cultural resources. Subsequent chapters devoted to museums, libraries, places of worship, and historic buildings contribute additional material specific to each type of resource. *(See NFPA 1, Fire Prevention Code, for comprehensive fire prevention information.)*

A-3-2.1 The following information on the use of Christmas trees is included from NFPA 1, *Fire Prevention Code,* Section 3-13.

3-13.1 Natural cut Christmas trees shall not be permitted in assembly, educational, health care, residential board and care, detention and correctional, mercantile, hotel, or dormitory occupancies.

Exception No. 1: Living trees in a balled condition with their roots protected by an earth ball shall be permitted provided they are maintained in a fresh condition and are not allowed to become dry.

Exception No. 2: Trees located in areas protected by an approved automatic sprinkler system.

3-13.2 Artificial Christmas trees shall be labeled or otherwise identified or certified by the manufacturer as being "flame retardant" or "flame resistive."

3-13.3 No Christmas trees shall be allowed to obstruct corridors, exit ways, or other means of egress.

3-13.4 Only listed electrical lights and wiring shall be used on Christmas trees and similar decorations.

3-13.5 Electrical lights shall be prohibited on metal artificial trees.

3-13.6 Open flames such as from candles, lanterns, kerosene heaters, and gas-fired heaters shall not be located on or near Christmas trees or other similar combustible materials.

3-13.7 Natural cut Christmas trees shall not be located near heating vents or other fixed or portable heating devices that could cause the tree to dry out prematurely or to be ignited.

3-13.8 In occupancies where natural trees are permitted, the bottom end of the trunk shall be cut off at an angle at least 1 in. to 2 in. (25 mm to 50 mm) above the end to help the tree absorb water. The tree shall be placed in a suitable stand with adequate water. The water level shall be checked and maintained on a daily basis. The tree shall be removed from the building immediately upon evidence of dryness.

A-3-3 In a fire, the prevention of interior spread of flames and smoke is critical to stopping a fire from rapidly growing. The simple act of ensuring that interior doors are kept closed when a building is not occupied is a major positive fire prevention action. Part of the facility's comprehensive fire protection program and plan should evaluate and incorporate procedures for ensuring that interior doors are closed wherever possible. The governing body or party responsible for the facility and the authority having jurisdiction must understand the potentially dangerous conflict in allowing interior doors to remain open to facilitate interior ventilation and air movement, thereby significantly enhancing the threat of unimpeded fire and smoke spread through the facility.

A-3-4 A high standard of housekeeping is the most important factor in the prevention of fire. Maintaining this high standard of housekeeping is every employee's responsibility; however, it is the facility director who assumes the final responsibility for this important activity.

A-3-4.3 Expendable materials that are directly associated with the proper operation or maintenance of equipment found within any of these rooms could be permitted (i.e., filters, light bulbs, and refrigerant). The supply of these materials should be kept to a minimum. Depending on the quantity of materials and degree of hazard either associated with the equipment or inherent to the materials themselves, the storage of these materials might be further restricted to specialized storage containers (i.e., metal cabinets or other suitable means). Coat closets or other spaces being used for both telephone or computer equipment along with general storage must be evaluated for fire integrity. Enhancement of the fire compartmentation and/or the installation of fire sprinklers might be required.

A-4 New Construction, Alterations, and Renovations.

General Principles for New Construction, Alterations, and Renovations

The more important general principles for fire-safe construction are set forth below. Detailed recommendations for good practice are also contained in various NFPA publications. In most localities, building codes and ordinances will govern the type of construction to be used.

Codes frequently provide for the safety of persons in the building, but not for the protection of the collections or the preservation of the historic fabric of the building or the collections. Therefore, it is of critical importance at the conception of the project to specify the level of fire safety to be achieved in the construction. It is recommended that a professional fire protection engineer be retained to participate in the development of the fire protection specifications and to verify that the specifications are fulfilled satisfactorily.

Design of the automatic fire protection and detection systems and building construction are interrelated. In addition to protecting combustible contents and providing improved safety to life, automatic fire suppression systems can in some cases enable the use of less expensive construction than would be permissible without them.

(a) *Construction Materials.* It is desirable to select materials and types of construction that are either noncombustible or that have resistance to fire. Fire-resistive construction is desirable and for multistory structures is essential. Fire-resistive construction is described in NFPA 220, *Standard on Types of Building Construction,* and requires structural members, including walls, partitions, columns, floor, and roof construction, to be of noncombustible materials and have fire resistance ratings from 2 to 4 hours, depending on the structural members.

The contents of a cultural resource facility are valuable, sometimes of very high value or even irreplaceable, and always combustible. Therefore, every effort should be made to construct the building to resist the spread of fire. This means that during a fire the walls, roof, floor, columns, and partitions should prevent the passage of flame, smoke, or excessive heat and continue to support their loads. "Fire resistant" is not the same as "noncombustible." Some materials that will not burn lose their strength when exposed to intense heat. This might cause walls or floors to collapse. Iron or steel multitier book stacks are an example of this type of structure. Many types of construction using various building materials have been tested and rated according to the length of time they will resist fire. The duration of resistance needed by the library depends on the amount of combustible material in the contents of each room as well as in the structure itself. Different structural assemblies have fire resistance ranging from less than 1 hour to more than 4 hours.

NOTE: NFPA 220, *Standard on Types of Building Construction,* classifies and defines various kinds of building construction. Testing laboratories list information on structural assemblies that have been tested in accordance with NFPA 251, *Standard Methods of Fire Tests of Building Construction and Materials.*

It is unwise to construct buildings that house cultural resource institutions of materials that will contribute fuel to a fire and that, by the nature of the construction, create combustible concealed spaces. Voids between a ceiling and the floor above are good examples of concealed spaces through which fire can spread rapidly and where access for fire fighting is difficult.

(b) *Compartmentation.* The term "compartmentation" in fire protection is used to mean subdivision of a building into relatively small areas so that fire or smoke can be confined in the room or section in which it originates. This principle can be applied to libraries and museums without restricting the flexibility of arrangement of library collections or the flow of visitors. Compartmentation requires fire-resistive wall and floor construction, with openings provided with self-closing or automatic fire doors having fire-resistive ratings in accordance with the fire resistance ratings of the wall or ceiling/floor membranes they are to protect.

In a similar way, properly enclosed stairways equipped with fire doors will prevent the spread of fire, smoke, and heat from one level to another. Elevator shafts, dumbwaiters, and all other vertical openings through the structure should be similarly safeguarded. Air-handling systems (ventilation, heating, and cooling) should be constructed and equipped to prevent the passage of smoke, heat, and fire from one fire area to another or from one level to another as provided in NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems.*

(c) *Smoke Control.* An engineered smoke management system should be considered as one of the means to achieve the fire safety objectives established for the cultural resource institution. Depending on building construction, interior finish, and furnishings and other contents, a substantial level of smoke damage can be sustained even from a relatively small, well-controlled fire. A smoke management system should generally be considered a complement to the protection provided by automatic sprinklers or other fire suppression systems and the barriers that define the fire zones. The smoke management system can assist in limiting smoke from spreading beyond the initial fire zone. See NFPA 92A, *Recommended Practice for Smoke-Control Systems,* NFPA 92B, *Guide for Smoke Management Systems in Malls, Atria, and Large Areas,* and NFPA 204, *Guide for Smoke and Heat Venting.*

(d) *Interior Finishes and Furnishings.* A most important consideration is the proper selection of interior finishes and furnishings. Highly flammable wall and ceiling finishes should be avoided. NFPA *101, Life Safety Code,* and most building codes specify minimum requirements for interior finish materials. Combustible draperies should be avoided. Extra care should be used in regard to the burning characteristics of upholstered furniture, insulating materials, and acoustical materials. Careful selection of interior finishes is always important and is especially so in the absence of automatic fire suppression protection.

A-4-1 Without automatic fire protection systems, fire-resistive or noncombustible construction can survive, but combustible contents in the fire compartment will not. Fire protection systems should provide for both detection and extinguishment. While these are separate functions, they can and often should be consolidated into one continuous fire protection system that detects a fire, sounds the alarm, alerts the fire service, and initiates automatic extinguishing devices. Smoke detection systems provide an opportunity for occupant action with portable fire extinguishers before fire development activates the automatic sprinkler or other fire suppression system. Careful planning permits the installation of the necessary equipment with a minimal effect on the appearance or use of the public spaces in the cultural resource facility.

Additional descriptions, applications, and limitations of the protective systems mentioned in this chapter are contained in Appendix F , Section F-2, Glossary of Fire Protection Systems.

Planning for the fire protection equipment must also include providing and maintaining an adequate water supply to support standpipe and hose systems for fire service use as well as for automatic sprinkler systems.

Procuring and Installing Fire Protection Systems. There is a vast selection of makes, models, and styles of fire protection equipment available today to meet practically any need a cultural resource institution might have. Choosing a reputable supplier and installer is a crucially important decision that a fire protection consultant can assist a library in making. In lieu of a consultant, other valuable information can usually be obtained from the insurer, other businesses in the area, or perhaps from the local fire department. The cultural resource institution should seek to procure a system for which parts and service will be readily available now and in the future. In addition, the fire protection equipment and system should be listed or approved.

Many states and jurisdictions now require designers and installers of fire protection systems to be licensed and certified by national boards *(see Appendix G).* Prospective installers should be asked to show proof of their qualifications, as well as have experience in installing similar systems, preferably in similar occupancies. Check to see how satisfied these other businesses were with the installation and final product. Libraries generally have special concerns and needs – especially in book-stack areas – and these must be discussed in detail with the contractor prior to beginning. A detailed construction schedule is helpful and should be worked out in advance. The staff should also be made aware of the improvements to take place and how these systems work.

Once a fire protection system is installed, it is imperative that the system be thoroughly inspected and tested to ensure that it functions properly.

A-4-1.3 Various devices with controlled sensitivity can detect a fire condition from smoke, a critical temperature, or the rate of temperature rise. These detectors can provide the warning needed to get people safely out of the building and start fire-extinguishing action promptly. Fire protection specialists should be consulted to determine what kinds of detectors best fit the conditions in different parts of the building. *(See Appendix F, Section F-2, Glossary of Fire Protection Systems.)*

The fire detection system sounds an alarm to alert the occupants. Detection systems should also transmit signals to a listed or approved central station or a fire department that is staffed or attended 24 hours a day, especially in the case of an unoccupied building. Maintenance and testing of the detection system are important, particularly in any building where it is the only automatic protection system. A number of fires have shown this to be true. Failures in these fire detection systems have been due to bad design, poor maintenance, and lack of testing.

NOTE: See NFPA 72, *National Fire Alarm Code,* and NFPA 1221, *Standard for the Installation, Maintenance, and Use of Public Fire Service Communication Systems.*

Alarms. Operation of any of these fire detection or suppression systems or signals from their supervisory systems should cause activation of an alarm at a constantly attended location. It could also cause activation of the building alarm system as described in NFPA *101, Life Safety Code.* The alarm can be bells, horns, live voice, prerecorded message, flashing lights, or other suitable means. All alarm systems should be installed and maintained in accordance with the applicable NFPA standards.

NOTE: See NFPA 72, *National Fire Alarm Code,* Chapter 3, Emergency Voice/Alarm Communication Systems.

A-4-1.4 Automatic sprinklers have proved their value in the reduction of fire losses in cultural resource institutions. They are designed to perform the following functions:

(a) Detect fires at the point of origin

(b) Cause the sounding of alarms

(c) Control or extinguish the fire

(d) Summon fire department assistance immediately when connected directly to a central station, auxiliary, proprietary, or remote station fire alarm system

Some cultural resource institutions have been reluctant to install automatic sprinklers for fear of water damage to their collections. Yet in actual fires the most extensive water damage has resulted from fire department operations with hose lines. Sprinkler protection minimizes water damage by placing a small amount of water directly on the fire and alerting the fire department at the same time. The sprinkler system controls the fire and reduces the need for a full-scale attack by the fire service. Many important libraries and museums built since 1970 have incorporated automatic sprinkler systems in the design. Many others have installed sprinklers to upgrade existing fire protection.

Some cultural resource institutions prefer preaction systems that can reduce the possibility of inadvertent sprinkler discharge. *(See Fire Extinguishing Systems in Appendix F.)* Also, water detection systems are available that provide further protection against extraneous water damage from other sources as well as the automatic sprinklers. They provide an early warning alarm in the presence of water and locate the point of water ingress. Such systems should be considered for potentially flood-prone areas such as below-ground-level collections, areas not protected against domestic water accidents, areas near water boilers, or areas in which water pipe or drain leakage are of concern.

NOTE: In a library it is desirable to use no more water than is necessary to control or extinguish the fire. When a fire occurs in an area protected by an automatic sprinkler system, heat opens the sprinkler or sprinklers nearest the fire. Only those close enough to the fire to be heated to the operating temperature will discharge water. Records show that 70 percent of fires in sprinklered buildings have been controlled or extinguished by four sprinklers or fewer. NFPA 13, *Standard for the Installation of Sprinkler Systems,* and NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems,* should be followed for the installation of any sprinkler system.

Some methods of sprinkler installation require high-temperature brazing that introduces a potential source of fire ignition. Where automatic sprinklers are installed in existing book stacks, only mechanical methods of assembly should be permitted unless collections are removed.

A minimum clearance of 18 in. (.45 m) is generally required between sprinklers and the top of storage. However, alternate provisions are described in NFPA 13, *Standard for the Installa-*

tion of Sprinkler Systems, for retrofit design of sprinkler systems in library stack rooms where shelves are installed continuously from floor to ceiling, for example, multitier book stacks.

NOTE: See A-4-1, *Procuring and Installing Fire Protection Systems,* and Appendix G-3.

Gaseous Fire Suppression Agents. Special fixed systems using a halogenated agent, clean agent, water mist, carbon dioxide, dry chemicals, high-expansion foam, or other extinguishing agents can provide needed protection for areas where especially valuable contents might be damaged by water. These systems can be automatically activated by a suitable smoke detection system.

Total flooding fixed systems using a gaseous agent depend upon achieving and maintaining the concentration of the agent required for effective extinguishment. Openings in the fire compartment (e.g., open windows or doors or ventilation system continuing to operate) can prevent the achievement of an effective extinguishing concentration. Where a high reliability of operation is required for protection of high-value collections, an automatic sprinkler system in combination with a total flooding gaseous agent system should be considered.

It is good engineering practice to utilize total flooding gaseous systems in combination with automatic sprinkler systems, rather than as an alternative. 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 head [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 (i.e., occupant manual extinguishing action) is the least reliable means of fire suppression – especially considering periods when the building is not occupied and therefore most vulnerable.

Carbon dioxide flooding systems are generally not recommended for occupied areas, and Halon 1211 total flooding systems are prohibited in normally occupied areas because they create an atmosphere immediately hazardous to life. Where these systems are installed, the life hazard should be carefully evaluated.

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

NOTE: NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems,* NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems,* NFPA 17, *Standard for Dry Chemical Extinguishing Systems,* NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems,* and NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems,* should be followed.

A-4-1.5 Where standpipes and hose lines are required or installed to provide reliable and effective fire streams in the shortest possible time, they shall be installed in accordance with NFPA 14, *Standard for the Installation of Standpipe and Hose Systems,* and maintained in accordance with NFPA 25, *Standard for the Inspection, Testing and Maintenance of Water-Based Fire Protection Systems.* Training and skill in the use of hose streams are essential to avoid personal injury and unnecessary property damage. Occupants should not attempt to use a fire hose unless they are part of an organized fire brigade that has received training in compliance with OSHA regulations. It must be emphasized that the use of standpipe hose lines, as with the use of fire extinguishers, should not be allowed to delay the transmission of alarms to the fire department.

A-4-1.7 Portable extinguishers are important items of fire protection equipment and should be installed in accordance with NFPA 10, *Standard for Portable Fire Extinguishers.* They permit the use of a limited quantity of extinguishing agent on a small fire at the moment someone discovers it. Therefore, they should be present in adequate numbers. The extinguisher should be of a kind intended for the class of fire anticipated. Multiclass portable extinguishers are available that remove any doubt whether the correct extinguisher is being 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 the proper use of fire extinguishers. It must be emphasized that the use of fire extinguishers should not be allowed to delay the transmission of alarms to the fire department.

A-4-8 Such protection can include fire windows with wired glass, fire doors, exterior automatic sprinklers, water curtains, automatic fire shutters, or a combination of these. *(See NFPA 80A, Recommended Practice for Protection of Buildings from Exterior Fire Exposures.)*

A-4-9(b) In the 1991 edition of NFPA 299, *Standard for Protection of Life and Property from Wildfire,* paragraph 3-3.2 provides the following direction for reducing fuel loading:

3-3.2 Reduction of Fuel Loading. Trees and brush shall be cleared away from structures for a distance that is determined to prevent ignition of either the structure or the vegetation, should the other burn. Vegetation existing away from the immediate area of the structure shall be thinned and pruned to prevent a fire from being carried toward or away from the structure. Annual grasses within 30 ft (9.1 m) of structures shall be mowed to 4 in. (101.6 mm) or less. Ground litter shall be removed annually. Over-mature, dead, and dying trees shall be evaluated as to their potential to ignite and to carry fire. All trees determined to contain such potential shall be removed.

A-4-10 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 is essential in preventing arson. The practice of good housekeeping 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 and additional security should be provided. Fires in museums, libraries, places of worship, and historic buildings have been set by arsonists with motives ranging from mindless vandalism to attempts to cover crimes such as burglary. Arsonists are usually from outside, but some deliberate fires are begun by a person within the building (possibly with a grudge or imagined grievance).

A-4-11(c) Smoke control systems should comply with the requirements of NFPA 92A, *Recommended Practice for Smoke-Control Systems,* NFPA 92B, *Guide for Smoke Management Systems in Mall, Atria, and Large Areas,* and NFPA 204, *Guide for Smoke and Heat Venting.*

A-5-2.1 See NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations.*

A-5-3.1(d) See NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations.*

A-5-3.2.2 Construction materials stored inside the building or structure should be kept to a minimum. Materials not immediately needed should be stored away from the structure to minimize fuel loading and to reduce the likelihood that excess materials will block egress routes. Where possible, equipment and materials should be stored in secured areas with a functional fire suppression system, or materials should be subdivided and stored in secured noncombustible structures. Equipment too large to be stored in the above areas should be stored in secured fenced-in yard areas.

A-5-3.2.2(a) Storage for excess quantities of flammable and combustible liquids should be stored downgrade from the project when possible. The storage site should also be a sufficient distance away from heavy traffic areas.

A-5-4.1.2 If security officers are not assigned to the work site, all welding or cutting operations should stop a minimum of three hours before the end of the normal work day to allow sufficient time for any fire conditions to be found at welding locations.

A-5-4.2(e) See NFPA 10, *Standard for Portable Fire Extinguishers.*

A-5-4.4.1(d) See NFPA 10, *Standard for Portable Fire Extinguishers.*

A-5-6.1 Prefire plans should be updated periodically with the local fire service. For large projects, a fire safety coordinator for the site should be appointed who should ensure that all procedures, precautionary measures, and safety standards are clearly defined in writing, understood, and complied with by all personnel on the construction site.

A-5-6.2 The local fire service should verify by on-site testing if the water supply is capable of sustaining adequate pressure and flow rates for fire-fighting operations anticipated in their prefire plan for the building. Where underground water mains are to be provided, they should be installed, tested, and placed in service prior to other construction work.

A-5-7 A qualified person should be assigned overall responsibility for site security during the project.

A-5-7(a) Welding operations on the work site can cause a fire long after work has stopped for the day. Therefore, if security officers are assigned to the work site, officers on duty should be informed of all locations where welding operations were performed during the work day. They should be instructed to thoroughly and carefully check each of these locations during their regular patrols of the work site, and to look for evidence of smoldering.

A-6-1 History has shown that the performance reliability of fire protection systems and equipment under fire-related conditions increases where comprehensive inspection, testing, and maintenance procedures are enforced. Diligence during an inspection is important.

A-6-6 Electrical systems should be maintained in accordance with NFPA 70B, *Recommended Practice for Electrical Equipment Maintenance.*

A-7-1 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.

(a) *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, as they might have been installed many years ago and have not 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.

(b) *Fire Spread Factors.* Fire growth and spread occur 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 below illustrate conditions under which fires spread or were confined to their origin and the resultant direct damage.

(c) *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 ($48 million U.S.)

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 19th-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 ($16.2 million U.S)

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 ignitable dry timbers; lack of automatic fire detection, suppression, and alarm; and difficult manual firefighting 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 18 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 parked automobiles.

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: $1.22 million, structural; $1.01 million 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 structural 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 $2500 by not installing heat detectors in the attic when the fire detection system was installed throughout the rest of the house.

A-7-1.2.6 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.

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.

A-7-1.2.7 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.

A-7-1.2.8 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.

A-7-1.2.9 Relevant documentation and 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.

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.

A-7-1.2.10 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.

A-7-1.3 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 include:

(a) *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.

(b) *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.

(c) *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.

(d) *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.

(e) *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.

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

(g) *Fire Hazards.* 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.")*

A-7-1.4 The contents of most buildings consist of combustible materials. Accumulations of readily ignitable 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.

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.

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, is likely to be rapid.

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.

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.

(a) *Means of Horizontal Fire Spread.* Means of horizontal fire spread include the following:

1. Doorways
2. Ceiling voids over walls
3. Floor cavities under walls
4. Utility and service chase-through walls
5. Voids in projecting eaves or cornices
6. Wall failure
7. Openings produced by distortion or failure of structural members in a fire
8. Open attic spaces and cocklofts
9. Corridors

(b) *Means of Vertical Fire Spread.* Means of vertical fire spread include the following:

1. Stairways

2. Conduction of heat through hearth slab to supporting timbers below

3. Wall cavities penetrating floor

4. Utility and service chases penetrating floor

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

6. Breaching of floor or ceiling by fire

7. Atriums

8. Windows or other exterior openings

A-7-2.1 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.

(a) *Fire Safety Plan Elements.* Possible elements of a fire safety plan are summarized in Table A-7-2.1 These are the alternative strategies for dealing with the identified fire hazards.

Table A-7-2.1 Elements of a Fire Safety Plan

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

(b) *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 can be found in Appendix M to this document.

1. *Human Resources.* Every building is unique, and no two fire safety problems exist under the 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 might be appropriate for a particular situation.

2. *Codes and Standards.* Almost every jurisdiction has applicable codes and standards for fire safety. However, not all building codes are the same. For example, NFPA *101, Life Safety Code,* is the only such code that provides specific chapters for both new and existing buildings. There might be situations where the approach to fire safety of one code is more fitting to particular circumstances than another code. Appendix M lists the most common model building codes and their specific approach to historic buildings.

Many codes have special provisions for historic buildings 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.

3. *Special Legislation.* Many states and provinces 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.

4. *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." They are described as follows.

a. *"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.

b. *"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 L.

5. *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 Fire Safety Concepts Tree.* The tree represents all possible means of meeting fire safety objectives. Increasing fire safety measures on one branch of the tree theoretically offset a lack of required measures on another branch, thus establishing an arrangement for equivalent fire protection.

A-7-2.3 Table A-7-2.3(a) shows categories and examples of fire hazards. Fire safety plan elements should address the specific hazards of each building.

Table A-7-2.3(b) 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 the following two points:

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

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

Table A-7-2.3(a) Categories of Fire Hazards in Historic Buildings

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

Table A-7-2.3(b) Effective Fire Safety Plan Elements and Associated Fire Hazards

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

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 can be so strong that the feature must be preserved, thus limiting the choice of design alternatives.

A-7-2.4 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.

A-7-3.1 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, 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 specialists, and others with experience and expertise in the design of fire protection systems and the historic building interface.

A-7-3.4 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. In addition, 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.

A-7-3.6 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.

A-7-3.7 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.)*

A-7-3.8 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.

A-7-3.12.1 Automatic fire extinguishing systems are the most effective means of suppressing fires in buildings. Their use in historic buildings is recommended.

A-8-1 Museums are vulnerable to a wide variety of common occurrences responsible for most fires. Careless smoking, malfunction of heating equipment, faulty wiring, improper use of a cutting torch, and incendiarism are some causes of fires in museums. Fires have occurred in museums with fire-resistive construction, in structures made largely of wood, in large fully staffed institutions, and in smaller museums with limited resources. Fires have broken out in museums during the day when they were open and filled with people and at night when they were closed. Between 1980 and 1988 there was an average of 102 museum fires per year, resulting in an annual average loss of $2.15 million in property damage, reported to U.S. fire departments. (This refers to whole building, not museum room, and includes art galleries, aquariums, and planetariums). Table A-8-1 indicates the major causes of these fires. Experience shows that the hazard of fire is increased when a museum is being renovated or when a new exhibit is being installed.

Table A-8-1 Fire in Museums[1] by Major Cause Annual Average of 1980–88 Structure Fires Reported to U.S. Fire Departments

Major Cause	Fires
Electrical distribution system	22
Incendiary or suspicious causes	20
Other equipment	9
Open flame	8
Smoking material	8
Heating equipment	7
Cooking equipment	6
Exposure (to other hostile fire)	4
Natural causes	3
Appliance, tool, or air conditioning	1
Child playing	3
Other heat source	0[2]
Unknown	9
Total	102

[1]Refers to whole building, not museum room, and includes art galleries, aquariums, and planetariums.
[2]Rounds to zero but is not zero.

(a) *Why Museum Fires Have Spread.* The museum fires briefly described below illustrate one or more of the conditions under which a fire will spread beyond its origin and why resultant damage can be extensive. First and foremost is the absence of sprinklers or other means of automatic protection. Second, and almost equally important, is the lack of adequate compartmentation (or subdivision of areas) where there is a continuity of combustibles. A third condition is the delay in discovering and reporting of the fire while in the earliest stage. The first moments following ignition can be critical, as it frequently takes only a few minutes for a small fire to grow. In the absence of automatic fire detection or protection, discovery of a fire might be left to chance, possibly a passerby or neighbor. At that point, a fire could be so well established that loss to the museum will inevitably be substantial.

(b) *Illustrative Fires.* The following descriptions of fires illustrate some of the more common sources of ignition, factors contributing to the spread of the fire, and the enormity of the losses suffered. It is important to note that every museum cited below was located in close proximity to a highly trained fire department that responded promptly upon notification of the fire.

National Museum of Natural History (Smithsonian Institution)

Washington, DC – January 22, 1989

A scientist mistakenly turned on a hotplate as he left his laboratory. A smoke detector alarm was later received in the museum's control room, and a security officer was immediately dispatched to the room. In the two minutes it took for him to arrive at the lab, a single sprinkler had activated to extinguish the fire. Total loss was under $1000.

Fort Hill John C. Calhoun Shrine

Clemson, SC – May 30, 1988

Criminals used gasoline to set fire to this 185-year-old home (museum) to create a diversion while they burglarized a jewelry store. The museum had been equipped with a sprinkler system in 1968. Three sprinklers operated (one outside and two inside) to extinguish this fire before the fire department arrived. Less than one percent of the museum and its contents was damaged by fire or water.

Louisiana State Museum (The Cabildo)

New Orleans, LA – May 11, 1988

During exterior renovation work on one of this country's most historic buildings, it is believed a torch being used to solder a copper downspout ignited the combustible felt paper or wood in the roof. The fire apparently entered the attic and burned unnoticed for some time before being detected by smoke detectors on the floor below. Notification to the fire department was not automatic and was finally made by a passerby on the street who noticed smoke. Despite heroic efforts by the fire department, the attic, third floor (which was used for collection storage), and the roof were lost to fire, and there was significant smoke and water damage to the floors below. An estimated 500,000 gallons of water were used to control this fire. The fire chief in charge stated that had the museum been protected by a sprinkler system only two sprinklers would probably have been necessary to control or extinguish this fire. Loss was $5 million.

Huntington Gallery

San Marino, CA – October 17, 1985

While this art gallery was protected by both smoke and heat detectors, none was installed in the elevator shaft where a fire of electrical origin is thought to have burned for some time before bursting out onto the first floor. As the outside air hit the fire source, a fireball was created that traveled 60 to 70 feet down the corridor, totally destroying a painting done in 1777. Loss was $1.5 million.

Byer Museum of Art

Evanston, IL – December 31, 1984

A fire of electrical origin is believed to have originated between the walls on the first floor of this three-story building. The fire apparently burned within the walls for some time before bursting through into the museum. For an unknown reason, the smoke detection system did not operate. The fire totally destroyed the upper two floors and roof and caused extensive water damage to the first floor. Loss was $3 million.

Museum of Modern Art

Rio de Janeiro, Brazil – July 8, 1978

Watchmen discovered a fire in this concrete and glass building about 4 a.m. The museum had no automatic fire detection or suppression systems, nor interior fire barriers. It also had no emergency plans. The fire probably started from a cigarette or defective wiring in an improvised room used for a show a few hours earlier. Spreading through flammable ceilings and partitions, within 30 minutes it destroyed 90 percent of the museum's permanent collection (about 1000 works of art) and the paintings borrowed for special exhibition. It would appear that the delay in alarm, the large amount of combustibles, and the lack of an automatic fire suppression system contributed to the large loss.

San Diego Aerospace Museum

San Diego, CA – February 22, 1978

The museum and the International Aerospace Hall of Fame occupied an old wood and stucco exposition building without automatic fire detection or suppression systems. Workers in a neighboring structure reported a fire at 8:13 p.m., apparently set by two arsonists seen running away. The fire department dispatched 14 units comprising 83 of its personnel. The first unit arrived at 8:17 p.m. but was unable to save the building or its contents. Only a specimen of moon rock survived, having been stored overnight in a fire-resistive safe. Loss to the building was $15 million. Loss to the museum was 40 planes, many other historic specimens and irreplaceable documents, and an aviation library valued at $1 million, and loss to the Hall of Fame was all its portraits and memorabilia.

National Museum of American History (Smithsonian Institution)

Washington, DC – September 30, 1970

Fire reported at 5:05 a.m. destroyed a combustible computer exhibit and damaged the Hall of Numismatics. None of the historic collections of coins and stamps was damaged. The fire walls worked well, but the museum had no automatic fire suppression systems. Water used in fighting the fire caused some damage to the exhibit floor below. Smoke damaged offices and storerooms on two floors above. The cause was probably an electrical short circuit in the exhibit. Loss was over $1 million.

Henry Ford Museum

Dearborn, MI – August 9, 1970

A fire started in a dressing room, possibly from an overheated hair-curling iron. Flames quickly spread through several historic shops reconstructed of wood and a section of agricultural and crafts displays. Excessive combustible storage behind the exhibits aided fire spread in the unsprinklered, undivided, one-story, fire-resistive main exhibit hall of which about 240,000 ft^2 (22,296 m^2) burned. Fire doors that employees kept wet with twenty-five 2 $^1/_2$-gal (9.5-L) water extinguishers prevented the fire from reaching the small museum theater. Loss was over $2 million.

Museum of Modern Art

New York City – April 15, 1958

Workmen repainting the second floor galleries and enlarging the air conditioning system failed to observe fire safety precautions. They smoked on the job while using nonflameproofed drop cloths, went to lunch leaving paint cans open, and tied stairway doors open for convenience in moving equipment. During the noon hour a workman saw a small fire in a drop cloth and called for help. A museum guard brought a hand extinguisher, and they tried to put out the blaze before turning in an alarm. The fire quickly spread to the cans of paint, untreated wood scaffolding, and combustible gallery partitions. Thick smoke poured into the clustered stairwells. Finally, someone pulled the building alarm and the separate alarm with direct connections to the fire and police departments. More than 500 people in the museum had considerable difficulty escaping. The smoke-filled stairways and elevator shaft delayed fire fighters in locating the fire. The fire was brought under control two hours after the alarm was given but not before one person was killed, 33 were injured, two major paintings were destroyed (including a Monet masterpiece), and seven were severely damaged. Property loss was $700,000.

A-8-2.1.1 Responsibility.

(a) While conducting the hazards analysis required by 2-2.1, the museum occupancy must include those special hazards often created by museum operations. Such hazards include, but are not restricted to, the following:

1. Conservation laboratories and areas where collections are treated using a variety of combustible and flammable materials

2. Special types or classes of collections such as the following:

   a. Scientific specimens stored in alcohol

   b. Cellulose nitrate negatives and motion picture film

   c. Military weaponry, arms, or artifacts that must be checked to ensure that they are not "live"

   d. Rare objects or specimens composed of unstable and combustible material(s)

   e. Objects, the demonstration or use of which can create a potential fire hazard, such as historic electrical equipment, steam engines, forging machinery, and so forth.

3. Special historic, artistic, and/or scientific processes that can be demonstrated to the public or used to recreate objects, such as the following:

   a. Cooking demonstrations

   b. Silver, gold, and pewter casting

   c. Blacksmithing and similar craft demonstrations

   d. Artillery and weaponry demonstrations

   e. Historic manufacturing processes of all types

   f. Art demonstrations and/or classes that use flammable solvents or materials

   g. Glassblowing and glass molding

4. Concentrations of combustible collections either on exhibit or in storage, which by their very concentration can create a fire hazard through fire loading, such as the following:

   a. Historic building fragments and representative parts often retained by historic properties as documentary collections. These collections, while important, can create heavy fire loading if they are not stored carefully and selectively chosen.

   b. Scientific specimens stored in alcohol or other flammable liquid.

   c. Large quantities of combustible objects. For example, historic wooden molds and patterns used to cast metal machine parts or components of an iron building (like a greenhouse). Numbering in the thousands, these can be stored in bulk containers rather than individually. *(Source: Fire Terms: A Guide to Their Meaning and Use)*

5. Exhibit fabrication and construction areas and workshops in which combustible and flammable materials, paints, and solvents are frequently present

6. Maintenance workshops, combustible supply storage areas, boiler and mechanical equipment rooms and other support areas

(b) The museum's governing board and its fire protection coordinator must understand that the special fire hazards of their institution might differ considerably from the examples given above. These are offered only as general guidelines for the types of hazards found in museums.

A-8.3.1 Smoking in museums presents not only a fire hazard, but also a threat to the museum's collection holdings. For these reasons, smoking should either be completely prohibited within museum building(s) or strictly controlled in accordance with the provisions of Section 3-5.

A-8-3.4 In the museum setting where many operational activities occur simultaneously and can create fire hazards, housekeeping, maintenance, and waste and rubbish removal are all important, interconnected fire prevention-related activities. The museum's governing board and its fire safety manager should ensure a high standard of housekeeping and maintenance throughout the museum's building(s). At a minimum the following should be included:

(a) Collections shipping and receiving areas should be kept clear of accumulated combustible packing and crating materials. Discarded packing materials should be properly disposed of in accordance with 3-4.

(b) In exhibit construction and fabrication areas, the following precautions should be taken:

1. Fire safety and prevention practices must be an integral part of daily operations in these areas.

2. Sawdust and combustible scrap generated during work should be collected and properly disposed of at the end of every workday.

3. Combustible supplies should not be permitted to accumulate in such quantities as to create a high fuel load.

4. Exhibit cases and components no longer in use should be disassembled and recycled whenever possible. Storage of unused exhibit cases and components in the museum building(s) should be strictly limited. Such storage contributes to fire loading in the museum.

5. Only containers approved for the disposal of solvent waste rags and materials should be used, and these should be emptied and properly disposed of at the end of each working day.

(c) In conservation laboratories and studios, collections restoration, cleaning and treatment areas, the following precautions should be taken:

1. Fire safety and prevention practices must be an integral part of daily operations in these areas.

2. Only containers approved for the disposal of solvent waste rags and materials should be used, and these shall be emptied and properly disposed of at the end of each working day.

3. Sawdust and combustible scrap generated during work should be collected and properly disposed of at the end of every workday.

4. Combustible supplies should not be permitted to accumulate in such quantities as to create a high fuel load.

(d) Maintenance work and support areas such as repair shops, boiler and mechanical rooms, utility closets, plumbing chases, supply rooms, and janitorial closets are often high-fire-risk areas, particularly if improperly used for the storage of combustible or flammable materials, and the following precautions should be taken:

1. Boiler and mechanical rooms should never be used for the storage of any combustible or flammable materials or liquids.

2. Plumbing and utility closets, access points, and chases should never be used for the storage of any combustible or flammable materials or liquids.

3. In maintenance work and repair rooms, the following precautions should be taken:

a. Fire safety and prevention practices must be an integral part of daily operations in these areas.

b. Sawdust and combustible scrap generated during work should be collected and properly disposed of at the end of every workday.

c. Combustible supplies should not be permitted to accumulate in such quantities as to create a high fuel load.

d. Only containers approved for the disposal of solvent waste rags and materials should be used, and these shall be emptied and properly disposed of at the end of each working day.

(e) Staff offices and support areas often contain fire risks. All office and support spaces should be kept clean and the following enforced:

1. Personal electrical appliances such as coffee pots, hot plates, microwaves, and similar devices should be subject to inspection by the museum, the fire safety manager, and the authority having jurisdiction. Faulty appliances should be removed from the museum.

2. Electric equipment such as coffee pots, copy machines, and other office equipment not intended or needed for continuous operation will be turned off at the end of each working day.

3. Electrical outlets will not be overloaded.

4. Office papers, files, boxes, and other combustible materials will not be permitted to accumulate on HVAC vents, ducts, fan coil units, or radiators.

5. Extension cords should not be used in place of electrical outlets; where additional power is required for more than temporary, very occasional use, a properly installed electrical outlet will be provided.

6. Extension or power cords should never be run under carpeting, cabinets, boxes, papers, or files, or across thresholds, over doorways, or in aisleways and egress routes.

7. Paper and other combustible materials should not be permitted to accumulate, thereby creating additional fire loading in the museum. All materials retained as institutional and staff records should be properly stored in closed filing cabinets.

8. Office supply closets and rooms should be kept well cleaned and organized. Combustible materials should not be permitted to accumulate to such an extent that they create additional fire loading for the museum or become a fire risk themselves.

A-8-6 Many museums accomplish their interpretive and educational goals through permanent, temporary, and special exhibits installed in the museum building. Exhibits are changed frequently. As a result, spatial configurations, means of egress, life safety, fire protection systems, occupancy loads, exits, and fire risks can all change and potentially cause adverse effects. The museum's governing board and its fire protection coordinator should include review procedures for all exhibits, existing and proposed, in the museum's fire protection plan and procedures.

A-8-9 NFPA 232A, *Guide for Fire Protection for Archives and Records Centers,* provides additional guidance on the storage and protection of archival material. In addition, using the protection schemes discussed here, consideration should be given to creating duplicate records and storing them at an off-site location.

A-9-1 While libraries generally have a good record of fire prevention, they house high fuel loads that can result in severe, even catastrophic losses when ignition occurs if adequate fire protection is not provided. Fires occur in libraries worldwide with considerable frequency and serious results. *[See Tables A-9-1(a) and A-9-1(b).]*

(a) *How Fires Have Started and Spread.* Fires have occurred in libraries of many different types and from a wide variety of causes. *[See Table A-9-1(a).]* Serious damage has occurred in buildings of fire-resistive as well as of combustible construction. Fires do occur in libraries worldwide with considerable frequency and serious results. *[See Table A-9-1(b).]*

Table A-9-1(a) Fire in Libraries[1] by Major Cause Annual Average by 1980–1993 Structure Fires Reported to U.S. Fire Departments

Major Cause	Fire	Civilian Deaths	Civilian Injuries	Direct Property Damage
Incendiary or suspicious causes	82	0	0[1]	$4,415,900
Electrical distribution system	40	0	0[1]	$278,900
Other equipment	15	0	0	$6,200
Unknown	13	0	0	$1,122,900
Smoking material (e.g., cigarette)	13	0	0[1]	$70,400
Heating equipment	11	0	0[1]	$156,400
Open flame	11	0	0	$13,700
Appliance, tool, or air conditioning	8	0	0[1]	$34,400
Cooking equipment	7	0	0	$11,200
Child playing	5	0	0	$500
Natural causes	3	0	0	$8,100
Exposure (to other hostile fire)	3	0	0	$86,800
Other heat source	2	0	0	$0[1]
Total	**212**	**0**	**0[1]**	**$6,205,300**

[1]Not zero but rounds to zero.
Direct property damage is rounded to the nearest hundred.
Sums may not equal totals due to rounding error.
Source: 1980–1993 NFIRS and NFPA Survey.

(b) *Representative Fires in Libraries.* The few examples below were chosen to illustrate the many ways in which library fires have started and spread and the great destruction they have caused. In these fires alone, tens of millions of valuable books, recordings, and other media have been needlessly lost to fire. Damage has been directly proportional to the promptness of discovery, the transmission of an alarm, the availability of automatic fire suppression, and the amount of combustibles in the fire area. The total situation can be such that even the most proficient fire-fighting service will be unable to cope with it — as evidenced by the great loss in the Jewish Theological Seminary Library fire, the Klein Law Library fire, and the Los Angeles Central Public Library fire.

Table A-9-1(b) U.S. Library Fires and Associated Loss by Year 1980-1993

Year	Fire	Civilian Deaths	Civilian Injuries	Direct Property Damage
1980	386	0	0	$2,169,700
1981	266	0	0	$215,200
1982	276	0	0	$13,864,000
1983	194	0	0	$3,556,900
1984	238	0	3	$224,600
1985	279	0	0	$1,423,900
1986	206	0	5	$42,858,700
1987	197	0	0	$15,162,800
1988	150	0	0	$481,900
1989	151	0	0	$1,915,800
1990	171	0	2	$679,500
1991	175	0	0	$118,000
1992	158	0	1	$1,940,500
1993	124	0	0	$2,263,500
Annual Average 1980-1993	**212**	**0**	**1**	**$6,205,300**

Direct property damage is rounded to the nearest hundred.
Sums may not equal totals due to rounding error.
Source: 1980-1993 NFIRS and NFPA Survey.

(c) *Representative Fires in Libraries Without Automatic Fire Protection Systems.* Factors common to the most destructive library fires are arson, delayed discovery, delayed reporting, and the absence of any automatic suppression or detection capability. Some typical fires involving one or more of these factors are listed below, including three disasters that tested the resources of three of our largest cities (Los Angeles, CA; New York, NY; and San Diego, CA).

Linkoping City Library

Linkoping, Sweden – September 20, 1996

This important city library was largely destroyed by fire that appeared to have been set deliberately at 11:00 p.m. in the immigrants information office, which was located in the same building. Six hundred people attending a conference escaped safely. Within 20 minutes the building was fully involved. The fire services were sparing in their use of water in order to prevent water from entering the basement storage areas where the manuscript collections were located. Most of these were saved, although about 70,000 books were lost. The loss is still to be evaluated.

Langley Air Force Base

Hampton, Virginia – July 1996

A fire of suspicious origin resulted in the total loss of the Air Force Base's important armed services library, including many unique documents. Dollar amount loss was estimated at $4 million.

Carrington City Library

Carrington City, North Dakota — November 5, 1994

An arson fire destroyed the building and its contents, valued at more than $200,000. Only half of that amount was covered by insurance. The library's entire collection of nearly 13,500 books had to be discarded, with the exception of about 300 books that were in circulation at the time of the fire.

Norwich Central Library

Norwich, England — August 1, 1994

Fire destroyed more than 350,000 books, with many priceless manuscripts, some dating to the 11th century, suffering water damage from fire fighter hose streams. The fire is believed to have started as a result of faulty wiring in a bookcase. The collections contain more than two million documents, including cathedral records dating back to 1090. The London Daily Telegraph reported that "Norwich refurbished its 31-year-old library earlier this year [1994] but decided not to install a sprinkler system, fearing it would cause too much damage if there was a fire." Even though the library was located adjacent to the city's main fire station, the fire was out of control by the time the fire department arrived.

Grand Canyon Community Library

Grand Canyon Village, Arizona — March 18, 1994

A 9 a.m. fire destroyed around 14,000 books in a building that had been listed on the National Register of Historic Places. Only 500 books that were in circulation at the time of the fire were not destroyed. Cause of the fire was not reported. Loss was estimated at over $1 million.

Dakota County Library Branch

Hastings, Minnesota — June 4, 1993

An arson fire involving a juvenile destroyed the entire library collection of 73,500 books and caused $300,000 damage to the building. Damage to books and library furnishings was estimated at more than $1 million. The fire was reported at 4:30 a.m. by a passing motorist. The building had no automatic fire detection or suppression systems because it was considered "up to code" since it was constructed in 1964.

Rio Vista Library

Rio Vista, California — January 16, 1993

The library's total collection of 32,000 books and the historic building that housed them were destroyed by a fire caused by combustible materials left near a radiator heater when staff departed at 5 p.m. The fire was discovered at 10:15 p.m. by persons attending a meeting in a second floor room. Losses were estimated at $1.3 million.

Calgary Public Library, Thornhill Branch

Calgary, Alberta, Canada — April 1, 1990

Fire fighters were called to an arson fire in a building that housed the library and a Calgary social and health services office at 4:30 a.m. Initial estimates of $1 million losses were subsequently reduced by more than half when it was determined that of 60,000 books damaged in the fire, more than 80 percent could be salvaged. These were mostly smoke-damaged books that could be cleaned.

Nellie McClung Public Library

Victoria, British Columbia, Canada — December 4, 1989

Fire was discovered shortly after midnight by a passing police patrol and was first suspected to be arson because of the explosive pace of fire development. Arson was subsequently ruled out because no trace of forced entry or use of flammable liquid accelerants was found. The 13-year-old building was gutted, and 34,000 books were destroyed. It took the fire fighters 45 minutes to control the fire and five hours to fully extinguish it. The fire caused damage in the range of $1 million to $2 million to the library and its collections. It was reported that the library only had automatic sprinkler protection in the boiler room.

Joliet Public Library

Joliet, Illinois — April 19, 1989

About 9:45 p.m. two flaming Molotov cocktails were hurled through a window in the children's wing from the alley. This incident was preceded by two arson incidents in Joliet school libraries — one earlier in the week and one a month and a half earlier. Arson caused the fire that resulted in smoke and water damage throughout the building but caused only minor damage to the building. There was total loss of the children's collections and an estimated $1.3 million loss to the library.

Los Angeles Central Library

Los Angeles, California — October 11, 1988

A third fire resulted when hot metal from welding operations on the third floor dropped down a chute into scrap lumber in the basement. Damage was limited to smudging of the elegant murals that had been cleaned after the 1986 fires at a cost of $500,000. The fire fighters put down the flames in 30 minutes. Plans for the expansion and remodeling of the library include complete automatic sprinkler protection.

Library of USSR Academy of Sciences

Leningrad, Russia — February 14, 1988

Fire that started as a result of an electrical defect in a newspaper collection storage room of this great library burned for 2 hours unnoticed because the detection system failed. Forty brigades then pumped water into the flames for the next 19 hours. It was a national disaster on a parallel with the Chernobyl nuclear catastrophe and was so described by Soviet journalists. Destroyed by fire were 400,000 volumes of rare or unique items; another 3.6 million books were water soaked. As Pravda reported, "The disaster could well have been prevented."

Los Angeles Central Library

Los Angeles, California — September 3, 1986

A second incendiary fire struck the Central Library, causing $2 million damage to music collections, where papers had been stacked to start the fire. The public had been excluded from the building since the April 1986 fire, and only staff members and security people were there.

Los Angeles Central Library

Los Angeles, California — April 29, 1986

An arsonist set a fire on tier 5 in the multitier book stacks at 10:40 a.m. when there were 400 persons in the library. A detection system gave immediate notice of the fire to a security officer, and the fire department was called. The security officer responded to tier 6 as indicated by the smoke detection annunciator panel but found no fire there at that time. The "deck slits" had not been sealed with smoke barriers *[see 9-5.2(c)]* when the smoke detection system was installed as they were still needed for book stack ventilation. As a result, the opportunity was lost for occupant extinguishment while the fire was small. Time available for occupant action was probably very short because, typical of fires in multitier book stacks without automatic sprinkler protection, vertical fire spread through the open deck slits would have been very rapid – possibly less than 10 minutes from tier 5 to the top tier in the book stack (tier 8). The fire department response was prompt, but the fire proved one of the most difficult Los Angeles had ever seen, and it was over 7 1/2 hours later that it was declared under control. More than 400,000 items were destroyed, and 700,000 wet books were placed in freezer warehouses to await eventual restoration. Damage to the reinforced concrete building structure and its historic fabric was extensive and significant. The senior fire service officer, Chief Donald Manning, said "If it had been sprinklered we might have had a few hundred books damaged; we might have had a few thousand dollars damage." *(See "Investigation Report" in NFPA Fire Journal, March/April 1987.)*

Hollywood Regional Library

Hollywood, California — May 2, 1982

Vandals broke into the library during the night and set it on fire. There were neither sprinklers nor automatic detection equipment. The destruction was almost total, and the loss amounted to more than $5 million. A new building replacing this library was dedicated in June 1986 with the design incorporating modern protection systems (i.e., automatic suppression and detection).

San Diego Aerospace Museum and Library

San Diego, California — February 22, 1978

Fire of incendiary origin destroyed the museum and library. The loss, estimated at $16.3 million, included artifacts, works of art, photographs, and the Prudden Collection of 10,000 volumes. At the time of the fire, the 62-year-old structure was undergoing reconstruction, which involved replacement of exterior cement plaster. During this operation the underlying plywood used in the construction was exposed, and the fire was set in the plywood. The building had neither sprinklers nor automatic fire detection systems.

Ceres Public Library

Ceres, California — August 14, 1977

The Gondring Library and several adjacent offices were destroyed in a fire that developed when two youths dropped a paper match into a book return slot. The library loss was approximately $230,000. There were neither sprinklers nor automatic fire detection equipment.

University of Toronto Engineering Library

Toronto, Ontario — February, 1977

Fire of undetermined origin in the Sir Sandford Fleming Building caused severe damage to the Engineering Library collections and to the building. The building loss was estimated at $5.85 million and the cost of repairs or replacement of books at $700,000. There were no sprinklers in the building. A detection system sent signals, but, because alarm circuits were being tested during the night, signals were confused, and a delayed response resulted.

Smith College Library

Northampton, Massachusetts — October 21, 1975

Fire of electrical origin damaged the reference room of the Neilson Library. Damage to the interior finish and furnishings and the loss of a considerable number of books was estimated at $342,000. Some areas of the library were equipped with automatic sprinklers and smoke detection systems, but the reference room was unprotected.

Temple University Law Library

Philadelphia, Pennsylvania — July, 1972

Fire originating in an office area gutted the Charles Klein Law Library and caused extensive damage to the collections. There were neither sprinklers nor automatic detection equipment, and the fire was reported by a passerby at 1:45 p.m. The fire department attacked the fire and subdued it in 90 minutes, pouring water into the building at the rate of 11,000 gallons per minute (41,635 L/min) at one point. Salvage of wet books held the damage to collections at $1.72 million, while the total loss was estimated at $5 million. *(See "Investigation Report" by A. Elwood Willey in NFPA Fire Journal, November 1972.)*

Jewish Theological Seminary Library

New York, New York — April, 1966

An incendiary fire on the 10th floor of a 12-story tower was fought by employees for 20 minutes before calling the fire department. There were no automatic systems for detection or suppression of fire. The loss was estimated at $8.18 million and included irreplaceable books and manuscripts.

Michigan State Library and Office Building

Lansing, Michigan — February 8–13, 1951

An incendiary fire burned for five days, resulting in a loss of $2.85 million and two floors of the building that could not be salvaged.

University of Michigan, Department of Government Library

Ann Arbor, Michigan — June 6, 1950

A daytime fire set by a faculty member resulted in $637,000 loss.

(d) *Representative Fires in Libraries with Automatic Fire Protection Systems.*

Broward County Main Library

Fort Lauderdale, Florida — March 23, 1993

The automatic sprinkler system contained a fire in a first-floor trash room at about 9:57 p.m. on a Sunday. The fire is believed to have been caused by a carelessly discarded cigarette. Excess trash from a weekend special event in the library contributed to the severity of the fire. Portions of the first floor were damaged, including security and delivery offices and storage rooms. Some library materials in those areas were also damaged.

South Bend Public Library

South Bend, Indiana — October 28, 1992

A fire that started in an elevator shaft during the unoccupied early morning hours spread into a mezzanine area, but damage to the building was minimal. The sprinkler system was credited with containing the fire and preventing it from extending into library collection materials. An alarm to the fire department from the building was delayed because the fire detection systems were still not connected more than two weeks after dedication ceremonies for the renovated and expanded building. The fire department found the fire nearly extinguished by the automatic sprinkler system. Damage was limited to smoke, carpet, elevator and elevator shaft, and glass windows to the main entrance door and rooftop skylights.

Bailey-Howe Library, University of Vermont

Burlington, Vermont — March 21, 1990

Staff arriving at 7:30 a.m. smelled an electrical burning odor. An electrical fault ignited the fabric wrapping on an air supply duct in the air return plenum above the suspended ceiling. By the time the source of the smoke was discovered, the fire had burned itself out. At the time of the fire there was no interconnection between the automatic smoke detection system and the air handling system to shut it down upon detection of smoke. Damage to the library was limited to the effects of the smoke and the removal of parts of the ceiling. Final cost to the institution was $105,965. The library reopened two days later, and the most affected part of the building was off-limits to students for the balance of that spring semester. An automatic sprinkler system was retrofitted to the building in 1981, but it was below the suspended ceiling.

Saint Joseph State Hospital

Saint Joseph, Missouri — July 31, 1982

Fire of incendiary origin in the second floor library of this three-story medical care facility was controlled with the operation of two automatic sprinklers. The minimal damage was confined to the room of origin.

University of Utah

Salt Lake City, Utah — December 17, 1981

Fire resulting from an overheated slide projector in the basement of the Eccles Health Sciences Library was extinguished with the operation of two automatic sprinklers. Notification of the public fire department was prompt through the action of smoke detectors. An estimated loss of $2600 was confined for the most part to visual aid equipment.

New York University Library

New York, New York — January, 1965

Fire in a library book stack was extinguished with the operation of one automatic sprinkler. Total loss was approximately $7000.

New York University Library

New York, New York — February, 1951

Fire in the book stacks of a 10-story, completely sprinklered, fire-resistive building was extinguished with the operation of one sprinkler. Total loss was approximately $1000.

NOTE: It is significant that in the last four fires described in this section, sprinkler operation was credited for prompt control and extinguishment with minimal damage. Many similar incidents have occurred without attracting public notice.

(e) *Library Fires — Causes and Prevention.* Incendiarism (i.e., the deliberate setting of fires) has been identified as the cause of most fires in libraries in the last 50 years, accounting for as many as 80 percent of all fires. The average annual fire loss due to incendiary or suspicious causes during the years 1980–1993 was $4,415,900. *[See Table A-9-1(a).]*

NOTE: See Appendix H-2 — Morris, John, *Library Disaster Preparedness Handbook.*

The disgruntled or unstable employee or patron can be the most difficult type of fire setter to recognize. Vandals who break in while the library is closed can be defeated by physically strengthening doors and windows, improving security, and installing intrusion alarms to make unauthorized entry and vandalism difficult. Those fire setters who place burning materials in book returns can be turned away simply by improving the book return or eliminating it in favor of an outside receiving bin – something that thousands of libraries have done in recent years.

(f) *Fire Prevention – Control Ignition Sources.* After incendiarism, the most common causes of fire in libraries involve the failure to control the ignition sources that are inherent in building operations (e.g., heating systems, electrical faults, hot work of contractors in construction and remodeling, heating systems, and lightning). Each of these categories has produced destructive fires in recent years. Another common cause of fire is the exposure fire that spreads to the library from an adjacent building or another occupancy in the same building.

These causes suggest preventive programs to minimize fire damage. Electrical wiring and appliances require proper installation and maintenance. Open flame devices should be permitted only upon the basis of written authorization signed by the responsible management official after evaluating the risks and prescribing the specific protective measures to be included as conditions of the authorization. Contractors must be held by contract specifications to stringent discipline in protecting cutting and welding operations, a prolific source of fires, and in other hot work. Standard lightning protection should be provided as well.

NOTE: Chapter 16, Section 9 of the NFPA *Fire Protection Handbook* (18th edition) provides guidance for control of ignition sources in library collections.

(g) *Fire Prevention – Control Fuel.* A fire prevention program in the library should provide for control of fuel as well as ignition sources. It should include inspections by designated supervisory persons to maintain good housekeeping and see to the proper removal of combustible trash, proper storage of flammable materials, and so on. It should also acquaint employees with emergency routines for fire: sounding the alarm, calling the fire department, and using whatever first-aid appliances (e.g., fire extinguishers) that might be available. The program should invite fire service officers into the library for inspection and orientation.

(h) *When Fire Prevention Fails.* Due to factors beyond the control of even the most effective fire prevention program (especially those against incendiarism), the risk of fire is always a distinct possibility, and any library depending entirely on fire prevention activities will be perpetually at risk of major disaster. According to Table A-9-1(c), nearly half of the fires in U.S. libraries (1980–1993) and more than half of the resulting fire losses occurred during the hours when most libraries are either closed or at minimum staffing levels. What determines the fate of the building and the collections when fire strikes in the middle of the night is the integrity of the structure in terms of proper design, fire-resistive construction, and automatic systems for protection.

Table A-9-1(c) U.S. Library Fires and Direct Property Damage by Time of Day 1980 – 1993, Annual Average

Time of Day	Fires	Percent of Fires	Direct Property Damage	Percent of Damage
Midnight to 1 a.m.	3	1.4	$6,700	0.1
1 a.m. to 2 a.m.	3	1.5	$35,300	0.6
2 a.m. to 3 a.m.	5	2.4	$891,500	14.4
3 a.m. to 4 a.m.	2	0.8	$1,125,700	18.1
4 a.m. to 5 a.m.	2	0.7	$150,700	2.4
5 a.m. to 6 a.m.	2	1.0	$6,600	0.1
6 a.m. to 7 a.m.	4	1.7	$11,300	0.2
7 a.m. to 8 a.m.	4	1.8	$27,800	0.4
8 a.m. to 9 a.m.	10	4.5	$24,200	0.4
9 a.m. to 10 a.m.	10	4.5	$11,200	0.2
10 a.m. to 11 a.m.	12	5.8	$2,704,700	43.6
11 a.m. to noon	12	5.8	$24,900	0.4
Noon to 1 p.m.	12	5.7	$3,800	0.1
1 p.m. to 2 p.m.	15	7.2	$77,800	1.3
2 p.m. to 3 p.m.	12	5.6	$194,700	3.1
3 p.m. to 4 p.m.	16	7.3	$12,400	0.2
4 p.m. to 5 p.m.	23	10.7	$35,900	0.6
5 p.m. to 6 p.m.	16	7.7	$80,600	1.3
6 p.m. to 7 p.m.	13	6.3	$401,800	6.5
7 p.m. to 8 p.m.	9	4.4	$38,500	0.6
8 p.m. to 9 p.m.	10	4.7	$29,000	0.5
9 p.m. to 10 p.m.	7	3.3	$219,000	3.5
10 p.m. to 11 p.m.	5	2.4	$4,900	0.1
11 p.m. to midnight	6	2.6	$86,300	1.4
Total	**212**	**100.0**	**$6,205,300**	**100.0**
Selected Time Periods				
9 a.m. to 5 p.m.	112	52.6	$3,065,400	49.5
5 p.m. to 9 p.m.	48	23.1	$549,900	8.9
9 p.m. to 9 a.m.	53	24.1	$2,590,000	41.7

Direct property damage is rounded to the nearest hundred.
Sums might not equal totals due to rounding error.
Source: 1980–1993 NFIRS and NFPA Survey

A-9-1.2 While this chapter prescribes minimum requirements for the protection of libraries and library collections from fire, additional guidance in fire prevention, fire protection, and fire loss contingency planning is provided in this appendix for library trustees, chief librarians, and other staff officers who are responsible for the fire safety of the library's building(s) and its collections and for the life safety of those persons who visit libraries or work in them. It emphasizes the responsibility of all such library officials to protect against fire (hazards) in their properties by using qualified personnel and consultants to present an analysis of the fire risk embodied in the library's collections, building(s), and operations. This analysis should also include an assessment of the impact of the loss or interruption that fire would impose on the library's service to the community.

A-9-5 An emergency plan should be developed that designates routes to access book stacks, means of venting smoke, and plans to reach and fight a fire at its source. The plan should be developed in cooperation with the local fire service.

A-9-5.2 Multitier Book Stacks. In many libraries the part of the building used to house books is only a shell within which the exposed (i.e., unprotected) metal book stacks are self-supporting and rise continuously through several floor levels of the building. The book stack walkways are suspended from the book stack structure with 7 ft (2.12 m) between levels or tiers. *[See Figure A-9-5.2(a).]* This results in openings between the stacks and the walkways that provide flue-like channels for the uninterrupted upward flow of air through the books from the base of the structure to the top. *[See "deck slit" in Figure A-9-5.2(b).]* Since there are no fire barriers between levels or tiers, the entire shell enclosing the multitier book stack structure must be regarded as one fire compartment, and everything it contains will be at risk to any fire that develops within or spreads to that compartment. Cast iron or steel structural members lose strength at the high temperatures encountered in fires. Under fire conditions, the cast iron or steel multitier book stacks might collapse. For this reason, the fire service could be unable to enter the multitier book stack structure for manual fire fighting.

Fire growth in multitier book stacks is very rapid. In the unsprinklered phase of the fire tests conducted by Factory Mutual Engineering in 1959, fire spread vertically through the open deck slits in a vase-shaped pattern (e.g., spreading horizontally at each tier as it advanced vertically), reaching the fourth tier of a four-tier book stack test assembly in 9.5 minutes *(see Appendix J)*.

The requirement to install smoke barriers in all vertical openings between tiers or decks not only restricts the spread of smoke, but will also help contain the smoke and heat to facilitate detection and sprinkler operation in the immediate area of the fire. Without these barriers, detectors and sprinklers can operate in areas remote from the fire before operation of these systems in the fire area. *(See description of the 1986 Los Angeles Central Library Fire in A-9-1.)*

In new libraries or in major renovations of existing structures this type of bookstack should be avoided. Floor assemblies should be of conventional building construction with appropriate fire-resistive ratings and the book stack ranges supported by the floor assembly upon which they are placed.

A-9-5.3(a) The automatic fire suppression system and the compact storage system should be designed to limit fire damage in accordance with the library's fire safety objectives (e.g., confine fire growth to the compact storage module of origin). Significant factors to consider would include the number and size of the storage modules, the separation provided between the modules (end-to-end and back-to-back), and the type of materials being stored.

A-9-5.8 The primary goal of this section is to separate the fuel from the ignition sources and other sources that bring risk, for example through the need for maintenance, into these areas.

A-9-7.1 *Prevention of Incendiarism and Arson.* It is important to control the threat of arson to libraries. The nature of libraries —their access to the public, with many areas obscured from view of attendants — results in their being an opportune target of incendiarists as well as other forms of malicious damage. The most common fire setters are vandals, disgruntled users, and employees. They can break in at night or gain legitimate access during normal operating hours. *[See Table A-9-1(c).]* A frequent method of external attack has been to place burning materials into the book return. See A-2-2.3(c) for precautions that can minimize the likelihood of a serious fire due to arson.

A-9-8.2 Cellulose nitrate film becomes less stable as it deteriorates with age and/or exposure to elevated temperatures. It can ignite spontaneously, deflagrate when it ignites, and burn without atmospheric oxygen, and the smoke causes a potentially fatal chemical pneumonia in persons exposed to it without respiratory protection.

A-9-8.4 Many libraries have laboratories for the preservation and restoration of books, documents, and other objects of art or artifacts. Invariably, there are quantities of flammable solvents, alcohol, waxes, and other materials that ignite readily or evolve explosive or poisonous fumes that require special attention to provide adequate general room ventilation, if not local exhaust fume hoods.

A-9-10 NFPA 232A, *Guide for Fire Protection for Archives and Records Centers,* provided additional guidance on the storage and protection of archival material. In addition, using the protection schemes discussed here, consideration should be given to creating duplicate records and storing them at an off-site location.

A-10-1 Fire losses in places of worship are not a modern phenomenon nor is the relatively high proportion of these that are purposely set. Even looking back to the Crusades of the Middle Ages, we find numerous stories of churches and cathedrals being set on fire by opposing armies. Destruction of the enemy's centers of community and symbols of their religious faith and culture was found to be a strong factor in weakening their morale and winning the battle. Today our places of worship remain a target for destructive individuals who wish to attack a particular social, political, or moral position that the structure represents to them. From 1987 to 1991, according to a recent NFPA study of fires in the U.S., an average of 1450 churches, chapels, and synagogues were seriously damaged or destroyed by fire every year. This is an average of four properties per day. The annual average for direct property damage was $37.5 million.

(a) *How Fires Have Started in Places of Worship.* In addition to fires that have been purposely set, places of worship are susceptible to the wide variety of common hazards associated with fires in most properties. A 1987–1991 study by NFPA includes fire loss data for churches and chapels alone. *(See Table A-10.1.)* Numerous other fires occurred in associated occupancies, such as kitchens, schools, orphanages, shelters, and so on, that were not included in this study.

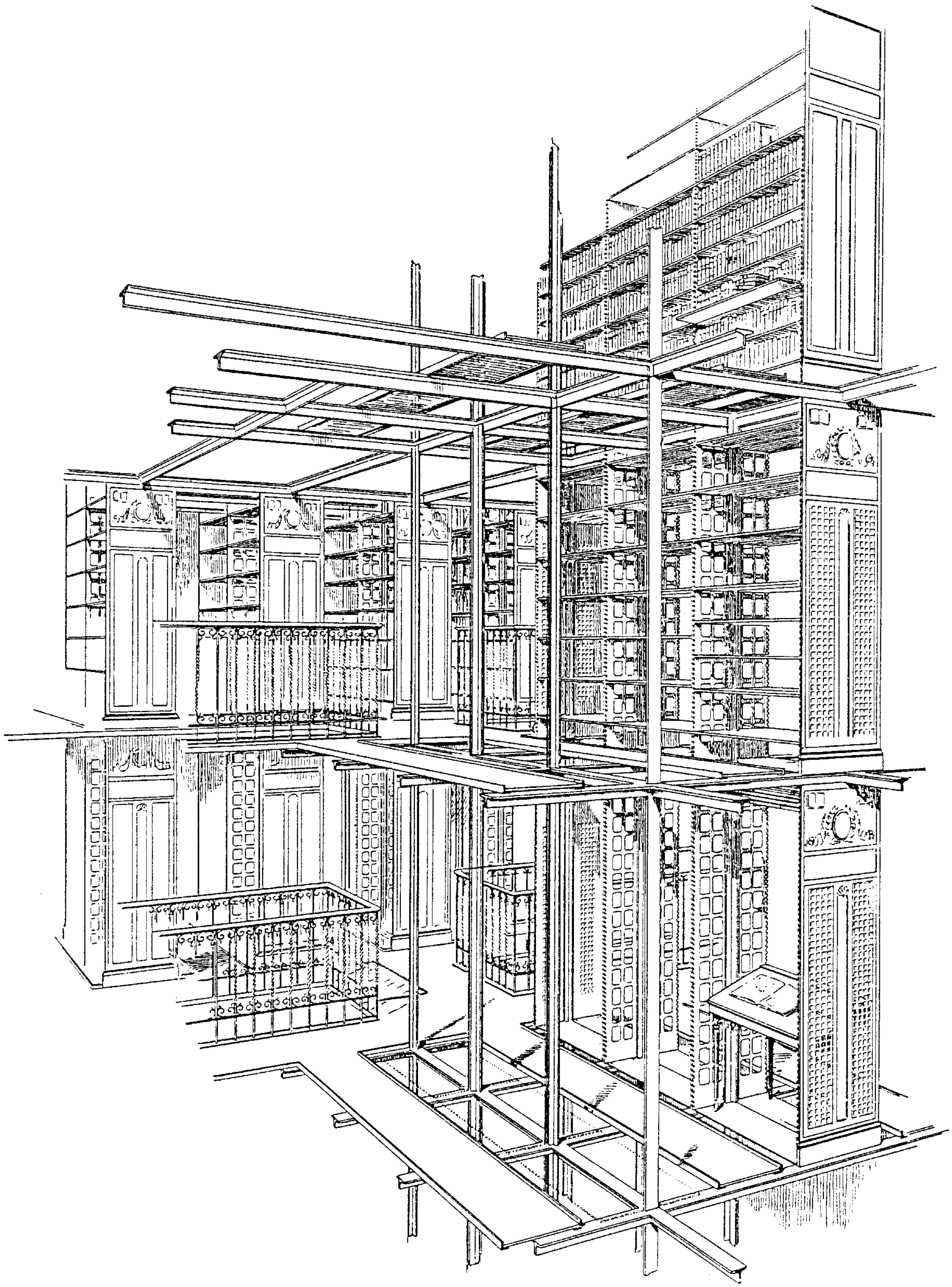

Figure A-9-5.2(a) Multitier book stack: perspective view.

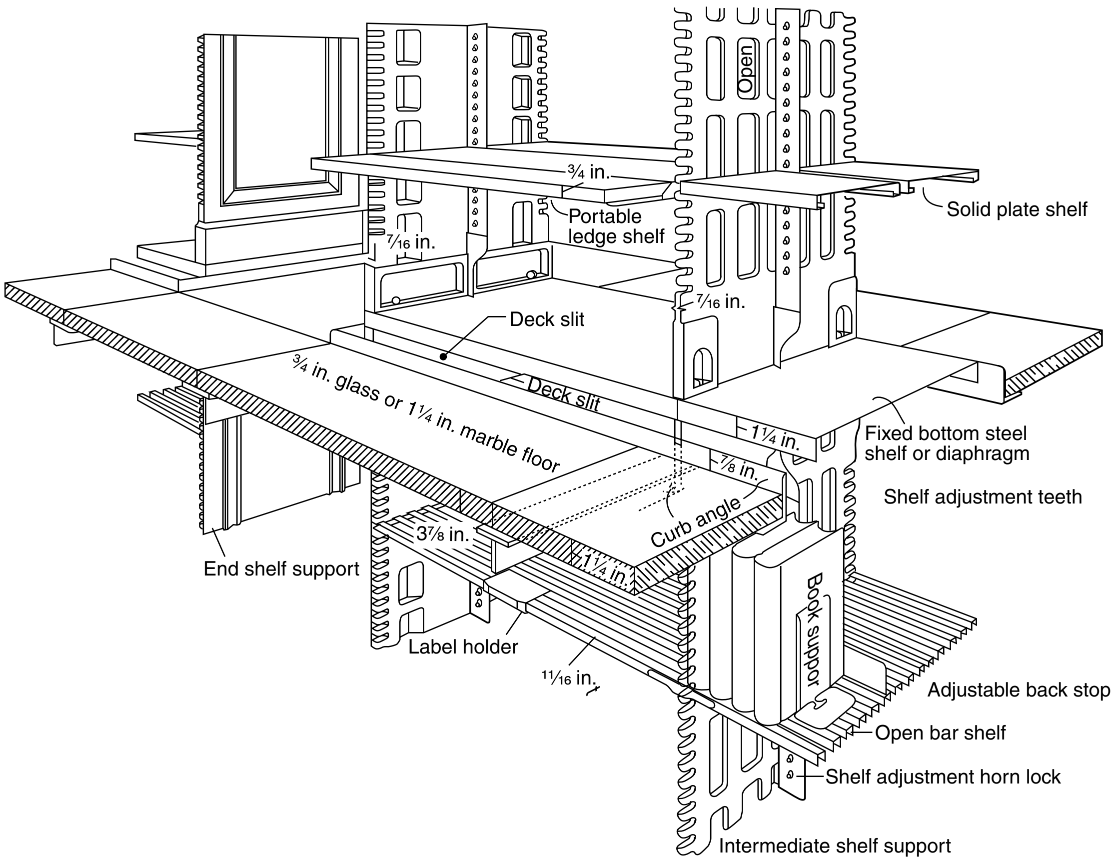

Figure A-9-5.2(b) Multitier book stack: perspective detail showing section through deck flooring, fixed bottom shelf, and adjustable shelves.

Table A-10-1 Fire Loss Data for Churches and Chapels

Cause	Fires	Civilian Deaths	Direct Injuries	Property Damage (in Millions)
Incendiary or suspicious causes	430	0	1	$15.0
Electrical distribution system	193	0	1	$3.8
Heating equipment	151	0	1	$3.1
Open flame (e.g., match, lighter, torch)	103	0	1	$1.7
Other equipment	95	0	3	$2.4
Natural causes	76	0[1]	3	$1.6
Exposure (to other hostile fire)	68	0	0[1]	$0.4
Appliances, tools, or air conditioning	49	0	0	$1.1
Cooking equipment	48	0	1	$0.4
Smoking material (i.e., lighted tobacco products)	36	0[1]	0[1]	$0.1
Other heat source	35	0	1	$0.4
Child playing	23	0	1	$0.1
Unknown	142	1	1	$7.4
Total[2]	**1450**	**1**	**13**	**$37.5**

[1]Not zero but rounds to zero.
[2]Sums might not equal total due to rounding error.

(b) *Arson.* Places of worship are either unoccupied or partially occupied a large part of the time. Customarily, many of them are left unlocked at all times; thus, they are accessible not only to casual worshipers and well-intentioned visitors, but also to arsonists, thieves, and vandals. Incendiarism is the leading cause of fire in places of worship. The best defenses against arson fires are improved security and access limitations and provision of automatic sprinkler protection throughout the facility.

(c) *Electrical Systems.* Overloaded, incorrectly installed, and old or damaged electricals are the second most frequent cause of fires in places of worship. Periodic inspections by an electrical engineer or licensed electrician, in conjunction with the required self-inspection program, can eliminate most of these losses.

(d) *Heating Equipment.* Again, correct installation and maintenance of this equipment combined with a regular inspection program should substantially reduce these losses.

(e) *Open Flame.* Most of these fires occur during building repair and alteration work. Assistance in building alterations and repair work is often volunteered by members of the congregation. Where those volunteers possess specialized skills and talents, their services are of great value. It is important, however, that such tasks as heating, plumbing, and electrical work be performed only by fully qualified licensed professionals. For additional precautions during these operations, refer to Chapter 5 of this standard. And, of course, unsupervised use of candles and other open flames outside of renovation work should not be permitted.

(f) *Why Fires in Places of Worship Have Spread.* If all fires were confined to their areas of origin, there would be few major losses. Most buildings comprise a connected series of compartments. As such, they are inherently fire safe if a fire can be contained to the compartment of origin. Unfortunately, in places of worship, design, construction, and use practices create many avenues for fire spread.

(g) *Building Use.* One of the primary reasons fires in places of worship generally result in great amounts of damage or a total loss is a delay in discovering and reporting the fire. The ability to detect and begin extinguishment during the first moments following ignition of a fire is generally critical, as it frequently takes only very few minutes for a small fire to grow large enough that even a very responsive fire department cannot extinguish it before major damage has been wrought.

More than three-fourths of fires in places of worship occur while the building is unoccupied; almost all of them occur in structures lacking automatic sprinkler protection or automatic fire detection and alarm systems. Nearly half of them happen between 11 p.m. and 7 a.m., when few people pass by the area. These statistics, coupled with simple logic, highlight the urgency and prudence of providing places of worship with effective fire detection and protection equipment that automatically notifies the fire department and begins fire extinguishment.

(h) *Design and Construction.* A fire needs only two ingredients to enable it to spread: air and combustible materials. Most places of worship are provided with both in great abundance. In addition to delayed detection and alarm, the principle factors affecting the spread of fires in places of worship are undivided open areas, concealed spaces, combustible construction, combustible interior finishes, and combustible furnishings. Undivided open areas and concealed spaces provide air to an incipient fire, and combustible structural parts, finishes, and furnishings provide fuel. Each of the following accounts of fires illustrates the effect of one or more of these factors. These accounts demonstrate why fire fighters particularly dislike these fires and why places of worship are often said to be “built to burn.”

Large open areas are traditional and perhaps largely unavoidable, yet there are ways to minimize their effect. In some cases, for instance, fire separations can be introduced without altering the essential character of the building or its usefulness for religious purposes. Doors customarily left open could be kept closed, other unprotected or inadequately protected floor and wall openings could be more effectively protected, concealed spaces could be provided with adequate firestopping or fire divisions, and combustible interior finishes could be replaced with less hazardous, aesthetically acceptable materials. Very few of the fires reported were in buildings in which such measures had been taken. This illustrates how rarely fires that are serious enough to be reported occur in places of worship with such protection.

Since a properly designed automatic sprinkler system is the most effective single means of preventing serious fires, automatic sprinklers combined with good building design and fire-resistive construction, finishes, and furnishings ensure safer places of worship.

(i) *Illustrative Fires in Places of Worship.* The following descriptions of fires illustrate some of the more common sources of ignition, factors contributing to fire spread, and the enormity of the losses suffered. It is important to note that these destructive fires are not limited to a particular geographical area or population, but occur across the country and in rural areas as well as big cities.

Church, October 1995. Total loss. An early-morning five-alarm fire completely destroyed this ornate, American gothic church built in 1894. The historic structure, built of virgin redwood, had survived the 1906 San Francisco earthquake and resultant fires, but the all-wood building burned quickly once this fire started.

Church, October 1995. Total loss. This 103-year-old Victorian church, listed on the National Historic Register, was destroyed by a fire that resulted from roofing work being done in conjunction with a major renovation project. It took 90 fire fighters to bring the blaze under control. Luckily, the 110 people who were attending meetings inside at the time the fire started managed to escape unharmed.

Church, May 1989. Loss was more than $1 million. A 135-year-old church was occupied by about 200 persons when fire was discovered by workers removing paint on the structure’s exterior. One of the workers activated the fire alarm system, alerting the occupants to evacuate and also notifying the fire department. The wood-frame structure was not sprinklered and was destroyed by the fire despite the efforts of 100 fire fighters. There were no injuries. *(See Figure A-10.1.)*

Church, September 1987. Loss of $2 million out of $2,743,600 value. An unspecified short circuit in the wiring in the middle of the attic area ignited wooden rafters. Fire engulfed and burned through the roof. The roof area was being renovated at the time, but workers had left before the fire began around 4 p.m. Staff were still working in the basement offices and discovered the fire approximately 15 to 25 minutes after it began. There was no automatic detection or suppression equipment. The 60-ft (18.3-m) building measured 80 ft by 110 ft (24.4 m by 33.6 m) and was of heavy timber and wood frame construction, with brick walls and metal sheeting on a wood frame roof. Six fire fighters were injured.

Church, February 1987. Loss of $2,575,243 out of $3.4 million value. Fire was ignited by an electrical source in a storage room on the main floor. The nature of the electrical failure and the materials first ignited were not identified. Fire then spread into the ceiling/floor space above and up a wall to the main church ceiling. There was no automatic detection or suppression equipment. The building was closed at the time, and fire officials estimate the fire burned for two hours before it was discovered by a passerby at 4:33 p.m. The three-story building measured 100 ft by 135 ft (30.5 m by 41.2 m) and had wood frame construction with brick walls and a wood roof with asphalt shingles. Two fire fighters were injured.

Church, May 1986. Loss of $2.5 million out of $2.5 million value. An incendiary fire was started in three places on the church’s wooden benches. The one-story building measured 60 ft by 100 ft (18.3 m by 30.5 m) and was of mixed construction with brick and concrete walls, wood and metal roof sections, and both asphalt shingle and built-up roof covering areas. The building was closed for the night when fire was discovered and reported by a police patrol at 2:13 a.m. There was no automatic detection or suppression equipment. There were no injuries.

Figure A-10-1 An electric paint remover was suspected of having started a fire that destroyed an historic Massachusetts church. (Photo Credit: Greg Derr, *Patriot Ledger*)

Church, November 1985. Loss of $2.2 million out of $2.2 million value. A floodlight located too close to a ceiling beam in the basement apparently ignited the beam, touching off an after-hours fire in the church. The one-story, 60 ft by 150 ft (18.3 m by 45.8 m), brick-walled, wooden building with a slate roof was closed for the night when fire began after 6 p.m. There was no automatic detection or suppression equipment, so the fire was not reported until a neighbor discovered it. There were no injuries.

Church, May 1985. Loss of $2.1 million out of $2.1 million value. In the late afternoon, lightning struck the roof of a one-story, 78 ft by 167 ft (23.8 m by 50.9 m), 120-year old church, igniting the wooden roof in a fire that grew slowly over 2 $^1/_2$ to 3 hours in the attic area. The building was of ordinary construction, with brick walls. It had no automatic detection or suppression equipment. A priest discovered the fire at 5:39 p.m. and reported it. Fire broke through the roof, was drafted upward through the bell tower, and destroyed its upper section, causing it to topple into the street. The roof collapsed. The sanctuary was engulfed in flames. Flooring collapsed into the basement. Fire department actions were necessarily limited to protecting exposures. There were no injuries.

Synagogue, November 1979. Two fire fighters lost their lives in this fire. The sanctuary and social hall were completely destroyed. Sections of the roof collapsed during the fire, resulting in total collapse of most of the roof trusses in these areas. Damage to other areas of the synagogue was minor. Though there was a local fire alarm and smoke detection system in the school classroom and catering areas, there was none in the sanctuary or social hall. In addition, there were no sprinkler or standpipe systems in the synagogue complex.

A-10-4.2 Sprinkler systems for specific areas associated with religious facilities should be designed as follows:

(a) All assembly areas, except state — Light Hazard

(b) Stages — Ordinary Hazard (Group 2)

(c) Kitchens — Ordinary Hazard (Group 1)

(d) Storage rooms — Ordinary Hazard (Group 2)

(e) Unused attics/lofts/steeples/concealed spaces — Light Hazard

(f) Schools/day-care centers — Light Hazard

(g) Gift shops — Ordinary Hazard (Group 1)

(h) Special exhibit area — Ordinary Hazard (Group 2)

(i) Libraries — Ordinary Hazard (Group 2)

(j) Offices — Light Hazard

A-10-4.3 When smoke detectors are to be installed in the sanctuary or other high-ceiling areas of a place of worship, consideration must be given to the possibility of the smoke stratifying and being diluted as it rises to the ceiling. NFPA 72, *National Fire Alarm Code,* Chapter 5 and Section A-5 provide guidelines for use of smoke detectors in high-ceiling areas.

Care must be exercised during worship services to prevent the occurrence of unwanted alarms caused by the use of candles, incense or other smoke-producing devices.

Appendix B Fire Risk Assessment in Heritage Premises

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

B-1 Introduction. Recent studies have shown that when use is made of the risk assessment technique in relation to fire safety then there are improved chances of ensuring that protection measures are more likely to be cost-effective.

In carrying out an assessment, the person responsible is required to consider not only employees but also any other people who might reasonably be expected to be present in the location being surveyed. This would include those resident in a hotel, the patients in a hospital, visitors to a museum, or children working in a public library.

The assessment must necessarily involve two quite distinct factors —the fire hazard and the fire risk — and must identify all the fire hazards and assess the potential impact of the associated fire risks.

If some fire safety measures have already been introduced into the building, their effectiveness in reducing the overall fire risk should be taken into account. An example of such a measure would be the existence of a sprinkler system.

B-2 The Meaning of "Fire Hazard" and "Fire Risk."

(a) *Fire Hazard.* Fire hazards are those elements in the building that could start a fire and the harmful consequences of such a fire. Fire hazards that could start a fire might be substances such as the reactivity of chemicals used in a conservation process or actions such as the use of welding or cutting equipment by contractors, whereas structural features such as poor compartmentation, or bad management practices such as allowing escape routes to become obstructed would be examples of fire hazards that could have harmful consequences in the event of fire.

(b) *Fire Risk.* A fire risk is simply the probability (likelihood) of a hazard being realized. While much easier to define than a fire hazard, it is difficult, if not impossible, to assign a precise numerical value to the fire risk.

Fire risk assessment should be seen as a specific part of a wider, overall assessment of the risk to which people at work are exposed and can be part of an overall program of risk reduction.

B-3 A Three-Part Exercise with a Threefold Outcome. There are three parts to the fire risk assessment: an initial assessment identifying the hazards and sizing the risks, followed by a hazard/risk reduction exercise, followed by a final assessment.

The final assessment will have three outcomes: it will determine whether the building, or parts thereof, is to be categorized as being of high, normal, or low risk. This in turn will determine the fire precaution measures required on the premises, and it will be the starting point in the formulation of an emergency plan.

B-4 Practical Considerations. In carrying out the risk assessment, it will be necessary to bear in mind the following factors:

(a) The people present in the building

(b) The use to which the building is put

(c) The sources of ignition present

(d) The use of flammable materials

(e) The contents of the building

(f) The storage of materials

(g) The furnishings and surface finishes present

(h) The structural features of the building

In large or complex museums or libraries, it could simplify the task, and indeed be more appropriate, if all three parts of the exercise are carried out by treating distinct areas such as workshops, offices, kitchens, and warehouses as separate entities.

B-5 Risk Reduction. Having made the initial assessment, there follows the all-important task of reducing the hazards and risks. It will almost certainly be the case that some reductions could be effected immediately, and these short-term measures would include such things as improving the housekeeping (the management of waste and rubbish) and the implementation of a program of fire safety training for employees.

Other long-term measures would include such things as the installation of a fire suppression system, the rewiring of the building, and the substitution of hazardous processes and materials with less-hazardous substitutes.

B-6 The Final Assessment. When the hazards and risks have been reduced to what, at the time, appears to be an irreducible level, there follows a more rigorous final assessment of the risk. The final assessment will determine the risk categorization, which will be conventionally defined as high, normal, or low. In larger premises it will be quite normal to have different risk categories for different parts of the building.

B-7 Risk Assessment Methods. As previously noted, there is no single "correct" way of carrying out the risk assessment. There are, however, three methods that might be useful, each of which makes clear what is to be understood by the terms high, normal, and low risk. These are the risk category indicator method, the risk value matrix method, and the algorithmic method.

(a) *The Risk Category Indicator Method.* This is a diagnostic method in which the various elements in the building are classified in such a way as to indicate that the building in which they are found should be categorized as being high, normal, or low risk.

1. *High-Risk Indicators.* Elements that can give rise to high-risk indicators include the following:

a. Sleeping accommodations

b. People

c. High-risk processes and areas

d. High-risk materials

e. High-risk structural features

a. *Sleeping Accommodations.* The presence of sleeping accommodations in the building must always indicate the high-risk category. When people are asleep, their ability to respond to fire is reduced and they are therefore more at risk of being overcome by smoke, fumes, or fire before reaching a place of safety. This response to fire could be further reduced if the people are elderly, disabled, deaf, or partially sighted.

Consequently, hotels, boarding houses, hospitals, nursing homes, and shelters for the homeless (all of which could be heritage buildings) will all be "high-risk buildings."

b. *People.* The presence of people can indicate a high risk if any of the following conditions apply:

i. There is a large number of members of the genral public present in a building with which they are unfamiliar — museums and galleries clearly fall into this category.

ii. There is a large number of young members of the public in the building, such as can be found in galleries or libraries that put on special events.

iii. There is a high density of people in the building.

iv. There are people working in isolated or remote parts of the building, such as basements, attics, lofts, lift shafts, or service ducts.

v. There is a high proportion of elderly or disabled people in the building, such as would be found in hospitals, day centers, and nursing homes.

vi. There are insufficient staffing levels available to assist members of the public in evacuating the building, such as a college library, where the night-time staffing levels are considerably lower than the daytime ones.

The above situations are considered to be high-risk indicators because, in the event of fire, they could seriously jeopardize the chances of evacuating the building in the expeditious manner required to ensure that everyone reaches a place of safety before being overcome by the effects of fire.

c. *High-Risk Processes and Areas.* There could be parts of the building where there is a greater risk of fires occurring and developing than elsewhere. This greater risk could arise from the nature of particular processes or operations that are carried out in these parts of the building, or from areas that contain or are used to store flammable or explosive materials.

The high-risk processes or areas can be either permanent or temporary. The temporary high risks could arise from work being done by either maintenance staff or outside contractors.

High-risk processes include any involving the following:

i. The use of highly flammable liquids or gases, including processes such as paint spraying, solvent extraction, and solvent degreasing; processes involving the use of adhesives based upon flammable solvents; and oxyacetylene welding or cutting

ii. The use of naked flames in such activities as glass-blowing, ampule sealing, metal forging or smelting, plumbing, and paint stripping

iii. The production of excessive heat by kilns, drying ovens, and furnaces

iv. The storage or use of highly flammable and/or explosive or reactive chemicals

d. *High-Risk Materials.* These are materials that are either easily ignited or when ignited are likely to cause the rapid spread of fire and smoke. The occurrence of these materials can be extremely widespread.

High risk materials include the following:

i. Synthetic textiles

ii. Polyurethane foams

iii. Dried or artificial foliage

iv. Paints

v. Adhesives based upon flammable solvents

e. *High-Risk Structural Features.* These high-risk indicators will include such items as the following:

i. A complete lack of, or insufficient, fire-resisting compartmentation

ii. Vertical or horizontal openings through which the fire could spread, and which would allow the movement of toxic smoke and gases from one part of the building to another

iii. The use of non-fire-resistant glass in separating walls or in vision panels in fire doors

iv. Wooden floors supported upon wooden joists

v. Long or complex escape routes

vi. Large areas of flammable or smoke-producing surfaces on walls and ceilings

All of these structural features are high-risk indicators because they would greatly increase both the speed of the fire and the chances of the spread of fire within the building, or because they would reduce the effectiveness of the escape routes in providing a safe means of reaching a place of safety before being overcome by the effects of fire.

In this context, it should be noted that some floor coverings will liberate large amounts of heat and large quantities of smoke when involved in a fire, even though they might contribute slowly to the surface spread of fire.

2. *Normal-Risk Indicators.* In general, premises will fall into the normal risk category if the buildings are of conventional construction and if neither the functional capacity nor the nature or disposition of its contents are likely to present a serious fire hazard to people in the event of fire.

The specific normal-risk indicators include the following:

a. A fire is likely to remain localized or at least to spread so slowly as to allow people the escape to a place of safety

b. There is little risk of the building or its contents catching fire easily, or of producing such large quantities of smoke as to constitute a serious hazard to life

c. There is an effective automatic means in the building for detecting and giving warning of fire, or an effective automatic system for the extinguishment, suppression, or containment of fire

d. The presence of such automatic systems allows what would otherwise be a high-risk building to be categorized as being of normal risk

3. *Low-Risk Indicators.* The low-risk indicators include the following:

a. A minimal risk to life safety

b. A negligible risk of fire occurring

c. A negligible risk of fire, smoke, or fumes spreading

There are probably very few such low-risk buildings in the cultural resources world. Perhaps the only obvious examples would be the sort of exhibits one might find in an outdoor museum of industrial heritage or a sculpture park.

(b) *The Risk Value Matrix Method.* Unlike the risk category indicator method, this method bases the risk assessment in quantitative terms. However, it cannot be too strongly stressed that the numbers involved are purely relative, and therefore, that they have no absolute significance whatsoever.

While all risks are made up of two elements – the probability that an event will occur and the consequences of that occurrence – the relative contributions that these two elements make to the risk can vary considerably.

1. *A Formula for Risk Value.* Bearing in mind that the two elements of risk are the fire hazard and the fire risk, it would be reasonable to call the overall risk the risk value, as defined by the following simple formula:

Risk value = fire hazard value × fire risk value

If we then express the size of the fire hazard and the fire risk by assigning values to them we could, by applying the formula, obtain a number that would be a measure of the risk value. The size of the risk value then becomes the basis for categorizing the building as being of high, normal, or low risk.

2. *Quantifying the Fire Hazard and the Fire Risk.* This is easily done if we classify the fire hazards by describing them as being between negligible and very severe and by assigning a numerical value to each description. Similarly, we could classify the fire risks by describing them as being between unlikely and very likely and by assigning a numerical value to each of these descriptions.

3. *Classification.* If we apply the risk value formula to all possible combinations of fire hazard values and fire risk values, we obtain a set of 25 numbers. The risk values could then be displayed as a two-dimensional grid that we could call a risk value matrix. An example is shown in Table B-7(b)3.

Table B-7(b)3 Risk Value Matrix

Fire Hazard Description	Value	Fire Risk Description
Negligible	1	Unlikely
Slight	2	Possible
Moderate	3	Quite possible
Severe	4	Likely
Very severe	5	Very likely

The final task in this method is to decide the ranges of the risk values that will correspond to our three categories of risk.

(c) *The Algorithmic Method.* An algorithm is a two-dimensional diagrammatic representation of the steps to be undertaken in order to make a decision, solve a problem, or carry out a process. In short, it is a flowchart.

An example of the type of risk assessment algorithm that might be used is shown in Figure B-7(c).

How to Use the Algorithm. Starting with box 1, we first identify the most flammable material in the building and ask the question, "Can it be removed?" If the answer is yes, we remove it from the building. We can repeat this process until we have reached the point where no more flammable materials can be removed.

Moving on to box 2, we identify the most likely source of ignition and then ask the question, "Can it be separated from flammable materials?" If the answer is yes, we undertake the separation and then identify the next most likely source of ignition and repeat the question. As with box 1, we continue this question and answer process until no further separations can be achieved.

Apart from these first two steps, which constitute cyclical loops, all the other steps in the algorithm form a self-explanatory linear progression that will lead to the conclusion that the building is to be categorized as being of high, normal, or low risk.

B-8 Conclusions. Risk assessment techniques provide a valuable tool in attempting to categorize the degrees and severity of risk for which an institution might be liable. While no method is infallible, sensible use of risk assessment and application of the lessons drawn can result in more cost-effective introduction of fire-protective measures.

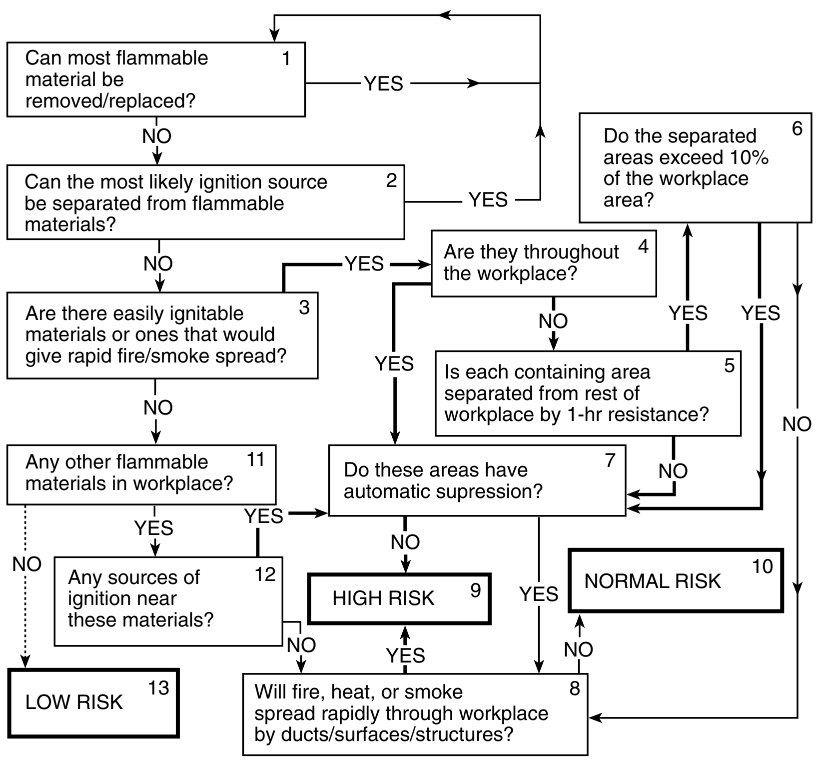

Figure B-7(c) A risk assessment algorithm.

Appendix C Compact Storage Fire Tests

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

C-1 Introduction. The test reports and summary included in this appendix provide fire size, site-specific information, storage configurations, and automatic fire suppression systems design information.

The following features were found to have a significant impact on this type of hazard:

(a) Fuel type and arrangement; for instance, a slow fire was observed in the 1979 tests in densely packed archive storage boxes (ordinary hazard sprinkler system design), and a fast fire growth was observed in the 1992 tests with loosely stored newspaper and corrugated cartons (extra hazard sprinkler system design)

(b) Configuration of storage including a gap between storage units

(c) Storage height

(d) Overhead clearance above storage

(e) Room height

(f) Open shelving versus closed shelving

(g) Sprinkler density and sprinkler response time

The following article, "Full-Scale Fire Tests and the Development of Design Criteria for Sprinkler Protection of Mobile Shelving Units," is from *Fire Technology,* Volume 30, No. 1 (1994).

Full-Scale Fire Tests and the Development of Design Criteria for Sprinkler Protection of Mobile Shelving Units

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Abstract

In early 1991, a new sprinkler system was planned for the existing National Archives/National Library of Canada building in Ottawa. A major challenge in the design and installation of the sprinkler systems was to protect mobile compact shelving units located in the three levels below grade. Storage of documents in these shelving units is typically within 178 mm of the concrete slab ceiling. The minimum clearance permitted by the sprinkler system installation standard is 457 mm from the sprinkler deflector to the top of the storage. To conform with the sprinkler design standard, the top level or levels of storage would have had to be removed and additional storage space acquired. Because of the annual cost of this additional storage, an investigation was begun to determine feasible alternatives that would permit a reduction in clearances between sprinklers and storage, while maintaining an acceptable level of fire safety. This paper describes the series of five full-scale fire tests that were conducted to assess various fire protection options. Based on these tests, design criteria were developed for a sprinkler system using quick response horizontal sidewall sprinklers to protect the mobile shelving units. An overview of this technically based fire protection system for use in protecting shelving units with reduced clearance is also presented.

Introduction

In early 1991, a new sprinkler system was planned for the existing National Archives/National Library of Canada building in Ottawa. A major challenge in the design and installation of the sprinkler systems was to protect mobile compact shelving units located in the three levels below grade in the building. Storage of documents in these shelving units is typically within 178 mm of the concrete slab ceiling. Since the minimum clearance permitted by the sprinkler system installation standard[1] is 457 mm from the sprinkler to the top of the storage, the potential impact on existing storage practices and space requirements for the National Archives/Library was significant. In order to comply with the sprinkler installation standard and to ensure adequate fire protection, the library faced the prospect of removing all storage from the top shelves and, in many cases, the top two shelving rows throughout the stacks. In addition to the library staff that would be needed to remove and reorganize files, there would also be considerable annual costs for additional storage space.

Because of the tremendous cost involved in fully protecting the building in accordance with the standard, Public Works Canada and the National Library of Canada began an investigation to determine feasible alternatives that would permit a reduction in clearances between the sprinklers and the storage, while maintaining an acceptable level of fire safety. The question was whether a sprinkler system could extinguish or control a fire in the shelving units, taking into consideration the specific geometry and nature of the fuel package.

Based on discussions with the Fire Commissioner of Canada, who was the authority having jurisdiction, it was determined that technically based alternatives to strict compliance with the applicable installation standard would be considered. However, any alternative arrangements would have to be evaluated on the basis of full-scale fire tests, which would demonstrate that the proposed sprinkler installation could extinguish or control a fire at least as well as an installation that conformed to the installation standard. This approach, based on equivalents, is allowed within the terms of the *National Building Code of Canada.*[2]

This paper describes the five full-scale fire tests that were conducted at the National Fire Laboratory's full-scale test facility near Almonte, Ontario. These tests were used to assess various sprinkler system options for protecting the compact shelving units. Based on the results of these tests, design criteria were developed for a fire protection system to be used in the basement levels of the library. This fire protection system would result in a minimal loss of effective storage space and was recommended to Public Works Canada as a technically based alternative.

Previous Work

Before the tests discussed in this paper were undertaken, two series of fire tests on compact mobile shelving units were conducted. The first series, conducted at Factory Mutual Research Corporation in 1978,[3] indicated that, with the available state-of-the-art sprinkler technology, the records stored in the shelving were substantially damaged by the fire despite "successful" sprinkler operation.

The second series of fire tests was conducted at Underwriters Laboratories Inc. in 1989 to develop the sprinkler protection system for a new U.S. Archives building in Washington, D.C. (Archives II). These tests showed that quick response sprinklers, along with enhancements in the operation and construction of the mobile shelving units, could limit fire damage to the archival records located near the ignition source.[4]

The sprinkler system developed for Archives II was intended for use in a new facility designed to meet current codes and standards. As such, it was possible to specify the requirements for both the sprinkler system and the shelving units to provide an optimum fire protection system. The sprinkler system developed as part of this current study was intended for retrofit in an existing facility in which a sprinkler system could not be installed to meet installation standards without a substantial loss of storage capacity.

Description of Hazard

The mobile stack units present in the basement levels of the National Library were "Compactur" mobile shelving units.* These were entirely open units; that is, the shelves had no tops, and there were no internal partitions. The shelving units were typically 4.6 m long. Fixed shelves were spaced approximately 6.1 m on center, with five to seven mobile shelves between them (see Figure 1).

The basic stack units were arranged to provide access aisles 1.2 m wide at the ends of the shelves. There was minimal clearance between the shelving units of stack arrays adjacent to walls and the walls themselves. Access to these stack arrays was from one end only.

Each mobile shelving unit consisted of a mobile carriage mounted on rails (see Figure 2). Six upright columns equispaced along the center line of the carriage were used to support cantilever shelves mounted on both sides. Typically, there were six levels of shelving mounted on each unit, for a total of 60 shelving sections per unit.

The contents of the shelves were predominantly paper documents, such as letters, reports, memos, and journals, stored in corrugated cardboard document boxes with closed lids. There were a number of plastic plan canisters in the building, but these were confined to a limited area and were not considered to represent a typical fuel load. There was no storage of micro-fiche, film, or cassettes.

*Certain commercial products are identified in this paper in order to adequately specify the experimental procedure. In no case does such identification imply recommendations or endorsement by the National Research Council, nor does it imply that the product or material identified is the best available for the purpose.

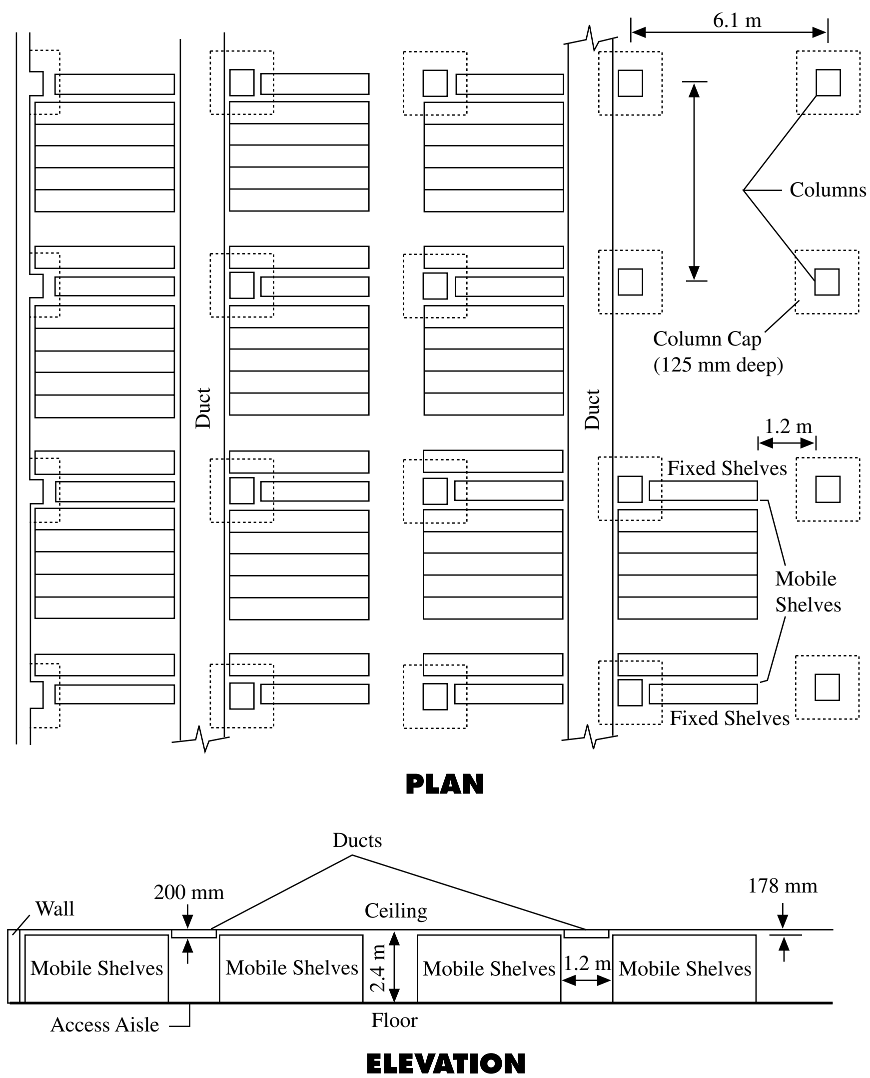


Figure 1. Layout for basement levels of National Library of Canada.

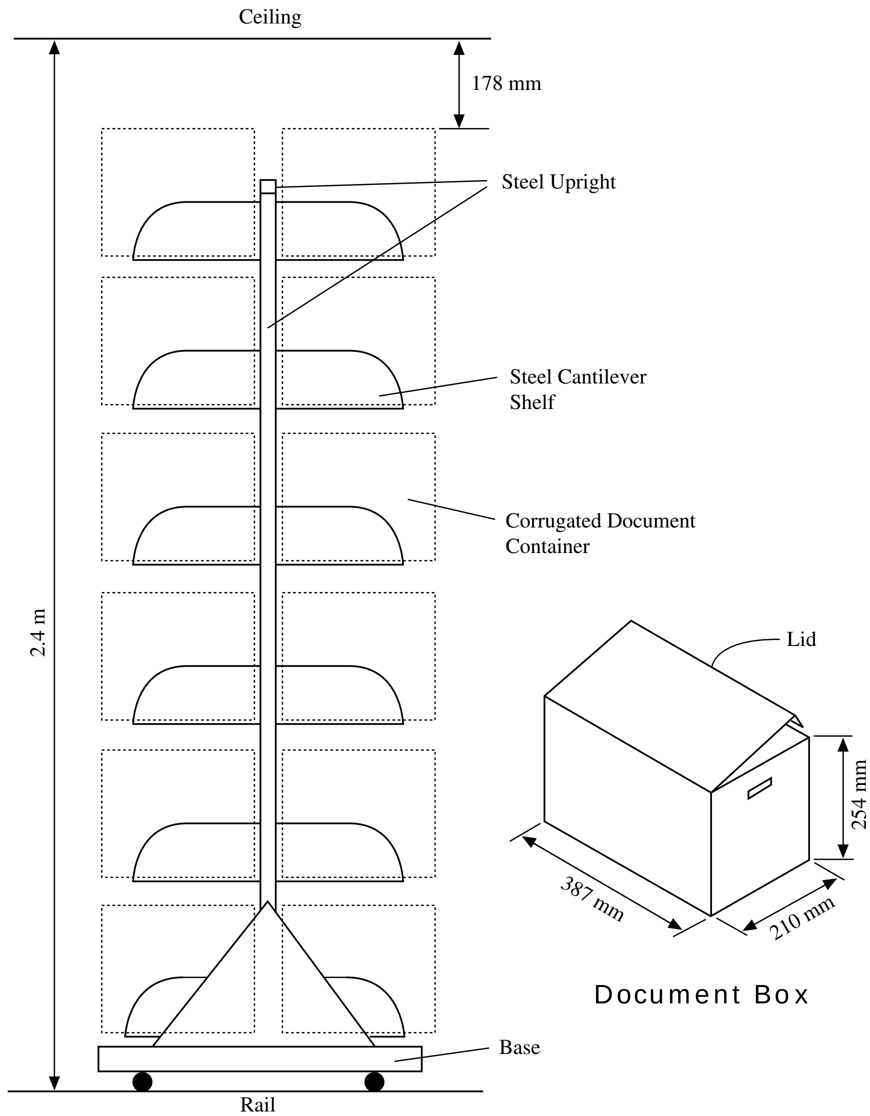


Figure 2. End view of mobile shelving unit.

The cardboard document boxes, which were 210 mm wide by 387 mm long and 254 mm high (see Figure 2), were packed side-by-side with four boxes on each shelf section and up to 240 boxes on each mobile unit. For the most part, they were partially filled with an average weight of 6.8 kg, including the box. The total fuel load on each mobile unit was thus approximately 1,650 kg. For a typical shelving area consisting of two fixed shelves and five mobile shelves, the fuel load density was approximately 375 kg/m^2 averaged over the shelving area.

In localized areas, there was also extensive storage of folded newspapers in open-topped, cloth-covered periodical boxes 102 mm wide by 228 mm long and 298 mm high. The average weight of each periodical box was 2.3 kg. When the shelves were closed, the boxes on adjacent mobile shelves were grouped so tightly that sprinkler spray could not penetrate below the top level. This was not the case where the mobile shelves faced fixed shelves, however. Rubber stops, which were placed at the ends of the rails to keep the mobile units from running off the tracks, also maintained a minimum clearance of 102 mm between the material stored on the fixed shelves and the first adjacent mobile shelf. The newspapers were packed tightly together in the periodical boxes. When the shelves were closed, the ends of the newspaper touched such that sprinkler spray could not penetrate below the top level.

The Test Facility

A full-scale mock-up of a shelving array typical of those found in the basement of the National Library was constructed at the National Fire Laboratory's full-scale test facility. The National Library of Canada provided typical shelving units that consisted of two fixed shelves and five double-row mobile units. The stack array covered an area approximately 4.6 mm by 6.7 m. The test facility is shown in Figures 3 and 4. As a basis for instrumentation and recording observations, each shelving section was labeled using an alphanumeric system. For this system, each side of a shelving unit was assumed to be a single row of shelves and was labeled alphabetically. The numbering system for Row H is illustrated in Figure 3.

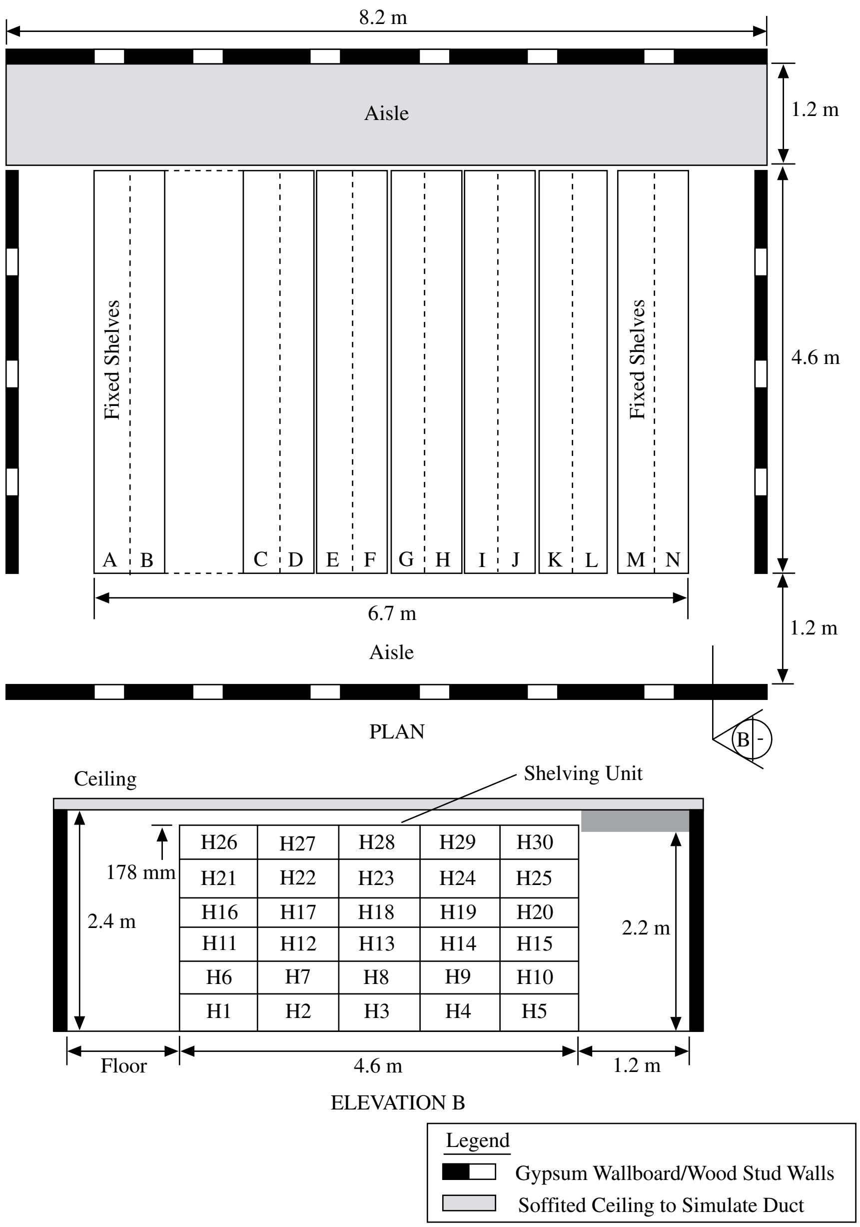


Figure 3. Test facility.

Four wall assemblies, constructed using wood studs and gypsum wallboard with approximately 25% of the wall area left uncovered, were positioned around the shelving bay to simulate adjacent shelving units. This partially closed perimeter was intended to replicate obstructions, such as adjacent columns and other stack units, that could affect air movement in the building. Two walls 4.6 m long were positioned 0.75 m from the fixed shelving unit to simulate mobile shelves in adjacent shelving bays. Two wall sections 8.2 m long were located 1.2 m from the sides of the shelving unit to simulate the normal access aisles and adjacent shelving bays.

The test facility was covered with a noncombustible ceiling assembly. The ceiling in the shelving area and above one corridor was 2.4 m high. In the other corridor, the ceiling height was reduced to 2.2 m to simulate the ventilation ducts that are located in every second corridor in the library and that are as wide as the aisle. There was minimal clearance (25 to 50 mm) between the sides of these ducts and the shelving units. The ducts act as barriers to the flow of hot gases and sprinkler spray; as such, they have a considerable impact on both the location and activation of the sprinklers.

A series of 600 mm square structure columns, with column caps 1.83 m square by 125 mm deep, were located throughout the basement, as shown in Figure 1. These columns, which are located at the end of the fixed shelving units, did not have an impact on the fire scenario used in the test program and were not simulated in the test facility. Because of the very limited clearances above the storage and the depth of the column caps, these columns limited the arrangement of sprinkler piping in the library and had to be taken into account when the sprinkler system design criteria were developed.

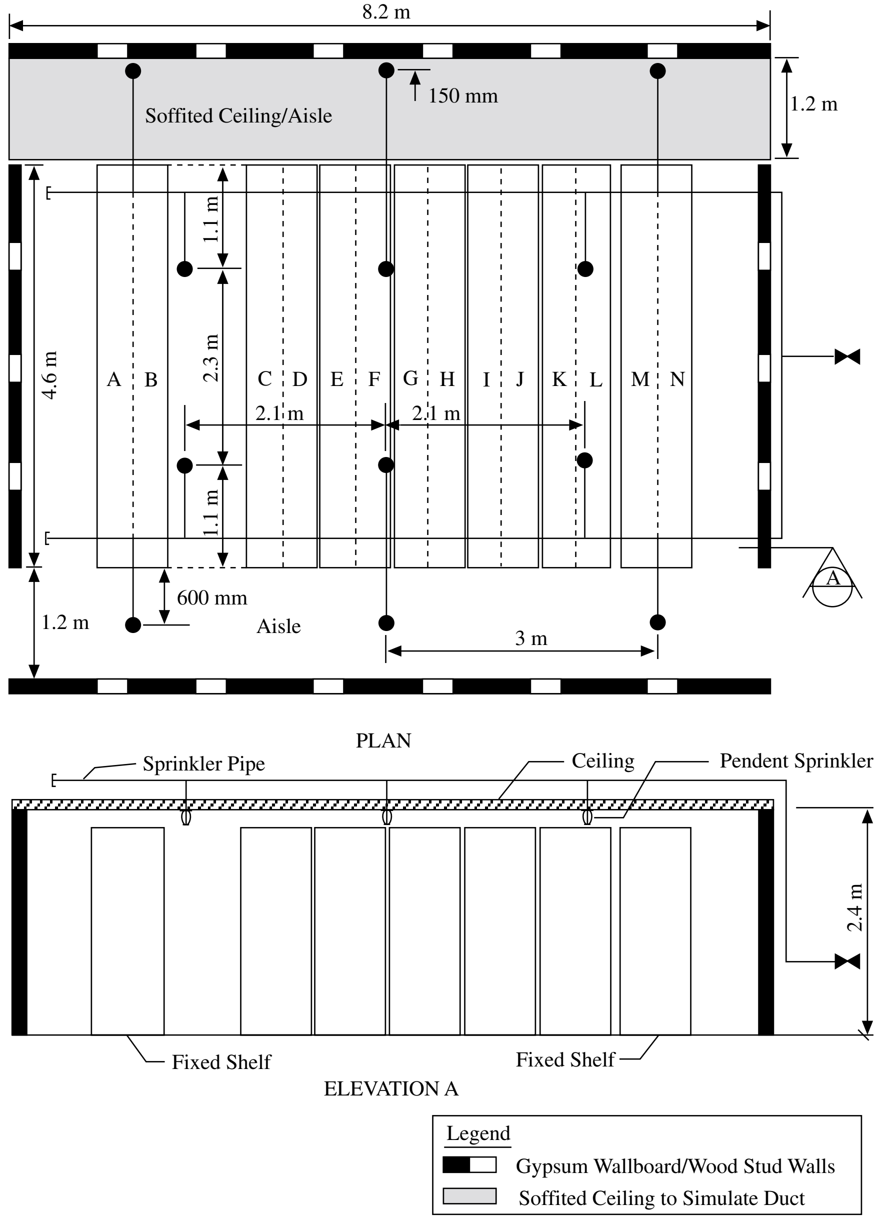


Figure 4. Pendent sprinkler layout.

Fire Scenario

Based on an assessment of the hazard as a result of the observations in the library, an initial worst-case fire scenario was developed for the full-scale fire tests:

1. All the mobile units would be pushed tightly together with minimal or no space between the storage on adjacent shelves.

2. The fire would start at the bottom center of the closed mobile units at the maximum distance from the nearest sprinklers. Such a fire could involve the maximum fuel before sprinkler activation. It would also be in the area to which there would be the least amount of sprinkler penetration.

3. The shelving units and the fuel load would be typical of that observed in the library.

4. A fuel load combination consisting of the open newspaper storage on the mobile units adjacent to the fire source and document boxes on the remaining shelves was thought to present the maximum challenge to the sprinkler system. In developing this scenario, it was assumed that the exposed edges of the newspaper would result in a very rapid initial fire spread. This rapidly developing fire could burrow into areas with high fuel load densities (the document boxes), thus posing the possibility of a sustained, high-severity fire.

5. The clearance between the ceiling and the top level of storage on the shelves would be 178 mm + 25 mm.

Despite the fact that there were areas in the library where there were clearances of only 102 mm, the 178 mm clearance for the initial tests was chosen for two reasons. First, Public Works Canada and the National Library of Canada asked that on-off sprinklers be used for the first sprinkler system tested, and such sprinklers are quite large in comparison to conventional pendent sprinklers. Assuming commercially available copper fittings and the copper tubing installed as close to the concrete ceiling as possible, along with the dimensions of the specified sprinkler, it was estimated that the sprinkler deflector would be a minimum of 133 mm below the ceiling in the closed position. When activated, the deflector extended 18 mm further. The specified clearance of 178 mm thus provided a minimum 25 mm clearance between the sprinkler deflector and the top of the storage. Second, the library would have had to remove the top level of shelves to provide a clearance greater than 178 mm.

Thus, the specified clearance of 178 mm would provide at least a minimum clear space for the development of the sprinkler spray without reducing the storage capacity in the library.

Sprinkler Layouts

The first sprinkler arrangement used pendent sprinklers to protect the stack area (see Figure 4). In developing the pendent sprinkler layout, it was assumed that the combination of the following factors would make it very difficult to get effective sprinkler coverage for all areas:

1. The minimal clearance between the sprinkler deflector and the material on the top shelves, and

2. The presence of obstructions such as light fixtures and column caps in the library stack areas.

In an attempt to improve the sprinkler coverage in the confined space between ceiling and storage, the sprinklers were spaced much closer together than would normally be the case for an NFPA 13 sprinkler system (see Figure 4). Each sprinkler covered an area of less than 4.5 m^2; normally, they would be permitted to cover up to at least 12 m^2 for this occupancy.

The on-off sprinklers were installed with the deflector 133 mm below the ceiling in the closed position. In the operating position, the deflector was 151 mm below the ceiling, providing a clearance of 27 mm between the sprinkler and the top of the storage. The quick response sprinklers were installed with the deflector 125 mm below the ceiling. This provided an additional 26 mm clearance between the top of the storage and the sprinkler.

The second sprinkler arrangement used horizontal sidewall sprinklers (HSW) to protect the stack array (see Figure 5). Even though NFPA 13, *Standard for the Installation of Sprinkler Systems*, does not recognize the use of horizontal sidewall sprinklers in this configuration, it was anticipated that HSW sprinklers would be able to provide a uniform spray distribution in the 178 mm clear space. The layout for the horizontal sprinklers was designed to maximize water spray coverage and minimize the possibility of spray from one sprinkler delaying the activation of adjacent sprinklers. To achieve this, the sprinklers were arranged in a staggered array on opposite sides of the shelving units. On the side of the stack array with three sprinklers, the two end sprinklers were centered on the gap between the fixed shelving unit and the first mobile unit. This ensured maximum water spray penetration into the one area where, because of the stops installed on the rails, relatively "good" penetration of water spray to the lower shelving levels was possible. The third sprinkler on that side was located on the center of the shelving array, giving a 2.6 m spacing between the sprinklers. The two sprinklers on the opposite side of the stack array were staggered so as to be exactly half way between the sprinklers on the opposite side.

For the initial tests with horizontal sidewall sprinklers, the sprinklers were installed with the deflectors a nominal 100 mm ± 12 mm below the ceiling. This is in accordance with the standard for the installation of sidewall sprinklers.[1] The distance between the ceiling and the top of the storage was 178 mm.

The fifth test investigated the possibility of providing sprinkler coverage over a stack array with only 100 mm clearance instead of 178 mm. In this test, the HSW sprinklers were positioned closer to the ceiling, with a nominal 50 mm clearance between the ceiling and the sprinkler deflector. It was thought that this arrangement could be achieved with commercially available fittings, and it ensured that the sprinkler deflector was at least 25 mm above the top level of storage.

In order to maximize spray coverage, the horizontal sprinklers were positioned with the deflectors as close as possible to the end of the shelving array. For the end with the HSW sprinkler against the aisle duct (soffited ceiling), it was assumed that, using commercially available hardware, the sprinkler would protrude 150 mm to 200 mm into the shelving array.

For both sprinkler layouts—that is, those using either pendent or HSW sprinklers—six pendent sprinklers were used in the aisles. These sprinklers were located at the centers of the fixed shelves and at the center of the stack array, giving a nominal spacing of 3.05 m along the length of the aisle. For the aisle with the higher ceiling, the three sprinklers were positioned on the center line of the aisle. In the second aisle, where the duct reduced the headroom, it was assumed that the sprinklers would be positioned near one side of the aisle for safety purposes. For the purpose of this test program, a worst-case scenario with the sprinklers positioned along the side of the corridor opposite the test array was selected. The pendent sprinklers under the duct were installed with the deflector 133 mm below the duct for the on-off sprinklers and 125 mm below the duct for the quick response sprinklers.

The sprinkler system was connected to the laboratory's 2,080 L/min fire pump with a maximum static pressure of 895 kPa. Provisions were made to control and measure the pressure and water flow rate at the base of the 50 mm diameter riser used to feed the test facility's sprinkler system. A series of flow measurement tests was carried out to map the water supply/demand curves for the system. These tests indicated that, for the five to seven sprinklers that typically activated during these tests, maximum flow rates of 870 to 1,040 L/min at pressures of 669 to 552 kPa could be supplied to the sprinkler system.

The specifications for the sprinklers used in all tests are given in Table 1. The two quick response glass-bulb-type sprinklers were from the same manufacturer.

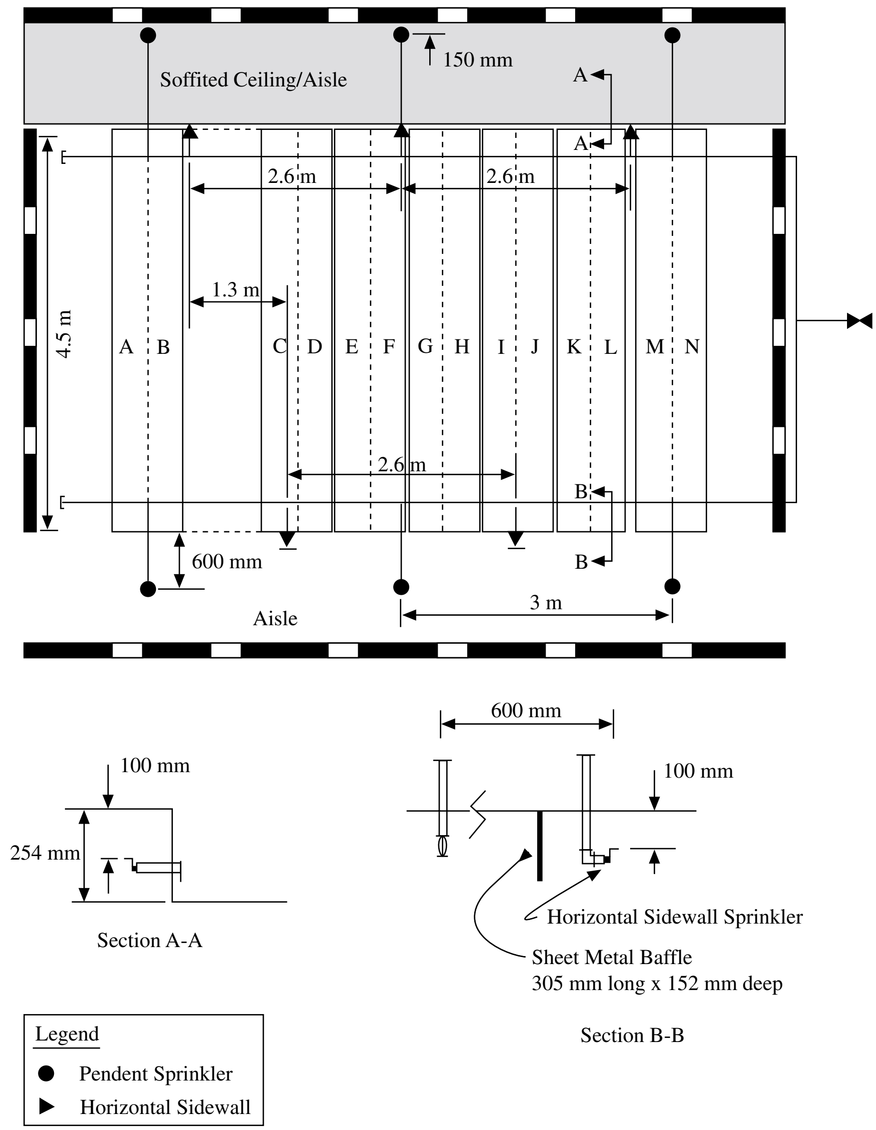


Figure 5. Horizontal sidewall and pendent sprinkler layout.

Table 1 Sprinkler Specifications

Sprinkler	Activation Mechanism	Temperature Rating (°C)	Orifice (mm)	K-factor (L/min/(bar)$^{1/2}$)
On/off pendent	Fusible alloy	60	12.5	80
	Bimetallic disk	74		
QR pendent	Glass bulb	68	12.5	80
QR horizontal sidewall	Glass bulb	68	12.5	80

Spray Distribution Tests

Preliminary spray distribution tests were conducted with the three types of sprinklers used for the full-scale tests. These tests concentrated on the sprinklers' ability to wet the top level of storage on the shelving array. The assessments were qualitative in nature, with the primary criterion being the ability of the sprinklers to wet the corrugated document boxes placed on the top level of shelving. No effort was made to determine the actual water spray distribution. However, these tests did play an important role in determining the sprinkler flow rates used for the full-scale tests.

On-Off Pendent Sprinklers

The spray distribution test was conducted with three of the four sprinklers closest to the fire source. The sprinklers were mechanically "opened," and the flow was initially set at an average of 58 L/min each. At a "K" factor of 80 L/min/

(bar) $^{1/2}$, the pressure at each sprinkler was approximately 50 kPa, which is the minimum pressure necessary to operate according to product listing/approval standards and NFPA 13. The average density at this flow rate was 12.2 (L/min)/m^2. This is higher than the minimum required by NFPA 13 but is consistent with the densities used to protect similar stack systems in the Archives II test series.[4] The test at this flow rate indicated that substantial portions of the upper level of the storage would receive minimal or no water spray.

In a second test, the average flow rate per sprinkler was increased to 84.4L/min, and the pressure was increased to 108 kPa. With the given spacing, this flow rate resulted in a density of 18.7 (L/min)/m^2, which is greater than the density NFPA 13 requires for facilities classified as "Extra Hazard." Although some improvement in the wetting pattern was observed, an unwetted area remained at the center of the sprinkler array.

With the limited clearance between the deflector of the on-off pendent sprinkler and the top of the storage and with the predominantly downward direction of the spray, most of the spray hit the boxes very close to the sprinkler. Wetting at the center of the sprinkler array was primarily due to splashing from the top of the boxes.

Based on the water spray tests, it was concluded that control probably would not be achieved using the lower flow rate. With the minimum spacing between the sprinkler deflector and the storage, it was also felt that any further increase in the flow rate would not result in a significant improvement in the spray pattern. As a result, the 84.4L/ min flow rate per sprinkler was chosen for the full-scale test.

Quick Response Pendent Sprinklers

Spray distribution tests were also conducted with the quick response (QR) pendent sprinklers. Three flow rates providing densities of 12.6 (L/min)/m^2, 15.8 (L/min)m^2, and 18.7 (L/min)m^2 were used. The results of these tests indicated that the added clearance provided by the low-profile sprinklers allowed for more effective wetting across the top of the storage than was achieved with the on-off sprinklers. However, wetting at the center of the array was only achieved with the higher flow rates. For Test 2, in which the QR pendent sprinklers were used, a density of 18.7 (L/min)m^2 was selected.

Quick Response Horizontal Sidewall Sprinklers

Spray distribution tests were carried out using only the three horizontal sidewall sprinklers closest to the fire source. Flow rates providing densities of 14.3 (L/min)/m^2 and 16.0 (L/min)m^2 were assessed. The horizontal sprinklers were able to provide uniform wetting over the entire shelf area at both pressures.

Sprinkler Response Times

Before the full-scale tests were conducted, the activation times for the pendent and horizontal sprinklers were estimated using the sprinkler/detector response model in FPETOOL.[5] For the fire scenarios used in the full-scale tests, the nearest pendent and sidewall sprinklers were 1.5 m and 2.5 m from the center line of the plume, respectively. An RTI of 28 (ms)$^{1/2}$ was assumed for both sprinklers.

For the sprinkler/detector response routine, the fire growth rate and the height of the ceiling above the fire must be input. With the limited flammability data available for the fuel package involved in the test, it was impossible to model the initial fire development. The four standard fire growth models—slow, medium, fast, and ultra-fast growth rates[5]—included with FPETOOL were used to compare the activation times for the pendent and horizontal sidewall sprinklers.

During preliminary tests with the fuel package in the test array, it was observed that, once it began, the fire spread rapidly upward on the material stored on the shelves above the fire source. Thus, there was fire at all levels of the shelving between the floor and the ceiling very early in the test. For these simulations, it was assumed that the base of the fire was located 1.5 m below the ceiling

The results for the four simulations using FPETOOL are shown in Table 2. These calculations were conducted using the 68°C quick response glass bulb sprinklers. Based on these results, it was estimated that the sidewall sprinklers would require 25% more time to activate than the pendent sprinklers. Since it was assumed that early sprinkler activation could be a crucial factor in controlling the fire, it was decided that the pendent sprinkler arrangement should be tested, even though it provided a very poor water spray distribution.

The results of the FPETOOL simulations were later confirmed by the full-scale tests. The temperatures measured at the sprinklers during the first 60 to 90 seconds of the full-scale tests were comparable to those calculated using the "fast" fire growth rate. The observed activation times for the sprinklers closest to the fire were comparable to those estimated by the computer model. That is, the pendent and sidewall sprinklers nearest the fire plume were typically activated within 50 to 60 seconds and 70 to 90 seconds, respectively, during the full-scale tests.

In addition to using FPETOOL to predict sprinkler response times, preliminary fire tests were conducted to assess the response times of the sprinklers. A propane gas burner, capable of generating 95 kW, was positioned in the same location as the ignition source for the full-scale tests. For these activation tests, sprinklers were mounted in the four pendent and three sidewall locations closest to the fire source. The horizontal sidewall sprinklers were located 1 m further from the fire source than the pendent sprinklers. The 95 kW heat release rate provided by the propane burner was lower than the minimum required to bring about early activation of the sidewall sprinklers. The sidewall sprinklers mounted in the open, below the smooth ceiling, required considerably more time to activate than the pendent sprinklers. However, it was noted that the sidewall sprinklers which were mounted against the duct at the low ceiling side of the test facility activated approximately 50% earlier than the sprinklers mounted in the open on the opposite side of the stack unit. It was decided, therefore, to mount a sheet metal baffle 152 mm deep behind the horizontal sprinklers located on the side of the shelving unit with the smooth ceiling. This baffle was intended to provide the same effect as the soffit created by the duct. The baffles also minimized the possibility that back spray from the sidewall sprinklers would affect the aisle sprinklers.

Table 2 Sprinkler Activation Times for 68°C Quick Response Glass Bulb Sprinklers

Distance from Fire Source (m)	Minimum Fire for Activation (kW)	Activation Time Medium Fire (s)	Activation Time Fast Fire (s)	Activation Time Ultrafast Fire (s)	Sprinkler Activation Fire Tests (s)
1.5	67	106	62	36	50-60
2.5	112	134	78	46	70-90

Full-Scale Tests

It should be emphasized that this was an engineering study directed at developing a sprinkler system that would provide protection equivalent to that intended by compliance with standards. This paper will not give detailed results for each of the five full-scale tests conducted. Instead, it will emphasize those results and observations that illustrate the sprinkler system's ability—or, in some cases, inability—to control or extinguish the fire.

For all full-scale tests, ignition was provided by 500 mL of 95% ethanol placed in a pan, measuring 305 mm, that was placed at floor level. This represented a small, low-heat release, flaming ignition source with minimal impact on sprinkler activation. The alcohol fire was started with an electric igniter which was remotely operated.

Instrumentation

Thermocouples were mounted at various locations in the test facility to monitor the temperatures within the stack array and at the ceiling. The locations of the thermocouples for the tests with pendent sprinklers (Tests 1 and 2) and for the tests with sidewall sprinklers (Tests 3, 4, and 5) are shown in Figures 6 and 7, respectively.

Thermocouples were mounted at two levels within the stack array, as shown in Figure 8. These thermocouples not only monitored the temperature within the stack array, but also gave an indication of fire spread along the row of fire origin and between mobile shelving units. (A particular concern noted during the evaluation of the hazard in the library was the possibility of a shielded fire in the lower levels spreading horizontally into adjacent shelving units.) The thermocouples were installed with the wire attached to the center of a shelving section and the thermocouple bead 12.5 mm below the outer edge of the shelf to measure the air temperature in the open space between two levels of shelving. The thermocouples were cross-referenced to the alphanumeric system used for labeling the shelving sections (see Table 3) with the shelving designation indicating that the thermocouple was positioned in the open space above the storage on the specified shelving section. In Test 1, for example, Thermocouple 20, shown in Figure 6, was located in the open space above the boxes on Shelf H13 and was thus at mid-level in the shelving unit directly above the initial fire source.

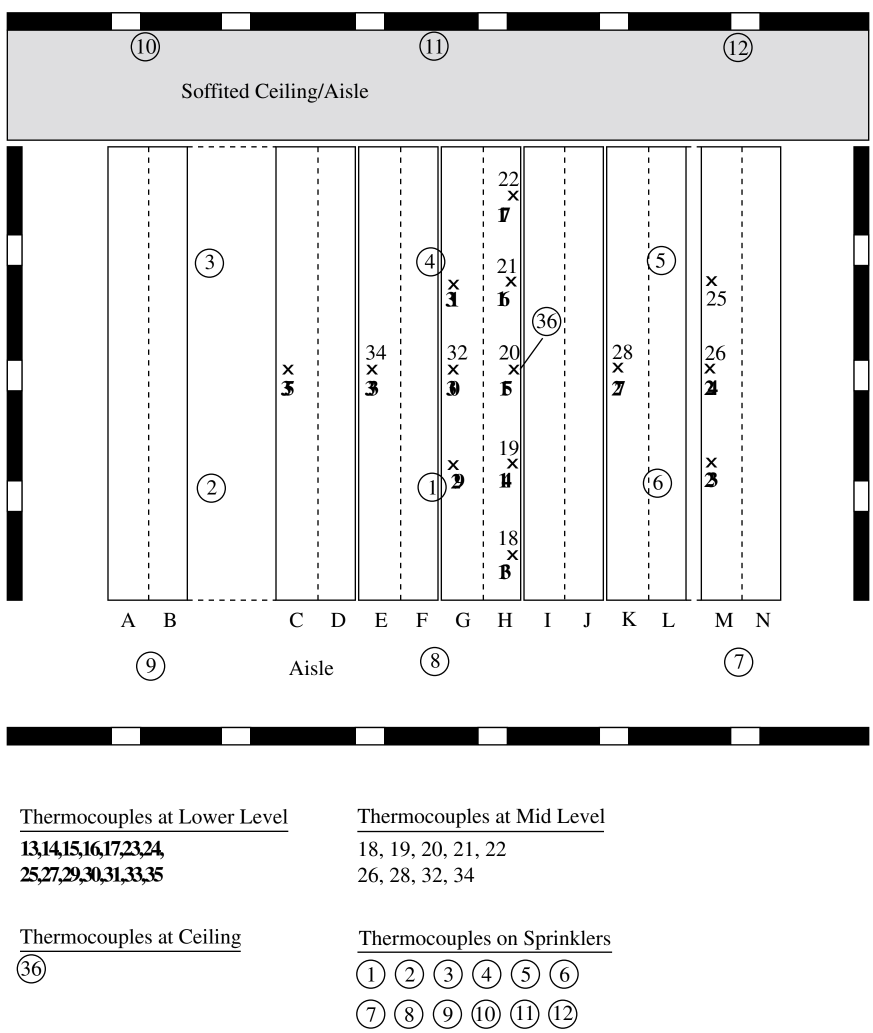
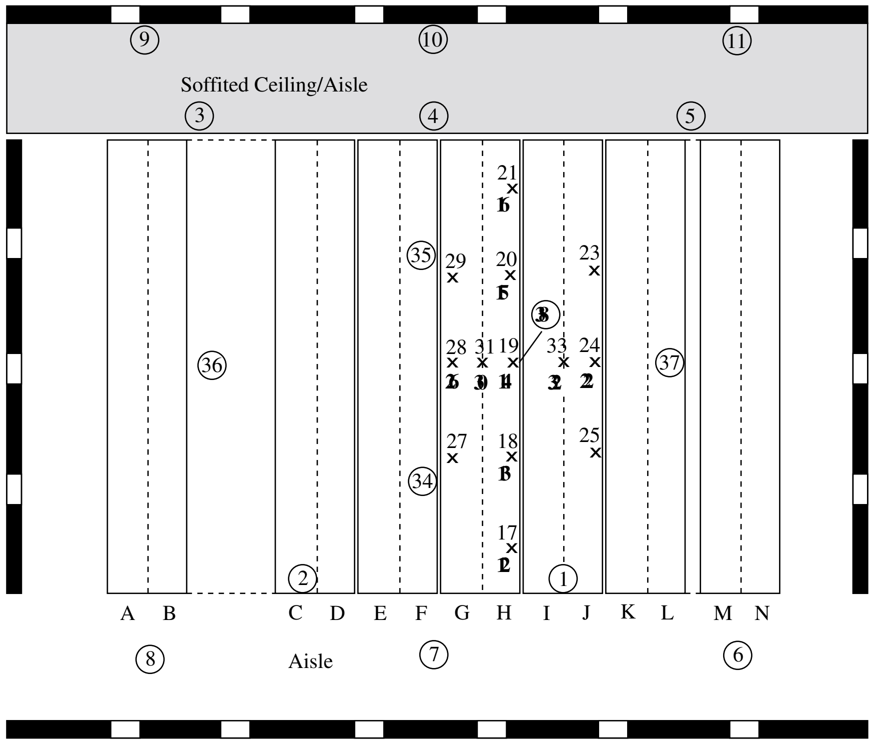


Figure 6. Thermocouple locations for Tests 1 and 2.



Thermocouples on Barrier
Mid-level **30, 32**
Upper level 31, 33

Thermocouples on Sprinklers
1 2 3 4 5 6 7
8 9 10 11

Thermocouples at Ceiling
34 35 36 37 38

Thermocouples at Lower Level
12,13,14,15,16,22,26

Thermocouples at Mid Level
17, 18, 19, 20, 21, 23
24, 25, 27, 28, 29

Figure 7. Thermocouple locations for Tests 3, 4, and 5.

For Tests 3, 4, and 5, four thermocouples were used to monitor the temperature on the non-fire side of the barriers that were installed in the center of the two mobile units on either side of the fire source. These thermocouples are labeled 30, 31, 32, and 33 in Figure 7. For each barrier, thermocouples were placed on the vertical centerline of the barrier at mid-height and at the fifth shelving level above the floor.

Thermocouples were also placed near each sprinkler. These thermocouples were used to not only monitor the temperatures at the ceiling, but also to record when the sprinklers operated. For the on-off sprinklers, the thermocouples were located just below the deflector in the closed position. For all other tests, the thermocouples were located near, but not in contact with, the sprinkler elements.

For all the tests, a thermocouple was located at the ceiling directly above the fire source. For Tests 3, 4, and 5, additional ceiling thermocouples were installed to monitor the temperature above the stack array. The location of these thermocouples is shown in Figure 7.

Provisions were also made to measure the smoke obscuration in the test facility using He-Ne lasers. In all tests, the obscuration was measured at the 1.5 m level in an access aisle. For this measurement, the laser was positioned at one end of the test facility. The measuring diode was positioned at the opposite end of the aisle 8.2 m away. A collimator was used to minimize beam divergence. For all tests, the mobile units were placed close together and positioned near one of the fixed units. This arrangement left a space of approximately 1 m between the other fixed shelf and the nearest mobile unit. In Tests 1 and 2, the smoke obscuration was measured in this open area. For this measurement, the He-Ne laser was mounted at the 1.5 m level at one side wall of the test facility. The detector was positioned at the opposite side of the facility.

Test 1: On-Off Pendent Sprinkler

As indicated previously, the analysis of the hazard in the library indicated that folded newspapers stored in periodical boxes could result in the most rapid fire spread and, thus, the most challenging fire scenario for the sprinklers. For the initial test, the mobile shelving units on either side of the fire source were completely filled with newspapers (Rows G, H, I, and J in Figure 9). The remaining shelving rows were filled with partially filled document boxes. The alcohol pan ignition source was located at the center of the closed units between Rows H and I.

Table 3 Thermocouple Locations

Channel Number	Location Tests 1 and 2	Locations Tests, 3, 4, and 5
1	Sprinkler 1	Sprinkler 1
2	Sprinkler 2	Sprinkler 2
3	Sprinkler 3	Sprinkler 3
4	Sprinkler 4	Sprinkler 4
5	Sprinkler 5	Sprinkler 5
6	Sprinkler 6	Sprinkler 6
7	Sprinkler 7	Sprinkler 7
8	Sprinkler 8	Sprinkler 8
9	Sprinkler 9	Sprinkler 9
10	Sprinkler 10	Sprinkler 10
11	Sprinkler 11	Sprinkler 11
12	Sprinkler 12	Shelving Section H1
13	Shelving Section H1	Shelving Section H2
14	Shelving Section H2	Shelving Section H3
15	Shelving Section H3	Shelving Section H4
16	Shelving Section H4	Shelving Section H5
17	Shelving Section H5	Shelving Section H11
18	Shelving Section H11	Shelving Section H12
19	Shelving Section H12	Shelving Section H13
20	Shelving Section H13	Shelving Section H14
21	Shelving Section H14	Shelving Section H15
22	Shelving Section H15	Shelving Section J3
23	Shelving Section M2	Shelving Section J12
24	Shelving Section M3	Shelving Section J13
25	Shelving Section M4	Shelving Section J14
26	Shelving Section M13	Shelving Section G3
27	Shelving Section K3	Shelving Section G12
28	Shelving Section K13	Shelving Section G13
29	Shelving Section G2	Shelving Section G14
30	Shelving Section G3	G13 Barrier (non-fire side)
31	Shelving Section G4	G23 Barrier (non-fire side)
32	Shelving Section G13	J13 Barrier (non-fire side)
33	Shelving Section E3	J23 Barrier (non-fire side)
34	Shelving Section E13	Ceiling
35	Shelving Section C3	Ceiling
36	Ceiling above ignition source	Ceiling
37		Ceiling
38		Ceiling above ignition source

After ignition, the flames rapidly involved the newspapers above the fire source. Within 50 seconds, the four pendent sprinklers nearest the fire source–Sprinklers 1, 4, 5, and 6–were activated (see Figure 6). Eventually, Sprinklers 3, 7, and 9 were also activated.

Despite the early response of the sprinklers, the fire continued to spread the length of Rows H and I on all levels and eventually involved the entire fuel load in these rows. There was also very early involvement in Rows F, G, J, and K. Within 6 minutes, it was clear that the sprinklers were not going to control the fire, and the test was terminated.

The lack of control is illustrated by some key temperature measurements. First, the temperature at the ceiling directly above the fire remained above 600°C, even with the four closest sprinklers operating (see Figure 10). Second, there was rapid fire spread at the mid-height of the row of fire origin, with sustained flames and temperatures of 800°C throughout the length of the row within 3 minutes 30 seconds (see Figure 11). Finally, there was rapid fire spread to the next mobile unit (Row K) with sustained temperatures of 700°C measured at the mid-height within 3 minutes (see Figure 12). The temperature measured at the lower level indicated substantial fire penetration within 3 minutes and sustained temperature of 700°C within 5 minutes.

Based on a review of the test observations, videos, and temperature data, the major findings for Test 1 are summarized as follows.

As expected, the fire involvement of the open, folded newspapers was rapid and sustained, despite early sprinkler activation and the use of relatively high sprinkler flow rates. The high percentage of exposed surfaces of combustibles throughout the stacks resulted in very rapid fire spread along the row of fire origin and to adjacent shelving units.

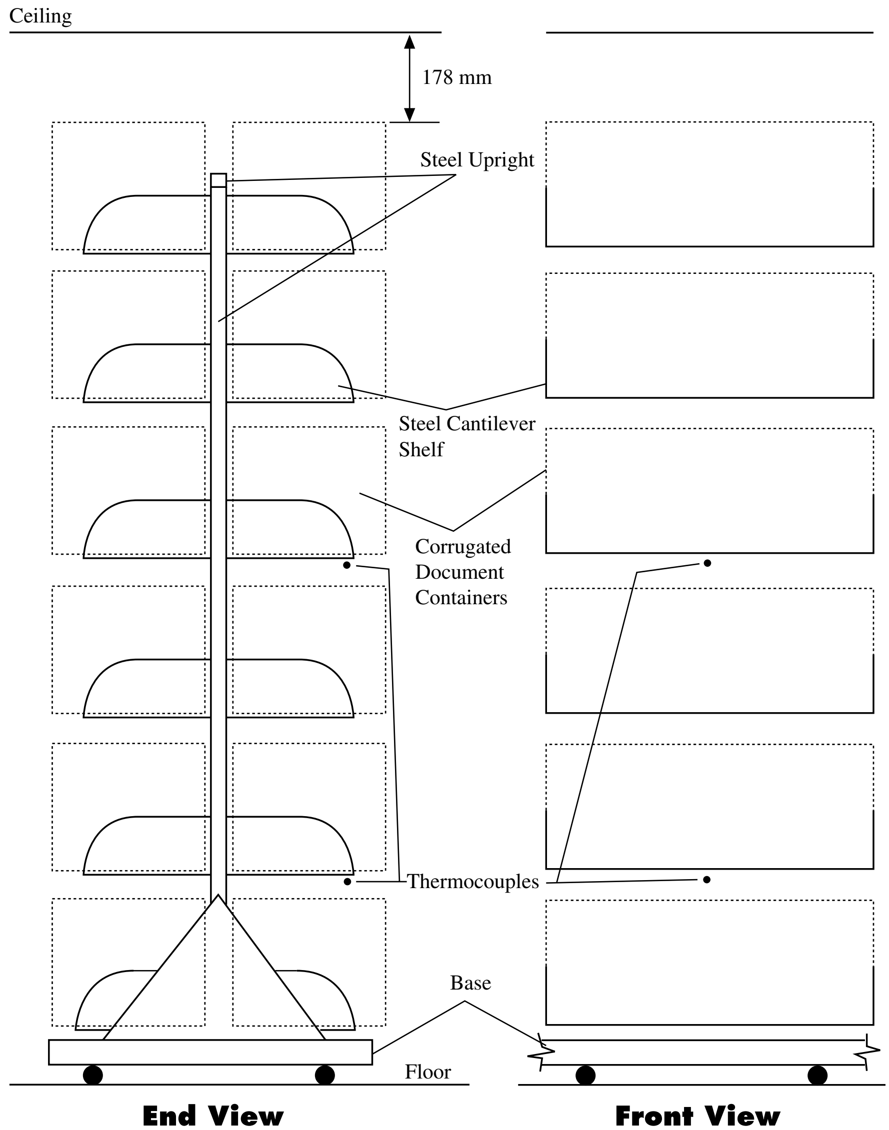


Figure 8. Thermocouple locations on mobile units.

The close proximity of the fuel on adjacent shelves, with the shelves in the closed position, allowed the fire to spread readily without the sprinkler spray being able to penetrate and cool the fire. Sustained temperatures of 700°C and higher were measured within the stack array.

It was also noted that tremendous quantities of smoke were generated during the test. The entire 20,400 m^3 volume of the burn hall was filled within a few minutes of ignition. It is possible that the ink content of the newspapers contributed to the production of the thick, dark smoke. It was also noted that the cooling effect provided by the sprinklers resulted in a more rapid build-up of smoke at lower levels of the burn hall. This smoke could present a threat to evacuation in the area of the fire and would probably make it difficult for the fire brigade to gain access to the area, find the fire, and complete extinguishment.

Test 2: Quick Response Pendent Sprinklers

Based on the results of Test 1, it was determined that it would be necessary to change the sprinkler arrangement to provide a more effective water spray coverage to the shelving area. In addition, it was determined that a part of the fire protection strategy would have to include modifications to the shelving units.

Three specific changes were incorporated into the test arrangement for Test 2. First, quick response pendent sprinklers were used for all areas of the test facility instead of on-off sprinklers. Second, the "worst-case" scenario with newspapers stored in open boxes was eliminated. It was recommended that the newspapers be stored in closed-top, corrugated cardboard document boxes similar to those used to store other materials. Third, sheet metal would be used to subdivide the shelving units lengthwise. It was expected that these barriers would act as firestops to slow the spread of fire between the rows of shelving. For Test 2, barriers were installed in the two fixed shelving units and in the center mobile unit, thus separating rows, AB, GH, and MN.

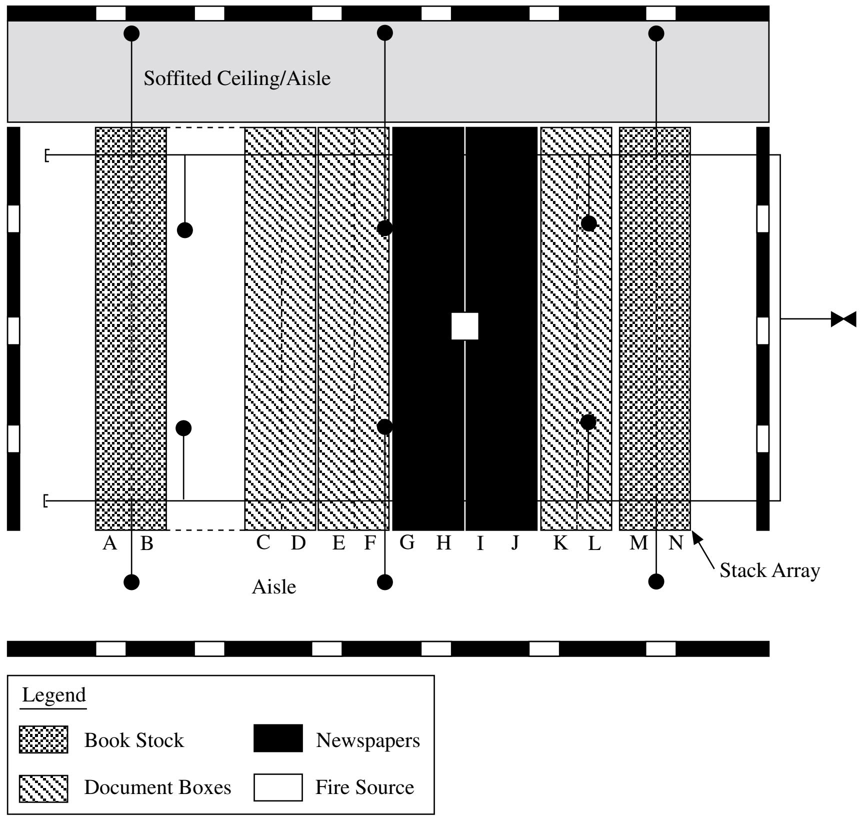


Figure 9. Fire scenario for Test 1.

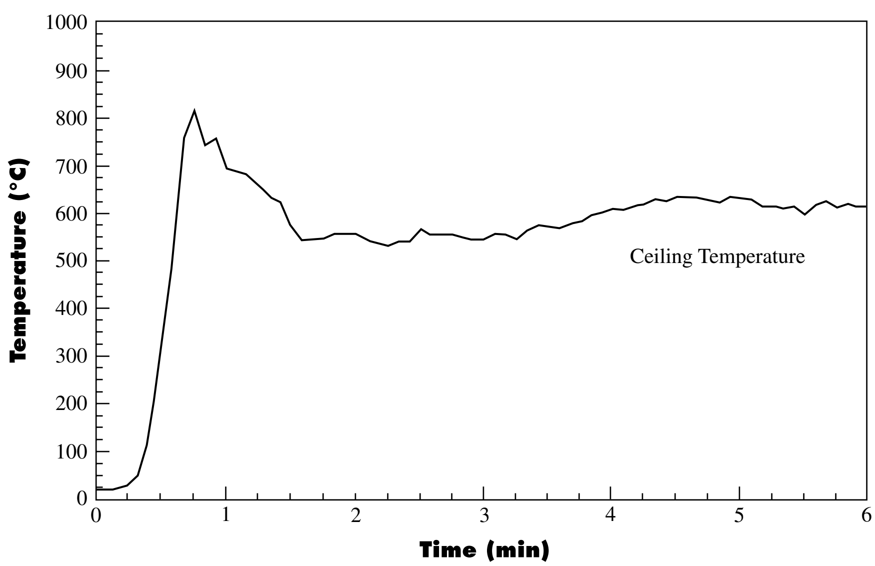


Figure 10. Ceiling temperature in Test 1.

All other conditions in Test 1 applied, except that it was considered unnecessary to completely load rows A, B, C, D, E, M, and N. The fire protection system would be deemed to have failed if the fire spread to these rows, and the test would be stopped. However, empty boxes were placed on the top level of all these shelving rows to ensure that the spray distribution from the sprinklers would not be compromised. The sprinkler flow rates were established to maintain a minimum density of 18.7(L/min)/ m^2, the same as that used in Test 1.

After ignition, the initial fire developed in the same pattern as the fire in Test 1, with a very rapid vertical fire spread on the boxes on Rows H and I above the ignition source. The four pendent sprinklers closest to the fire operated at approximately 50 seconds. Several aisle sprinklers activated later.

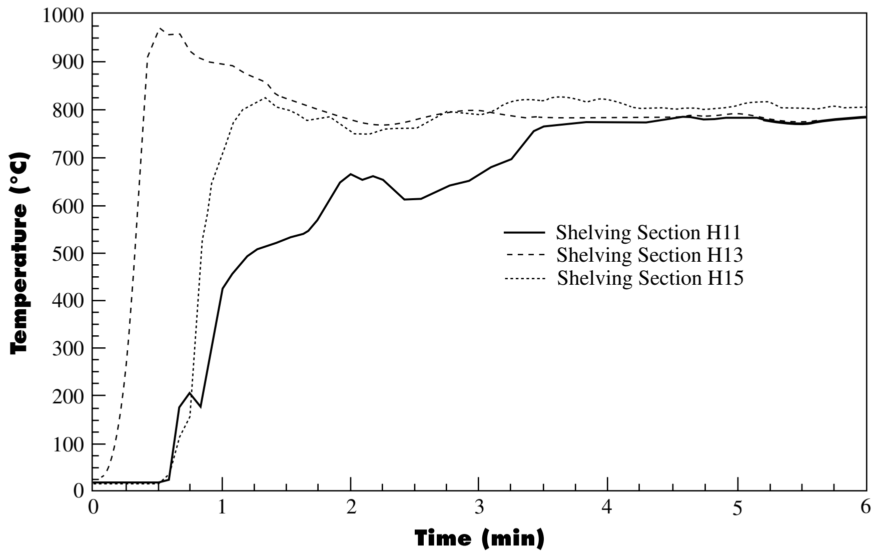


Figure 11. Shelving Section H temperatures in Test 1.

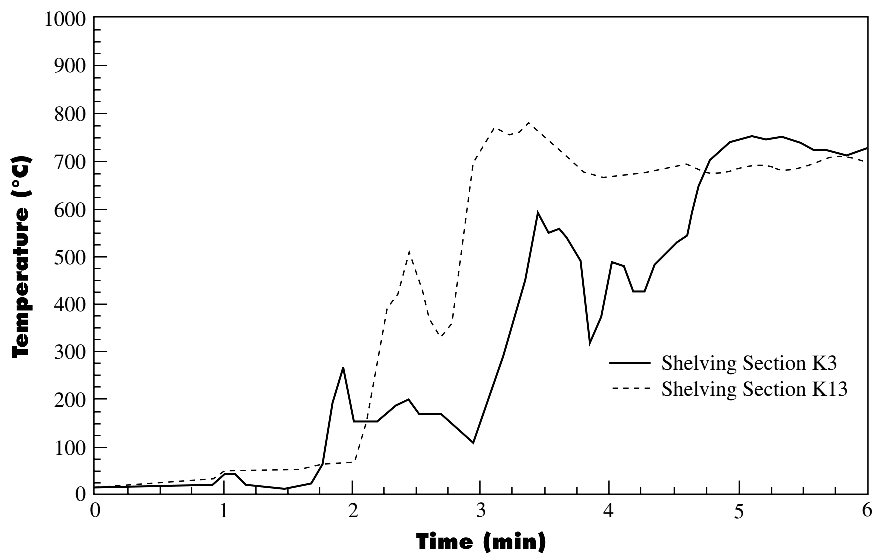


Figure 12. Shelving Section K temperatures in Test 1.

The spread of fire along the length of Rows H and I was very rapid and nearly as intense as the fire in Test 1 (see Figure 13). These results indicate sustained burning, with temperatures greater than 800°C at the mid-level of these rows after 6 minutes. There was also rapid fire spread to the adjacent rows (Row K) which were not protected by the steel barrier. This is illustrated in Figure 14, where sustained burning is indicated at the mid-level of Row K after 5 minutes and at the lower level after 9 minutes.

The fire barrier between Rows G and H delayed the fire spread to Row G. Figure 15 indicates that the barrier was penetrated at approximately 10 minutes, with sustained burning after 12 minutes.

The ceiling temperature directly above the ignition source is shown in Figure 16. After an initial "knockdown," the ceiling temperature increased slowly as the fire began to involve more fuel. Despite the continued operation of the sprinklers, the ceiling temperature began to increase rapidly after 6 minutes; sustained temperatures greater than 800°C were reached within 10 minutes.

Based on a review of test observations, videos, and temperature data, the major findings for Test 2 are summarized as follows.

First, with the mobile shelving units close together, the faces of the document boxes touched. The close-packed document boxes in adjoining units prevented sprinkler spray from reaching the burning fuel package stored on lower shelving levels. Despite the early response of the sprinklers, there was minimal "prewetting" of the boxes on the shelving rows adjacent to the fire rows.

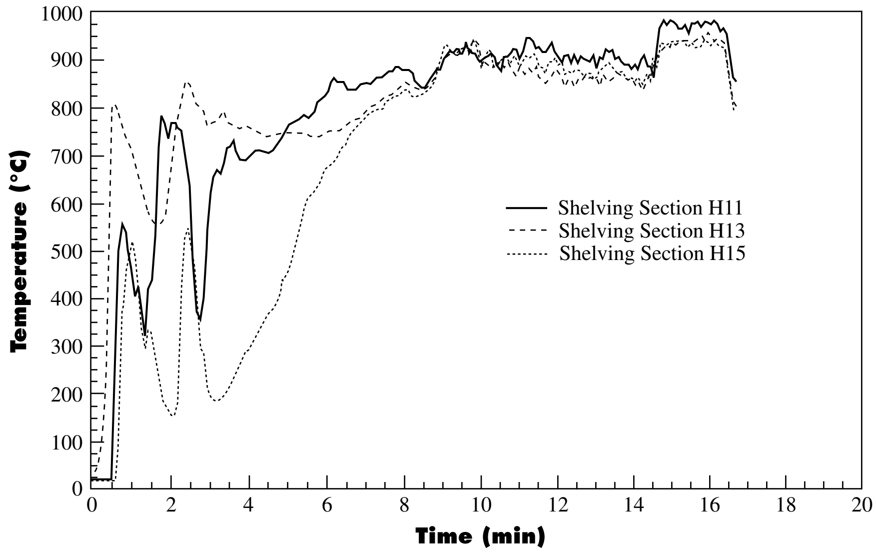


Figure 13. Shelving Section H temperatures in Test 2.

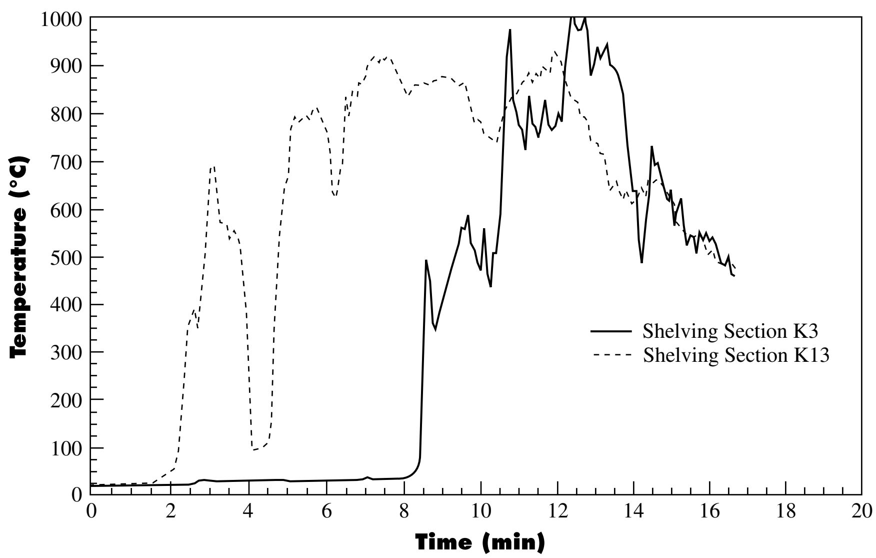


Figure 14. Shelving Section K temperatures in Test 2.

Second, there was relatively rapid fire spread on the corrugated cardboard document boxes, even though the removal of the open newspaper storage decreased the initial fire growth rate. The rapid involvement in the lower shelving levels allowed the fire to overcome the limited firestopping benefits of the single sheet-steel barrier. This barrier did delay fire spread by approximately 7 minutes, however.

Third, this storage represents a significant fire load, even though the boxes were only partially filled with documents. There was considerable structural damage to the shelving frames, and the shelves in the central portion of Rows I and J collapsed completely.

Test 3: Quick Response Horizontal Sprinklers

Test 3 was primarily intended to examine the ability of QR horizontal sidewall sprinklers to protect the shelving array (see Figure 5). QR pendent sprinklers were used to protect the aisle areas.

As a result of the analysis of Test 2, three further changes were made for this test. First, the fire barrier separating Rows G and H was upgraded to improve fire resistance. The barrier consisted of mineral insulating board 12.5 mm thick sandwiched between two 26-gauge sheet steel panels. In addition, a fire barrier consisting of two layers of 26-gauge sheet steel separated by a 3 mm air gap was installed between Rows I and J.

Next, spacers were used to prevent the mobile shelving units from closing so that adjacent storage touched. In this manner, a minimum 26 mm gap was maintained between the boxes stored on adjacent shelves.

Finally, the water flow rate was increased to provide a minimum density of 28.5 (L/min)/m^2 over the mobile shelving units.

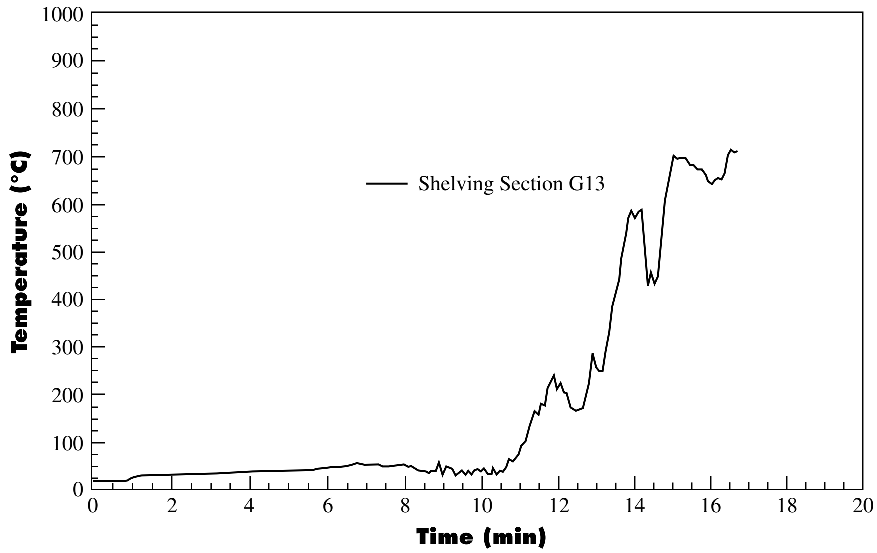


Figure 15. Shelving Section G temperatures in Test 2.

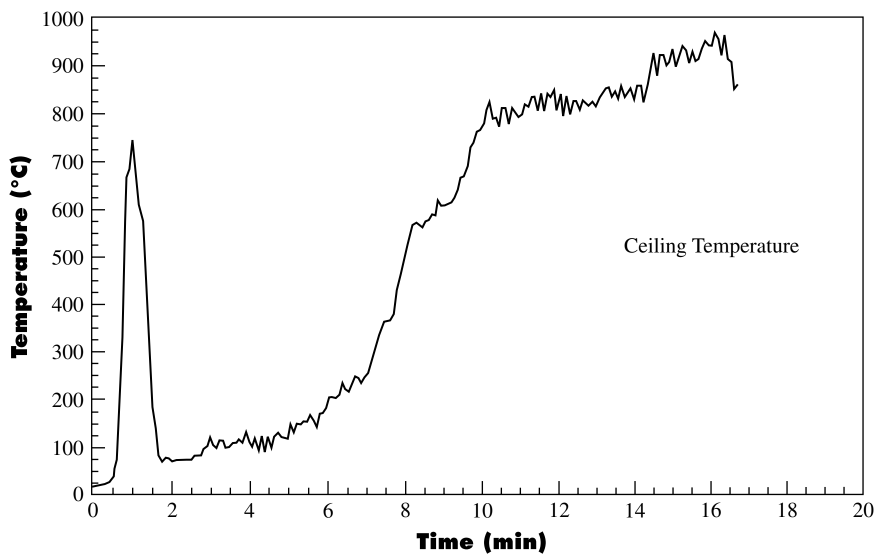


Figure 16. Ceiling temperature in Test 2.

After ignition, the initial fire developed in the same pattern as it did in Tests 1 and 2, with a very rapid vertical fire spread on the boxes on Rows H and I above the ignition source. The three closest horizontal sidewall sprinklers and one aisle sprinkler—Sprinklers 1, 4, 5, and 7 — operated between 1 minute 15 seconds and 1 minute 22 seconds after ignition (see Figure 7). The sprinklers were able to control and extinguish the fire quickly. This is illustrated by the rapid decrease in temperatures measured at the mid-level of Row H (see Figure 17) and at the ceiling directly above the fire (see Figure 18). The fire damage was limited to the center portions of Rows H and I.

The horizontal sidewall sprinklers, in combination with the fire barriers and the 26 mm gap between the mobile units, allowed for effective cooling and extinguishment in the initial area involved in the fire. Further, the high spray density, combined with the favorable water spray projection pattern, provided cooling at the ceiling and prevented the operation of an excessive number of sprinklers.

Test 4: Quick Response Horizontal Sprinklers at Lower Density

Test 4 was arranged to duplicate the conditions in Test 3, except the water flow rate was reduced. The initial flow rate was set to provide a density of 20.5 (L/min)/m^2.

The initial fire development duplicated the conditions observed in Test 3, with the sprinklers operating at precisely the same time. With the lower flow rate, however, the fire was not immediately extinguished. The temperatures measured at the mid-level of Row H indicate that there was sustained burning at the lower levels of Rows H and I (see Figure 19).

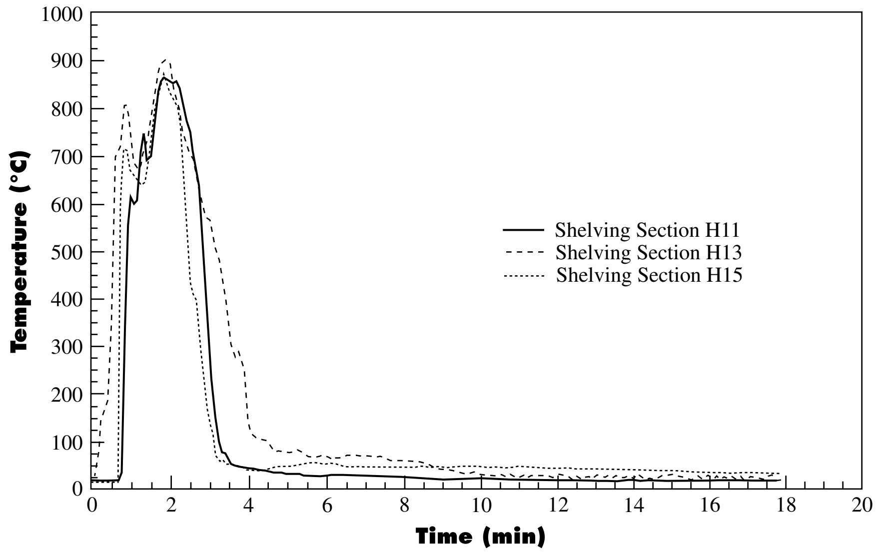


Figure 17. Shelving Section H temperatures in Test 3.

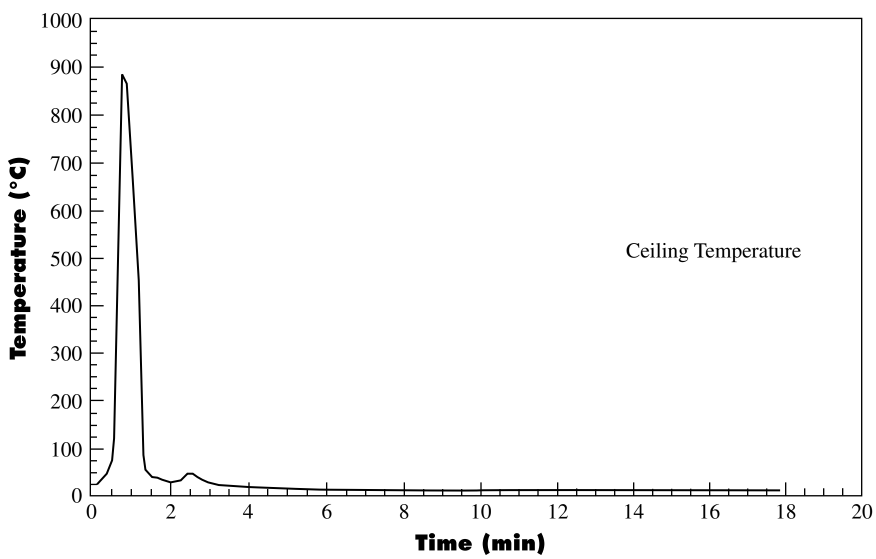


Figure 18. Ceiling temperature in Test 3.

The thermocouples mounted on the non-fire side of the fire barrier separating Rows I and J indicated that the fire penetrated this barrier at approximately 15 minutes (see Figure 20). However, this delay was sufficient to allow water to drip down the 26 mm gap between facing shelves and prewet the boxes on the lower levels. With the extended period of prewetting, the fire did not spread rapidly after breaching the barrier. There was a continued decrease in the temperatures in the stack array throughout the test.

At 25 minutes, the water flow rate was increased to 24.6 (L/min)/m^2. With the increased flow rate, the fire was extinguished within 5 minutes.

The results of Test 4 indicated that, with the reduced water application density, the HSW sprinklers were unable to rapidly extinguish the fire. However, the fire barriers limited initial fire spread, allowing for an extended period of prewetting throughout all levels of the shelving. The continued decrease in temperatures indicated that the sprinklers were able to control the fire. It is probable that the fire would have been extinguished eventually.

Taking into consideration the importance of limiting fire and water damage to the archival material, it was decided to recommend use of the higher density used in Test 3 to ensure complete extinction in the shortest possible time. This provided for a considerable degree of engineering safety for the system. In addition, the fire barriers and spacer blocks on the mobile shelving bases allowed effective prewetting of the fuel on the shelves surrounding the fire and were thus essential elements in the fire protection system.

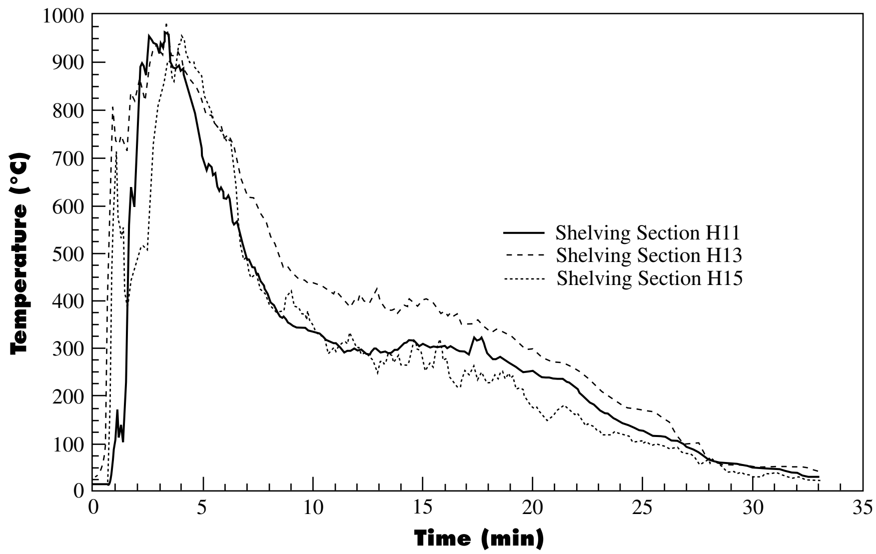


Figure 19. Shelving Section H temperatures in Test 4.

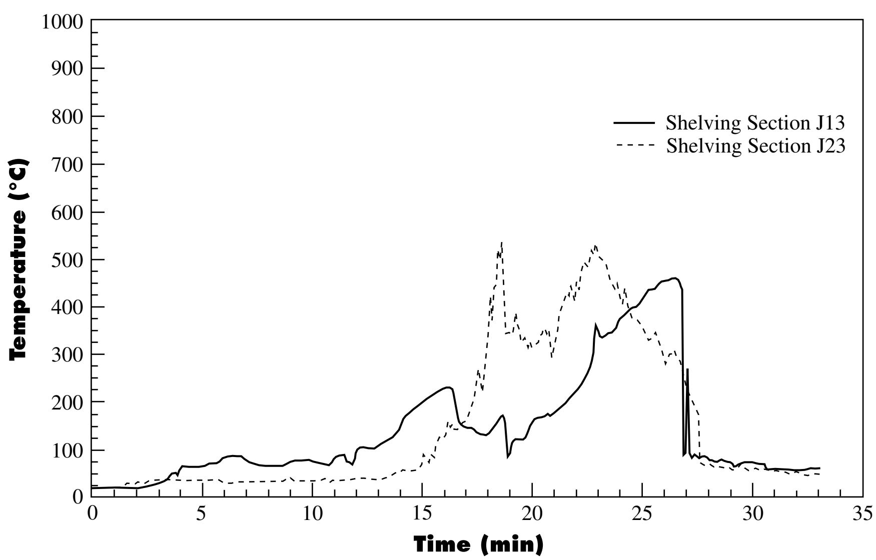


Figure 20. Shelving Section J temperatures in Test 4.

Test 5: Quick Response Horizontal Sidewall Sprinklers with Reduced Clearance

As noted previously, the clearance between the top of the storage and the ceiling in some areas in the library was 76 to 100 mm. To address this reduced clearance, a fifth test was conducted to determine whether the sprinkler system could control the fire with less clearance. For this test, the top storage was raised to within 100 mm ± 25 mm of the ceiling.

The horizontal sidewall sprinklers were installed with the deflectors within 50 mm of the ceiling (see Figure 21). All other conditions were the same as those in Test 3.

The initial fire development replicated that observed in Tests 3 and 4. However, the close proximity of the storage to the ceiling affected the convective flow above the shelving, so that one of the three sidewall sprinklers closest to the fire did not operate for several minutes. This was Sprinkler 4, which was located on the soffit at the center of the stack array (see Figure 7). It did not operate until 9 minutes into the test. The other two sprinklers located on the soffit operated within 90 seconds, even though Sprinkler 3 was located considerably further from the ignition source than Sprinkler 4.

As is shown in Figures 22 and 23, the fire was able to regain some momentum approximately 8 minutes into the test, with high temperatures, measured in shelving Row H and at the ceiling. Once Sprinkler 4 activated at 9 minutes, the sprinklers were able to control and extinguish the fire. The 15 minutes required for the sprinklers to control the fire provided the fire with enough time to break through the fire barrier separating Rows G and H. However, the ability of the sprinkler system to regain control of the fire indicates that there is an inherent safety margin in the protection system.

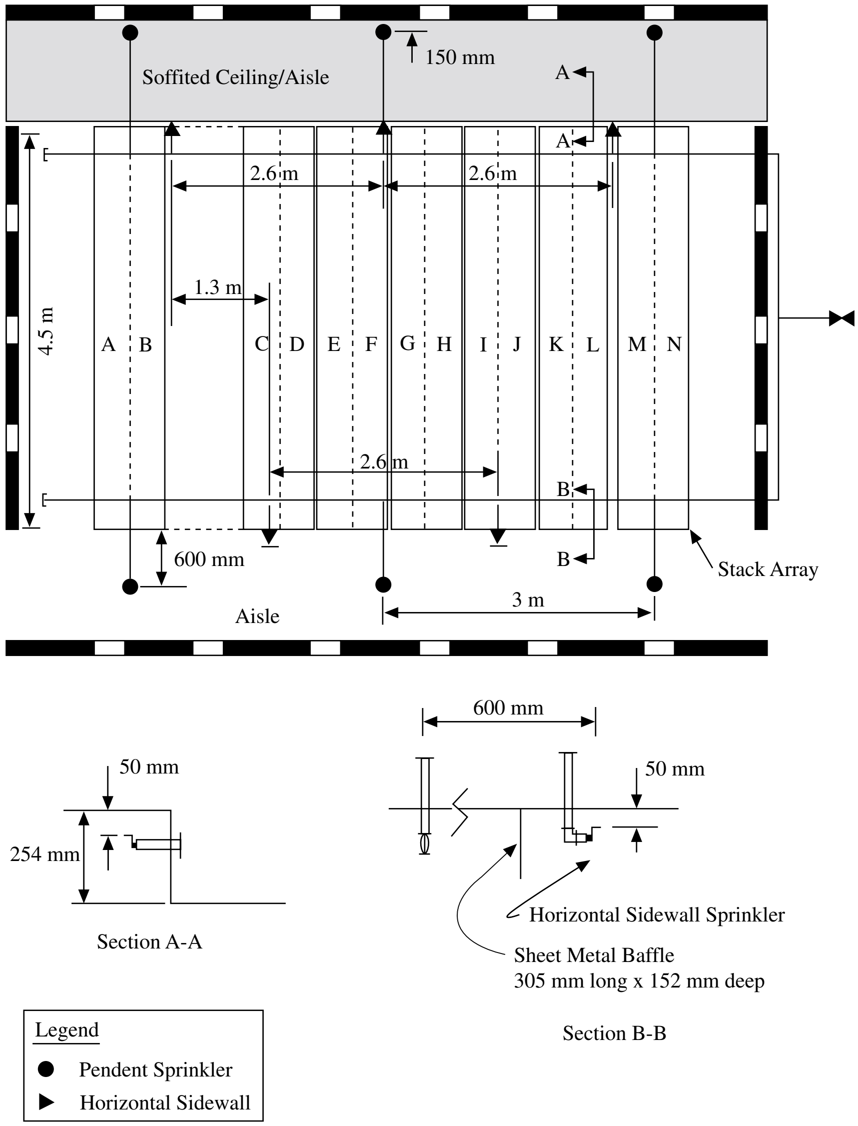


Figure 21. Horizontal sidewall and pendent sprinkler layout for Test 5.

Substantially more damage was sustained in this test than in Test 3. Based on the results of Test 5, it was decided that the 178 mm clearance between the ceiling and the top of the storage used in Test 3 would be specified as the minimum for general use. However, it was also noted that control, and eventually extinguishment, was obtained with the reduced clearance of 100 mm.

Smoke Production

As an additional point of interest, it was observed that large quantities of smoke were produced during all five fire tests, particularly in those tests in which the sprinklers could not immediately extinguish the fire. It was also noted that the cooling of the smoke by the sprinklers resulted in a very rapid build-up at lower levels. This is illustrated by the smoke obscuration measurements from Test 1 shown in Figure 24, which shows a very rapid increase in obscuration at the 1.5 m level within 2 minutes 30 seconds of ignition. In low ceiling spaces, smoke build-up could be very fast and could rapidly obscure exit routes, making it very difficult for the fire brigade to operate in the floor area.

Design Criteria

As a result of these investigations, criteria were recommended for the design of the sprinkler systems over the mobile shelving in the basement of the library. These criteria were based on the findings from spray distribution tests, sprinkler activation tests, a survey and analysis of existing stack systems and fuel loads, and a series of full-scale fire tests involving stack systems with document storage and shelving.

It is beyond the scope of this paper to provide a detailed description of the design criteria recommended for the library. However, the general principles used to develop the design guide are summarized.

Modifications to the Shelving Units

The full-scale fire tests indicated that it would be very difficult or impossible to control a fire in the compact shelving area using only sprinklers. Several modifications to the shelving units and storage practices were recommended as essential aspects of the fire protection system.

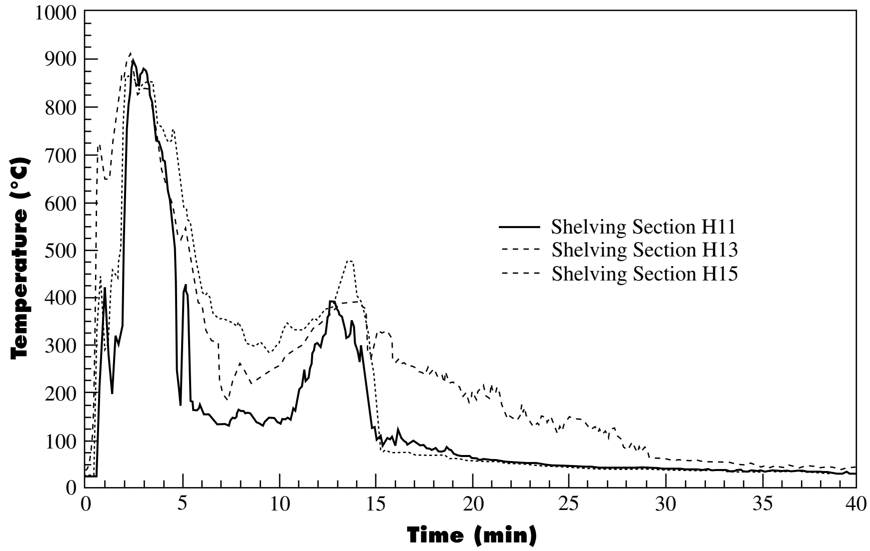


Figure 22. Shelving Section H temperatures in Test 5.

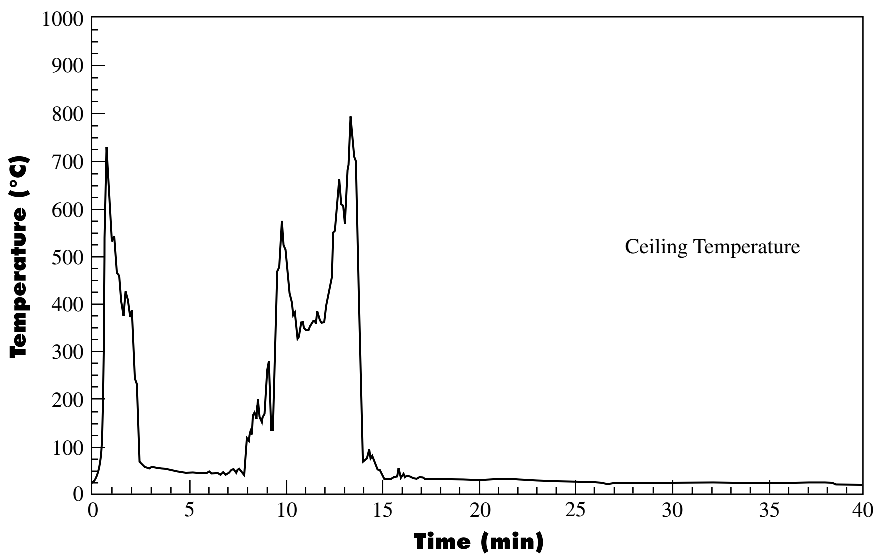


Figure 23. Ceiling temperature in Test 5.

Provisions should be made to ensure that a minimum clearance of 26 mm is maintained at all times between document boxes or other materials on adjacent mobile shelves when they are moved to the "closed" position. The purpose of the 26 mm space is to permit sprinkler water to drip down the face of shelving materials, thus ensuring good wetting at lower levels.

Each back-to-back stack unit should be subdivided lengthwise with a steel firestopping barrier that extends the full length and height of each section of the mobile and fixed stack units. These barriers will inhibit rapid fire spread through intermediate levels to adjacent shelving units. The barriers were of particular importance immediately after sprinkler operations, when the rapid cooling at the ceiling level tends to cause large horizontal flame extension at various levels within the shelving units. The barriers also delay the spread of fire into adjacent shelves and provide time for sprinkler water to drip down the 26 mm space between shelves to wet the lower levels. If fire penetrates the barrier, it encounters prewetted fuel and does not grow as rapidly.

Newspapers should no longer be stored in open periodical boxes. During Test 1, it was noted that the newspaper hazard exposed a large quantity of loosely packed fuel to the fire. This resulted in a rapid lateral fire spread within the shelving unit which allowed the fire to involve a large quantity of fuel during the initial fire growth. By eliminating the open newspaper scenario, the initial fire growth was reduced, thus decreasing the fire challenge for the sprinkler system.

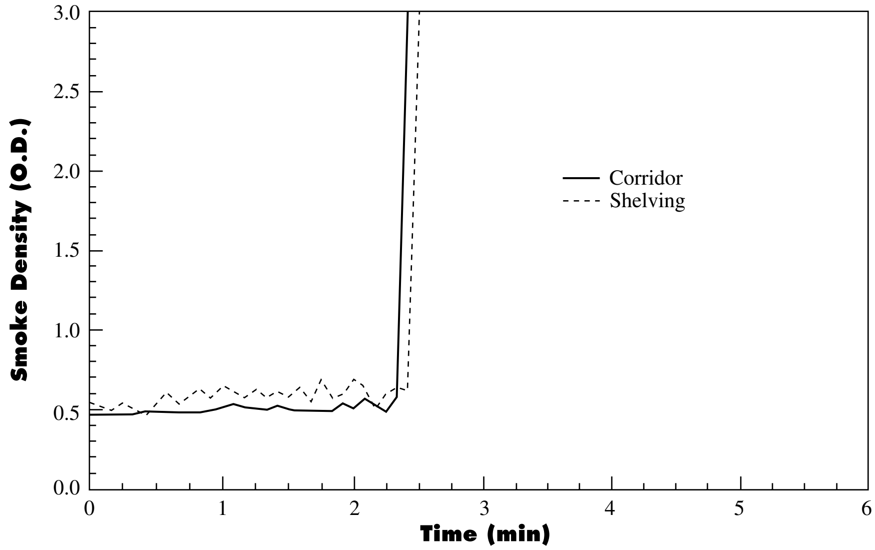


Figure 24. Smoke obscuration at 1.5 m level in Test 1.

Sprinkler System Design

The design criteria for the sprinkler system is based on the sprinkler configuration used in Test 3. In this configuration, six quick response pendent sprinklers with 57 to 77°C ratings, nominal 12.5 mm orifices, K factors of 5.3 to 5.8 in U.S. units, and a 3.05 m spacing were used to protect the aisle. Five quick response horizontal sidewall sprinklers with 57 to 77°C ratings, nominal 12.5 mm orifices, and K factors of 5.3 to 5.8 in U.S. units were used to protect the mobile shelving area.

The layout for the horizontal sprinklers is designed to maximize water spray coverage and to minimize the possibility of spray from one sprinkler delaying the activation of adjacent sprinklers. To achieve this, the sprinklers are arranged in a staggered array on opposite sides of the shelving units. The spray distribution tests demonstrated that, with the geometry used in this test series, there was no direct spray impingement on a sprinkler from adjacent sprinklers. As a result, reproducible activation of the three sprinklers closest to the fire source was obtained in Tests 3 and 4, the two tests with the 178 mm clearance between the ceiling and the storage.

The horizontal sidewall sprinklers are arranged to maximize water spray coverage in critical shelving areas. On the side of the stack array with three sprinklers, the two end sprinklers are centered on the gap between the fixed shelving unit and the first mobile unit. This ensures maximum water spray penetration into the one area where, because of the stops installed on the rails, relatively good penetration of water spray to the lower shelving levels was possible. The third sprinkler on that side is located at the center of the shelving array, giving a 2.6 m spacing between the sprinklers. The two sprinklers on the opposite side of the stack array are staggered so as to be exactly halfway between the two sprinklers on the opposite side, 4.5 m away. The spray distribution tests showed that, with the horizontal sprinklers mounted a nominal 100 mm below the ceiling, the sprinklers were able to provide uniform wetting over the entire mobile shelving area.

Even with the newspaper scenario removed, relatively fast fire development was observed in the full-scale fire tests. The results of Tests 3 and 4 demonstrated that, in order for the sprinklers to control the fire and minimize damage to the shelving contents, it was essential that water be applied as early as possible with a relatively high spray density. For this reason, it is recommended that a wet pipe sprinkler system be used in the library.

Two levels of coverage are needed for the design of the sprinkler system:

1. A minimum average density of 28.5 L/min/m^2 from five HSW sprinklers over a single bay of compact shelves. Each sprinkler is assumed to cover approximately 5.92 m^2.

2. A minimum average density of 12.3 L/min/m^2 over a 139 m^2 design area. This design area includes both sidewall sprinklers and pendent aisle sprinklers.

Such a system will provide the high application density required to control the rapidly developing fire in the shelving area while minimizing the demand on the water supply system.

For Test 5, the clearance between the storage on the mobile shelving units and the ceiling was 100 mm ± 25 mm. The HSW sprinkler deflectors were located 50 mm below the ceiling. This test showed that a fire could be controlled for this scenario. However, this test also showed that localized cool areas may occur above the mobile units, delaying the activation of some sprinklers and thus increasing fire spread and fire damage. The delay in controlling the fire could result in the activation of an increased number of sprinklers. Because the reduced clearances increased the potential fire and water damage to the contents of the shelving, it was strongly recommended that the sprinkler layout conform to the conditions used in Test 3 wherever possible — that is, that a 178 mm clearance be maintained between storage and the ceiling.

Summary

This paper provides a technical solution for sprinkler protection of the compact shelving units in the basement of the National Library of Canada. The fundamental basis for accepting an equivalent to a sprinkler installation that conforms to the standards is that the proposed arrangement demonstrate a high probability that it can extinguish or control the fire in the fuel package. Based on this criterion, the sprinkler layouts with pendent sprinklers used Tests 1 and 2 did not provide an acceptable level of performance.

The sprinkler layout in Test 3, which used horizontal sidewall sprinklers and a high spray density to protect the mobile shelving units, extinguished the fire with minimal fire damage to the shelving contents. This system formed the basis for general design criteria for shelving units in which the clearance from the top of the document boxes to the ceiling was at least 178 mm.

Tests 4 and 5 investigated the boundary conditions for the sprinkler system and showed that the average density and the clearance height above the shelving unit used in Test 3 were critical elements in determining the performance of the sprinkler system. In these tests, the sprinkler system took longer to control and eventually extinguish the fire, which resulted in greater damage to the stack's contents.

The effectiveness of the sprinkler system, as outlined in this paper, depended on implementing all the recommendations noted: vertical fire barriers in all shelving units, bumpers or other measures to ensure a minimum 26 mm clearance between commodities on adjacent mobile shelving units, and no storage of newspapers in open document boxes.

It should be emphasized that this was an engineering study directed at developing a sprinkler system which would provide protection equivalent to that provided by a system in full compliance with standards. This investigation did not evaluate all alternative sprinkler arrangements or the impact of all parameters on the effectiveness of the fire protection system.

Although useful information can be inferred from these tests, the criteria presented in this paper are intended to apply to the conditions found in the National Library of Canada. The technology outlined can certainly form the basis for fire protection systems for other situations, including retrofits where it is difficult to obtain explicit compliance with current installation standards. However, changes in types of storage, ceiling construction, and room elevations could all influence a sprinkler system's ability to control a fire. The authors suggest, therefore, that considerable caution be used in adapting the solutions presented here for other applications and suggest that full-scale fire testing be required if any major changes are made to the design.

Acknowledgment

The authors acknowledge the contribution of G.P. Crampton in carrying out the fire tests. Thanks are also due D.W. Carpenter, V.F. Fortington, R.A. MacDonald, B.C. Taber, M. Ryan, and M. Wright, who assisted in the tests.

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The following are excerpts from: "Engineering Analysis of Compact Storage Fire Tests" by Harold R. Cutler — an unpublished report prepared by Firepro Inc. for the Library of Congress, 1979.

C-2 Abstract. A series of three full-scale tests involving a mobile shelving storage system of the moving aisle type has been conducted by Factory Mutual Research Corporation under contract to the General Services Administration. The objective of the tests was to determine the nature of fire development within archival materials in this storage format and to determine the effectiveness of a specific automatic sprinkler system configuration in controlling that fire development.

These tests show a moderate rate of fire development when ignition involves materials in the open aisle of the storage module and the packing density (number of boxes per shelf) is high. They also show a relatively slow rate of development when ignition is in the closed portion of the module and the packing density of materials is high.

The tests reveal that there is a high probability that automatic sprinkler protection will prevent serious flame and heat damage outside the storage module of origin but will not significantly limit production of smoke and fire gases. The tests also indicate a low probability that automatic sprinkler protection will limit flame involvement to a portion of the storage module of origin in the storage configuration tested.

Several characteristics of the moving-aisle-type compact storage situation are analyzed. Tentative conclusions concerning fire development and fire protection for compact storage based on those characteristics are presented. The most important tentative conclusion drawn is that a combination of carriage subdivision by sheet metal panels and greater vertical openness such as provided by louvered or perforated module tops and shelves should permit limitation of open flaming to a portion of a module.

Several specific tests are proposed to allow assessment of the validity of the tentative conclusions.

C-3 Compact Storage Systems — The Problem. High-density storage of files, records, or books has become increasingly popular in recent years as cost considerations force users to seek the higher storage efficiencies available in special arrangements of storage hardware. This type of storage is especially appropriate where only limited access is required to the materials in storage. These storage systems are known by such names as "compact storage," "mobile shelving," "moving aisle storage," or "moving shelf storage."

There are two principal arrangements of shelving utilized to achieve these higher storage densities. For the purposes of this report, these arrangements are called moving aisle storage and moving shelf storage. These two storage types are described below.

(a) *Moving Aisle Storage.* In moving aisle storage, several ranges of shelves are placed on carriages between a pair of fixed ranges, as illustrated in Figure C-3(a). Space for a single aisle is also left between the fixed ranges. Access to the shelving of a specific range is obtained by moving the carriages to a position that places the aisle along the specific face of the desired range. In such storage, a typical ratio of aisle space to storage space is 1:10.

(b) *Moving Shelf Storage.* In typical moving shelf storage, a single fixed aisle serves two or more ranges of shelving on one or both sides of the aisle, as illustrated in Figure C-3(b). The rear range of shelving is fixed. One section of shelves in each of the front ranges is omitted and all other shelves of those ranges are mounted on carriages that allow them to travel to the left and right. Thus, the front ranges of shelves can be moved to permit access to any range of shelves. The ratio of aisle space to storage space in such a system with two ranges of shelving is approximately 1:2.

Typical standard fixed shelving [one 30-in. (762-mm) aisle providing access to two 15-in. (381-mm) shelves] has an aisle-to-storage area ratio of 1:1.

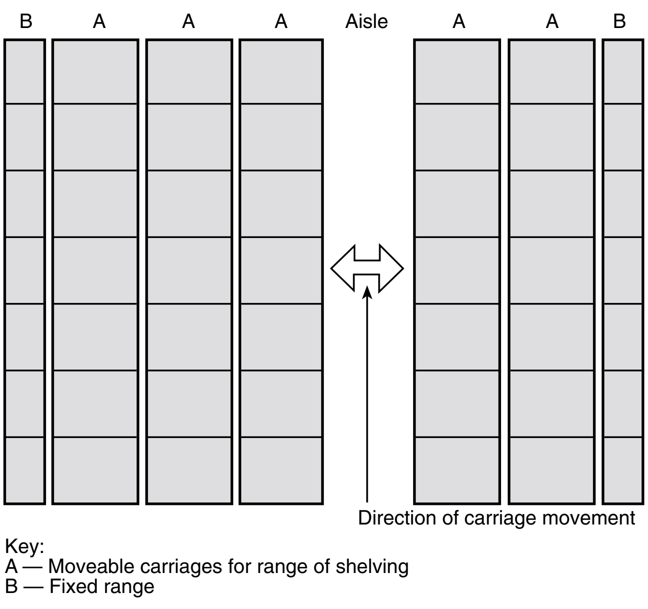


Figure C-3(a) Moving aisle storage.

C-4 Characteristics Affecting Fire. Several characteristics of compact storage systems are expected to affect the pattern of fire development and the effectiveness of detection and suppression systems (manual and automatic) as compared to standard fixed shelving. These characteristics include the following:

(a) Module components, especially shelves and module tops that discourage vertical fire development and encourage horizontal fire development

(b) Module components, especially shelves and module contents that restrict movement of fresh air, smoke, and fire gases within the structure

(c) Module components, especially shelves and module tops that restrict distribution of water discharged from sprinklers within the storage module

(d) A module "envelope" consisting of the top and end panels of moveable ranges and the top, end, and back panels of fixed ranges that can hinder movement of heat, smoke, and fire gases from within the module and hinder penetration of extinguishing agent into the module

(e) Module construction materials that can be either energy absorbing (metal) or energy generating (wood, plastics)

(f) High fuel loading resulting in the possibility of fire duration, possibly threatening structural elements

Materials in storage can also have an impact upon fire development and the effectiveness of detection and suppression activities and equipment. Some of these characteristics include the following:

(a) Packing density

(b) Moisture content

(c) Fuel type (cellulosic, plastic)

The tests that are the subject of this analysis were performed utilizing moving-aisle-type storage. The characteristics of the combustible contents of the shelving module were varied as discussed for the specific test.

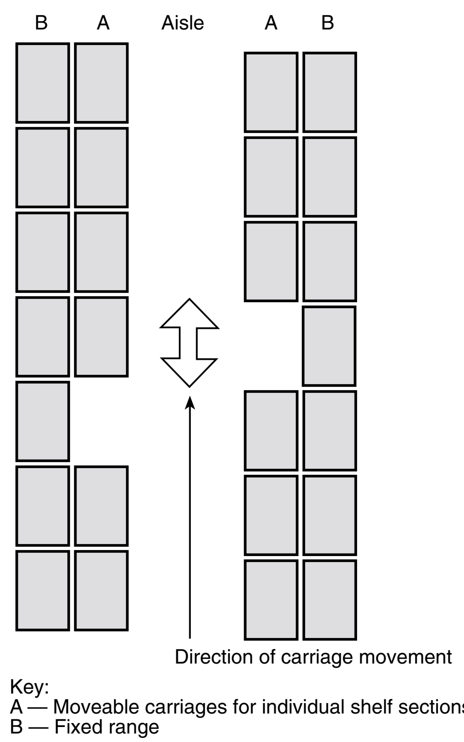


Figure C-3(b) Moving shelf storage.

C-5 Summary of Conclusions. This summary will list the conclusions drawn as a result of analysis of the specific General Services Administration/Factory Mutual test program and the tentative conclusions drawn by extrapolation of the test results beyond characteristics of the storage situation examined by the specific tests.

(a) Analysis of Test Results.

1. There is a high probability that automatic sprinklers (including on/off sprinklers) installed on an ordinary hazard basis over a compact storage module will prevent structural damage to building structural elements when structural elements are not enclosed partially or wholly by the storage module. (It is not possible to conclude whether or not sprinkler protection will adequately protect structural elements that are enclosed partially or wholly by the module.)

2. The relatively low rate of heat release observed in these fires will permit the use of 165°F (74°C) sprinklers without overtaxing water supplies.

3. There is a high probability that the combined effects of automatic sprinklers and spatial separation will prevent fire spread across a 4-ft (1.2-m) wide aisle at the end of compact storage modules to the end of an adjacent module where sprinklers are installed on an ordinary hazard basis.

4. There is a high probability that the fire will not spread between back-to-back shelves of the fixed ranges of adjacent modules when each shelf is backed by a sheet metal panel and the panels are separated by 1 in. (25 mm) or more.

5. Test No. 3 produced a more severe fire than Test No. 2 because of the higher degree of openness and the more severe burning characteristics of the fuels in Test No. 3 as compared to Test No. 2. (It is not possible to separate the effect of openness from the effect of burning characteristics on the basis of this test series.)

6. Manual overhaul of a fire in a compact storage module will be required to extinguish all combustion before total consumption of fuels not directly wetted by sprinkler discharge.

7. Mechanical or effective natural draft smoke removal will be required to permit manual overhaul operations.

8. The effect of test room humidity and the moisture content of the test materials could not be judged in these tests.

(b) Extrapolation of Test Results.

1. Single-thickness metal dividers between back-to-back shelves within a moveable carriage will reduce the rate of fire development. (It is not possible to conclude whether or not a single-thickness sheet metal divider between back-to-back shelves on a movable carriage will prevent fire spread between combustibles on those shelves.)

2. Improved vertical openness as provided by louvered, perforated, or rolled bar module tops and shelves can improve the effectiveness of ceiling-mounted sprinklers.

3. A combination of improved vertical openness, as provided by louvered or perforated module tops and shelves and decreased horizontal openness resulting from installation of longitudinal carriage dividers, can allow ceiling-mounted automatic sprinkler protection to limit flame damage to a portion of a storage module.

4. The use of wooden structural framing and shelving can increase the rate and duration of burning and can also lead to earlier structural collapse of shelves than the use of steel framing and shelving.

5. Chemical and physical characteristics of materials in storage will have a major impact upon the rate of fire development and the fire duration experienced in compact storage modules.

6. The moisture content of a material in storage will affect its ease of ignition and the rate of subsequent flame spread over its surface.

7. A smoke detection system can be utilized to provide relatively early warning of a fire in a compact storage module if properly engineered to take into account ventilation conditions, and if it is recognized that the slow release of smoke from the module can lead to apparently delayed detection compared to a fire unconfined by a compact storage module.

8. It is highly unlikely that thermal detection would take place in time to permit manual fire fighting without self-contained breathing apparatus and without incurring serious visibility problems.

9. Given the difficulty of achieving Halon 1301 saturation of the compact storage module and the smoldering nature of fires in compact storage, Halon 1301 does not appear to be well suited for protection of materials in compact storage.

10. Limitation of the quantity of the material in a common enclosure can limit the extent of flame, heat, smoke, and fire gas damage to the materials.

C-6 Additional Testing. A series of limited and full-scale fire tests are discussed that would permit assessment of the validity of the tentative conclusions drawn concerning various module and protection system characteristics. *[See Figures C-6(a), C-6(b), and C-6(c).]*

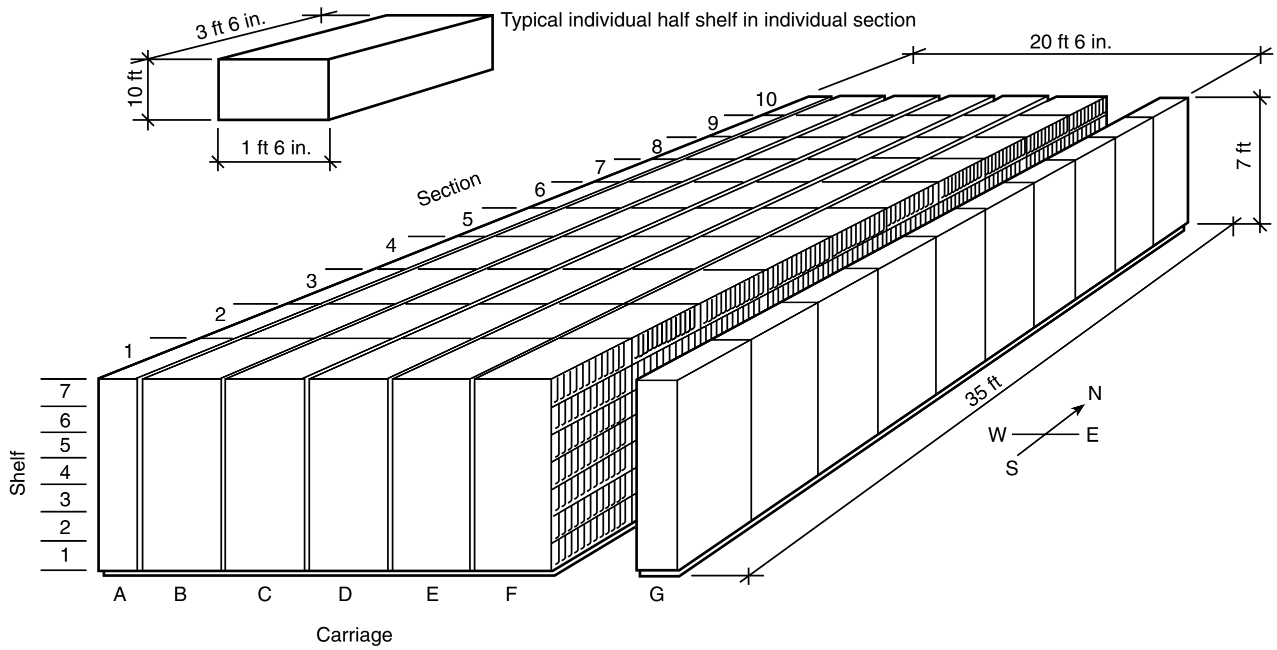


Figure C-6(a) Mobile shelving array terminology and dimensions.

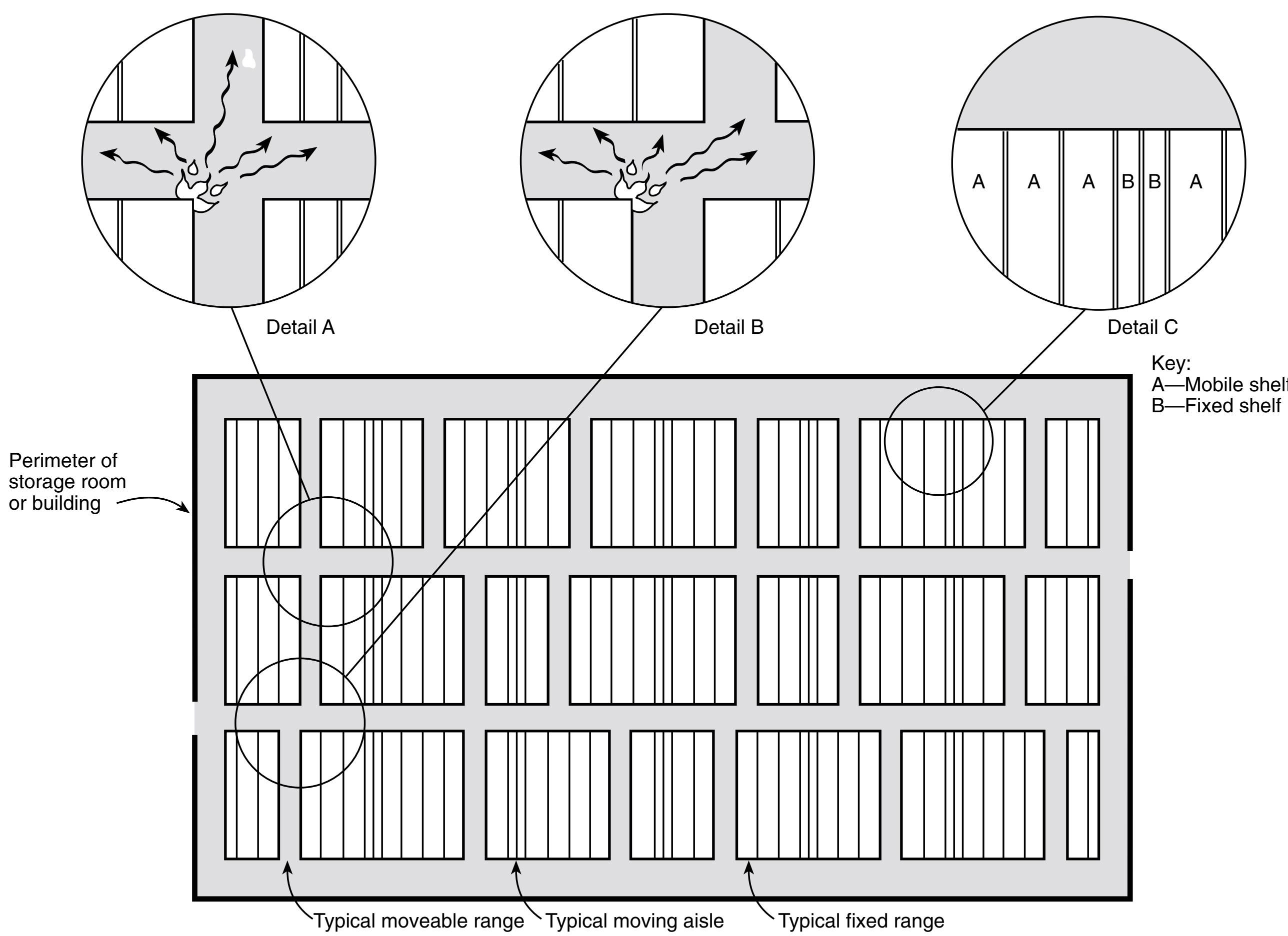
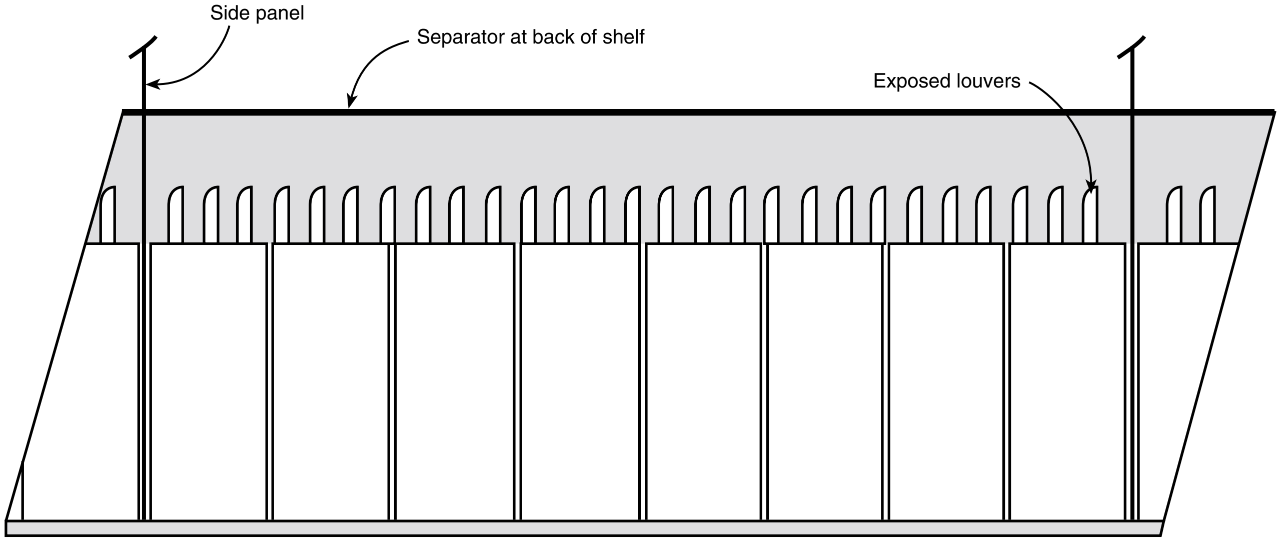
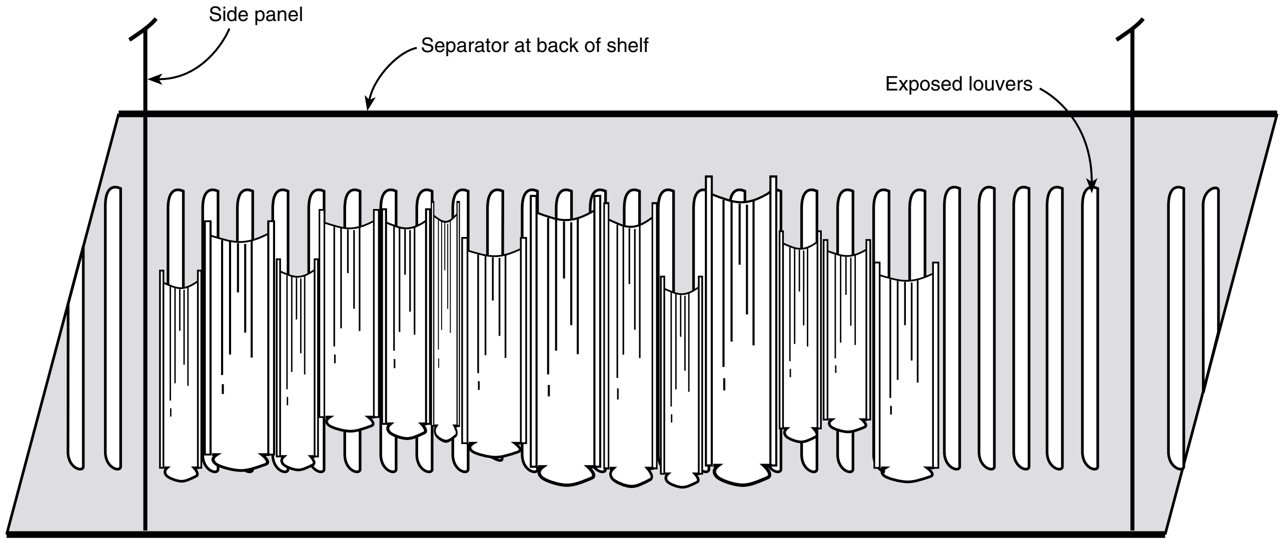


Figure C-6(b) Multiple module storage.



Plan view—archival boxes, 100% packing density



Plan view—library books, 80% packing density

Figure C-6(c) Potential improvement in vertical openness.

Appendix D Fire Safety Inspection Form

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

Monthly Fire Protection Self-Inspection Checklist

The following checklist should be used as a reminder during inspections. Items requiring corrective action should be reported on a Notice of Fire Hazard form.

X Satisfactory 0 Correction required / Not applicable

Life Safety

❏ Ability to use exit doors is not hampered by security measures during occupancy.
❏ Stairwell and hallway fire doors are kept in the closed position.
❏ Stairwells and evacuation routes are free and clear of obstructions.
❏ Fire escape stairs appear to be in good condition.
❏ Emergency lighting units operate when tested.
❏ Exterior emergency exit routes are clear and free from snow and ice.
❏ Illuminated exit signs are all lit, not blocked, and can be easily seen.

Fire Protection Equipment

- ❑ Portable fire extinguishers are in their proper location and fully charged and tagged.
- ❑ A space of at least 18 in. (457 mm) is kept between sprinklers and materials.
- ❑ Fire hose cabinets are in good order, easily visible, and accessible.
- ❑ Fire detectors are free from obstructions.
- ❑ Sprinkler control valves are open and locked/secured, and dry pipe systems register at normal air pressures.
- ❑ Sprinkler tanks, piping, and supports appear in good condition.
- ❑ Alarm systems function and are tested regularly.
- ❑ Lightning arresters appear in good condition.

Housekeeping and Storage

- ❑ Rubbish is not left to accumulate in excessive quantities; trash receptacles are emptied daily.
- ❑ Storage areas are kept clean and orderly; cleaning materials are safely stored.
- ❑ Combustible materials are not kept in unprotected areas such as a crawlspace.
- ❑ Roof scuppers and drains are unobstructed. Roof covering is in good condition.
- ❑ Aisles are unobstructed.

Hazardous Liquids

- ❑ Emergency measures are posted in case of accidental spills.
- ❑ Flammable/combustible liquids are kept in approved safety containers.
- ❑ Flammable/combustible liquids are stored in an approved cabinet.
- ❑ Safety storage cabinet vents are clear of obstructions.
- ❑ Soiled rags are kept in an approved self-closing waste container.
- ❑ Portable fire extinguishers are in their place and of the proper type.

Exhibits/Collections/Book Stacks

- ❑ Exhibits and collections are not overcrowded.
- ❑ Exhibit case lights do not show signs of overheating.
- ❑ Exhibits are not blocking exit routes and/or access to fire protection equipment.
- ❑ Extension cords are not used.
- ❑ All vertical/horizontal openings in fire barriers are firestopped.
- ❑ Salvage equipment and materials are provided and accessible.
- ❑ The fire department is familiar with and has access to these areas.
- ❑ Smoking regulations are enforced with employees and visitors.
- ❑ Temporary wiring conforms with NFPA 70, *National Electrical Code.*

Auditoriums and Classrooms

- ❑ Safe capacity is posted and enforced.
- ❑ Standing and sitting in aisles is prohibited.
- ❑ Smoking regulations are enforced.

Restaurants and Eating Areas

- ❑ Safe capacity is posted and enforced.
- ❑ Aisles and exit routes are unobstructed and illuminated.
- ❑ Ranges, hoods, and exhaust ducts are clean.

Shops/Laboratories/Packing Areas

- ❑ Laboratory wastes are disposed of daily using appropriate precautions.
- ❑ Spray coating facilities are safely ventilated, and scrubbers/filters are clean.
- ❑ Electrical equipment in areas near where flammable liquids are in use are explosionproof.
- ❑ Electrical appliances have warning lights and are unplugged when not in use.
- ❑ Employees are aware of special hazards and trained in any special precautions necessary.
- ❑ Entry is limited to authorized persons.
- ❑ Power tools and machines are grounded.
- ❑ Woodworking equipment dust collectors are functioning adequately and collector bins emptied regularly.
- ❑ Power tools are unplugged when not in use.

Exterior and Environment

- ❑ All exits, emergency exits, and fire escapes afford unobstructed passage to a safe area.
- ❑ Grounds surrounding the facility are clear of accumulations of combustible material and brush.
- ❑ Fire service access is maintained clear.
- ❑ Fire hydrants and sprinkler system siamese connections are visible, accessible, and operable.

Personnel/Training

- ❑ All staff members know how to transmit a fire alarm.
- ❑ All emergency team members have received training and are aware of their assigned duties.
- ❑ All staff members have received training in the use of portable extinguishers and fire prevention.

Building Changes Since Last Inspection

❑ Do not interfere with fire detection and/or fire suppression systems.
❑ Do not contribute unreasonable fire loading.
❑ Do not create vertical and horizontal openings in fire-rated walls and ceilings.
❑ **Items requiring action have been noted on a Notice of Hazard form.** *(See Figure D-1.)*

Area inspected: ______________________________________

Inspected by: ______________________________________

Date of inspection:____________________________________

NOTICE OF FIRE HAZARD

DATE REPORTED: __________ HAZARD CONTROL NO.: ______
AREA WHERE HAZARD WAS NOTICED: ____________________

THE FOLLOWING HAZARD WAS NOTICED:
____
____
____
____
____
____

THE POTENTIAL RISK IS:
____
____
____
____
____
____

THE FOLLOWING ACTION IS RECOMMENDED:
____
____
____
____

______________________ ______________________
Reported to: (print name) Reported by: (print name)

Figure D-1 Notice of Fire Hazard form.

Appendix E Fire System Maintenance Checklists

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

Exhibit 1

Maintenance of Automatic Sprinkler and Standpipe Systems

Each alarm, dry pipe, preaction, and deluge valve should have maintenance tags (annual, 5-year, 50-year, and so forth) attached for recording the inspector's initials, date, pressure readings, and confirmation on maintenance/inspections performed on the system. Checklists detailing maintenance should be kept by the office responsible for maintenance. All problems noted should be corrected before initialing the maintenance tag.

During any renovation or inspection of an automatic sprinkler system, the following should be reported to the facility manager for correction:

❑ Sprinklers that are damaged, blocked by storage, painted, or otherwise impaired. (Construction, occupancy changes and changes to heating, lighting, and air conditioning systems might require relocating, adding, or replacing sprinklers.)
❑ Pipe hangers with mechanical injury and corrosion.

General Requirements for All Sprinkler and Standpipe Systems

❑ Annually inspect water pressure and air pressure gauges to make sure they are within normal range. Investigate a loss of pressure of more than 10 percent. Record new pressure readings on the attached tag.
❑ Annually inspect control valve labels to ensure they are accurate. Replace missing signs and relabel inaccurate signs.
❑ Annually inspect fire department connections to make sure inlets are unobstructed, that the protective caps are in place, that they are conspicuously marked and accessible for the fire department, and that hose threads are in good condition.
❑ Annually lubricate each valve stem and reseal to prevent leaks.
❑ Annually close and reopen each post indicator and Outside Stem and Yolk (OS&Y) valve.
❑ Annually inspect fire department connections before freezing weather. The connection should be drained through the ball drip from the check valve to ensure it will not freeze.
❑ Every five years replace the gaskets in check valves.
❑ Every five years recalibrate and/or replace pressure gauges, if necessary.
❑ Fifty years after installation, remove a representative sample of sprinklers (at least two per floor) and have them operationally tested at a testing laboratory. Based on tests, replace sprinklers if necessary. Test a sampling of the sprinklers every 10 years thereafter.
❑ Fifty years after installation, inspect the sprinkler system in at least five remote and low-point locations to determine the degree of pipe corrosion. Where corrosion is found, have a fire protection engineer or sprinkler designer determine the hydraulic performance of the sprinkler system.

Wet Pipe and Antifreeze Systems

❑ Annually open the inspector's test connection and test all alarms (water motor alarm and/or flow/pressure switch).
❑ Annually, before freezing weather, test the freezing point of antifreeze solutions with a hydrometer. Maintain the solution below the estimated minimum temperature.
❑ Annually make sure wet pipe systems are properly protected from freezing.

Dry, Deluge, and Preaction Systems

❑ Annually, before freezing weather, operate the heating system in enclosures housing valves to ensure temperature can be maintained above 42°F (5.5°C).

- ❑ Annually, before freezing weather, open all low-point drains to remove condensation and clean plugged or obstructed sprinklers.
- ❑ Annually remove face plates of dry, deluge, and preaction valves and examine interior for corrosion and condition of gasket.
- ❑ Annually trip test the dry pipe, deluge, or preaction valve. Ensure quick opening devices operate properly. Once the main valve trips, quickly close the control valve.
- ❑ Every 3 years, flush system with water. The system should be filled with water for two days before flushing to allow pipe scale and deposits to soften. Drain system and then flush. Flush cross mains first by attaching 2-in. (50-mm) fire hose at the end of the cross main. Flow water until clear. Also, record the residual water pressure from the supply-side water pressure gauge. Remove and reinstall all pendent sprinklers after flushing is complete.
- ❑ Annually activate preaction and deluge systems by operating the fire detection devices. Close the control valve to prohibit water from entering the system.
- ❑ Annually lubricate air compressors on preaction and dry systems in accordance with manufacturer recommendations.
- ❑ Annually test low air pressure alarm on preaction and dry systems. Close the water supply valve. Slowly release air from the system by slowly opening the inspector's test valve. Release enough pressure to sound the alarm. Avoid tripping the dry pipe valve.
- ❑ Quarterly determine dry pipe system priming water level by slowly opening the priming water level test valve. If only air escapes, close the test valve and add about one quart of water. Repeat the procedure until water comes out of the test valve.
- ❑ Annually flow test open sprinklers on deluge sprinkler systems during warm weather.

Exhibit 2

Maintenance of Fire Detection and Alarm Systems

Fire detection and alarm systems should be tested at regular intervals. Test methods and frequency of tests should be in accordance with NFPA 72, *National Fire Alarm Code*. Some of the tests that should be performed are as follows:

Alarms

- ❑ Annually test audible devices, visible devices, and emergency voice/alarm communication equipment.

Control and Annunciation Units

- ❑ Quarterly for unmonitored systems and annually for monitored systems, test all functions, interfaced equipment, main and standby power supply, and fuses.

Batteries

- ❑ Annually test the charger. Conduct a 30-minute discharge test semiannually for lead acid batteries and annually for nickel-cadmium batteries.

Alarm Initiation Devices

- ❑ Annually test all smoke detectors, fire alarm boxes, and restorable heat detectors. Smoke detector sensitivity should be checked as detailed in NFPA 72.
- ❑ Other tests, depending of the type of fire alarm system installed, should be conducted as detailed in NFPA 72.

Exhibit 3

Maintenance of Fire Hose Stations

Where fire hose is allowed, hose stations should have monthly and annual (all-weather) maintenance tags attached for recording the inspector's initials, date, and confirmation on maintenance/inspections performed on the system. Checklists detailing maintenance should be kept by the office responsible for maintenance. All problems noted should be corrected before initialing the maintenance tag.

- ❑ Inspect fire hose stations monthly. Hose stations must contain a minimum of 150 ft (45 m) of hose, a hose nozzle, and a hydrant wrench. Hose should not be damaged or show mildew. Hose must be neatly rolled or racked.
- ❑ Test nozzles monthly to confirm that they can be easily opened and closed.
- ❑ Rerack or rewind hose annually.

Exhibit 4

Maintenance of Fire Hydrants

Fire hydrants should have annual maintenance tags attached for recording the inspector's initials, date, and confirmation on maintenance/inspections performed on the system. Checklists detailing maintenance should be kept by the office responsible for maintenance. All problems noted should be corrected before initialing the maintenance tag.

- ❑ Annually inspect fire hydrants in the fall to ensure the following:
  - (a) Tightness of hydrant outlet
  - (b) No leaks in top of hydrant
  - (c) No cracks in hydrant barrel
  - (d) Hydrant drain is clear
  - (e) Turning nut is not worn down with rounded corners
  - (f) Nozzle threads are not damaged
- ❑ Annually lubricate operating nut, parking, and trust collars.
- ❑ Annually perform a flow test to check for proper hydrant operation and to test the available water supply in accordance with NFPA 291, *Recommended Practice for Fire Flow Testing and Marking of Hydrants*. Flow water from each hydrant.

Exhibit 5

Maintenance of Fire Pumps

Fire pumps should have weekly and annual maintenance tags attached for recording the inspector's initials, date, and confirmation on maintenance/inspections performed on the system. Water flow meters should have 5-year maintenance tags attached. Checklists detailing maintenance should be kept by the museum. All problems noted should be corrected before initialing the maintenance tag.

Weekly

- ❏ Close system valve to avoid pressurizing the automatic sprinkler system. Turn jockey pump off and gradually release pressure in the sprinkler system to confirm that low system pressure turns fire pump on. Run pump for 10 minutes. Check for excessive heat or water leakage at packing glands. At the end of the test, confirm that the fire pump and jockey pump controllers are on automatic, and the pump supply and discharge valves and the sprinkler system valves are open.
- ❏ Record suction and discharge pressure on the maintenance tag.

Annually

- ❏ Perform annual flow test in accordance with NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*.
- ❏ Turn jockey pump off and gradually release pressure in the sprinkler system to confirm that low system pressure turns fire pump on.
- ❏ Confirm proper operation of remote annunciation for pump-on and power supervision on fire alarm control unit.
- ❏ Close and open control valves to ensure proper operation. Also, confirm that tamper switches on control valves are operational.
- ❏ Lubricate motors and engines in accordance with manufacturer recommendations.

Every 5 Years

- ❏ Calibrate the water flow meter, if one is installed, during the annual flow test.

Exhibit 6

Maintenance of Water Storage Tanks Used for Fire Protection

Water storage tanks used for fire protection should have monthly, annual, and 5-year maintenance tags attached at the main control valve for recording the inspector's initials, date, and confirmation on maintenance/inspections performed on the system. Checklists detailing maintenance should be kept by the office responsible for maintenance. All problems noted should be corrected before initialing maintenance tag.

- ❏ Check water level in storage tanks monthly.
- ❏ Operate control valves monthly to ensure that they are properly arranged (generally open) and operational.
- ❏ Inspect storage tanks annually for the following:

  (a) General condition of the tank, including loose scale, leaky seams or rivets, and paint

  (b) Ladders on tanks for structural adequacy and the presence of rust

  (c) The roof of storage tanks for structural stability and the presence of rust

  (d) Sway bracing for elevated water storage tanks for structural adequacy and the presence of rust

❏ Conduct a flow test annually to make sure that equipment is performing properly, pipes are unobstructed, and appropriate valves are open. Perform in conjunction with fire hydrant annual tests *(see Exhibit 4)*.

- ❏ Approximately every 5 years, thoroughly clean the interior and exterior of the tank and repaint. Temporary water supplies for fire protection must be provided before the tank is drained.

Exhibit 7

Maintenance of Halon Systems

Halon systems should have monthly, annual, and 5-year maintenance tags attached to the halon cylinders for recording the inspector's initials, date, and confirmation on maintenance/inspections performed on the system. Checklists detailing maintenance should be kept by the office responsible for maintenance. All problems found should be corrected before initialing the maintenance tag. (Fire alarm functions should be maintained in accordance with Exhibit 1.)

Monthly

- ❏ Inspect the halon cylinders and piping for physical damage.
- ❏ Record the new pressure reading on the maintenance tag. Pressure must be within 10 percent of previous reading on the maintenance tag. Low readings require weighing the tank to confirm low pressure. Report confirmed low readings. Do not refill system.

Annually

- ❏ Weigh cylinders and determine if weight is within 5 percent of previous reading on the maintenance tag. Record pressure on maintenance tag. Report low readings. Do not refill system.
- ❏ Operate control valves and correct any problems found.
- ❏ Perform an operational test on system without discharging halon. (Remove the control heads from the halon cylinders and operate the fire detectors.) Correct any problems found.

Every 5 Years

- ❏ Replace rubber hoses.
- ❏ Perform a fan pressurization test in the room.

Exhibit 8

Maintenance of Emergency Generator and Emergency Lighting

Emergency generators should have weekly and annual maintenance tags attached for recording the inspector's initials, date, and confirmation of maintenance/inspections performed on the system. Checklists detailing maintenance should be kept by the office responsible for maintenance.

- ❏ Operate emergency generators weekly. Correct potential operational problems.
- ❏ Operate emergency generator under a simulated load bi-annually.
- ❏ Lubricate motors and engines annually in accordance with manufacturer recommendations.
- ❏ Perform an emergency lighting test bi-annually using the emergency generator. Fire pump(s), fire alarm systems, and electronic exit locking systems should be tested on emergency power concurrently.

Exhibit 9

Maintenance of Waterspray Systems for Kitchens

Annually inspect contracts to confirm waterspray systems are being maintained in accordance with manufacturer recommendations, including the following:

(a) The monthly inspection of systems is done by a company specializingal in the maintenance of these systems.

(b) Sprinklers are clean of grease.

(c) Gas and electric power shutoff are tested.

(d) Water-wash hood cleaning systems are operational.

(e) Sprinklers must be replaced in accordance with manufacturer recommendations.

(f) Manual pull stations send a signal to the control room.

(g) Sprinklers are of the correct temperature rating and located directly above grease-producing equipment at the correct height.

(h) Monthly and annual maintenance tags are attached for recording the inspector's initials, date, and confirmation on maintenance/inspections performed on the system. Checklists detailing maintenance should be kept by the responsible office.

Exhibit 10

Maintenance of Dry Chemical Systems

Annually inspect contracts to ensure dry chemical systems are being maintained in accordance with manufacturer recommendations, including the following:

(a) The monthly inspection of a system is done by a company specializing in the maintenance of these systems.

(b) Nozzles are clean of grease.

(c) Gas and electric power shutoff are tested.

(d) Water-wash hood cleaning systems are operational.

(e) Fusible links are replaced annually.

(f) Manual pull stations send a signal to the control room.

(g) Fusible links are of the correct temperature rating.

(h) Nozzles are located directly above grease-producing equipment at the correct height.

(i) Pressure on gauge is adequate.

(j) Manual release stations are operational and accessible.

(k) Monthly and annual maintenance tags are attached for recording the inspector's initials, date, and confirmation on maintenance/inspections performed on the system. Checklists detailing maintenance should be kept by the responsible office.

Exhibit 11

Maintenance of Fire Doors and Fire Dampers

Personnel responsible for maintenance should have location maps of fire doors and fire dampers and checklists detailing maintenance on each door or damper.

Fire Doors

❑ Annually inspect fire doors for the items listed below. Correct any problems found.

(a) Door envelope does not have punctures or broken seams.

(b) Self-closer is intact and allows door to latch closed.

(c) A sliding door, chains, and cables should operate smoothly over all pulleys and guides.

(d) Doors have not been modified in the field (e.g., by the installation of louvers).

(e) Coordinators are securely attached and adjusted properly.

(f) Clearances around the door do not exceed the following:

1. Between door and frame $\frac{1}{8}$ in. (3.2 mm)
2. Between meeting edges of doors $\frac{1}{8}$ in. (3.2 mm)
3. Between bottom of door and raised sill $\frac{3}{8}$ in. (9.5 mm)
4. Between bottom of door and floor (no sill) $\frac{3}{4}$ in. (19.0 mm)

❑ Annually test doors normally held open by automatic closing devices to confirm proper operation. Sliding doors must be allowed to close completely to check the operation of the guides and rollers. Correct any problems found.

❑ Annually lubricate guides and bearings.

Fire Dampers

❑ Annually test fire dampers to ensure hinges and other moving parts operate properly. Remove fusible links, operate damper, and check latch (if provided). It is desirable to operate dampers with normal system air flow to ensure that they are not held open by the air stream. Correct any problems found.

❑ Annually lubricate moving parts of fire damper.

NOTE: Smoke dampers should be tested with the operation of fire detectors in accordance with Exhibit 2.

Exhibit 12

Maintenance of Stair Pressurization and Smoke Venting Systems

Fans used for stairwell pressurization and smoke venting should have annual maintenance tags attached for recording the inspector's initials, date, and confirmation on maintenance/inspections performed on the system. Checklists detailing maintenance should be kept by the office responsible for maintenance.

❑ Annually perform an air pressure test in stairwells having pressurization fans to make sure all system parts and controls are operational and design air pressures (not to exceed NFPA *101, Life Safety Code,* requirements) are obtained. Correct any problems found before initialing the maintenance tag.

❑ Annually lubricate fan motors in accordance with manufacturer recommendations.

Exhibit 13

Maintenance of Portable Fire Extinguishers

❑ Each extinguisher must have an inspection tag.

❑ Monthly inspect extinguishers. An extinguisher inspection includes ensuring that extinguishers are fully charged, in their designated locations, physically undamaged, not tampered with, and not obstructed, and that the hydrostatic test is up to date. The inspector should initial the inspection tag after the extinguisher is found in good working order.

(a) Report obstructed or out-of-place extinguishers to the building manager.

(b) Replace any extinguisher that is physically damaged or that has a broken or missing tamper indicator (plastic seal around the handle).

(c) Replace any extinguisher on which the gauge indicates "recharge" or in the case of carbon dioxide extinguishers when there is a weight loss of 10 percent or more (the weight is listed on the label of the extinguisher). For example, if the label indicates 33 ½ lb (15.2 kg), replace the extinguisher when the weight goes below 31 lb (14.0 kg). The weight should be checked semiannually.

(d) Replace any extinguisher requiring a hydrostatic test in accordance with the dates listed below. Each extinguisher is marked with the date of the last hydrostatic test (e.g., 1/26/80 or 1@80). Look for the most recent date and calculate when the extinguisher needs to be tested again. For example, a carbon dioxide extinguisher dated 1@80 should be retested in January 1985.

Extinguisher Types	Hydrostatic Test Period
Dry chemical	12 years
Carbon dioxide	5 years
Stored water pressure	5 years
Halon	12 years

(When an extinguisher needs to be replaced, use a spare extinguisher of the same type and at least equal rating as the one being replaced.)

Exhibit 14

Maintenance of Lightning Protection Systems

Those responsible for maintenance/inspection should have detailed drawings of lightning protection systems and checklists detailing maintenance.

- ❑ Annually inspect system for mechanical damage.
- ❑ Annually test all connections for electrical resistance. If resistance to ground is more than 5 ohms, make necessary changes to reduce it to 5 ohms or less.

Appendix F 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.

F-1 Most fires that occur in cultural properties 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 gaseous clean agent or smothering agent is needed.

F-1.1 Fire Detection and Alarm Systems. Technology is available to customize a fire detection system for the particular needs of specific properties. Early detection of fires affords the opportunity of occupant intervention and potentially faster response by automatic fire suppression.

F-2 Glossary of Fire Protection Systems. Tables F-2(a), F-2(b), F-2(c), and F-2(d) describe detection, alarm, and extinguishing systems that are appropriate for use in cultural properties. 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 F-2(a) 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, cloud chamber, or other smoke particle analysis 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. Aspiration-type smoke detectors use either the ionization, photoelectric, cloud chamber, or other particle analysis principle of operation. Properly installed, smoke detectors can detect smoke particles in very early stages of fire in the areas where they are located. The selection of a particular detector or mixture of detectors should be based on building and fire-load conditions by a fire protection specialist.	These systems are intended for early warning. Some are designed for installation in ventilation ducts. *(See NFPA 72, National Fire Alarm Code.)*
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).	These systems are relatively low 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.

Table F-2(a) Glossary of Fire Detection and Alarm Systems
Classification of Fire Detection Systems by Method of Detection *(continued)*

Type	Description	Comments
2. Heat detection systems *(continued)*	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.	Rate compensation devices compensate for thermal lag and respond more quickly when the surrounding air reaches the set point. Given the monetary value and irreplaceable nature of typical museum collections, early-warning, air-sampling-type detector systems should be considered for optimum protection. These systems are also less conspicuous and minimize disruption to architectural integrity. Proper selection of a particular detector or a mixture of detectors should be based on building and fire load conditions by a fire protection specialist.
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 required area of fire in the zone that is 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.)*

Table F-2(b) Classification of Fire Alarm Systems by Method of Operation

Type	Description	Comments
1. Local fire alarm system	An alarm system operating in the protected premises that is 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-detecting 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 that connects protected premises to a privately owned central station and that monitors the connecting lines constantly and records 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.)*
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-hr 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 listed above by permitting voice communication throughout a building so that instructions can be given to building occupants. During a fire emergency, prerecorded messages can be played or fire department personnel can transmit live messages, or both.	*(See NFPA 72, National Fire Alarm Code.)*

Table F-2(c) 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 require sophisticated technical expertise to maintain and service, so this should be considered in the design process. Addressable fire detection systems allow for the execution of preprogrammed sensitivity levels for smoke detectors based on the time of day or days of the week, ranging from a "low sensitivity" level during the period the premise is occupied to a "high sensitivity" level when only employees are present or the protected premise is vacant.
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 F-2(d) 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 can be equipped with mechanically operated on-off or cycling heads 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.)*

Table F-2(d) Glossary of Fire Extinguishing Systems *(continued)*

Type	Description	Comments
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 million 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 requires 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 one has found a way 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 to 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.)*
4. Dry-pipe automatic prinkler 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. Clean agent 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.)*

Table F-2(d) Glossary of Fire Extinguishing Systems *(continued)*

Type	Description	Comments
7. Dry chemcal 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 could be a source of ignition. Might 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 in the following ways: (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.)*
10. Fine water mist system	In general, a piped system or modular, pressurized container system that delivers a fine water mist and that has a water droplet size ranging to a maximum 1000 microns.	

Appendix G Resources

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

A fire protection consultant can be a valuable resource in evaluating the current status of fire safety for a cultural property and in recommending creative solutions to improve fire safety and achieve fire safety goals. In order to realize maximum benefit from engaging a fire protection consultant, the consultant's qualifications and the client's needs should be properly matched. The consultant should have qualifications equivalent to member grade in the Society of Fire Protection Engineers.

One should evaluate the consultant's experience, both as a company and as individual consultant team members in providing fire protection consulting services to libraries. Other experience that might also be considered is that for historic buildings or structures and museums.

One should also compare the consultant's experience with the nature of the work to be performed and the size of the project being considered. As a final evaluation factor for experience, one should consider whether the specific team proposed has worked together and the degree to which the experience is team experience.

Other factors that should be used in evaluating a consultant's qualifications are membership and participation in organizations such as NFPA, the American Institute of Architects for registered architects, the National Society of Professional Engineers for registered engineers, and the model building code organizations. Participation on committees of these organizations is a further measure of the consultant's understanding of library fire safety issues.

After having collected information on the fire protection consultant's qualifications, one should contact references to determine how the consultant has actually performed on similar projects.

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

NFPA publishes this document and related documents on fire protection, and they will answer inquiries on these documents. They also conduct educational seminars, studies, and literature searches for a fee.

NFPA maintains a list of fire protection consultants.

G-2 SFPE. Society of Fire Protection Engineers, 1 Liberty Square, Boston, MA 02116.

SFPE is a professional society of fire protection engineers. They meet annually, publish technical information, conduct technical seminars, and support 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.

G-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 system layout (i.e., automatic and manual foam water, halon, carbon dioxide, and dry chemical systems), and (c) fire detection and alarm systems. People with a NICET certification can also assist in the selection and use of fire protection systems. NICET provides certification for four levels of competence in all three of the listed areas of fire protection.

G-4 UL. Underwriters Laboratories, 333 Pfingsten Road, Northbrook, IL 60062.

UL has a certification service through which alarm companies can be qualified to issue certificates stating 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 H Related Publications

This appendix lists publications that are not referenced within this standard but that might provide additional helpful information. This appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

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

Marchant, E. W., "Preventing Fire in Historic Buildings: the Acceptable Risk," Fire Technology, Vol. 25, No. 2, 1989, pp. 67-69.

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

H-2 Other Publications.

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

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

Bailey, Alan, Insall, Donald, and Kilshaw, Philip, "Fire Protection Measures for the Royal Palaces," Department of National Heritage, London, 1993.

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

"Fire Prevention in the Conservation Laboratory," Center for Occupational Hazards, New York, NY 1985.

"Fire Protection in Old Buildings and Historic Town Centres," Fire Protection Association, London, 1992.

"Fire Safety Retrofitting in Historic Buildings," Advisory Council on Historic Preservation and the General Services Administration, Washington, DC, 1989.

Fischer, Walter R., "Fire Safety Systems: Protecting Our Treasures from Threat of Fire," *Technology and Conservation,* Vol. 25, No. 2, February 1980, pp. 21-24.

Fisher, Thomas, "Fire Breaks: Fire Safety in Historic Buildings," *Progressive Architecture,* Vol. 67, No. 11, November 1986, pp. 116-121.

Fishlock, Michael, *The Great Fire at Hampton Court,* The Herbert Press, London, 1992.

Hunter, John E., "Security for Museums and Historic Houses: An Annotated Bibliography," Technical Leaflet 114 (History News 34:4), American Association for State and Local History, Nashville, TN, 1979.

Kidd, S., "Heritage Under Fire: A Guide to Protection of Historic Buildings," 2nd edition, Fire Protection Association, London, 1994.

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

Martin, John H., "The Corning Flood: Museum Under Water," Corning Museum of Glass, Corning, NY, 1977.

Morris, James Archibald, "Alloway: The Protection and Preservation of Its Memorials of Robert Burns," Ayrshire Association of Federated Burns Clubs, Ayreshire, UK, 1930.

Morris, John, "Managing the Library Fire Risk," 2nd Edition, University of California, 1979.

Nelson, Carl L., "Protecting the Past from Natural Disasters," Preservation Press, Washington, DC, 1991.

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.

"Procedures for Salvage of Water-Damaged Library Materials," Peter Waters, Restoration Officer, Library of Congress, 1975. (Copies available upon request from the Library of Congress, Washington, DC 20540.)

"Protecting Our Records and Archives from Fire — Report of the GSA Advisory Committee on the Protection of Archives and Records Centers," April 1977. Available from the Superintendent of Documents, Government Printing Office, Washington, DC 20402 (Stock No. 022-002-00049-0).

"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.

Sellers, David Y. and Strassberg, Richard, "Anatomy of a Library Emergency," *Library Journal,* American Library Association, Vol. 98, No. 17 (October 1, 1973), pp. 2824-2827.

Tillotson, Robert G., "Museum Security," International Council of Museums and American Association of Museums, Paris, 1977.

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.

Willman Spawn, "After the Water Comes," PLA Bulletin, Pennsylvania Library Association, Vol. 28, No. 6 (November 1973), pp. 243-251.

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, American Association of Museums, Washington, DC, November/December 1989, pp. 68-72.

Appendix I Salvage of Water-Damaged Library Materials

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

The following material is extracted from *Procedures for Salvage of Water-Damaged Library Materials* by Peter Waters, Restoration Officer, Library of Congress, 1975 (an LC Publication on Conservation of Library Materials). The reader will find additional references in Appendix H, Related Publications.

I-1 Assessment of Damage and Planning for Salvage. Weather is the critical factor in determining what course to take after any flood or fire in which museum, archival, or library materials are damaged. When it is hot and humid, salvage must be initiated with a minimum of delay to prevent or control the growth of mold. When the weather is cold, more time can be taken to plan salvage operations and experiment with various drying procedures.

The first step is to establish the character and degree of damage. Once an accurate assessment of the damage has been made, firm priorities and plans for salvaging the damaged materials can be drawn up. These plans must include a determination of the special facilities and equipment required. Overcautious, unrealistic, or inadequate appraisals of damage can result in the loss of valuable materials. Speed is of the utmost importance, but careful planning is equally essential in the salvage effort.

Where water damage has resulted from fire-fighting measures, cooperation with the fire marshal is vital for a realistic appraisal of the feasibility of salvage efforts. Fire marshals and safety personnel will decide when a damaged building is safe to enter. In some cases, areas involved in the fire can require a week or longer before they are cool enough to be entered. Occasionally, parts of a collection can be identified early in the salvage planning effort as being especially vulnerable to destruction unless they receive attention within a few hours after the fire has abated. If the fire marshal appreciates such needs, he can provide means of access to the area even when other parts of the building remain hazardous.

Once all entrances and aisles are cleared, the most important collections, including rare materials and those of permanent research value, should be salvaged first, unless other materials would be more severely damaged by prolonged immersion in water. Examples of the latter are books printed on paper of types widely produced between 1880 and 1946, now brittle or semi-brittle. However, materials in this category that can be replaced should be left until last.

Salvage operations must be planned so that the environment of flooded areas can be stabilized and controlled both before and during the removal of the damaged materials. In warm, humid weather, mold growth can be expected to appear in a water-damaged area within 48 hours. In any weather, mold will appear within 48 hours in unventilated areas made warm and humid by recent fire in adjacent parts of the building. For this reason, every effort should be made to reduce high temperatures and vent the areas as soon as the water has receded or been pumped out. Water-soaked materials must be kept as cool as possible by good air circulation until they can be stabilized. To leave such materials more than 48 hours in temperatures above 70°F (21°C) and humidity above 70 percent will almost certainly result in heavy mold growth and lead to high restoration costs.

Damaged most by these conditions are volumes printed on coated stock and such highly proteinaceous materials as leather and vellum bindings. Starch-impregnated cloths, glues, adhesives, and starch pastes are affected to a lesser degree. As long as books are tightly shelved, mold will develop only on the outer edges of the bindings. Thus no attempt should be made in these conditions to separate books and fan them open. Archival files packed closely together on the shelves in cardboard boxes or in metal file cabinets are the least affected.

As a general rule, damp books located in warm and humid areas without ventilation will be subject to rapid mold growth. Archival files that have not been disturbed will not be attacked as quickly by mold. Very wet materials, or those still under water, will not develop mold. As they begin to dry after removal from the water, however, both the bindings and the edges of books will be quickly attacked by mold, especially when in warm, unventilated areas. A different problem exists for books printed on coated stock, since if they are allowed to dry in this condition, the leaves will be permanently fused together.

I-2 Summary of Emergency Procedures.

(a) It is imperative to seek the advice and help of trained conservators with ealxperience in salvaging water-damaged materials as soon as possible. The Library of Congress is an excellent information source for technical advice where needed. Contact: Preservation Office, Library of Congress, Washington, DC, Telephone (202) 707-5212.

(b) Turn off heat and create free circulation of air.

(c) Keep fans and air conditioning on at night, except when a fungicidal fogging operation is in process, because a constant flow of air is necessary to reduce the threat of mold.

(d) Brief each worker carefully before salvage operations begin, giving full information on the dangers of proceeding except as directed. Emphasize the seriousness of timing and the priorities and aims of the whole operation. Instruct workers on means of recognizing manuscripts, materials with water-soluble components, leather and vellum bindings, materials printed on coated paper stock, and photographic materials.

(e) Do not allow workers to attempt restoration of any items on site. (This was a common error in the first 10 days after the Florence flood, when rare and valuable leather- and vellum-bound volumes were subjected to scrubbing and processing to remove mud. This resulted in driving mud into the interstices of leather, vellum, cloth, and paper, caused extensive damage to the volumes, and made the later work of restoration more difficult, time consuming, and extremely costly.)

(f) Carry out all cleaning operations, whether outside the building or in controlled environment rooms, by washing gently with fresh, cold running water and soft cellulose sponges to aid in the release of mud and filth. Use sponges with a dabbing motion; do not rub. These instructions do not apply to materials with water-soluble components. Such materials should be frozen as quickly as possible.

(g) Do not attempt to open a wet book. (Wet paper is very weak and will tear at a touch.) Hold a book firmly closed when cleaning, especially when washing or sponging. A closed book is highly resistant to impregnation and damage.

(h) Do not attempt to separate single-sheet materials unless they are supported on polyester film or fabric.

(i) Do not attempt to remove all mud by sponging. Mud is best removed from clothes when dry; this is also true of library materials.

(j) Do not remove covers from books, as they will help to support the books during drying. When partially dry, books can be hung over nylon lines to finish drying. Do not hang books from lines while they are very wet because the weight will cause damage to the inside folds of the sections.

(k) Do not press books and documents mechanically when they are water soaked. This can force mud into the paper and subject the materials to stresses that will damage their structures.

(l) Use soft pencils for making notes on slips of paper but do not attempt to write on wet paper or other artifacts.

(m) Clean, white blotter paper, white paper towels, strong toilet paper, and unprinted newsprint paper can be used for interleaving in the drying process. When nothing better is available, all but the color sections of printed newspapers can be used. Great care must be taken to avoid rubbing the inked surface of the newspaper over the material being dried; otherwise some offsetting of the ink could occur.

(n) Under no circumstances should newly dried materials be packed in boxes and left without attention for more than a few days.

(o) Do not use bleaches, detergents, water-soluble fungicides, wire staples, paper or bulldog clips, adhesive tape, or adhesives of any kind. Never use felt-tipped fiber or ballpoint pens or any marking device on wet paper. Never use colored blotting paper or colored paper of any kind to dry books and other documents.

Appendix J Factory Mutual Engineering Division Laboratory Report

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

(Report by P. E. Cotton, 14000/Res., December 21, 1959)

J-1 Fire Tests of Library Book Stacks. Consideration of library fire protection usually brings out two questions. First, would fire be expected to spread in a book stack? And second, if so, will automatic sprinklers keep the damage to a minimum? Two tests were made to show the answers. In both cases it was emphatically, yes.

The stack used in the tests is illustrated by Figures J-1(a), J-1(b), and J-1(c). It is a segment of a typical library stack, consisting of a steel structure supporting steel shelves that hold discarded library books. This structure was purchased from and erected by a manufacturer of library equipment. In the plan, the segment contains four ranges (lines of shelving) 12 ft (3.72 m) long facing on two aisles 4 $^1/_2$ ft (1.4 m) on centers. Thus, the area occupied is 9 ft (2.79 m) wide by 12 ft (3.72 m) long. In elevation there are four tiers or stories, each 7 $^1/_2$ ft (2.3 m) high, making a total height of 30 ft (9.3 m).

J-2 Test 1 — With Standard Automatic Sprinklers. For the first fire test, standard automatic sprinklers were installed in both aisles in all four tiers of the stack. Since the sprinklers were spaced the maximum practical distance apart in the aisles [15 ft (4.6 m)], platforms were provided at each end of the stack to extend its effective length insofar as the sprinklers were concerned.

The fire was started in a small quantity of paper contained in a wooden book cart arranged as shown in Figure J-2(a). Its location in one aisle of the lowest tier of the stack is illustrated in Figures J-2(b) through J-2(e), which also show the fire growth, the action of the sprinklers, and the limitation of damage.

In this test, one sprinkler opened in the second tier at 3 minutes, 43 seconds after the fire was lighted and one sprinkler opened in the first tier 7 minutes, 53 seconds after the start. The sprinkler discharge stopped the spread of fire in the books almost immediately and gradually extinguished the fire.

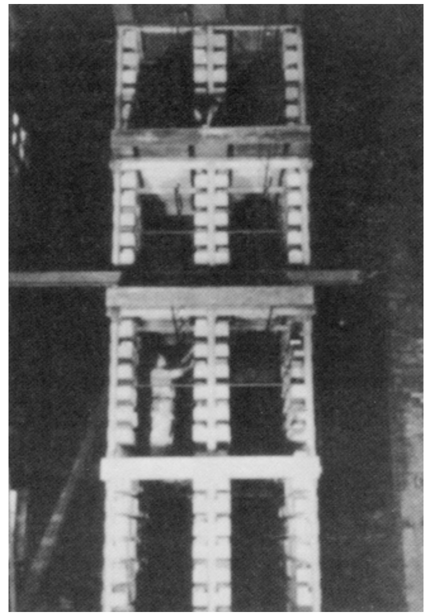


Figure J-1(a) General view of four-tier book stack loaded with 11,200 books.

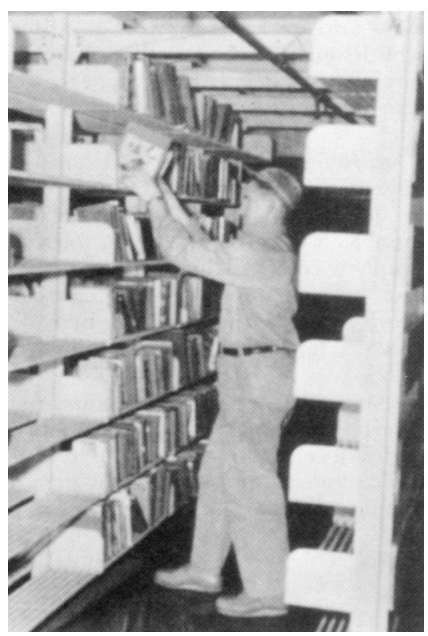


Figure J-1(b) Illustration of structural elements of stack; note one sprinkler position.

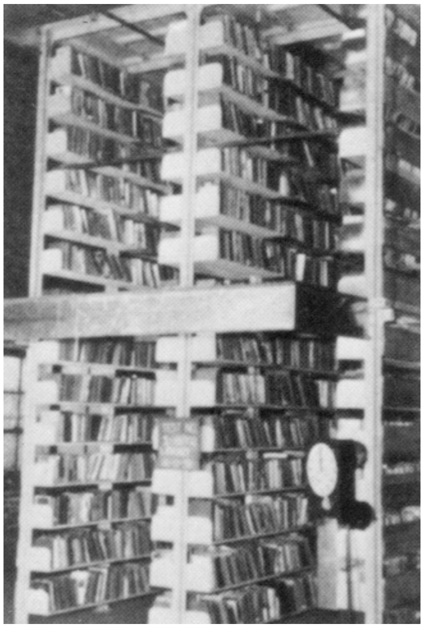


Figure J-1(c) General view of books in the first and second tiers before tests.

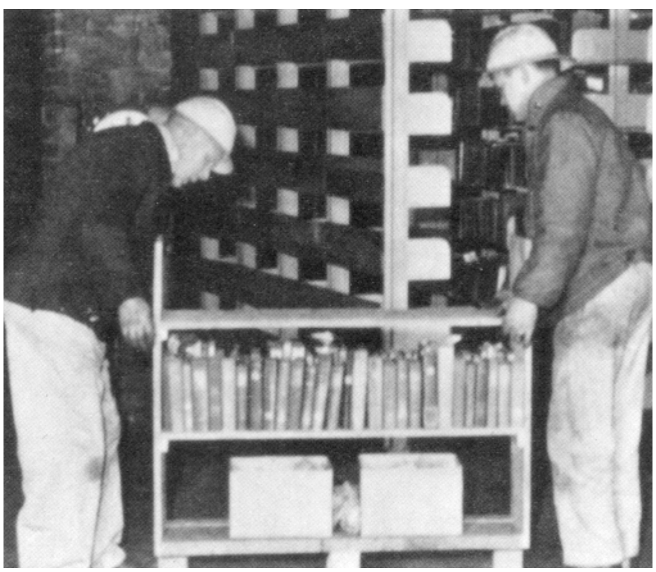


Figure J-2(a) Wood book cart before being placed in aisle of first tier. After placement, books were put on top shelf of book cart. The fire was started with an ordinary match by igniting the crumpled piece of paper between the two cartons on the bottom shelf of the cart.

There was fire damage to books in 10 percent of the storage space of the stack *[see Figure J-2(f)]*, and this damage would be repairable for practically all of the books involved. Books in an additional 27 percent of the storage space of the test segment were wet in varying degrees ranging from dampness to soaking. All books so involved would be repairable by drying. Nine 3-ft-(.93-m-) long shelf sections were deformed by heating, although the structural members of the stack were unharmed except for paint damage.

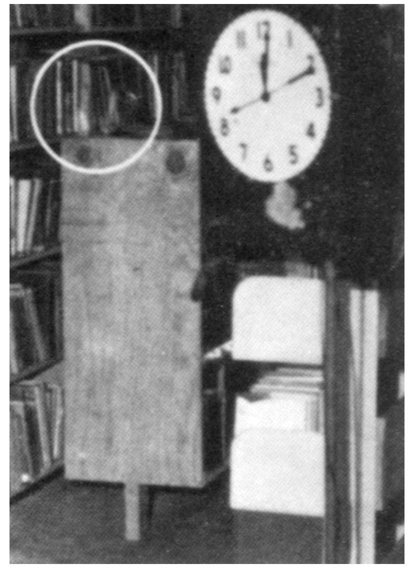


Figure J-2(b) One minute, 10 seconds; flame showing above book cart; sprinklers not yet operating.

J-3 Test 2 — No Automatic Sprinkler System. After replacing all fire- and water-damaged books and shelving following the first test, a second test was made using the same method of ignition as in the first test.

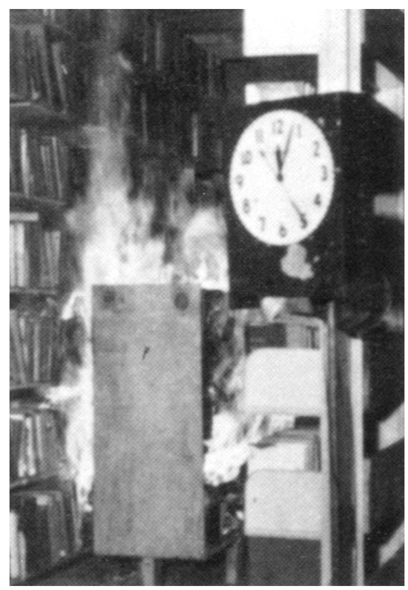


Figure J-2(c) Three minutes, 25 seconds; active burning in first tier; sprinklers not yet operating.

The spread of fire upward through the four tiers of the book stack is described best by Figures J-3a through J-3(d). Added to this are the visual observations that books in the second tier began burning at approximately $3\,^1/_4$ minutes, in the third tier at $7\,^1/_2$ minutes, and in the fourth tier at 9 minutes. By 10 minutes, there was intense fire in all areas of the book stacks except at the lower shelves of the first tier in the aisle not containing the ignition source. A 1-in. (25-mm) hose line was used to attack the fire at 10 minutes, 23 seconds, followed by a $2\frac{1}{2}$-in. (63-mm) hose line at 10 minutes, 40 seconds since the first hose stream was only slightly effective. Together, these hose streams controlled and essentially extinguished the fire, although smoldering continued for hours afterward.

Some indication of the extent of the damage to the books and stacks is given by the photographs in Figures J-3(e) through J-3(g). Quantitatively, 89 percent of the books were charred deeply or completely destroyed, $2\frac{1}{2}$ percent were scorched, and the remaining $8\frac{1}{2}$ percent were soaked.

Approximately three-fourths of the shelving was irreparably damaged. Some of the structural elements were visibly deformed *[see Figure J-3(h)];* others would not be safely reusable for live loads. These observations indicate that complete collapse of the structure was imminent when hose streams were applied. Figures J-3(i)1 through J-3(i)4 give a comparison of temperatures of various points in the structure for both tests.

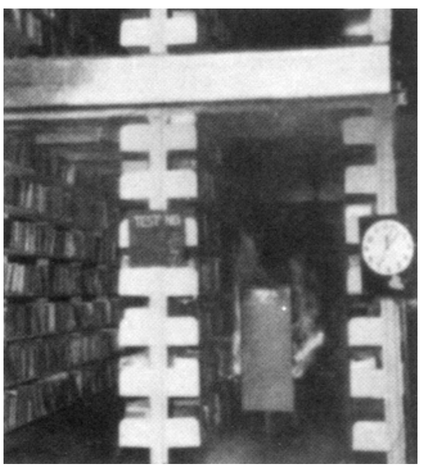


Figure J-2(d) Eight minutes, 3 seconds; two sprinklers operating; fire in stack under control.

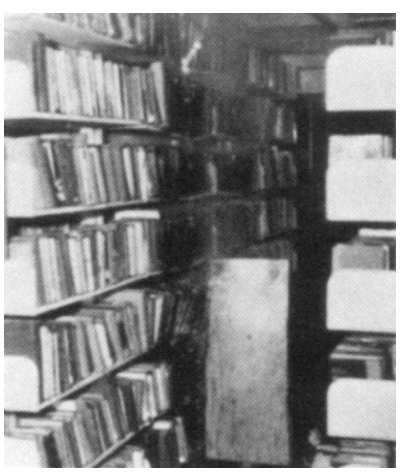


Figure J-2(e) After fire extinguishment by sprinklers; fire damage to books in only 10 percent of space.

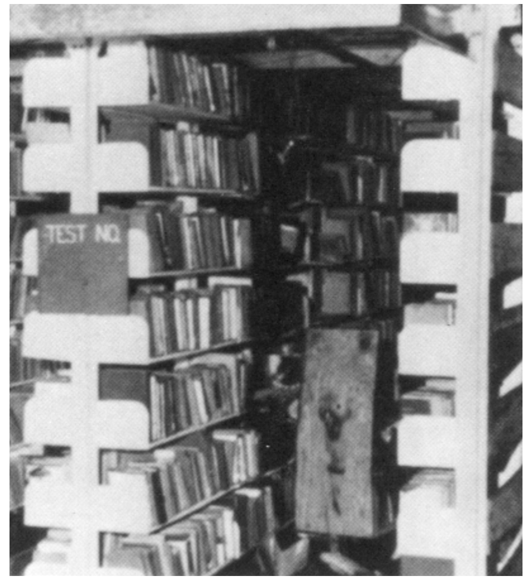


Figure J-2(f) Close-up of extent of fire damage after Test 1 with automatic sprinklers. Note limited area of fire damage.

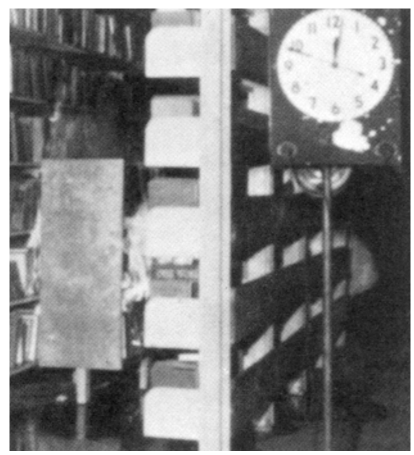


Figure J-3(a) One minute, 48 seconds; books in stack ignited; no sprinklers.

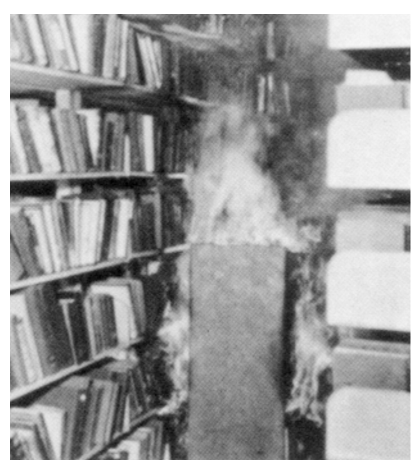


Figure J-3(b) After approximately 3 minutes; active burning in first tier; no sprinklers.

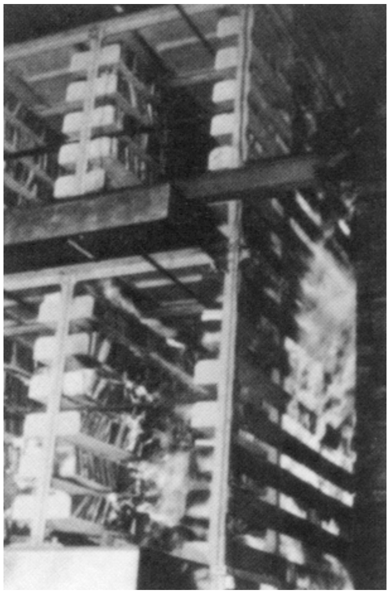


Figure J-3(c) After approximately 7 ½ minutes, fire involved second and third tiers.

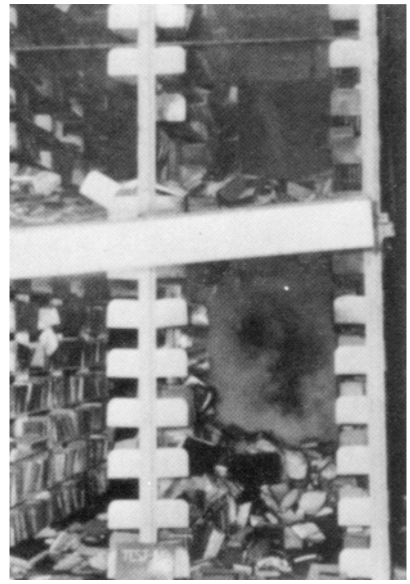


Figure J-3(e) General view of first and second tiers after Test 2 (no sprinklers).

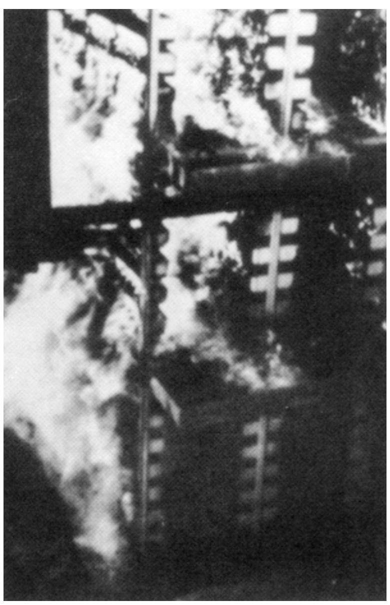


Figure J-3(d) After about 9 ½ minutes, flame spread to top tier and across aisles on lower tiers.

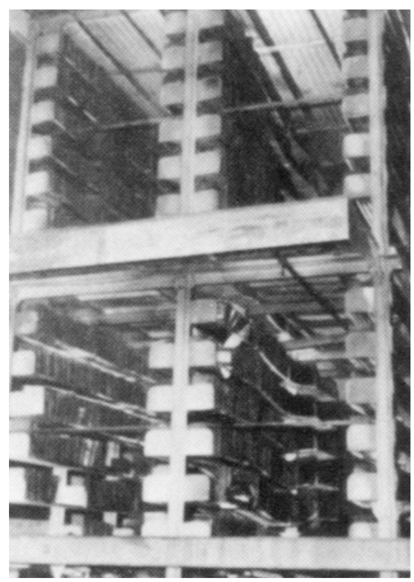


Figure J-3(f) General view of third and fourth tiers; all exposed book surfaces charred.

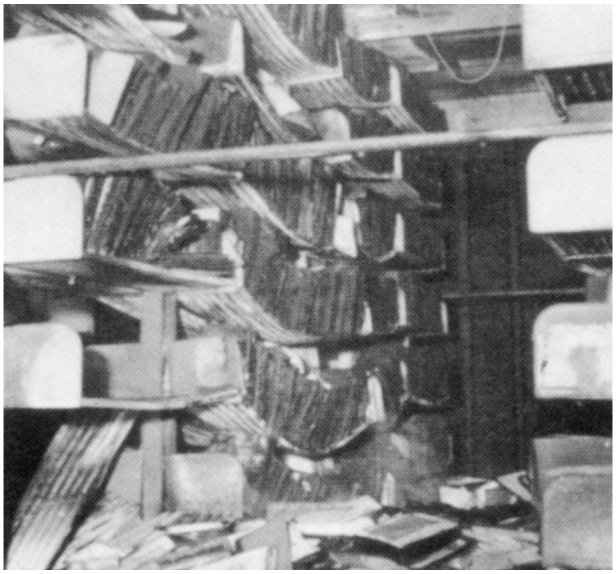


Figure J-3(g) Extent of damage to shelving after Test 2 (no sprinklers) on second tier, right aisle. Note severe charring of books and collapse of shelving.

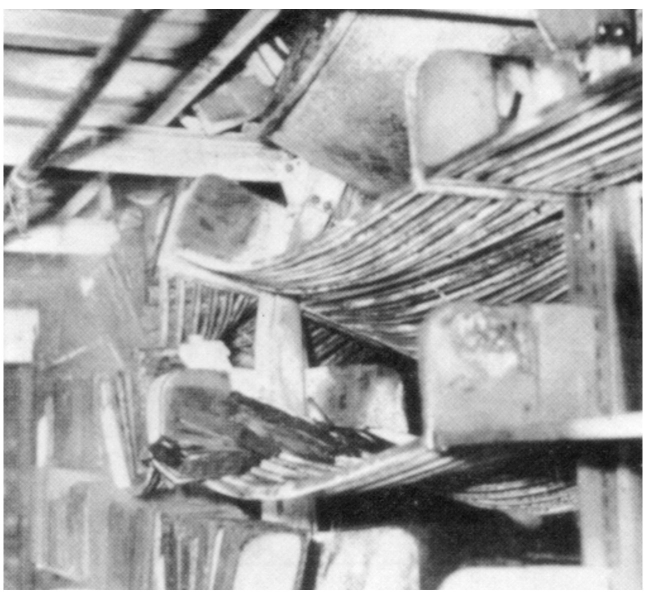


Figure J-3(h) View of first tier, left aisle after Test 2 (no sprinklers). The temperatures reached 1500°F (780°C) in each recorded location, whereas in Test 1 (with sprinklers) temperatures did not go above 500°F (260°C). Note failure of column (center of photo).

From these results, it is apparent that fire can be expected to spread quickly through library stacks from a modest local ignition source. It is also apparent that standard automatic sprinklers will fill their normal industrial role of minimizing the consequent damage from such a fire.

Factory Mutual Engineering Division

E.W. Cousins
Chief Research Engineer

J.M. Rhodes, Director
Engineering and Laboratories

Book Stack	
Size:	9 feet wide, 12 feet long, 30 feet high (four 7 ½ ft-high tiers)
Book Storage:	Four ranges of four compartments each in each tier
Shelves:	Seven shelves in each compartment; all U-bar type except floor shelf, which is solid Shelves are 3 feet long by 8 inches deep spaced 1 foot apart vertically except at floor and ceiling where spacing is 15 inches 112 shelves per tier; 448 shelves total
Aisles:	3 feet wide, two 3-in. slots plus 30-in. walkway
Weight of Structure:	7000 pounds

Books	
Average:	25 per shelf, 175 per compartment, 700 per single range, 2800 per tier, 11,200 total
Approximate Average Weight per Book:	1 pound dry, 2 ½ pounds soaking wet
Moisture Content of Books:	5 percent to 9 percent

Book Cart and Contents

Book cart [shown in Figure J-2(a)] was made of wood (moisture content: 7 percent) and was 15 inches wide, 42 inches long, and 36 inches high. During the tests 120 books were placed on the two top shelves (fully loaded), and the bottom shelf contained two open-top cardboard cartons (12 by 12 by 8 inches). Each carton contained two crumpled wrapping papers that were 3 feet by 3 feet each and between cartons was crumpled wrapping paper 1½ feet by 3 feet. The weight of the cartons and paper was 2 pounds; the weight of the book cart empty was 57 pounds. The test engineers considered this book cart fire "a modest local ignition source" for these library tests.

Sprinkler Protection

The sprinklers used were 160° standard sprinklers, pendent mounted, on 4 ½ -ft by 15-ft spacing staggered vertically and horizontally. There were sprinklers in all tiers and all aisles of the test library book stack setup.

Sprinkler deflectors were located 10 inches below the ceiling and 6 inches off center to allow for fluorescent lighting in actual library installations.

The pressures were designed so that the static pressure at the end sprinkler was 5 psi on the fourth tier, 14 ¾ psi on the first tier, 11 ½ psi on the second tier, and 8 ¼ psi on the third tier.

The approximate discharge per sprinkler was 22 gallons per minute on the first tier, 19 gpm on the second tier, 16 gpm on the third tier, and 13 gpm on the fourth tier.

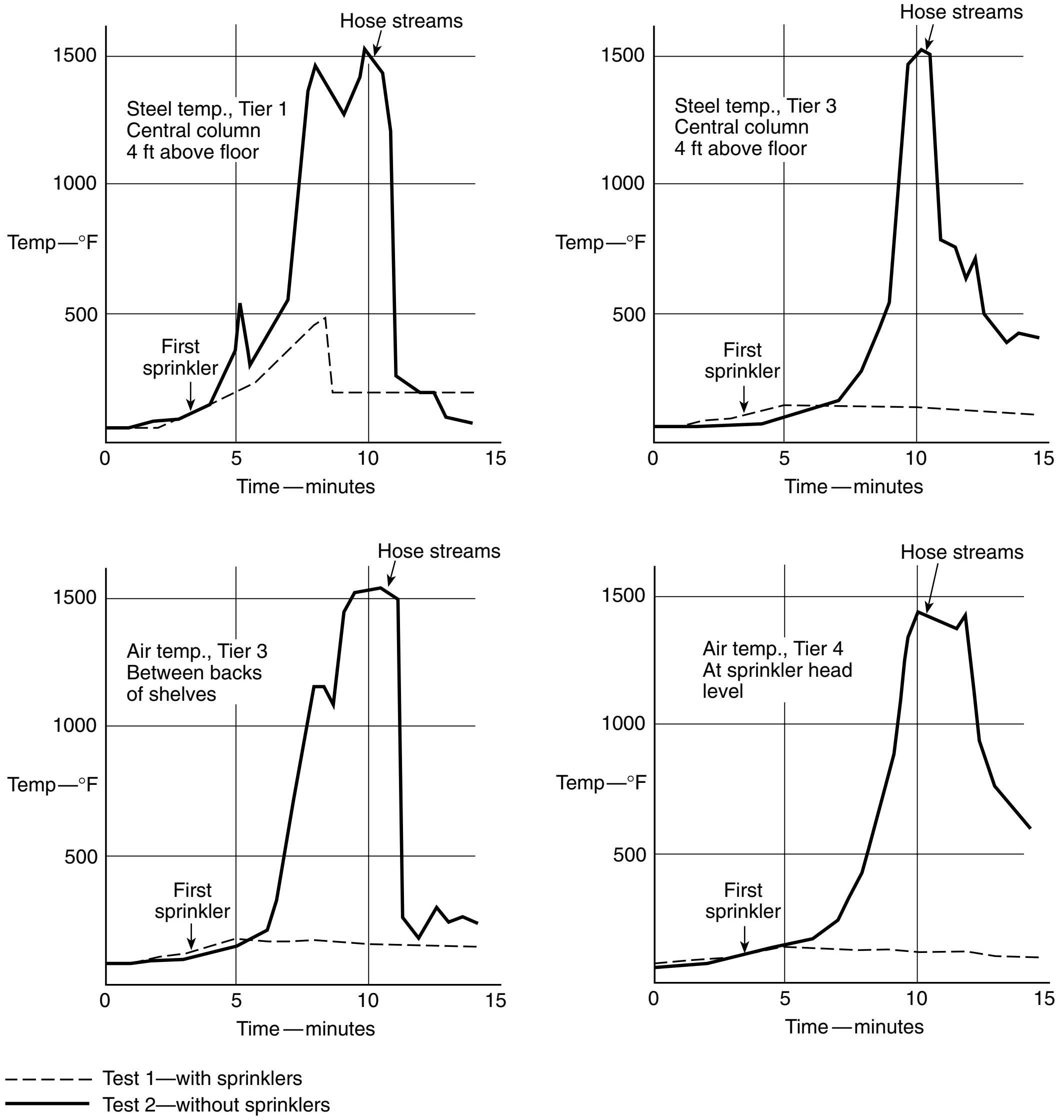


Figure J-3(i) Temperatures at various locations in book stacks.

Appendix K Secretary of the Interior's Standards

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

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 that 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 that have no historical basis and that seek to create an earlier appearance shall be discouraged.

(d) Changes that could 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 could have acquired significance in their own right, and this significance shall be recognized and respected.

(e) Distinctive stylistic features or examples of skilled craftsmanship that 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.

Appendix L Guideline on Fire Ratings of Archaic Materials and Assemblies

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

Prepared by the National Institute of Building Sciences, Washington, DC, 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.

Acknowlegements

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Overall management and production of the Rehabilitation Guidelines was directed by William Brenner of the Institute, with David Hattis of Building Technology, Inc. the principal technical consultant.

Table of Contents

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 that 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 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 mechanically sound. 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. The assessment can often be difficult because process and quality control was poor in many industries, and variations among locally available raw materials and manufacturing techniques often resulted in a product that 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 and do not necessarily relate to concerns for safety. The high cost of labor has 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 does not matter 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 judgement is more difficult because building officials might 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 must be removed and replaced. Both alternatives are time consuming and wasteful.

This guideline is 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

Chapter L-1 Fire-Related Performance of Archaic Materials and Assemblies

L-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 that follows a "standard" time-temperature curve. This test method has changed little since the 1920s. The test results tabulated in Chapter L-4 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, such as 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 1940s, 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 Table L-1.1.

Table L-1.1 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

L-1.1.1 Flame Spread. The flame spread of interior finishes is most often measured by the ASTM E 84, *Standard Test Method for Surface Burning Characteristics of Building Materials,* "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 (some codes use roman numerals, while others use letters), with a 0-25 FSR, Class II or B, with a 26-75 FSR, and Class III or C, with a 76-200 FSR. NFPA *101, 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.

L-1.1.2 Smoke Production. The evaluation of smoke density is part of the ASTM E 84, *Standard Test Method for Surface Burning Characteristics of Building Materials,* tunnel test. For the eight species of lumber shown in Table L-1.1, 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 ceiling 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.

L-1.1.3 Degree of Combustibility. The model building codes tend to define "noncombustibility" on the basis of having passed ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C,* or if the material is totally inorganic. The acceptance of gypsum wallboard as noncombustible is based on limiting paper thickness to not over $^1/_8$ in. (3.2 mm) and a 0-50 flame spread rating by ASTM E 84, *Standard Test Method for Surface Burning Characteristics of Building Materials.* 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 noncombustible according to ASTM E 136, it can be expected that it will not contribute fuel to the fire.

L-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-hr 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.

Chapter L-2 Building Evaluation

L-2.1 Introduction. 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.

L-2.2 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. See Tables L-2.2(a) and L-2.2(b) for two work sheets that are shown in order 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 might 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 that can 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.

Table L-2.2(a) Preliminary Evaluation Field Notes

Building Element		Materials	Thickness	Condition	Notes
Exterior Bearing Walls					
Interior Bearing Walls					
Exterior Nonbearing Walls					
Interior Nonbearing	A				
Walls or Partitions	B				
Structural Frame: Columns					
Beams					
Other					
Floor/Ceiling Structural System Spanning					
Roofs					
Doors (including frame and hardware): a) Enclosed vertical exit way					
b) Enclosed horizontal exit way					
c) Other					

Table L-2.2(a) 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 could 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. (Problems providing adequate exiting are discussed at length in the "Egress Guideline for Residential Rehabilitation.")

The following notes explain the entries in Table L-2.2(a).

Note 1 Exterior Bearing Walls. Many old buildings utilize heavily constructed walls to support the floor/ceiling assemblies at the exterior of the building. There could 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 can be considered nonbearing.

Note 2. Interior Bearing Walls. It can 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.

Note 3. Exterior Nonbearing Walls. The fire resistance of the exterior walls is important for two reasons. These walls (both bearing and nonbearing) are depended upon for one of the following purposes:

(a) To contain a fire within the building of origin

(b) To keep an exterior fire outside 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 and its thickness and framing, and should 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.

Note 4. Interior Nonbearing Walls (Partitions). A partition is a "wall that extends from floor to ceiling and subdivides space within any story of a building." Table L-2.2(a) has two categories (A and B) for interior nonbearing walls (partitions) that can be used for different walls, such as hallway walls as compared to inter-apartment walls. Under some circumstances there might be only one type of wall construction; in others, three or more types of wall construction might 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 [$^1/_4$ in. (6.3 mm)] 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 that allows a cataloging 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.

Note 5. Structural Frame. There might 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 10-in. square columns located on a 30-ft 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 $^1/_4$ in. (6.3 mm). As discussed above, the preliminary field survey usually relies on accidental openings in the cover materials rather than a systematic coring technique.

Note 6. 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.

Note 7. 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 that have been used. Be aware that there could be several layers of roof materials.

Note 8. 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 Table L-2.2(a).

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.

Note 9. 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 in.^{3} (164 cm^3) so that an ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C,* fire test can be conducted to determine if it is combustible.

Note 10. 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.

Note 11. 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.

Note 12. 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. Table L-2.2(b) is a suggested work sheet for organizing this information.

The required fire resistance and flame spread for each building element is 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 can 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 either to 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.

L-2.3 Fire Resistance of Existing Building Elements. The fire resistance of the existing building elements can be estimated from the tables and histograms contained in Chapter L-4. Chapter L-4 is organized first by type of building element (i.e., 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.

Table L-2.2(b) 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 Nonbearing Walls								
Interior Nonbearing Walls or Partitions	A							
	B							
Structural Frame: Columns								
Beams								
Other								
Floor/Ceiling Structural System Spanning								
Roofs								
Doors (including frame and hardware): a) Enclosed vertical exit way								
b) Enclosed horizontal exit way								
c) Others								

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 L-4.5.13, Wood Frame Walls 4 in. (100 mm) to Less than 6 in. (150 mm) 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-hr 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-hr 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 tables in Chapter L-4 not only guarantees the accuracy of the fire resistance rating, but also provides a source of documentation for the building official.

L-2.4 Effects of Penetrations in Fire-Resistant Assemblies. There are often many features in existing walls or floor/ceiling assemblies that 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 just to 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 might 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 that 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 L-4.5.58 in Section V of Chapter L-4 contains 41 entries of doors mounted in sound tight-fitting frames. Part L-3.4 below outlines one procedure for evaluating and possibly upgrading existing doors.

Chapter L-3 Final Evaluation and Design Solution

L-3.1 Introduction. The final evaluation begins after the rehabilitation project has reached the final design stage and the choices have been 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 can involve local building and fire officials reviewing the preliminary evaluation as depicted in Tables L-2.2(a) and L-2.2(b) 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 tables in Chapter L-4 and the fire performance properties satisfy code requirements. Other approaches must be used, though, if the assembly cannot be found within the tables in Chapter L-4 or the fire performance needs to be upgraded. These approaches have been grouped into two classes, experimental and theoretical.

L-3.2 The Experimental Approach. If a material or assembly found in a building is not listed in the tables in Chapter L-4, 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 that routinely conduct the various fire tests. A current list can be obtained by writing the Center for Fire Research, National Institute of Standards and Technology, Washington, DC 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 might be no alternative to a full-scale test.

A "nonstandard" small-scale test can be used in special cases. Sample sizes need only be 10 ft^2 to 25 ft^2 (.93 m^2 to 2.3 m^2), while full-scale tests require test samples of either 100 ft^2 (9.3 m^2) or 180 ft^2 (16.7 m^2) in size. This small-scale test is best suited for testing non-load-bearing assemblies against thermal transmission only.

L-3.3 The Theoretical Approach. There will be instances when materials and assemblies in a building undergoing rehabilitation cannot be found in the tables in Chapter L-4. Even where test results are available for more or less similar construction, the proper classification might not be immediately apparent. Variations in dimensions, loading conditions, materials, or workmanship can 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*. Harmathy's Rules provide a foundation for extending the data within the tables in Chapter L-4 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 characteristic of the individual layers when exposed separately to fire.

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°F (121°C) when the other side is exposed to the "standard" fire specified by ASTM E 119, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials.*

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." Tables L-3.3(a) and L-3.3(b) 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 (121°C) above ambient or 325°F (163°C) 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 possibly causing 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.

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 midplane 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 can 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. The following are examples:

Table L-4.5.4, item W-8-M-82: Cored concrete masonry, nominal 8-in. (0.20-m) thick wall with one unit in wall thickness and with 62 percent minimum of solid material in each unit, load bearing [80 psi (5.5 bar)]. Fire endurance 2 $\frac{1}{2}$ hours.

Table L-4.5.5, item W-10-M-11: Cored concrete masonry, nominal 10-in. (0.25-m) thick wall with two units in wall thickness and a 2-in. (50-mm) air space, load bearing [80 psi (5.5 bar)]. The units are essentially the same as item W-8-M-82. Fire endurance 3 $\frac{1}{2}$ hours.

Table L-3.3(a) Finish Ratings — Inorganic Materials

Item Code	Thickness	Construction Details	Performance: Finish Rating	Reference Number: Pre-BMS-92	Reference Number: BMS-92	Reference Number: Post-BMS-92	Notes	Rec F.R. (min)
F.R.-I-1	$^9/_{16}$"	$^3/_8$" gypsum wallboard faced with $^3/_{16}$" cement asbestos board	20 min		1		1,2	15
F.R.-I-2	$^{11}/_{16}$"	$^1/_2$" gypsum sheathing faced with $^3/_{16}$" cement asbestos board	20 min		1		1,2	20
F.R.-I-3	$^3/_{16}$"	$^3/_{16}$" cement asbestos board over uninsulated cavity	10 min		1		1,2	5
F.R.-I-4	$^3/_{16}$"	$^3/_{16}$" cement asbestos board over insulated cavities	5 min		1		1,2	5
F.R.-I-5	$^3/_4$"	$^3/_4$" thick 1:2, 1:3 gypsum plaster over paper backed metal lath	20 min		1		1–3	20
F.R.-I-6	$^3/_4$"	$^3/_4$" thick portland cement plaster on metal lath	10 min		1		1,2	10
F.R.-I-7	$^3/_4$"	$^3/_4$" thick, 1:5, 1:7.5 lime plaster on metal lath	10 min		1		1,2	10
F.R.-I-8	1"	1" thick neat gypsum plaster on metal lath	35 min		1		1,2,4	35
F.R.-I-9	$^3/_4$"	$^3/_4$" thick neat gypsum plaster on metal lath	30 min		1		1,2,4	30
F.R.-I-10	$^3/_4$"	$^3/_4$" thick 1:2, 1:2 gypsum plaster on metal lath	15 min		1		1–3	15
F.R.-I-11	$^1/_2$"	Same as F.R.-I-7, except $^1/_2$" thick on wood lath	15 min		1		1–3	15
F.R.-I-12	$^1/_2$"	$^1/_2$" thick, 1:2, 1:3 gypsum plaster on wood lath	15 min		1		1–3	15
F.R.-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
F.R.-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
F.R.-I-15	$^3/_8$"	$^3/_8$" gypsum wallboard	10 min		1		1,2	10
F.R.-I-16	$^1/_2$"	$^1/_2$" gypsum wallboard	15 min		1		1,2	15

Notes:
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 to 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.

These walls show one hour greater fire endurance by the addition of the 2-in. (50-mm) 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 that attains high temperatures during fire exposure.

Some of the clay tile designs take advantage of these factors. The double cell design, for instance, ensures 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 $^1/_2$ in. (12.5 mm), 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.

Table L-3.3(b) Finish Ratings — 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)
F.R.-0-1	$^{3}/_{16}$"	$^{7}/_{16}$ wood fiber board faced with $^{1}/_{8}$" cement asbestos board	15 min		1		1,2	15
F.R.-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
F.R.-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
F.R.-0-4	$^{1}/_{2}$"	$^{1}/_{2}$" thick wood fiberboard	5 min		1		1,2	5
F.R.-0-5	$^{1}/_{2}$"	$^{1}/_{2}$" thick flameproofed wood fiberboard	10 min		1		1,2	10
F.R.-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
F.R.-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
F.R.-0-8	$1\,^{1}/_{4}$"	$1\,^{1}/_{4}$" thick plywood	30 min		1	35		30

Notes:
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 to weight of dry sand; second ratio is for the brown coat.

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

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 might not be applicable to materials undergoing physio-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 can 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 could 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 that, 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. *(See Figure L-3.3.)*

Illustration of Harmathy's Rules. Harmathy provided one schematic figure that 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 show how the rules can be applied to practical cases.

Example 1

Problem

A contractor would like to keep a partition that consists of a $3^3/_4$-in. (95-mm) thick layer of red clay brick, a $1^1/_4$-in. (32-mm) thick layer of plywood, and a $^3/_8$-in. (9.5-mm) thick layer of gypsum wallboard, at a location where 2-hr fire endurance is required. Is this assembly capable of providing a 2-hr protection?

Solution

(a) This partition does not appear in the tables in Chapter L-4.

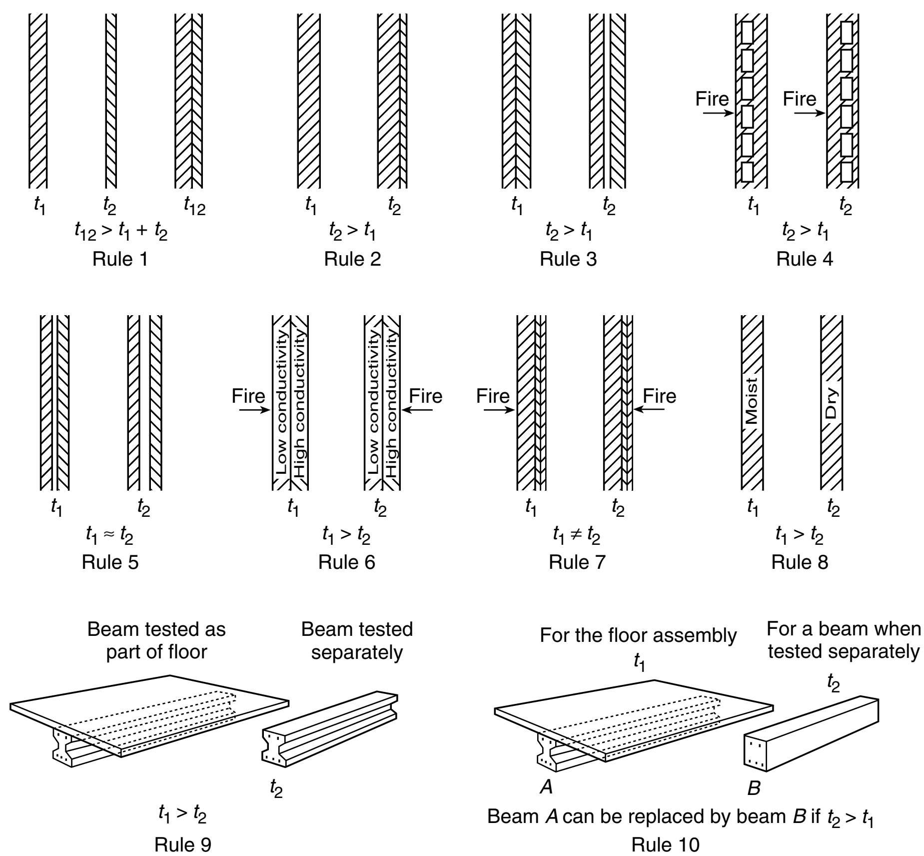
(b) Bricks of this thickness yield fire endurances of approximately 75 minutes (Table L-4.5.2, item W-4-M-2).

(c) The $1^1/_4$-in. (32-mm) thick plywood has a finish rating of 30 minutes.

(d) The $^3/_8$ in. (9.5 mm) gypsum wallboard has a finish rating of 10 minutes.

(e) 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

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



Diagrammatic illustration of 10 rules
t = fire endurance

Figure L-3.3

Discussion

This example illustrates how the tables in Chapter L-4 can be utilized to determine the fire resistance of assemblies not explicitly listed.

Example 2

Problem

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

(b) The designer and contractor would like to determine whether or not this roof slab is capable of yielding a 2-hr fire endurance. According to a rigorous interpretation of ASTM E 119, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials,* 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.

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

Solution

(a) The answer to the question is yes.

(b) 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-hr fire endurance, the endurance of an assembly, including the slabs, cannot be less than 2 hours.

(c) 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.

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

Discussion

If the tables did not include tests on assemblies that 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 that, 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-hr endurance is required. What is the most economical way of increasing the fire endurance by at least 25 minutes?

Solution

(a) 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.

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

Discussion

(a) The additional plaster has at least the following three effects:

1. The layer of plaster is increased and thus there is a gain of fire endurance (Rule 1).
2. There is a gain due to shifting the air gap farther from the exposed surface (Rule 4).
3. There is more moisture in the path of heat flow to the structural elements (Rules 7 and 8).

(b) 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 (a) above would further increase this by a factor of two or more, depending upon the geometry of the assembly.

Example 4

Problem

The fire endurance of item W-10-M-1 in Table L-4.5.5 is 4 hours. This wall consists of two $3^3/_4$-in. (95-mm) thick layers of structural tiles separated by a 2-in. (50-mm) air gap and $^3/_4$-in. (19-mm) 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-in. (102-mm) 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 as follows:

(a) 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.

(b) 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.

L-3.4 "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 (the protective layer or membrane of material that slows the flow of heat to the structural elements) 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.

L-3.5 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 Section 2-4 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 tables in Chapter L-4 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 Table L-4.5.58, 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 one hour fire resistance is noted in the tables as providing only 5 minutes. The likelihood of achieving the required one 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 that could measurably affect fire performance. The wood could have dried over the years or 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 nondestructive 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.

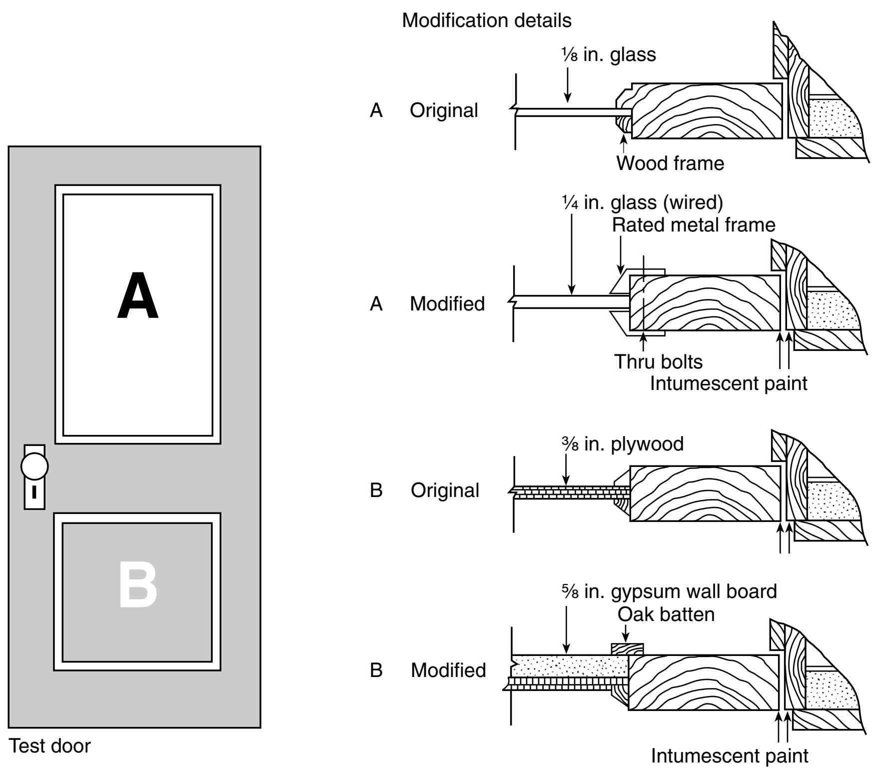


Figure L-3.5

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 L-3.5 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.

Chapter L-4 Summary

L-4.1 Introduction. 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 that 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 should be considered equivalent.

L-4.2 The fire resistance of a building element can be established from the tables in Chapter L-4. This is subject to the following limitations:

(a) The building element in the rehabilitated building should bebebebe constructed of the same materials with the same nominal dimensions as stated in the tables.

(b) All penetrations in the building element or its cover for services such as electricity, plumbing, and HVAC should be packed with noncombustible cementitious materials and so fixed that the packing material will not fall out when it loses its water of hydration.

(c) The effects of age and wear and tear should 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.

L-4.3 The fire resistance of a building element that does not explicitly appear in the tables in Chapter L-4 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 should be the fire resistance recommended in the table. This is subject to the following limitations:

(a) The actual element in the rehabilitated building shall be constructed of the same materials as listed in the table. Only the following dimensions could 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.

(b) All penetrations in the building element or its cover for services such as electricity, plumbing, or HVAC should be packed with noncombustible cementitious materials and so fixed that the packing material will not fall out when it loses its water of hydration.

(c) The effects of age and wear and tear should 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 Section L-3.4 of the guideline. There should be many instances when a thicker building element was utilized than the one listed in the tables in Chapter L-4. 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 tables in Chapter L-4. If other data are used, it must be in connection with the approach below.

L-4.4 The fire resistance of building elements can be established by applying Harmathy's Ten Rules of Fire Resistance Ratings as set forth in Section L-3.3 of the guideline. This is subject to the following limitations:

(a) The data from the tables can be utilized subject to the limitations in Section L-4.3 above.

(b) Test reports from recognized journals or published papers can be used to support data utilized in applying Harmathy's Rules.

(c) 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.

L-4.5 Summary Tables and Figures. The summary tables and histograms that follow are to be used only within the analytical framework detailed in the main body of this guideline.

Histograms precede any summary table with 10 or more entries. The use and interpretation of these histograms is explained in Chapter L-2. The summary tables are in a format similar to that found in the model building codes. Table L-4.5, taken from an entry in Table L-4.5.2, best explains the summary table format.

Table L-4.5 Example of Summary Table Format

Item Code	Thickness	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
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	$^1/_3$

Notes:
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 1-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 L-4.5.2
2. The specific name or heading of this column identifies the dimensions which, if varied, have 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 that 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 shown in Appendix M 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.

The following is a list of the summary tables and figures.

Section I — Walls

Section II — Columns

L-4.5.29	Hexagonal Reinforced Concrete Diameter — 20"–22"
L-4.5.30	Round Cast Iron Column Minimum Dimension
L-4.5.31	Steel — Gypsum Encasements Minimum Area of Solid Material
L-4.5.32	Timber Minimum Dimension
L-4.5.33	Steel/Concrete Encasements Minimum Dimension less than 6"
L-4.5.34	Steel/Concrete Encasements Minimum Dimension 6"–8"
L-4.5.35	Steel/Concrete Encasements Minimum Dimension 8"–10"
L-4.5.36	Steel/Concrete Encasements Minimum Dimension 10"–12"
L-4.5.37	Steel/Concrete Encasements Minimum Dimension 12"–14"
L-4.5.38	Steel/Concrete Encasements Minimum Dimension 14"–16"
L-4.5.39	Steel/Concrete Encasements Minimum Dimension 16"–18"
L-4.5.40	Steel/Plaster Encasements Minimum Dimension 10"–12"
L-4.5.41	Steel/Brick and Block Encasements Minimum Dimension 12"–14"
L-4.5.42	Steel/Brick and Block Encasements Minimum Dimension 14"–16"
L-4.5.43	Steel/Plaster Encasements Minimum Dimension 6"–8"
L-4.5.44	Steel/Plaster Encasements Minimum Dimension 8"–10"
L-4.5.45	Steel/Miscellaneous Encasements Minimum Dimension 6"–8"
L-4.5.46	Steel/Miscellaneous Encasements Minimum Dimension 8"–10"
L-4.5.47	Steel/Miscellaneous Encasements Minimum Dimension 10"–12"
L-4.5.48	Steel/Miscellaneous Encasements Minimum Dimension 12"–14"
Section III — Floor/Ceiling Assemblies	
L-4.5.49	Reinforced Concrete Assembly Thickness
L-4.5.50	Steel Structural Elements Membrane Thickness
L-4.5.51	Wood Joist Membrane Thickness
L-4.5.52	Hollow Clay Tile with Reinforced Concrete Assembly Thickness
Section IV — Beams	
L-4.5.53	Reinforced Concrete Depth — 10"–12"
L-4.5.54	Reinforced Concrete Depth — 12"–14"
L-4.5.55	Reinforced Concrete Depth —14"–16"
L-4.5.56	Steel/Unprotected Depth — 10"–12"
L-4.5.57	Steel/Concrete Protection Depth — 10"–12"
Section V — Doors	
L-4.5.58	Resistance of Doors to Fire Exposure Thickness

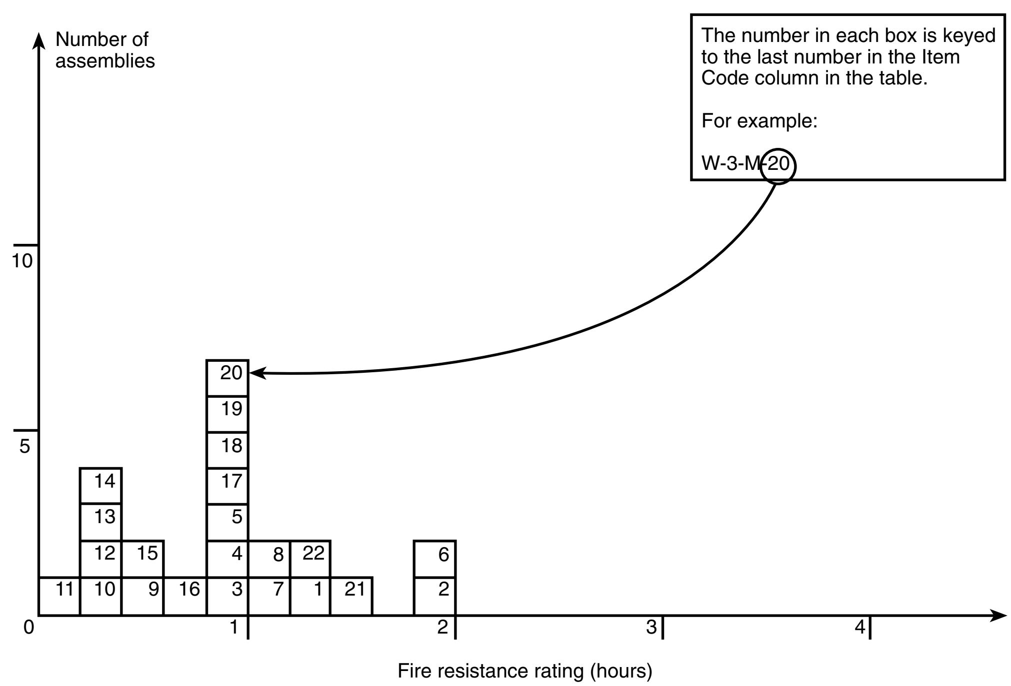


Figure L-4.5.1 Masonry walls 0 in. (0 mm) to less than 4 in. (100 mm) thick.

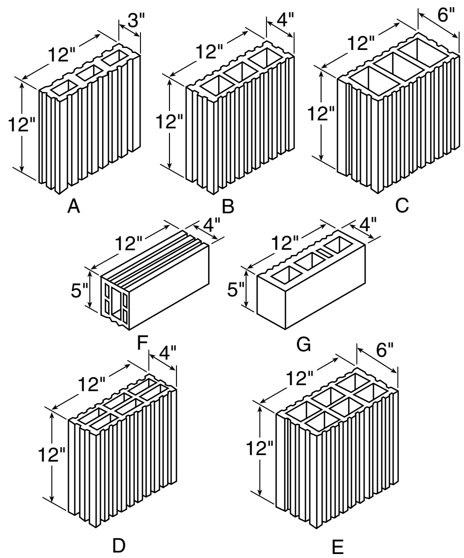
Table L-4.5.1 Masonry Walls 0" (0 mm) to less than 4" (100 mm) thick

Item Code	Thickness	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
W-2-M-1	$2\frac{1}{4}$"	Solid partition; $\frac{3}{4}$ gypsum plank — 10' × 16"; $\frac{3}{4}$" + gypsum plaster each side	n/a	1 hr 22 min			7	1	$1\frac{1}{4}$
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 $\frac{1}{2}$" 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: $\frac{1}{2}$" 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 $\frac{5}{8}$" (both sides) 1:3 sanded gypsum; construction "A"; design "E"	n/a	1 hr 6 min			2	5,6,7 11,12	1
W-3-M-8	3"	Clay tile; Illinois surface clay; single cell thick; face plaster $\frac{5}{8}$" (both sides) 1:3 sanded gypsum; design "A"; construction "E"	n/a	1 hr 1 min			2	5,8,9 11,12	
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	$\frac{1}{3}$
W-3-M-10	$3\frac{7}{8}$"	8" × 4 $\frac{7}{8}$" glass blocks; width 4 lb. each; portland cement-lime mortar; horizontal mortar joints reinforced with metal lath.	n/a	15 min		1		4	$\frac{1}{4}$
W-3-M-11	3"	Core: structural clay tile; see notes 14, 18, 23; no facings	n/a	10 min		1		5,11 26	$\frac{1}{6}$
W-3-M-12	3"	Core: structural clay tile; see notes 14, 19, 23; no facings	n/a	20 min		1		5,11 26	$\frac{1}{3}$
W-3-M-13	$3\frac{5}{8}$"	Core: structural clay tile; see notes 14, 18, 23; facings on unexposed side per note 20	n/a	20 min		1		5,11 26	$\frac{1}{3}$
W-3-M-14	$3\frac{5}{8}$"	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	$\frac{1}{3}$
W-3-M-15	$3\frac{5}{8}$"	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	$\frac{1}{2}$
W-3-M-16	$3\frac{5}{8}$"	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	$\frac{3}{4}$
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

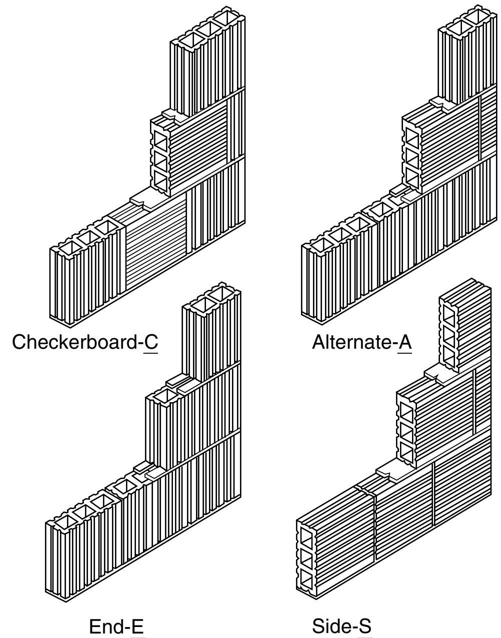
Table L-4.5.1 Masonry Walls 0" (0 mm) to less than 4" (100 mm) thick *(continued)*

Item Code	Thickness	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
W-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:
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.



Designs of tiles used in fire-test partitions.



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

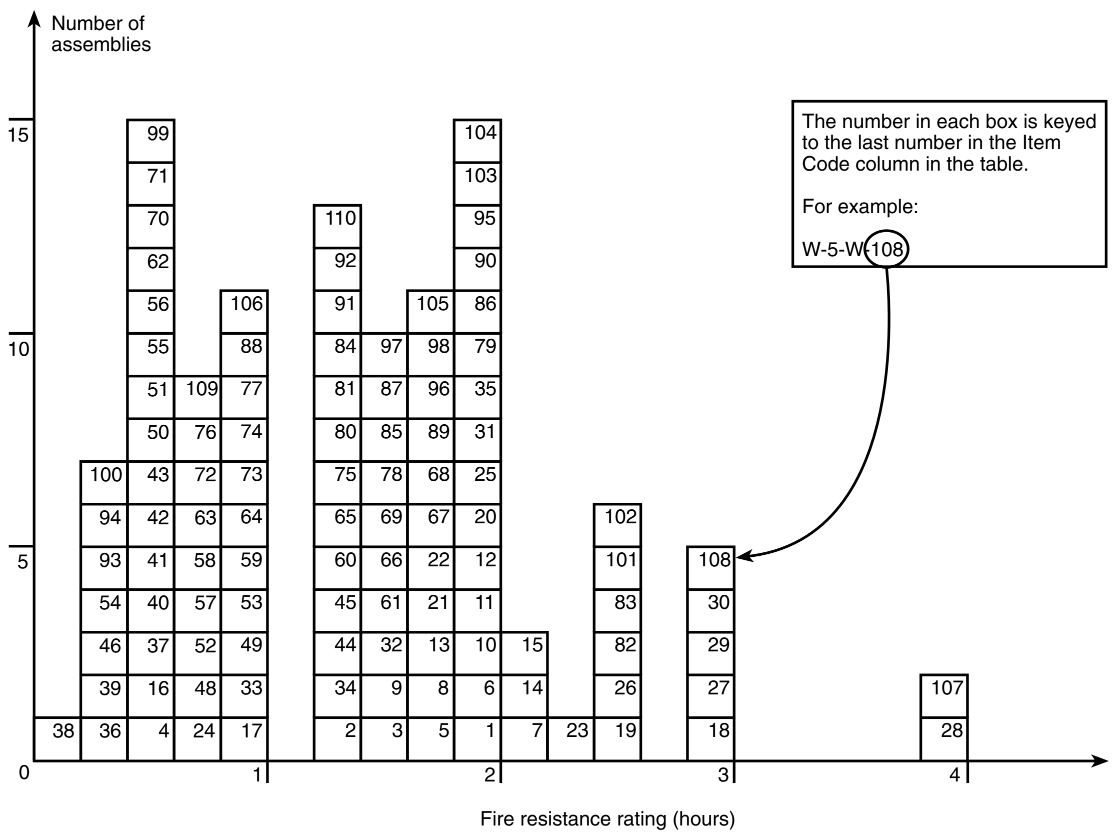


Figure L-4.5.2 Masonry walls 4 in. (100 mm) to less than 6 in. (150 mm) thick.

Table L-4.5.2 Masonry 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-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	$^1/_3$
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	$4^3/_{16}$"	$4^3/_{16}$"× $2^5/_8$" 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	$^1/_2$
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	$^3/_4$
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

Table L-4.5.2 Masonry Walls 4" (100 mm) to less than 6" (150 mm) thick *(continued)*

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-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	$1^3/_4$
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	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 acings 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	$2^3/_4$
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	$1^3/_4$
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 "S"	n/a	1 hr 34 min			2	2–5,9	$1^1/_2$
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	$^3/_4$
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	$1^1/_4$
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	$1^3/_4$

Table L-4.5.2 Masonry Walls 4" (100 mm) to less than 6" (150 mm) thick *(continued)*

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-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	$1^1/_4$
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

Table L-4.5.2 Masonry Walls 4" (100 mm) to less than 6" (150 mm) thick ***(continued)***

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-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
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

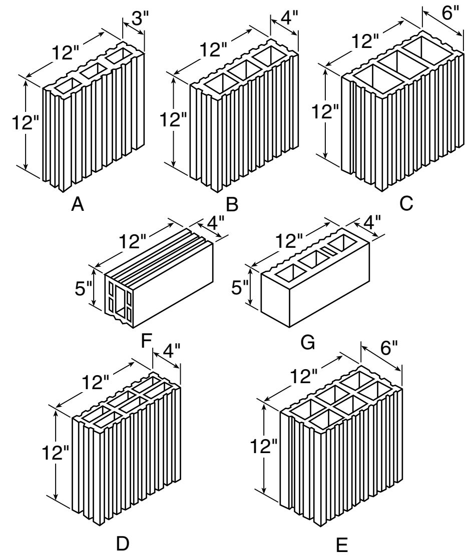
Table L-4.5.2 Masonry Walls 4" (100 mm) to less than 6" (150 mm) thick *(continued)*

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-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			$2^1/_2$

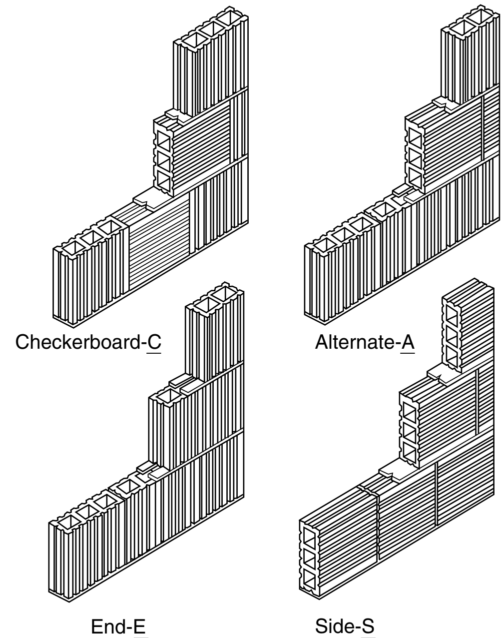
Table L-4.5.2 Masonry Walls 4" (100 mm) to less than 6" (150 mm) thick *(continued)*

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-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
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:
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.



Designs of tiles used in fire-test partitions.



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

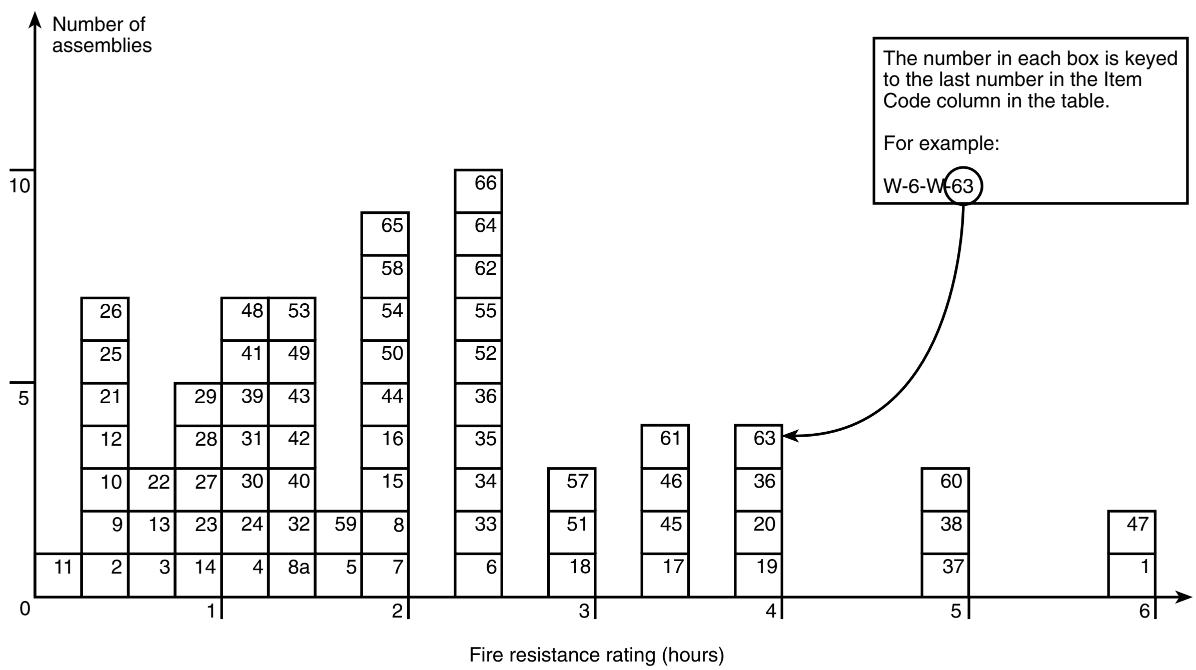


Figure L-4.5.3 Masonry walls 6 in. (150 mm) to less than 8 in. (200 mm) thick.

Table L-4.5.3 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	$^1/_4$
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	$^3/_4$
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	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	$1^2/_3$
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	$2^1/_3$
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	$2^3/_4$
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	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

Table L-4.5.3 Masonry Walls 6" to less than 8" thick (150 mm)/(200 mm) *(continued)*

Item Code	Thickness	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
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
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	$1^1/_2$

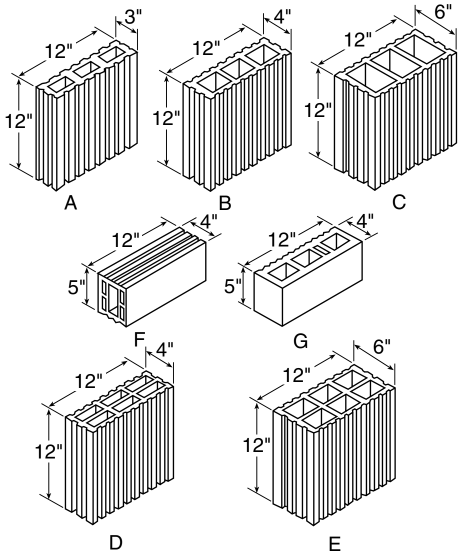
Table L-4.5.3 Masonry Walls 6" to less than 8" thick (150 mm)/(200 mm) *(continued)*

Item Code	Thickness	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
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
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

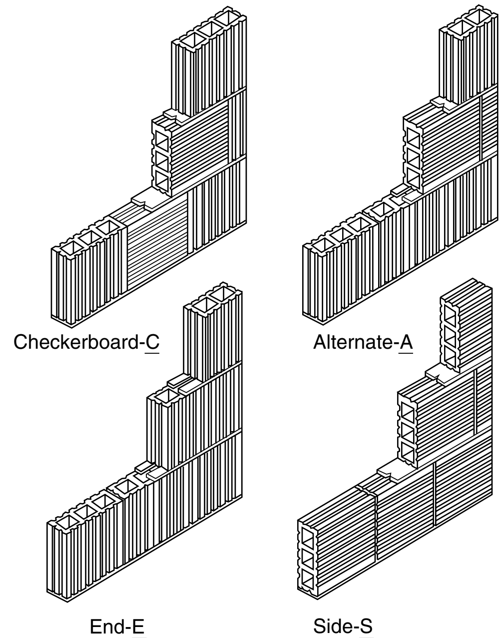
Table L-4.5.3 Masonry Walls 6" to less than 8" thick (150 mm)/(200 mm) ***(continued)***

Item Code	Thickness	Construction Details	Performance		Reference Number			Notes	Rec Hours
			Load	Time	Pre-BMS-92	BMS-92	Post-BMS-92		
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:
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. nit minimum 73% solid.
54. Ratings based on 1 unit and 1 cell in wall section.



Designs of tiles used in fire-test partitions.



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

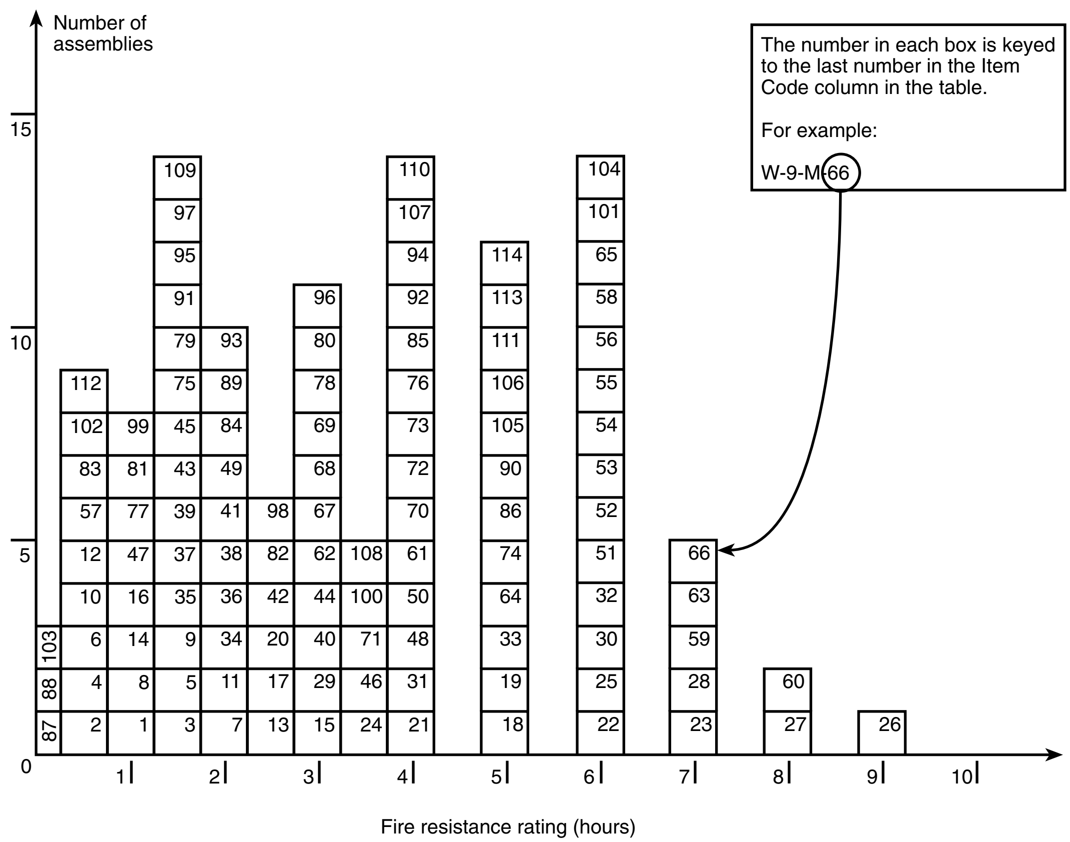


Figure L-4.5.4 Masonry walls 8 in. (200 mm) to less than 10 in. (250 mm) thick.

Table L-4.5.4 Masonry Walls 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-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 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

Table L-4.5.4 Masonry Walls 8" (200 mm) to less than 10" (250 mm) thick *(continued)*

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-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
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	$1^1/_2$

Table L-4.5.4 Masonry Walls 8" (200 mm) to less than 10" (250 mm) thick *(continued)*

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-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
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, 18,20,211	$2^1/_2$
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

Table L-4.5.4 Masonry Walls 8" (200 mm) to less than 10" (250 mm) thick *(continued)*

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-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
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

Table L-4.5.4 Masonry Walls 8" (200 mm) to less than 10" (250 mm) thick *(continued)*

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-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 3 3/4" brick face	80 psi	5 hr		1		1,20	5
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	80 psi	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 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

Table L-4.5.4 Masonry Walls 8" (200 mm) to less than 10" (250 mm) thick *(continued)*

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-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:
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.

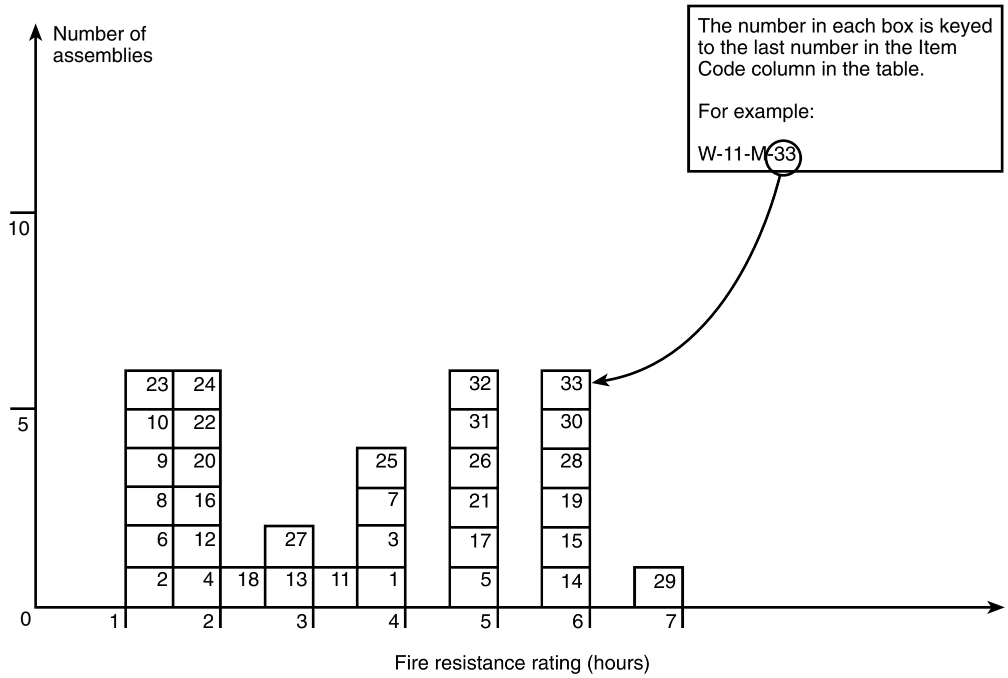


Figure L-4.5.5 Masonry walls 10 in. (250 mm) to less than 12 in. (300 mm) thick.

Table L-4.5.5 Masonry Walls 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 ($11^3/_4$" × 9" × $4^1/_4$") with 2 – 2" thick voids included; $^3/_8$" P.C. plaster $^1/_8$" neat gypsum	n/a	1 hr 53 min			7	23,24	$1^3/_4$
W-10-M-13	10"	Hollow clay tile block wall — 8 $^1/_2$" block with 2 – 3" voids in each $8^1/_2$" section; $^3/_4$" gypsum plaster — each face	n/a	2 hr 42 min			7	23,25	$2^1/_2$
W-10-M-14	10"	2 layers $4^1/_2$" brick with $1^1/_2$" 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 $4^1/_4$" thick fletton brick — 1910 psi brick; $1^1/_2$" air space; ties — 18" O.C. vertical; 3' O.C. - horizontal	n/a	6 hr			7	23,24	6
W-10-M-16	$10^1/_2$"	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

Table L-4.5.5 Masonry Walls 10" (250 mm) to less than 12" (300 mm) thick *(continued)*

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-10-M-17	$10^1/_2$"	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	$10^1/_2$"	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	$2^1/_2$
W-10-M-19	$10^1/_2$"	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	$10^1/_2$"	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	$10^1/_2$"	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	$10^1/_2$"	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	$1^3/_4$
W-10-M-23	$10^1/_2$"	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	$1^1/_4$
W-10-M-24	$10^1/_2$"	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	$10^1/_2$"	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	$10^5/_8$"	Core: 8", 40% solid tile plus 2" furring tile; $^5/_8$" sanded gypsum plaster between tile types; facings on both sides $^3/_4$" portland cement plaster or stucco	80 psi	5 hr		1		1,20	5
W-10-M-27	$10^5/_8$"	Core: 8", 40% solid tile plus 2" furring tile; $^5/_8$" sanded gypsum plaster between tile types; facings on one side $^3/_4$" portland cement plaster or stucco	80 psi	3 hr 30 min		1		1,20	$3^1/_2$
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

Table L-4.5.5 Masonry Walls 10" (250 mm) to less than 12" (300 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-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 ($4^1/_2$" 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:
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.

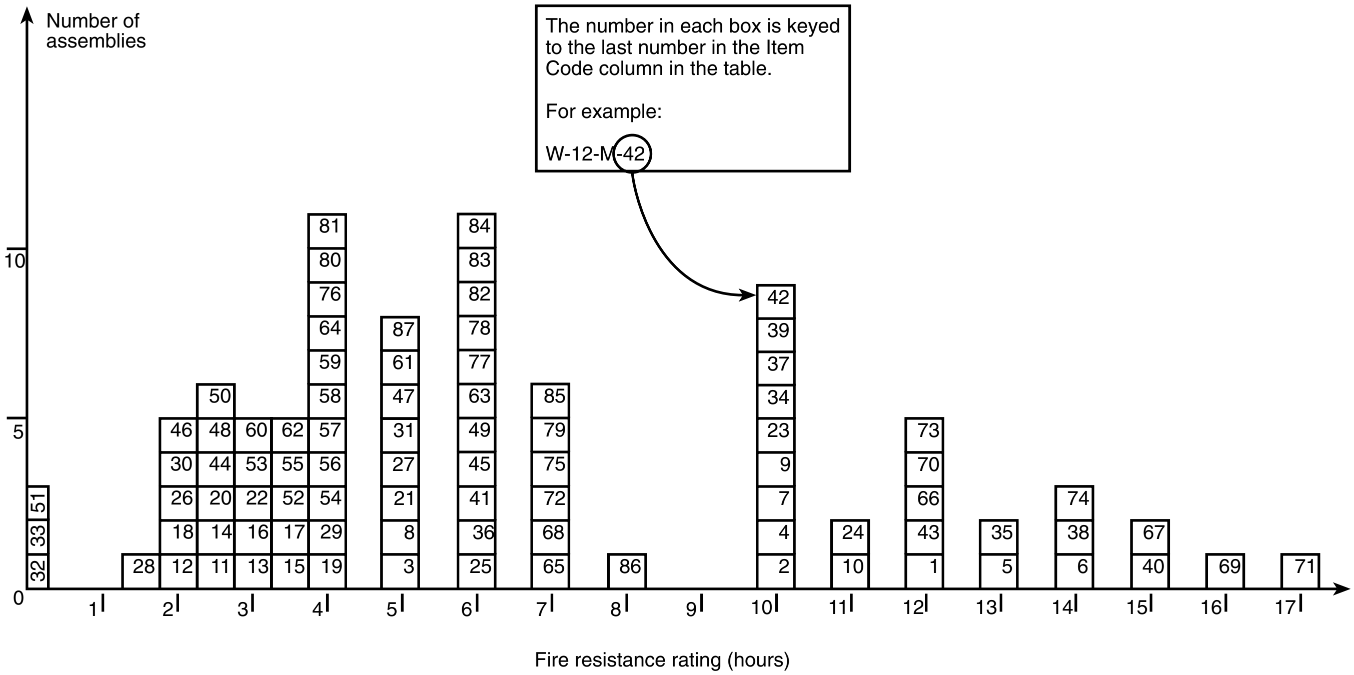


Figure L-4.5.6 Masonry walls 12 in. (300 mm) to less than 14 in. (350 mm) thick.

Table L-4.5.6 Masonry Walls 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

Table L-4.5.6 Masonry Walls 12" (300 mm) to less than 14" (350 mm) thick *(continued)*

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-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	$1^1/_2$
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

Table L-4.5.6 Masonry Walls 12" (300 mm) to less than 14" (350 mm) thick *(continued)*

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-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	$3^1/_2$
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

Table L-4.5.6 Masonry Walls 12" (300 mm) to less than 14" (350 mm) thick *(continued)*

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-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

Table L-4.5.6 Masonry Walls 12" (300 mm) to less than 14" (350 mm) thick *(continued)*

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-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
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:
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.

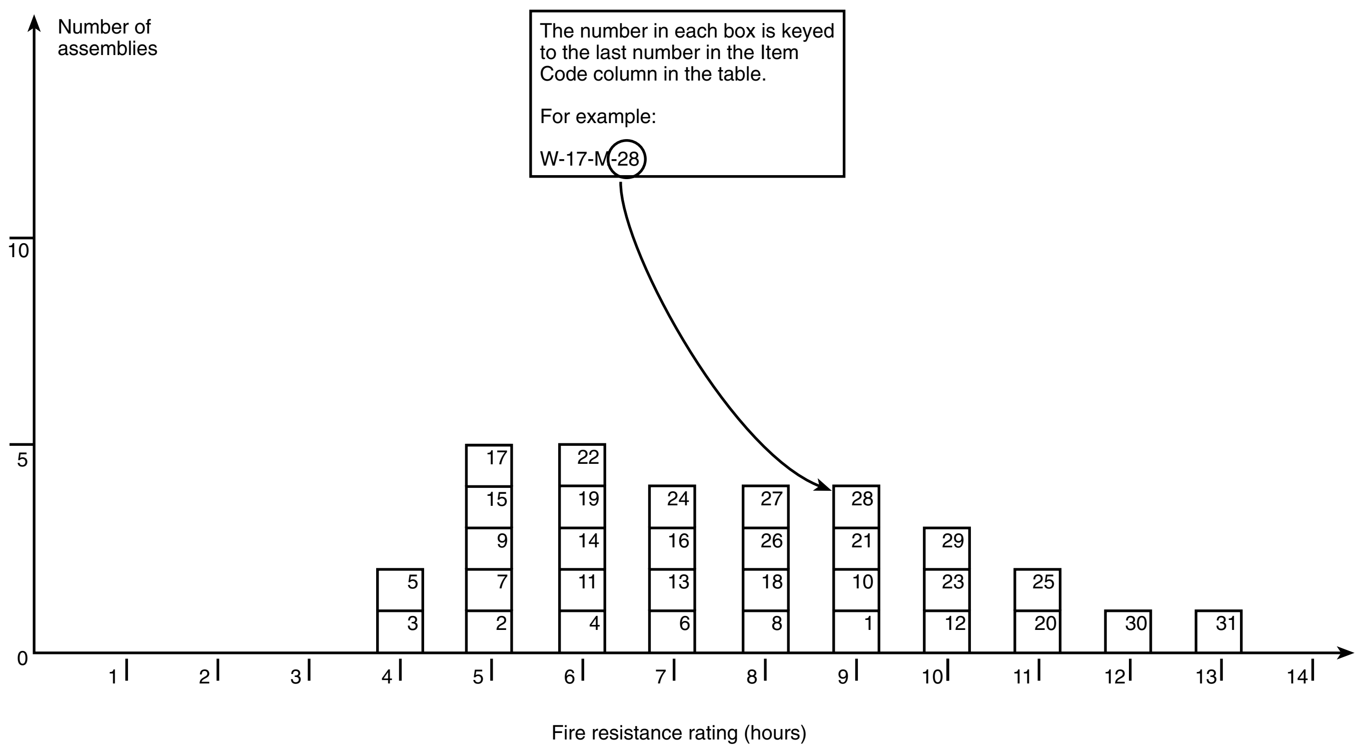


Figure L-4.5.7 Masonry walls 14 in. (350 mm) or more thick.

Table L-4.5.7 Masonry Walls 14" (350 mm) or more 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-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
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

Table L-4.5.7 Masonry Walls 14" (350 mm) or more thick *(continued)*

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-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 and 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 and 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 and 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 and 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 and 2: see note 17	80 psi	13 hr		1		1,20	13

Notes:
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.

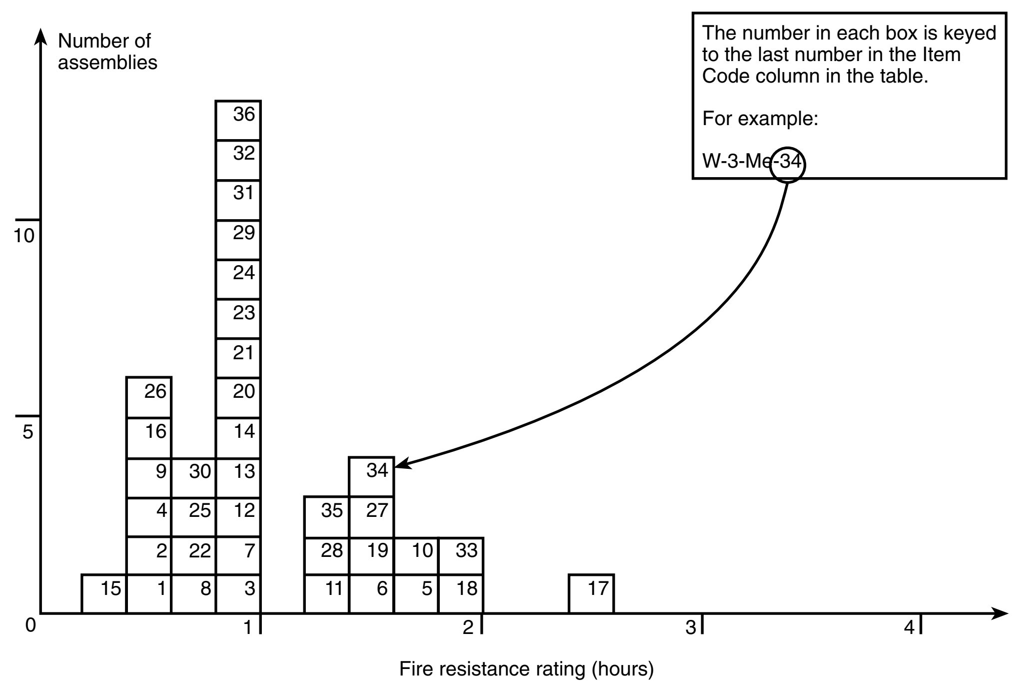


Figure L-4.5.8 Metal frame walls 0 in. (0 mm) to less than 4 in. (100 mm) thick.

Table L-4.5.8 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-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
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

Table L-4.5.8 Metal Frame Walls 0" (0 mm) to less than 4" (100 mm) thick *(continued)*

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-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 oxysulfat-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

Table L-4.5.8 Metal Frame Walls 0" (0 mm) to less than 4" (100 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-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:
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.

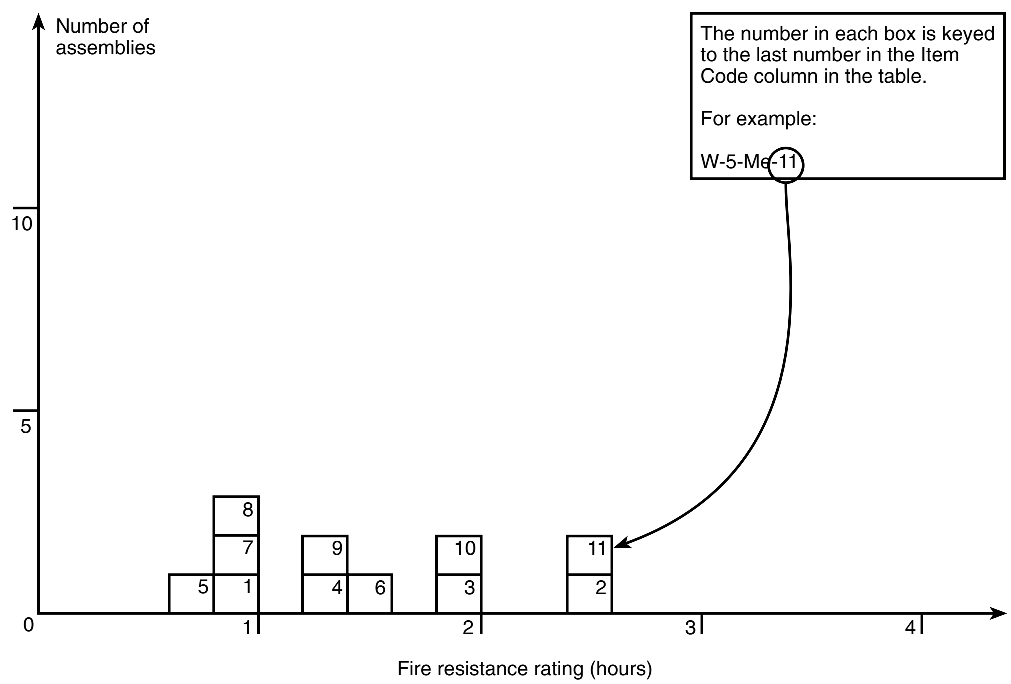


Figure L-4.5.9 Metal frame walls 4 in. (100 mm) to less than 6 in. (150 mm) thick.

Table L-4.5.9 Metal 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-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
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:
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 L-4.5.10 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 fiberboard 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 fiberboard 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; 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 fiberboard 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:
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 L-4.5.11 Metal Frame Walls 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-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:
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 L-4.5.12 Wood 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-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:
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.

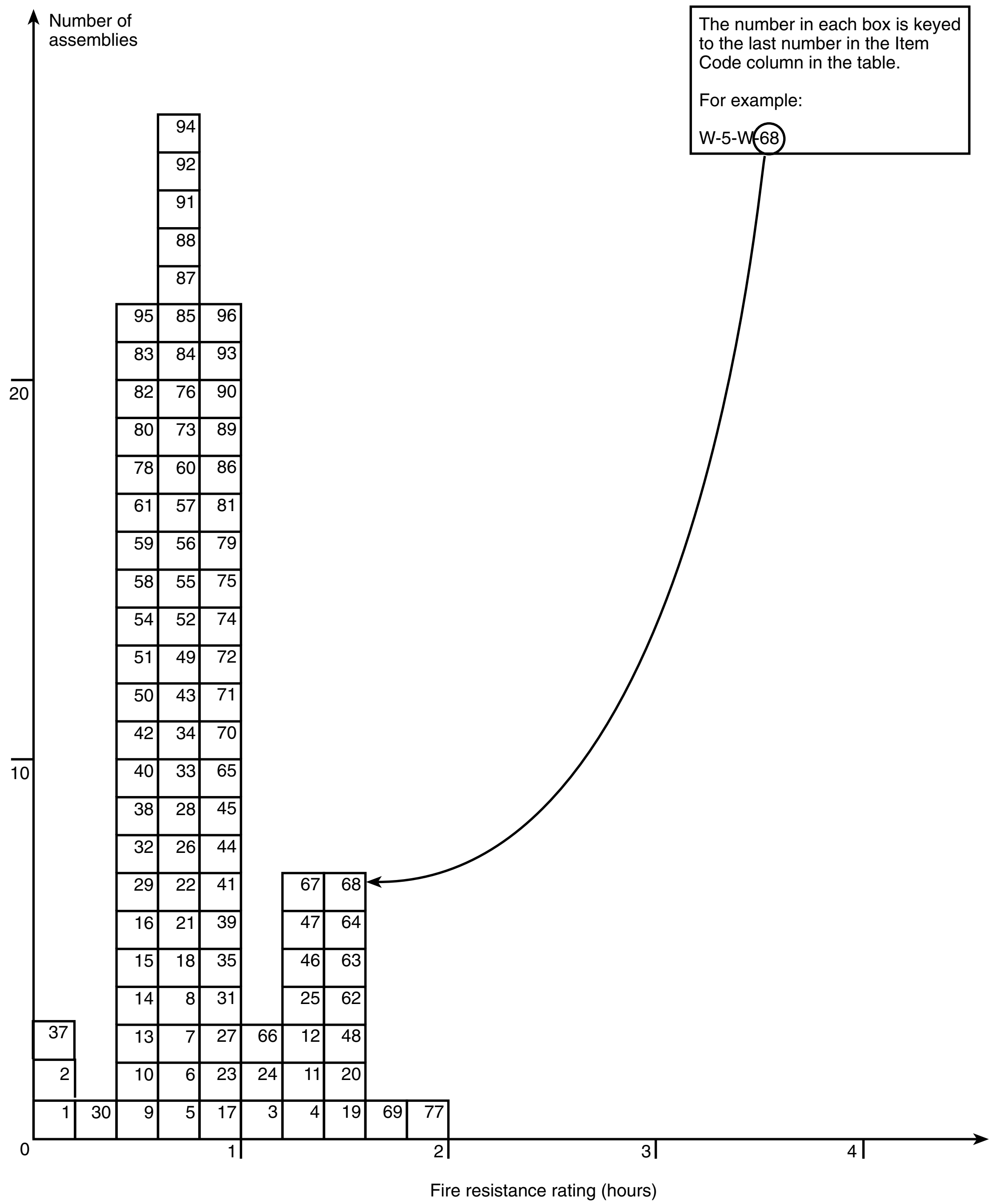


Figure L-4.5.13 Wood frame walls 4 in. (100 mm) to less than 6 in. (150 mm) thick.

Table L-4.5.13 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 wool 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); designE	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

Table L-4.5.13 Wood Frame Walls 4" (100 mm) to less than 6" (150 mm) thick *(continued)*

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-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	–
W-5-W-22	5 5/8"	2" × 4" stud wall; exposed face - CAB sheet, gypsum board @ stud edges; unexposed face - CAB shingles 1" × 6" sheathing; 5 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.; 1/2" gypsum board each side; 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.; 1/2" gypsum board each side; 1/2" gypsum plaster each side	n/a	68 min			7	16	1
W-6-W-25	6 7/8"	2" × 4" stud wall; 18" O.C.; 3/4" gypsum plank each side; 3/16" gypsum plaster each side	n/a	80 min			7	15	1 1/3
W-5-W-26	5 1/8"	2" × 4" stud wall; 16" O.C.; 3/8" gypsum board each side; 3/16" gypsum plaster each side	n/a	37 min			7	15	1/2
W-5-W-27	5 3/4"	2" × 4" stud wall; 16" O.C.; 3/8" gypsum lath each side; 1/2" gypsum plaster each side	n/a	52 min			7	15	3/4
W-5-W-28	5"	2" × 4" stud wall; 16" O.C.; 1/2" gypsum board each side	n/a	37 min			7	16	1/2
W-5-W-29	5"	2" × 4" stud wall; 1/2" fiberboard both sides 14% M.C. with F.R. paint @ 35 gm/ft^2	n/a	28 min			7	15	1/3

Table L-4.5.13 Wood Frame Walls 4" (100 mm) to less than 6" (150 mm) thick *(continued)*

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-30	4 3/4"	2" × 4" stud wall; fire side - 1/4" (wood) fiberboard; back face - 1/2" CAB; 16" O.C.	n/a	17 min			7	15,16	1/4
W-5-W-31	5 1/8"	2" × 4" stud wall; 16" O.C.; 1/2" fiberboard insulation with 1/32" asbestos (both sides of each board)	n/a	50 min			7	16	3/4
W-4-W-32	4 1/4"	2" × 4" stud wall; 3/8" thick gypsum wallboard on both faces; insulated cavities	note 23	25 min		1		17,18, 23	1/3
W-4-W-33	4 1/2"	2" × 4" stud wall; 1/2" thick gypsum wallboard on both faces	note 17	40 min		1		17,23	2/3
W-4-W-34	4 1/2"	2" × 4" stud wall; 1/2" thick gypsum wallboard on both faces; insulated cavities	note 17	45 min		1		17,18, 23	3/4
W-4-W-35	4 1/2"	2" × 4" stud wall; 1/2" thick gypsum wallboard on both faces; insulated cavities	n/a	1 hr		1		17,18, 24	1
W-4-W-36	4 1/2"	2" × 4" stud wall; 1/2" thick, 1.1 lb/ft² wood fiberboard sheathing on both faces	note 23	15 min		1		17,23	1/4
W-4-W-37	4 1/2"	2" × 4" stud wall; 1/2" thick, 0.7 lb/ft² wood fiberboard sheathing on both faces	note 23	10 min		1		17,23	1/6
W-4-W-38	4 1/2"	2" × 4" stud wall; 1/2" thick, "flameproofed," 1.6 lb/ft² wood fiberboard sheathing on both faces	note 23	30 min		1		17,23	1/2
W-4-W-39	4 1/2"	2" × 4" stud wall; 1/2" thick gypsum wallboard on both faces; insulated cavities	note 23	1 hr		1		17,18, 23	1
W-4-W-40	4 1/2"	2" × 4" stud wall; 1/2" thick, 1:2, 1:3 gypsum plaster on wood lath on both faces	note 23	30 min		1		17,21, 23	1/2
W-4-W-41	4 1/2"	2" × 4" stud wall; 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 1/2"	2" × 4" stud wall; 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	1/2
W-4-W-43	4 1/2"	2" × 4" stud wall; 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	3/4
W-4-W-44	4 5/8"	2" × 4" stud wall; 3/16" thick cement-asbestos over 3/8" thick gypsum board on both faces	note 23	1 hr		1		25,26, 23,27	1
W-4-W-45	4 5/8"	2" × 4" stud wall; studs faced with 4" wide strips of 3/8" thick gypsum board; 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 5/8"	Same as W-4-W-45 but non-load bearing	n/a	1 1/4 hr		1		24,28	1 1/4
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

Table L-4.5.13 Wood Frame Walls 4" (100 mm) to less than 6" (150 mm) thick *(continued)*

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-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	$1\,^1/_2$

Table L-4.5.13 Wood Frame 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-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
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

Table L-4.5.13 Wood Frame Walls 4" (100 mm) to less than 6" (150 mm) thick *(continued)*

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-78	5 1/2"	2" × 4" stud wall; 1/2" thick 1:2, 1:2 gypsum plaster on 1/2" thick, 0.7 lb/ft^2 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
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

Table L-4.5.13 Wood Frame Walls 4" (100 mm) to less than 6" (150 mm) thick *(continued)*

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-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:
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.

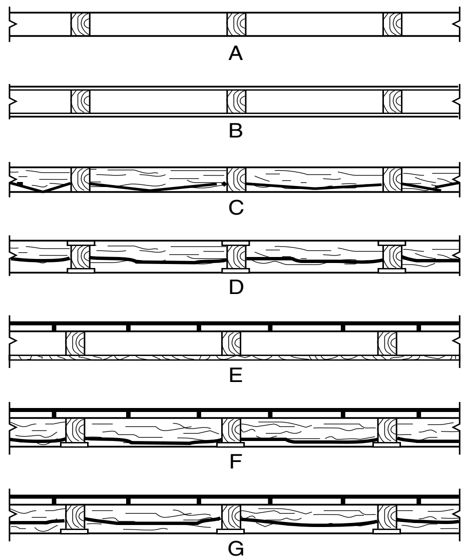


Diagram L-4.5.13 Wall design

Table L-4.5.14 Wood Frame Walls 6"(150 mm) to less than 8" (200 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-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/ft^2 - 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/ft^2.

Table L-4.5.15 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" × 5 3/4" × 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" × 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:
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 L-4.5.16 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:
1. 1/2" sanded gypsum plaster. Voids in hollow blocks to be not more than 30%.

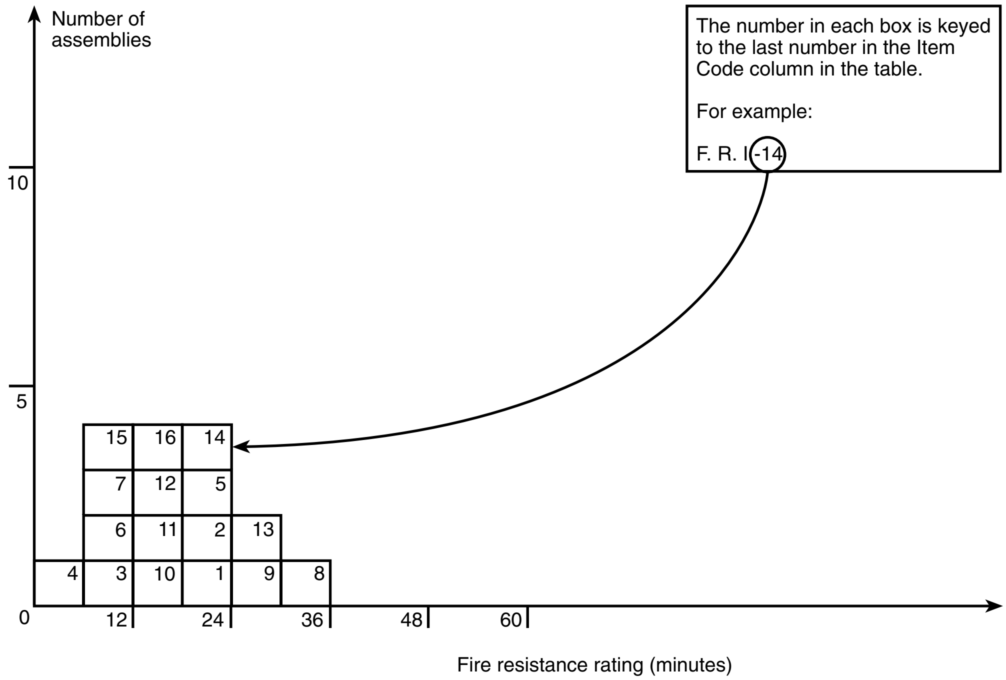


Figure L-4.5.17 Finish ratings — inorganic materials.

Table L-4.5.17 Finish Ratings — Inorganic Materials

Item Code	Thickness	Construction Details	Performance Finish Rating	Reference Number Pre-BMS-92	Reference Number BMS-92	Reference Number 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

Table L-4.5.17 Finish Ratings — Inorganic Materials ***(continued)***

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-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:
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 L-4.5.18 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:
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.

Table L-4.5.19 Reinforced Concrete Columns Minimum Dimension 0" (0 mm) to less than 6" (150 mm)

Item Code	Minimum Dimension	Construction Details	Performance: Load	Performance: Time	Reference Number: Pre-BMS-92	BMS-92	Post-BMS-92	Notes	Rec Hours
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:
1. Collapse
2. British test.

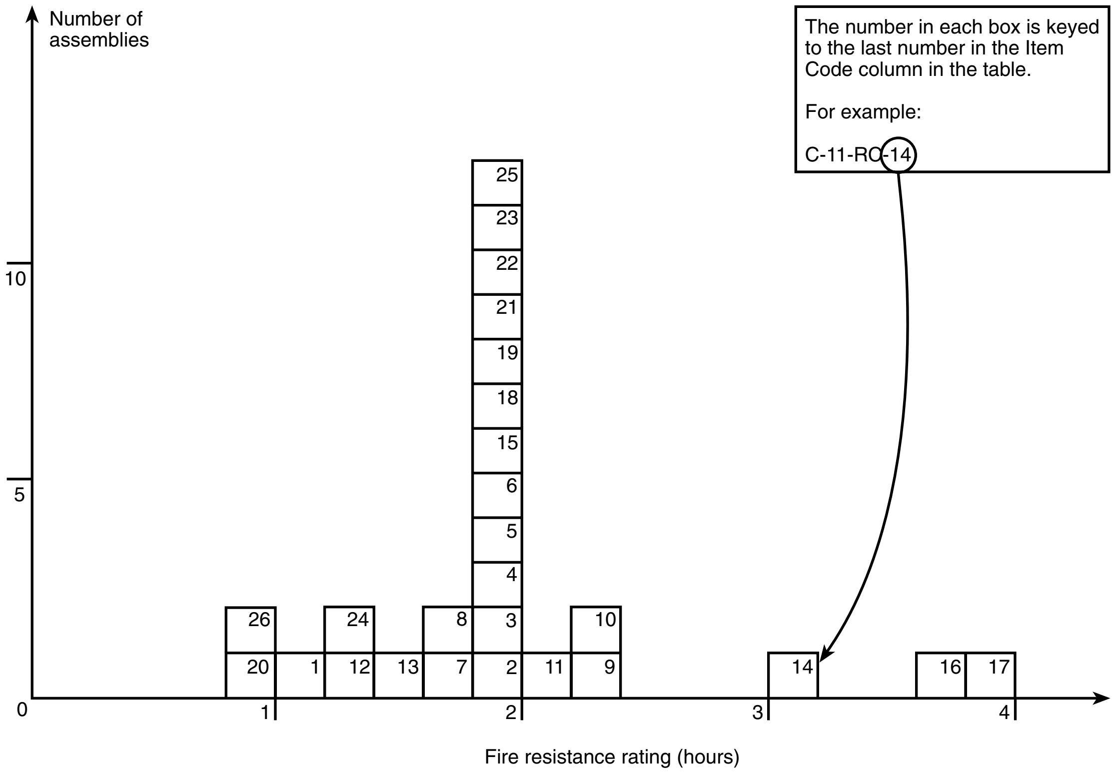


Figure L-4.5.20 Reinforced concrete columns with minimum dimension 10 in. (250 mm) to less than 12 in. (300 mm).

Table L-4.5.20 Reinforced Concrete Columns 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-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

Table L-4.5.20 Reinforced Concrete Columns Minimum Dimension 10" (250 mm) to less than 12" (300 mm) ***(continued)***

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-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 min			7	1	$^1/_4$
C-10-RC-9	10"	10" square columns; aggregate concrete (2510 psi); inforcement: vertical 4- $^1/_2$" rebars; horizontal $^5/_{16}$" ties @ 6" pitch; cover 1"	72.8 tons	1 hr 8 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 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 gregate concrete (4140 psi); einforcement: 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 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$^1/_2$

Table L-4.5.20 Reinforced Concrete Columns Minimum Dimension 10" (250 mm) to less than 12" (300 mm) ***(continued)***

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-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 7 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
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:
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 L-4.5.21 Reinforced Concrete Columns 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 column12"; 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
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:
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 L-4.5.22 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-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:
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 the 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.

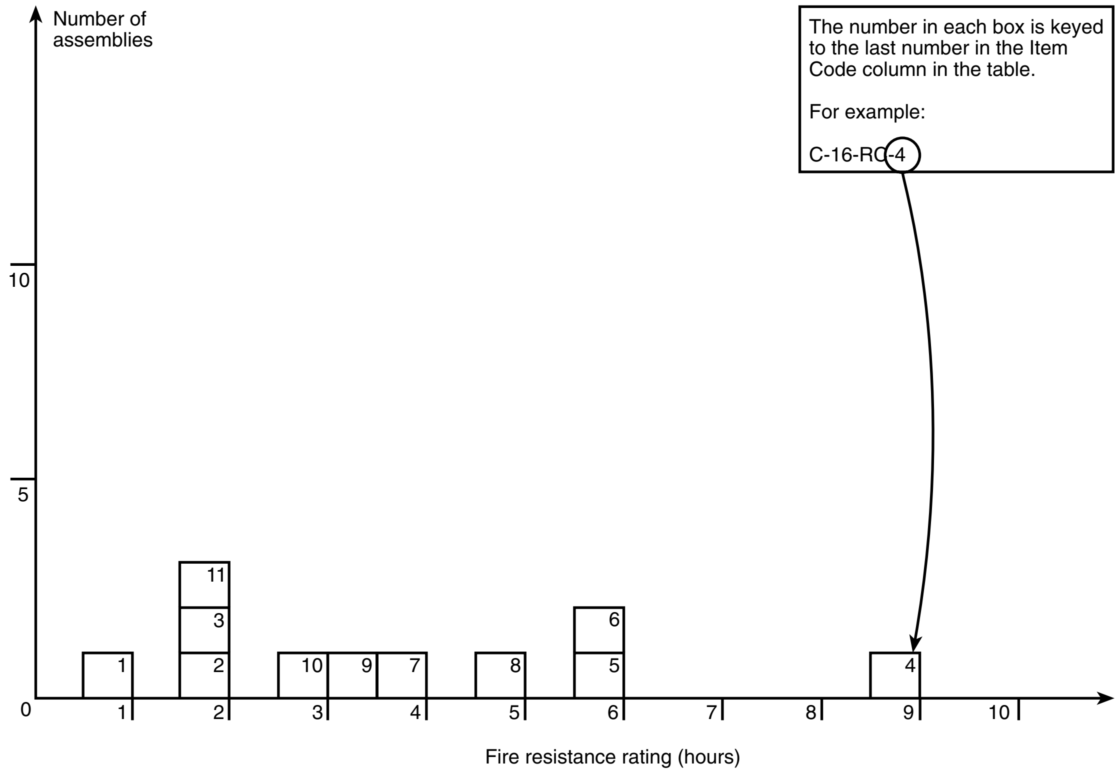


Figure L-4.5.23 Reinforced concrete columns with minimum dimension 16 in. (400 mm) to less than 18 in. (450 mm).

Table L-4.5.23 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

Table L-4.5.23 Reinforced Concrete Columns Minimum Dimension 16" (400 mm) to less than 18" (450 mm) ***(continued)***

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-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:
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 L-4.5.24 Reinforced Concrete Columns Minimum Dimension 18" (450 mm) to less than 20" (500 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-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:
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.

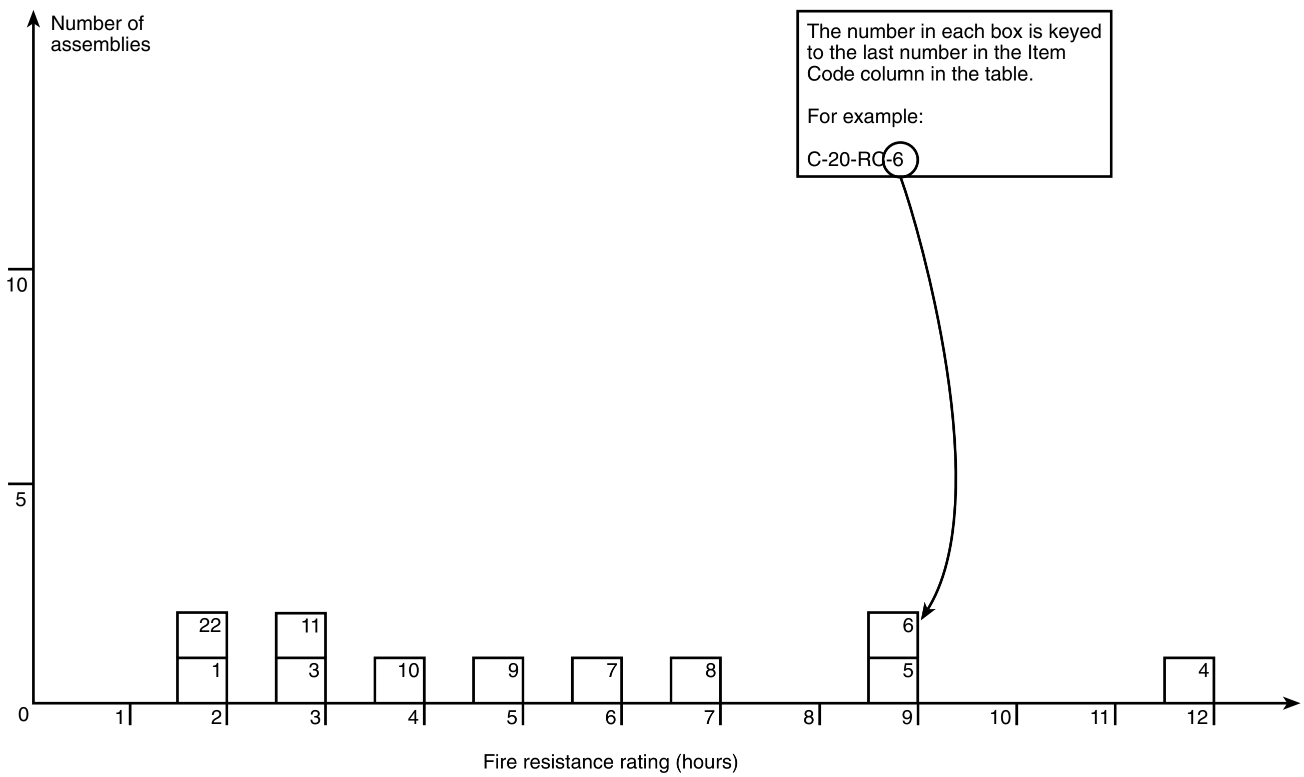


Figure L-4.5.25 Reinforced concrete columns with minimum dimension 20 in. (500 mm) to less than 22 in. (550 mm).