U. S. DEPARTMENT OF COMMERCE

BUILDING MATERIALS AND STRUCTURES

REPORT BMS92

Fire-Resistance Classifications of Building Constructions

Report of
Subcommittee on
Fire-Resistance Classifications
of the
Central Housing Committee
on Research, Design
and Construction

NATIONAL
BUREAU OF STANDARDS

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BUILDING MATERIALS *and* STRUCTURES

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Fire-Resistance Classifications of Building Constructions

Report of Subcommittee on Fire-Resistance Classifications
of the
Central Housing Committee on Research, Design, and Construction

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Foreword

The object of this report is to present a classification of building construction based on essential features having a bearing on the restricting and retarding effect on fire offered by the different types. The classes within each type are differentiated by the degree of fire resistance of structural members. As an assistance in applying these classifications, data are included from surveys of combustible contents of buildings and from fire tests of building constructions and materials conducted at this Bureau and other laboratories. The report should be of value in presenting building classifications and pertinent related data on the basis of which restrictions on size, location, and structural components of buildings can be applied to give a required degree of safety with the economical use of a wide range of acceptable materials.

Lyman J. Briggs, *Director.*

Fire-Resistance Classifications of Building Materials

Report of Subcommittee on Fire-Resistance Classifications of the Central Housing Committee on Research, Design, and Construction

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ABSTRACT

A classification of building construction from the standpoint of fire safety is presented by a committee of representatives of Federal agencies concerned with the design, construction, and operation of buildings. By considering only the basic properties having a bearing on fire hazard and fire resistance, four types were found sufficient to cover the whole range of building construction. Within each type are two or more classes which are defined by the fire resistance required for their structural members. In chapter I this classification is outlined and information given on how it can be applied with reference to the fire severity obtaining for given structural and occupancy conditions. Chapter II contains a discussion of the types of restrictions and limitations generally incorporated in building codes, with particular reference to their application to the classification of building types herein presented. Chapter III gives results of surveys of combustible contents of buildings housing typical occupancies as a basis for estimation of fire severity, In chapter IV are given available fire-resistance ratings of building constructions and fire-resistance classifications of roofing materials.

CONTENTS

INTRODUCTION

The purpose of this report is to present to architects, engineers, and public officials responsible for fire safety in buildings, a classification of building constructions which represents the recommendations of the Subcommittee, a discussion thereof, and certain factual data which have been assembled by the Subcommittee. The report is not proposed as a fire-protection section of a building code, but it is intended to indicate some of the changes from current practice that should be considered in writing or revising building codes and to supply some of the factual data necessary to a proper consideration of the changes indicated.

It appears desirable that codes should be written to permit the use of new systems of construction where they can be demonstrated to be comparable in performance to the systems now described in current codes in terms of materials.

The Subcommittee believes that the idea of designing some buildings for the full fire severity corresponding to the occupancy and others for a given established fire resistance, is a logical advance in fire protection engineering. It offers no more complications as regards possible occupancy changes and code requirements than does the idea of designing buildings for predetermined live loads. For example, buildings designed for residential use with live loads in the neighborhood of 40 lb/ft^2 cannot be used for heavy mercantile occupancy, and it is illogical to require them to be designed for the same fire severity.

The subdivision of types of construction is proposed in order to embrace the useful range of resistance that is obtainable within each type and to provide a convenient means of designating the position of a particular construction within that range.

Chapter I offers a classification of building types from the standpoint of fire safety. The relations between combustible contents, fire severity, and fire-resistance ratings are outlined and a method of evaluating the combustible contents of a building is given.

Chapter II contains a discussion of the restrictions and limitations which experience indicates should be applied to buildings with respect to occupancy and construction for the purpose of limiting the use of the several constructions to situations in which a satisfactory degree of

safety from fire can be attained economically. The discussion is supplemented by the illustrative summary of restrictions and limitations on construction in six typical building codes, which comprise appendix A. They are presented as giving a typical cross section of current building codes, not necessarily ideal nor illustrative of the recommendations of the Subcommittee.

Chapter III summarizes the findings of actual surveys of combustible contents of buildings for a number of typical occupancies. This material is considered to be a reliable guide in making an estimate of the probable combustible contents of projected occupancies similar to those surveyed.

Chapter IV presents a tabulation of fire-resistance ratings for building constructions and materials. Derivations of the values are indicated in that chapter and in appendix B. This tabulation is for use in selecting constructions that will fulfill the given requirements and enables a choice to be made in a range of constructions having a required fire-resistance rating.

For definitions of terms used in this report reference is made to BMS91, A Glossary of Housing Terms (1942).

CHAPTER I. A FIRE-RESISTANCE CLASSIFICATION OF BUILDING TYPES

The fire-resistance classifications of building types heretofore generally have been defined in terms of established constructions and materials. The classification contained in this chapter is based on performance in fires and fire tests, graduated within each type. Materials are differentiated only as regards combustibility or incombustibility.

The Fireproof type includes all buildings of incombustible structure which will either withstand complete combustion of their contents without collapse or which will have a general fire-resistance rating of 4 hr and in addition other safeguards designed to prevent a more severe fire. Within this type, the classification is such that a building may be designed to have a fire resistance corresponding to the fire severity that may be created by the occupancy. This eliminates the common practice of requiring a uniform fire resistance for all Fireproof-type buildings, which results in excessive resistance for occupancies having light combustible contents and insufficient resistance where the combustible contents are very heavy. Economies are thus made possible in the former case and increased protection is required in the latter for buildings classed as Fireproof.

It is assumed that in setting the required degree of fire resistance for Fireproof buildings, due consideration will be given to possible changes in occupancy and tenancy that may increase the amount of combustibles above that estimated for the occupancy immediately contemplated, this applying particularly to manufacturing, mercantile, and storage buildings. As a further control, the fire rating of floors in such buildings can be posted, as is now being done for permissible loading. A higher fire resistance for the lower floor or floors may also be in order for construction such as office buildings and apartment buildings in commercial districts, considering possible use for mercantile and similar occupancies. The surveys (chapter III) also indicate a large range in combustible contents of office buildings, depending on the relative amount of space used for record filing and storage and the type of equipment provided for the purpose. The effective fire exposure from paper records is greatly decreased with incombustible containers (see page 10).

For buildings or portions of buildings used for residential purposes, the combustible contents were found to be uniformly within the low range. Even with concentrated furniture storage, they were equivalent to no more than 15 lb/ft^2. The same applies for schools and hospitals except for small storage areas usually in basements. Such buildings and others housing occupancies corresponding to them in combustible contents can be regarded as strictly Fireproof provided the protection is adequate for the fire hazard presented even if the construction is rated no more than 1 hr. The damage from fires in such buildings will be largely to contents and building finish, although damage not causing collapse of any structural member may occur. As a further safeguard, Fireproof buildings with the lower fire ratings

can be limited in height so that if any subsequent use should result in greater fire severity they would present no greater hazard than buildings of nonfireproof types.

The three other types are each subdivided into two classes which with differentiation in height and area limitations will assist in obtaining safe and economical application for each type. The ¾-hr limit was chosen for the A class, since it is attainable with less exacting details of protection than the 1-hr rating and is near the maximum practically attainable with types III and IV, considering the possibility of spread of fire at junctions of floor, wall, and partition constructions.

The Incombustible type covers the range of buildings of incombustible structure from unprotected construction to that having a general fire-resistance rating of ¾ hr. Although this construction will not of itself contribute to a fire, structural collapse should be expected in a fire of severity exceeding that indicated by the titles of the subtype.

The Exterior-Protected type covers the range from ordinary masonry wall and wood-joist construction to and including mill construction. A fire in this type of building will eventually involve the structural members and produce collapse unless extinguished. The general ratings given in the titles of the subtypes indicate a time within which extinguishment might be expected to prevent collapse.

Wood construction has been extended to include combustible constructions having considerable fire resistance. The remarks in regard to the Exterior-Protected type also apply to this type.

Although no requirements for exterior protection are indicated for the Incombustible and Wood construction type buildings, it is assumed that they will be restricted in location with respect to common property lines unless such protection is provided. If Incombustible buildings are built to a property line on which another building can be built, it would be in accord with requirements for Fireproof and Exterior-Protected buildings to require 2-hr exterior protection. The requirements for exterior protection and location with respect to common property lines should also take into account the size of the building in making allowance for the lower hazard from small structures such as private garages.

The party- and fire-wall requirements for buildings of the nonfireproof types are intended to afford protection to the construction on one side after collapse from fire on the other side and ensuing prolonged fire and heat exposure from burning debris. The thicknesses needed are in most cases no more than required for stability even as supported by the construction framed in on the unexposed side. For a given amount of combustible contents the requirements for the Incombustible type are higher than for the Exterior-Protected and Wood construction types, since the incombustible floor constructions after collapse tend to confine the heat from the burning debris and cause prolonged fire exposure on a proportionately greater height above the base of the wall.

1. Types of Construction

The following definitions divide buildings into types with respect to fire resistance as follows:

Type I. Fireproof construction.
Type II. Incombustible construction.
Type III. Exterior-Protected construction.
Type IV. Wood construction.

The requirements for roof covering set forth herein are to be regarded as the minima for the several building types. Where a higher class is required by the local fire zoning, the covering of such higher class shall be applied. The relation of combustible contents to fire severity is indicated on page 7.

(*a*) *Type I. Fireproof Construction*

That type of construction in which the structural elements are of incombustible materials with fire-resistance ratings sufficient to withstand the fire severity resulting from complete combustion of the contents and finish involved in the intended occupancy but not less than the rating specified in table 1, and for which the roof coverings are as specified hereafter.

TABLE 1.—*Minimum fire-resistance ratings of structural elements for type I construction*

Subtype	I–A	I–B	I–C	I–D	I–E	I–F
General fire-resistance rating in hours	Over 4	4	3	2	1½	1
Weight of combustibles, lb/ft² of floor area	Over 35	35	30	20	15	10
Exterior walls—outside exposure:						
Distance from common property-line or other buildings on the same property:						
Under 10 ft (including common-property-line walls)	*hr* 2	*hr* 2	*hr* 2	*hr* 2	*hr* 2	*hr* 2
From 10 to 20 ft	1½	1½	1½	1½	1½	1½
More than 20 ft	1	1	1	1	1	1
Exterior walls—inside exposure	[a]	4	3	2	1½	1
Interior bearing walls	[a]	4	3	2	1½	1
Columns, girders, trusses	[a]	4	3	2	1½	1
Floor construction	[a]	4	3	2	1½	1
Roof construction [b]	[a]	4	3	2	1½	1
Fire walls, fire division walls, and party walls [c]	[a]	4	3	2	2	2
Fire-resistive partitions	1	1	1	1	1	1
Interior partitions [d] enclosing:						
Public hallways	1	1	1	1	1	1
Public stairways and other vertical openings	2	2	2	2	1½	1
Other permanent partitions	[e]	[e]	[e]	[e]	[e]	[e]

[a] When the combustible contents exceed 35 lb/ft²:
These structural elements shall be designed to have a fire-resistance rating sufficient to withstand the fire severity resulting from complete combustion of the contents; *or*
These structural elements shall be designed to have fire-resistance ratings as indicated in table 1 for 35 lb/ft² and additional safeguards shall be provided in accordance with *any one* of the following:
(1) The height shall be limited to 50 ft for warehouses and 75 ft for other buildings.
(2) The combustibles shall be placed wholly or partly in incombustible containers so that the expected fire severity is reduced to the equivalent of 4 hr or less. (See table 6.)
(3) Automatic sprinklers shall be provided in the area where the excess combustibles occur.
(4) Automatic fire detection shall be provided for the building or fire area, together with a standpipe and hose system.

[b] In type I buildings, unprotected incombustible roof framing and sheathing may be used to enclose an unusable attic space, provided that the construction separating the attic from the story below is of incombustible materials with a fire-resistance rating against fire exposure from below, not less than that specified for floor construction in table 1.
Where every part of the roof framing is more than 20 ft above a floor having total combustibles not in excess of 6 lb/ft² of floor area, roof framing may be unprotected, or an incombustible ceiling thereon of no required fire resistance may be used.

[c] The required fire resistance shall be determined by the combustible content on the side of the wall on which it is the higher. In the case of party walls, and fire-division or fire walls serving as party walls, if subsequent adjoining construction and occupancy require a higher fire resistance than originally incorporated, the fire resistance of such walls shall be increased to meet the new condition.

[d] The rating shall apply for fire exposure on the side away from the public space or vertical opening. For fire exposure on the other side the fire-resistance rating shall be not less than ½ hr.

[e] No required fire-resistance rating. To be of incombustible material.

Roof Coverings for Type I Construction.—Buildings of type I construction shall have roof coverings which meet the requirements prescribed for class 1, 2, or 3 roof covering in chapter IV.

(*b*) *Type II. Incombustible Construction*

That type of construction which has exterior walls, bearing walls, floor and roof construction, and other structural members, of incombustible materials all assembled to have fire-resistance ratings as given in the titles of the following subtypes, and roof coverings as specified hereafter.

In type II–A buildings, unprotected incombustible roof framing and sheathing may be used to enclose an unusable attic space, provided that the construction separating the attic from the story below is of incombustible materials with a fire-resistance rating against fire exposure from below not less than ¾ hr.

Type II–A. Incombustible construction, ¾ hr.

Type II–B. Incombustible construction, less than ¾ hr.

Fire walls and party walls shall be ground-supported and of masonry or other incombustible construction, suitably proportioned as to strength and stability, and shall have fire-resistance ratings not less than those given below. Connections of building members with such walls shall be made so that failure of the floor or roof construction due to fire on one side will not cause collapse of the wall. The fire resistance of the wall construction shall be not less than as given in the following table, the first column of which is based on the total combined weight of combustible contents for all stories plus any in the construction itself.

TABLE 2.—*Minimum fire-resistance ratings for fire walls and party walls for type II construction*

Total weight of combustibles, lb/ft² of ground area	Minimum fire resistance		
	Lower 8 ft	8 to 20 ft above base	Over 20 ft above base
	hr	*hr*	*hr*
Less than 25	2½	2	2
25 to 50	4	2½	2
50 to 75	5	3	2
75 to 100	6	4	2½
100 to 150	8	5	3
150 to 200	9	6	3½
200 to 250	10	8	4
Over 250	12	10	5

NOTE.—The wall heights are to be measured from the average interior ground level at the base of the wall.

Thicknesses corresponding to higher fire-resistance ratings than given in the above table may be required on the score of stability.

Interior walls and partitions enclosing public stairways and other vertical openings and exits from them in type II–A buildings shall

conform with the requirements for fire walls and party walls from the standpoint of type of construction and shall have a minimum fire-resistance rating of 2 hr. Walls and bottom and top enclosures for public stairways and other vertical openings and exits from them for type II–B buildings may be of the same general type as the interior construction and shall have a minimum fire-resistance rating of ¾ hr. The connections to adjoining construction having a lower fire-resistance rating shall be such that the fire resistance of the enclosure shall be maintained.

Interior partitions enclosing public hallways shall have fire-resistance ratings of not less than ¾ hr.

Common property-line walls may be of the same general type as the exterior walls, but shall have fire resistance against exterior fire exposure of not less than 2 hr.

Roof Coverings for Type II Construction.—Buildings of type II construction shall have roof coverings which meet the requirements prescribed in chapter IV for class 1, 2, or 3 roof covering.

(*c*) *Type III. Exterior-Protected Construction*

That type of construction in which the exterior walls, party walls, and fire walls are ground-supported and of masonry or other incombustible construction, suitably proportioned as to strength and stability, and the interior framing is partly or wholly of wood or other similar materials, all assembled to have fire-resistance ratings not less than the minima indicated in table 3, and having roof coverings as specified hereafter.

TABLE 3.—*Minimum fire-resistance ratings of structural elements for type III construction*

Subtype	III–A	III–B
General fire-resistance ratings in hours	¾	Less than ¾
Exterior walls:		
Distance from common property line or other buildings on the same property:		
Under 10 ft (including common property-line walls)	2 hr	2 hr
From 10 to 20 ft	1½	1½
Over 20 ft	1	1
Fire-resistive partitions	¾	¾
Interior bearing walls	¾	
Columns, girders, trusses	¾	
Floor construction	¾	
Roof construction	¾	
Interior partitions enclosing:		
Public hallways	¾	¾

In type III–A buildings, unprotected roof framing and sheathing may be used to enclose an unusable attic space, provided that the construction separating the attic from the story below has a fire-resistance rating against exposure from below of not less than ¾ hr.

Fire walls and party walls shall have minimum fire-resistance ratings, as given in table 4, based on the total combined weight of combustible contents for all stories plus any in the construction itself. The fire resistance of the wall shall be taken as limited by any combustible members projecting into it from the protected area. Floor and roof members shall release as required for Type II construction.

TABLE 4.—*Minimum fire-resistance ratings for fire walls and party walls of type III buildings*

Total weight of combustibles, lb/ft² of ground area	Minimum fire resistance		
	Lower 8 ft	8 to 20 ft above base	Over 20 ft above base
	hr	hr	hr
Less than 50	3½	2	2
50 to 75	4	2½	2
75 to 100	5	2½	2
100 to 150	6	3	2½
150 to 200	8	3	2½
200 to 250	10	4	2½
Over 250	12	5	2½

NOTE.—The wall heights are to be measured from the averge interior ground level at the base of the wall.

Walls enclosing public stairways and other vertical openings and exits from them, for type III–A buildings shall be of the same general type as fire walls and party walls with fire-resistance ratings of 2 hr, and the top enclosure shall have a fire-resistance rating of not less than 1 hr. Walls and bottom and top enclosures for public stairways and other vertical openings and exits from them, for type III–B buildings may be of the same general type as the interior construction and shall have a minimum fire-resistance rating of ¾ hr. The connections to adjoining construction having a lower fire-resistance rating shall be such that the fire resistance of the enclosure will be maintained.

Interior partitions enclosing public hallways shall have fire-resistance ratings of not less than ¾ hr.

Roof Coverings for Type III Construction.—Buildings of type III construction shall have roof coverings which meet the requirements prescribed in chapter IV for class 1, 2, or 3

roof covering subject to the following limitations:

(1) When the distance of the building from other buildings or lines on adjacent property on which other buildings may be built is less than 12 ft, class 1 or 2 roof coverings shall be provided.

(2) When the distance of the building from other buildings or lines on adjacent property on which other buildings may be built is 12 ft or more, class 1, 2, or 3 roof covering shall be provided.

(*d*) *Type IV. Wood Construction*

That type of construction which has exterior and bearing walls and floor and roof construction, wholly or partly of wood or other combustible materials, all assembled to have fire-resistance ratings as given in the titles of the following subtypes and roof coverings as specified hereafter.

In type IV–A buildings, unprotected roof framing and sheathing may be used to enclose an unusable attic space, provided that the construction separating the attic from the story below has a fire-resistance rating against exposure from below not less than ¾ hr.

Type IV–A. Wood construction, ¾ hr.
Type IV–B. Wood construction, less than ¾ hr.

The requirements for fire walls and party walls shall be the same as for type III construction.

Walls and bottom and top enclosures for public stairways and other vertical openings and exits from them may be of the same general type as the interior construction and shall have a minimum fire-resistance rating of ¾ hr. The connections to adjoining construction having a lower fire-resistance rating shall be such that the fire resistance of the enclosure will be maintained.

Interior partitions enclosing public hallways shall have fire-resistance ratings of not less than ¾ hr.

Roof Coverings for Type IV Construction.— Buildings of type IV construction shall have roof coverings which meet the requirements prescribed in chapter IV for class 1, 2, 3, or 4 roof covering subject to the following limitations:

(1) When the distance of the building from other buildings or lines on adjacent property on which other buildings may be built is less than 12 ft., class 1, 2, or 3 roof covering shall be provided.

(2) When the distance of the building from other buildings or lines on adjacent property on which other buildings may be built is 12 ft. or more, class 1, 2, 3, or 4 roof covering shall be provided.

2. Fire Severity

Fire severity is used herein as a measure of the intensity and duration of a fire. It is expressed in terms of time of exposure equivalent to that in the standard furnace test as defined in American Standards Association Standard A–2, 1942.

It has been found from burn-out tests performed in fireproof structures with various concentrations of combustibles having a calorific value in the range of wood and paper (7,000 to 8,000 Btu/lb) and assembled to represent building occupancies, that the relation between the amount of combustibles present and the fire severity is approximately as given in table 5.

Table 5.—*Relation of amount of combustibles to fire severity*

Average weight of combustibles, lb/ft² of floor area	Fire severity	Average weight of combustibles, lb/ft² of floor area	Fire severity
	hr		*hr*
5	½	30	3
7½	¾	40	4½
10	1	50	6
15	1½	60	7½
20	2		

It is considered sufficiently accurate in computing combustible contents to take wood, paper, cotton, wool, silk, straw, grain, sugar, and similar organic materials at their actual weights and to take animal and vegetable oils, fats, and waxes, petroleum products, asphalt, bitumen, paraffin, pitch, alcohol, and napthalene at twice their actual weights.

When the calorific value of combustibles differs greatly from that of wood or paper, or where the combustibles are stored in steel or equivalent incombustible containers, a correspondingly corrected weight should be used in

determining expeeted fire severity from the foregoing table.

It is eonsidered suffieiently accurate to use the percentages, as given in table 6, of the weights of enclosed combustibles stored in steel eontainers in estimating the fire severity.

TABLE 6.—*Effective combustible contents of steel containers*

Type of container	Part of combustibles in containers		
	Less than one-half	One-half to three-fourths	More than three-fourths
	Percent	*Percent*	*Percent*
Backed and partitioned shelving	75	75	75
Shelving with doors and transfer cases	60	50	25
Filing cabinets and desks	40	20	10
Safes and cabinets of 1 hour or more fire-resistance rating	0	0	0

In computing combustible eontents, concentrations higher than the average over continuons areas exceeding 500 ft² or exceeding 25 pereent of the floor area between fire separations, whiehever is the smaller, shall be eonsidered separately, otherwise the average for the entire area shall apply. With special construction or containers provided as indicated in table 6 for areas where the concentration is deeidedly above the average, it will, in general, not be neeessary to inerease the fire resistance of the eonstruction of the whole building to give protection against such localized hazards.

The data on eombustible contents of buildings as eontained in chapter III indicate the range whieh generally ean be expeeted to be associated with the various occupancies surveyed.

In apartments and residences, even with combustible floors and other woodwork, the amount of combustible eontents was found to be relatively light, with the average below 10 lb/ft² of floor area. In areas eontaining eoneentrated furniture storage, the eombustible contents were found to be no more than 14 or 15 lb/ft², which ineludes allowance for a woodfinish floor and wood trim.

In sehools the average amount of eombustible eontents in classrooms, gymnasiums, and most laboratories was found to be well within 10 lb/ft² of floor area. In areas such as storage rooms, file rooms, paint shops, libraries, stock rooms, etc., the eoncentrations varied greatly with the type of combustibles encountered, but the areas with high eoncentrations constituted only a small percentage of the total.

In office buildings the surveys indicate that the eombustible contents in from 80 to 90 pereent of the building will come within 20 lb/ft² of floor area. This would include such areas as offices and reception rooms, even those containing files. In rooms used exclusively for filing or library purposes, the combustible contents might run as high as 80 lb/ft².

The survey of hospitals indicates that the amount of combustible contents is light, with the average below 5 lb/ft² for the greater pereentage of the building. Concentration of eombustibles sueh as was found in laundries, rooms used for clothes storage, and supplies did not exceed 20 lb/ft².

The amount of combustible contents in warehouses was found to vary considerably, according to the type of contents stored. This would indicate that warehouses require individual study and consideration in relation to the intended use.

3. Fire-Resistance Ratings

The fire-resistance rating of a structural element is the length of time that it performs satisfactorily in the standard furnace test. Unless otherwise indieated, the fire-resistanee ratings specified are for fire exposure on either side of walls, partitions, and floors and on the lower side of roof construction. Fire exposure from below only is assumed for floors or ceilings under unusable attic spaces, the rating being based only on absence of collapse or occurrence of openings allowing free passage of flame and hot gases through the construction.

Although almost all the data on fire resistance of floor constructions were obtained with fire exposure from below, a few tests with fire above the floor indieate a comparatively less severe exposure to the construction for a given fire condition.

CHAPTER II. RESTRICTIONS AND LIMITATIONS IN THEIR RELATION TO TYPES OF CONSTRUCTION

The essential conditions which can be provided by design for the safety of life and property against loss by fire in a building are

structural resistance to collapse due to fire and to spread of fire, sufficient exit facilities, and adequate facilities for extinguishment. The degree of safety in a given case is dependent on the extent to which the foregoing conditions are realized.

The major factors which will determine the extent to which the above conditions can be attained are the hazards due to location, occupancy, and contents; the height and area of the buildings; the size of areas not effectively separated with respect to fire; and the materials and construction of the building. It is usual, therefore, to apply restrictions and limitations to certain of these factors for the purpose of obtaining safe conditions to the degree considered economically possible and desirable from a public standpoint.

The degree of restrictions and limitations which have been applied vary considerably, and the Subcommittee is not here proposing any definite recommendations but the subject is discussed in general terms.

The following general classes of limitations have been applied to types of buildings differentiated by the materials, design, and degree of fire resistance of their component parts.

Location with respect to fire zones.
Permissible height of building.
Permissible spacing from adjacent construction or property lines.
Permissible area of building or area within fire subdivision walls.
Permissible materials in building members and building finish.
Required degree of fire resistance of structural members.
Permissible occupancies.

The following discussion will be referenced to the types of buildings defined in the preceding chapter and is intended to be suggestive in obtaining a safe application thereof. It will be limited to considerations of safety from fire only. It is recognized that other restrictions may be applied from the standpoint of general zoning regulations.

1. Location With Respect to Fire Zones

From the standpoint of fire zoning, cities are generally subdivided into one or two fire zones and an unrestricted area. In the larger cities two fire zones may be justified in which new construction is restricted to the Fireproof type within the inner zone, except that other types may be permitted if rigidly limited in height and area. In the outer fire zone, besides fireproof buildings, those built with structural members of incombustible materials irrespective of the fire resistance thereof, and those with exterior ground-supported masonry walls and interior non-fire-resistive construction, are permitted to the limits of height and area applicable for these types. Outside of the fire zones all types of construction are permitted to the respective limits of permissible height and area. In cities subdivided into only two districts the restrictions outlined above pertaining to outer fire zone are generally applied to construction within the fire limits.

Restrictions not necessarily directly connected with permissible types of construction are also applied with respect to roof materials, which may also be applied outside of fire limits. This is deemed justified on account of the possibility of rapid spread of fire in the more combustible and less fire-resistive construction prevailing outside of fire limits.

The main object of the restrictions is to reduce to a practical minimum the possibility of rapid spread of fire. This has been found desirable and necessary not only within congested high-value districts but also in residential districts, based on experience in numerous conflagrations from the beginning of historic times up to the present. The provision of exterior self-supporting walls of incombustible materials is a considerable measure of protection but has not prevented conflagrations where buildings are near the limits of permissible heights, closely spaced, and with the larger amounts of combustible contents, even with good fire-fighting facilities. For such conditions the Fireproof type has proved, however, to be very effective.

2. Restrictions Based on Height of Building

In applying restrictions of this class, some consideration apparently should be given to the required fire resistance of building members, permitting buildings having constructions with

the higher ratings to be built to relatively greater heights.

(*a*) *Fireproof Construction*

In general no restrictions as to height have been applied to the Fireproof type of building, except for occupancies deemed specially hazardous. This may be justified on the basis that the building should withstand a fire completely consuming all combustible contents and trim without collapse of structural members, or that for the higher amounts of combustible contents, the fire resistance incorporated in the building, in combination with its fire-extinguishing equipments and the public fire protection, is deemed adequate to prevent such collapse.

Structural protection against fire exposure from the outside also is assumed and can be provided without difficulty, since the lack of confinement for the products of combustion will prevent high exposure temperatures over long periods. While exposure from radiation may be intense, this will be limited in time to the most active stage of the fire. The resistance against exterior fire exposure is usually limited by the openings in fire-exposed walls. Although opening protectives are required for major buildings where the openings are within 30 to 50 ft from exposing construction or openings, it is recognized that under severe fire conditions fires can be communicated through unprotected openings at greater distances. The opening protectives generally required do assist materially in preventing communication of fire where large buildings are closely spaced. Greater spacings will decrease materially the degree of fire fighting from within and without required to prevent ingress of fire.

Another reason for the very moderate restrictions on height applied to the Fireproof building is its inherent advantages in point of limiting the spread of fire and smoke, resulting in greater safety to occupants and less difficulty in extinguishing fire. With incombustible floor construction of the required degree of fire resistance and enclosed vertical openings, the fire will be prevented from spreading from floor to floor through interior channels and the travel of smoke will be greatly restricted. For other than the lighter amounts of combustible contents, fire may be communicated from floor to floor through unprotected exterior wall openings, but this can be prevented with moderate fire-fighting effort. The building is relatively safe for entry by fire-fighting forces, and fire-fighting equipment can be provided within the building with the outlets and connections so located or protected as to give good assurance of its availability in case of fire.

These properties of the construction also enable conditions having a bearing on the safety of occupants to be evaluated with a good degree of reliability. While with non-fire-resistive construction it is generally considered necessary to provide for exit of all occupants from the building or fire-division thereof within a given time, the greater barrier to spread of fire and smoke offered by the floors and other subdividing constructions in Fireproof buildings makes it necessary to provide means for immediate exit only from the area directly involved. This greatly reduces the required capacity of stairs which otherwise would be prohibitive for high buildings.

With occupancies involving large amounts of flammable liquids or other readily combustible materials, the building construction affords less protection and the application of height restrictions is justified irrespective of the type of construction. Fires in such contents progress rapidly, with production of large volumes of smoke and gases that may be forced into protected exit ways, making them untenable, hence the need of facilities for prompt egress of occupants. Fire-fighting operations are more difficult and hazardous than for fires in ordinary combustibles, and explosions, even if not violent, may endanger the stability of the building. Without special provisions, no building presents any considerable resistance to explosive effects, although the Fireproof building has generally less inherent weakness in this respect than those of other types, and with proper choice of materials and design and provision of suitable vents, its resistance can be greatly increased.

(*b*) *Incombustible Construction*

While the Fireproof building must have sufficient structural protection, and other associated facilities, if needed, to assure freedom from collapse due to fire, such restriction does

not apply to those of the Incombustible type. Hence, provision for prompt egress of occupants must be made. Also, the possibility of conducting fire-fighting operations from within the building is not assured unless the fire is of low or moderate severity or is controlled in its early stage. The general limit of height to which an effective fire department hose stream can be directed from the ground to fight fires in a building is near 50 ft. This can be increased some 30 ft by mounting the hose on the first section of the aerial ladder. Any added range would have to be obtained with hose towers, the limit of height of which is near 100 ft. At this height the water pressure available from the pumpers and safely carried by the hose lines, becomes a limiting factor. These considerations will limit the height to which buildings other than those of the Fireproof type can be safely built.

Buildings of the Incombustible type with structural connections or adequate ties between the exterior and interior framing would present little hazard due to possibility of collapse onto adjacent property when failure occurs, assuming that the ratio of least lateral dimension to height of building is not excessive, since there would be a tendency for the framing to be pulled inwards. For self-supporting exterior walls, such as of masonry, on which interior construction is supported and secured with only the usual forms of ties or anchorage, the conditions from the standpoint of hazard to adjacent property would be substantially the same as for the Exterior-Protected building outlined below.

The incombustible floor and roof constructions in collapsing tend to blanket the fire and prevent hazard to the surroundings from flying brands. Although the resistance of unprotected members to collapse due to fire is comparable with what obtains for unprotected wood-joist construction, fire and smoke are better confined. The absence of any consequential amount of combustible materials in the structural members and accordingly, in the materials forming the boundaries of any concealed spaces formed by them, further removes conditions inducive to rapid spread of fire. It also would be expected that irrespective of any restrictions applied, the amount of combustible insulation, finish, and trim would be less than for wood interior construction. These all have a bearing on the safety of occupants and the case with which fires can be controlled in their early stages.

As protected to obtain given fire-resistance ratings, Incombustible construction would be the equivalent in this respect to similarly protected Wood construction except that where failure under load or other structural collapse is not involved, the incombustible constructions would continue to present a barrier to the spread of fire and smoke for a longer period after limiting technical end points, such as temperature rise on the unexposed side, have been reached.

(c) *Exterior-Protected Construction*

In an effort to prevent the conflagrations that repeatedly have devastated centers of population, buildings in closely built-up areas have been required to have exterior and party walls of masonry. These walls are required to be self-supporting in the sense that they are carried directly on their foundations, and as supported laterally by the floor and roof constructions, are stable under the normal lateral forces to which they are subjected. Such stability also can be regarded as maintained under exterior fire exposure, and protection to interior construction and building contents can be given substantially as for the other building types discussed above. To achieve such protection in the same degree, care must be taken in the details employed at the eaves, cornices, and projecting dormers or towers, to eliminate possibility of ready ingress of fire through open spaces or spaces sheathed or filled only with combustible materials. The ends of combustible members projecting into the walls must have sufficient thickness of protective material to the outside to prevent ignition from the exposing fire, a condition generally attained without difficulty in exterior walls but which may be a limiting factor in the protection given by party and fire walls. The effect of unprotected and protected wall openings on the protection afforded by the wall construction is the same as for the other building types.

When the interior construction of Exterior-Protected buildings collapses because of fire, the stability of the exterior walls of multistory

buildings is largely destroyed. The heat from the fire causing expansion of the inner face will deflect the top of the wall outward thus increasing its instability, and collapse to within a story-height or two from the ground is to be expected in a fire consuming the interior construction and contents. This instability of the walls under fire exposure from within the building introduces an element of hazard to adjacent property and to firemen, for buildings of any considerable height. The protection given adjacent construction is limited by this condition and even heavy built-up or metal roof coverings exert little blanketing effect in a severe fire, since they are consumed or disintegrated into their component units. This, as well as the practical heights to which fire-department hose streams can be applied, is a consideration that limits the height of buildings of this type.

From the standpoint of safety to occupants, facilities for egress from the building or fire subdivision thereof within a limited time, need to be provided. Protected stair shafts increase the allowable time for egress and also serve as a protection for fire-fighting operations. It is apparent, however, that the height of the building must be restricted for these reasons, as well as on the score of hazard to adjacent construction. Even with its limitations this building type has served very effectively in preventing ready communication of fire from building to building. With a moderate degree of public protection, fires in buildings presenting the lighter degrees of hazard, such as those of the residential type, can be controlled without much likelihood of spread to adjacent construction.

No separate classification is made for the heavy timber or mill construction type since its fire resistance in the lower range as unprotected is not higher than the ¾-hr limit designated for the present type and attainable with protected interior wood constructions framed with lighter members.

(d) Wood Construction

The essential difference between this type of construction and that designated as Exterior-Protected is in the exterior framing and facing. The latter may vary from wood or metal siding to masonry veneer, and the sheathing against which they are placed may be of combustible or largely of incombustible materials. As for the preceding type, there may be also a wide range in combustibility and fire resistance of the interior construction and finish, greatly affecting the safety of occupants and the ease with which fires can be controlled in their early stages or prevented from spreading to adjacent construction.

Although the higher range in exterior protection attainable may approximate that with Exterior-Protected construction, masonry veneer is less stable than solid masonry walls and with combustible exterior finish the building is more vulnerable to exterior fire exposure. These considerations justify further restrictions in height for this type, although the hazard to occupants with the same type of interior framing and finish may not be much different from that obtaining for the Exterior-Protected type.

3. Restrictions on Locations with Respect to Common Property Lines or Adjacent Buildings

The objects of these restrictions apparently are to decrease the possibility of rapid spread of fire and afford a space between buildings for fire-fighting operations. It does not appear to have been practical by such restrictions to achieve much assurance that the walls of a building will not collapse on adjacent buildings or property when the building or its interior construction is destroyed by fire.

The restrictions that have been applied refer mainly to Wood construction, walls of which have been required by building codes or other restrictions to be located from 1½ to 10 ft from the common property line or from 2½ to 20 ft from the adjacent building, the most usual range being 3 to 5 ft for the former and 6 to 10 ft for the latter. In many codes the restriction is applied to the wall concerned rather than to the whole building, the wall located within a given distance from the common property line or adjacent building being required to have a specified fire-resistance rating. It is questionable whether requirements thus phrased achieve

the desired object, since the matters of interest are quite apparently the material in the wall and its stability, which are not necessarily directly determined by its fire-resistance rating.

Very few restrictions have been applied in this respect to buildings of the Fireproof or Exterior-Protected type where the walls concerned are without openings. Where there are openings, or for places of public assembly, a minimum distance to the common property line or between buildings has been required, for the latter to afford a passage for egress.

From the standpoint of the hazards with which restrictions of this class are concerned, it is apparent that buildings of the Fireproof type give the greatest protection. The next in order would be those of the Incombustible or the Exterior-Protected type, depending on conditions. Where there is a space between the buildings, those of the Incombustible type with members having ½-hr or greater fire-resistance rating may present the lesser hazard. This concerns degree of hazard to adjacent property from collapse of building and building walls and the blanketing effect on the fire of floor and roof constructions both before and after collapse. Where the building extends to the common property line, there are advantages in favor of the Exterior-Protected type over the Incombustible type unless similarly protected, particularly if the buildings where they adjoin are of approximately the same height and depth. Whether the adjoining walls are built as party walls or as individual common-property-line walls, a fair assurance of stability of the party wall or adjacent common-property-line wall is had when the construction on one side or the other collapses because of fire. This assumes that the floor and roof constructions on both sides are tied into the wall in such manner as to give the required degree of support to the wall when exposed to fire from the outside, but in the case of party walls, collapsing members are released to an extent that will enable the wall to retain its stability and fire resistance.

It appears that walls of buildings of the Incombustible and Wood construction types when built to the common property line should conform with the requirements for party and common-property-line walls of buildings of the Exterior-Protected type, from the standpoint of both stability and fire resistance. Although the stability of walls of buildings of the Fireproof type is assumed established at least for the applicable fire-resistance rating, their fire-resistance rating as party walls should at least correspond to the expected fire severity for the adjacent area in the original building. If subsequent construction on the other side introduces a higher fire severity, the fire resistance of the wall should be correspondingly increased.

For common-property-line walls a uniform requirement of 2 hr is applied on the assumption that a wall subsequently built in contact with it will have equal fire resistance. If the two walls so constructed do not in combination meet the requirements for a party wall in the given location, the fire resistance thereof should be increased or some of the other provisions under table 1, footnote (a) applied. The fire resistance of exterior walls other than common-property-line walls is based on ability to support load and retain stability under fire exposure and on temperature rise only as it concerns fire exposure from the outside.

The practice of permitting unmodified walls of the designs typical for Incombustible and Wood construction type buildings as party and common-property-line walls does not appear justified, even where the wall and construction on each side have up to 1-hr fire-resistance ratings. For occupancies involving the lower amounts of combustible contents in buildings of the Incombustible type, no great hazard may be involved but it may be increased with changes in occupancy. Wood construction, irrespective of its fire resistance, will eventually collapse in any fire involving a considerable portion of the construction or building contents, assuming no fire extinguishment. Even with good fire fighting, fire and smoke are likely to be communicated through concealed spaces in the construction, the firestopping of which cannot be fully assured. Some improvement is obtainable with double construction at the common property line, with an intervening continuous fire barrier in the form of incombustible fire-resistive blankets or similar separations, designed to remain in place when the construction on either side collapses. However, in general, party and common-property-

line walls conforming with the requirements for Exterior-Protected construction constitute more effective barriers.

Requirements based on distance from the common property line can be made unduly restrictive unless tempered with respect to size of building. Thus, a certain separation deemed proper for buildings several stories high cannot with justification be applied to small one-story buildings, such as private garages. Such buildings, even if of Wood construction, particularly with incombustible facings, can safely be permitted closer to the common property line or similar adjacent building. Assuming some separation, incombustible unprotected buildings of such size present less hazard from this standpoint than those with masonry walls and combustible roof construction.

4. Restrictions Based on Area of Building

The objects of regulations of this type are to restrict the spread of fire, obviate conditions unduly hazardous to occupants from the standpoint of egress, and to provide access for fire-fighting purposes. The practice of permitting greater areas for buildings fronting on two or more streets than for those with a single frontage may be justified on the score of access for fire-fighting equipment, although the additions generally permitted on this score in building codes appear relatively large. Under some regulations, areas having a long street frontage are permitted to be larger than those having a greater ratio of depth to frontage, presumably for the same reason. Buildings or groups of buildings located some distance back of any public street front but having improved roads or streets leading up to them equal to public streets, will in general give accessibility to fire apparatus equivalent to frontage on two or more public streets.

Increases in permissible areas of 50 to over 100 percent are generally allowed if automatic fire-extinguishing equipment is installed. Some regulations restrict such permissible increases to business buildings, garages, and other commercial types. In a few regulations, low buildings are permitted larger areas than those that can be built to the limit of permissible height, although there has been no general systematic application of this principle. For non-fire-resistive construction, the hazard from spread of fire appears to be fully as much a function of the volume of the building or fire subdivision thereof as of the ground area occupied.

In applying area restrictions, some allowance might be made for the required fire resistance of building members by allowing buildings with members of the higher ratings to have larger undivided areas.

(*a*) *Fireproof Construction*

Buildings of this type are generally unrestricted as to area, with the exception of those considered specially hazardous, such as public garages. It is a question whether a number of other occupancies involving large amounts of combustible materials or readily flammable materials do not present as great or greater hazard. The inherent protection given by Fireproof construction is recognized where light or moderate contents of ordinary combustible materials are involved, but for higher concentration or more readily combustible materials the retarding effect of the construction is of less import. This construction has the advantage that structural fire subvidision can be made with good assurance that the subdividing construction will fully serve its purpose, assuming its fire-resistance rating is adequate for the conditions presented. The full value of fireproof construction can be attained only where such subdivision is logically applied. However, many occupancies require such large areas from the standpoint of operating conditions, of the order of several hundred thousand square feet, that any restrictions applied above such limits would have little meaning. Examples are certain types of metal working and assembly plants. If the contents are largely incombustible and there is a minimum of combustible building finish and trim, such large areas would present no greater hazard than smaller spaces with higher combustible content. For others, the safety to property and under some conditions, to occupants, can be appreciably improved by judicious subdivision. The safety from the standpoint of emergency egress in establishments such as retail stores would be greatly increased with at least one subdividing construction for large areas.

Assuming an occupancy that can be safely permitted without restriction as to area or within a given permissible area, it appears illogical to stipulate in effect further subdivision of this area by requiring ordinary room partitions to have given fire-resistance ratings. This applies especially where the whole area is covered by the same occupancy or tenancy. Such partitions, if wholly or largely of incombustible materials, will retard the progress of fire to some extent, but there appears no justification for requiring a fire-resistance rating.

It is recognized that partitions serving as protection for shafts and egress corridors should be required to have some degree of fire resistance. For egress corridors this need be no greater than one-half to one hour. Considering that shafts may be used by fire-fighting forces, a greater protection for them is justified. The actual fire exposure on the shaft side of protected enclosures is very light, justifying in general a lower limit of fire resistance for the enclosing construction exposed from the inside than from the other. The same applies also to some extent for corridor partitions.

(*b*) *Incombustible Construction*

With this as with other buildings not of the Fireproof type, collapse in whole or part may occur from fire exposure and hence the need of providing protected ways of egress for occupants. This may be a limiting consideration from the standpoint of permissible area, since the distance to any exit must be limited and vertical exit ways are located preferably on or near exterior walls.

This type of building affords more favorable conditions than those of combustible interior construction in restricting the spread of fire and for fire-fighting operations in case collapse does not occur, or before it occurs in fires taxing the building constructions beyond their ultimate fire resistance. Beyond this stage, although the fire may be subdued by the collapsed incombustible constructions, fire fighting is made more difficult, since hose streams are diverted by them and fire spread to portions that have not collapsed and are within the same fire area can with difficulty be prevented. Such buildings if of one story are generally unrestricted as to area and height even if structurally unprotected. This may be justified as far as light-hazard occupancies are concerned, but for the larger amounts and more hazardous types of contents, restrictions apparently should be applied, considering what is done in the case of other buildings not of the Fireproof type.

(*c*) *Exterior-Protected Construction*

The same considerations from the standpoint of area limitations apply in general as for buildings of the Incombustible type. The interior construction will afford somewhat greater opportunity for rapid spread of fire and on this account the individual areas might logically be restricted to a little greater extent than for buildings of the Incombustible type. Unless the floors are of heavy laminated wood, or of lighter construction having fire-resistive plaster or other equally effective soffit protection, the vertical spread of fire will be less restricted.

To obtain the protection premised with the exterior wall construction, it appears that all walls forming a boundary of the building, including walls bordering on interior courts, should be constructed the same as the exterior walls. The practice of permitting interior-court walls to be of wood frame appears inconsistent, even if protected to give 1-hr fire resistance, considering the decreased protection from fires in adjacent wings. Further, court walls thus constructed would not qualify as boundaries for fire subdivisions based on area.

(*d*) *Wood Construction*

Although it may appear that there is no decided difference between buildings of this type and Exterior-Protected buildings in features governing area restrictions, actually as constructed a considerable degree of distinction is discernible. The undivided areas for the latter type generally will be distributed in wings separated by courts or light wells, the required incombustible self-supporting walls of which will retard appreciably the spread of fire, as compared with combustible construction, and spread to adjacent construction is relatively more readily prevented with self-supporting exterior walls. However, considering that buildings of the Wood construction type are also more restricted as to height, justification

for the large differences in permissible area often applied as between the two types, is not readily apparent. In some regulations the permissible size of buildings of this type is conditioned on distance from the nearest common property line.

5. Restrictions on Type of Materials in Building Members and Building Finish

As far as the type of materials in structural portions of buildings is concerned, this is largely defined for the different types of construction. Thus, in buildings of the Fireproof and Incombustible types as defined herein, all structural members are required to be of incombustible materials irrespective of the degree of fire resistance. For the Exterior-Protected type the requirement for incombustible materials is limited to the exterior wall construction and certain subdividing constructions such as party walls, fire walls, and shaft enclosures. For Wood construction, there would be no requirements as to materials except for subdividing constructions, although it is implied that no materials more readily flammable than wood can be used at least in structural members. Accordingly, from this standpoint, the materials would be restricted in their use by the requirements pertaining to the different types of construction.

As concerns materials in building finish and trim, restrictions based thereon have been applied, although not to the extent that might be justified. Thus, according to the New York Building Code, no untreated combustible finish floors or trim can be used in buildings over 150 ft high. Otherwise, in type I buildings generally, wood finish floors and the usual amount of wood trim can be used. This, however, should not be taken as implying that such buildings can be finished over the whole or the larger portions of the interior surfaces with combustible materials. This would introduce a much greater hazard than their use in doors, baseboards, moulding, and similar trim which does not constitute a large percentage of the wall area and does not afford ready opportunity for the spread of fire. As a concession in this direction, some codes permit interior partitions of wood, or wood and glass, in areas not exceeding 5,000 ft^2. This will in general include subdividing partitions only, corridor partitions being otherwise required to be of incombustible materials.

It is apparent that the application of combustible trim over any considerable portion of the interior surfaces of buildings greatly increases the fire hazard irrespective of the degree of fire resistance of building members. Such trim will accelerate the spread of fires started in combustible contents that otherwise might be easily restricted to the room or area in which they originate. After air temperatures have been built up to or near the ignition temperature, rapid spread of fire can take place on combustible finishes and veneer of no greater thickness than $\frac{1}{32}$ in. The prohibition of readily combustible curtains and other decorations in places of public assembly is fully justified on the basis of experience. Many fires disastrous from the standpoint of life loss have occurred in them even where the building itself suffered little damage.

Although for the non-fire-resistive building types, building codes apply few restrictions in point of materials for interior finish, it is conceded that a wide range in safety to life as well as to property is presented by the different materials used for the purpose. In the evolution of modern building construction a decided improvement in this respect was achieved by the substitution of plaster for wood finish. The more recent introduction of materials in sheet form, as readily or more readily combustible than wood, has modified this trend.

Of materials used on the exterior of buildings, those used for roof covering are generally the subject of restrictions from the standpoint of spacing of buildings, type of construction, and occasionally occupancy. This has been done with the object of limiting the community fire hazard. Also, such restrictions may be required in order that the exterior construction may achieve a given resistance against fire exposure from the outside. The wall finishes applied to wood construction present a considerable range in this respect, including as they do masonry veneer, stucco, metal, or wood finish. Little recognition has been given in building codes to the difference in the fire hazard thus presented except for requirements in relation to spacing from the lot line or adjacent buildings.

6. Restrictions Based on Degree of Fire Resistance of Structural Members

Restrictions on the above score have been applied mainly in the different uses permitted for the different types of building constructions. Whereas buildings of the Fireproof type can be constructed to have a high degree of fire resistance, that of the other types is necessarily limited from the standpoint of practicability with the types of materials available. In some codes, buildings essentially of the Fireproof type are placed in two classes, a higher degree of fire resistance being required for one than for the other. Those to which the lower requirements pertain are however limited as to height and area, whereas few restrictions in these respects are applied for the more fire-resistive type. In the code developed by the Pacific Coast Building Officials Conference, the dividing line in point of permissible height is placed at 85 ft. and in other codes recommended requirements have nearly the same limitations.

Assuming that Fireproof buildings are designed to withstand a complete burning-out of contents and combustible trim without collapse, there should in effect be no limitations imposed on the score of degree of fire resistance other than in its relation to the expected fire severity for the given building. However, considering that public control over the amount of combustible contents in a given building can be exercised only within limits even where the occupancy is subject to control, and further, that the degree of fire resistance of building members cannot be achieved within very definite limits, there is justification for applying more rigid restrictions to buildings with the lower degree of fire resistance, particularly from the standpoint of height.

For buildings generally associated with the lower range in combustible contents, such as residential and office buildings, it does not appear justifiable even from this standpoint to apply an unduly large factor of safety. Where the expected fire severity is in the range ½ to 1½ hr, a 2-hr requirement for high buildings should give good assurance of stability under fire conditions. It is noted that fire-resistance ratings are based on the performance of members near the lower range in size. For the larger size of members used in all but the upper stories of such high buildings, there would be considerable increase in fire resistance above the nominal ratings for the same kind and thickness of protecting materials. Also, the structural continuity inherent in the type of construction increases the margin of safety on stability above that indicated in test furnaces for comparable fire exposure and loading of segregated columns, beams, and floor and wall assemblies.

For buildings other than those of the Fireproof type it is apparent that even in the range of fire resistance up to ¾ hr a decided difference in hazard to life and property is presented that would justify recognition in height and area limitations. Present restrictions are based largely on the use of the ordinary type of interior constructions having fire resistance of less than ½ hr.

7. Restrictions Based on Occupancy

The fire hazard of an occupancy can be evaluated in terms of the number and concentration of occupants, whether or not such occupants are able-bodied and free or confined or restrained, and the degree of combustibility and amount of combustible building contents associated with the occupancy. The larger places of public assembly have been restricted to buildings of the Fireproof type according to some regulations, although distance of the main assembly floor above ground, facilities for exit, and interior finish apparently would be at least equally important. Where the occupants are restrained as in prisons, reformatories, and insane asylums, rigid restrictions on construction and interior finish of buildings appear justified, considering that disastrous fires from the standpoint of loss of life have occurred even in one-story buildings where these conditions were unfavorable. Similar, although less rigid restrictions with respect to permissible type of construction, have been applied for hospitals and schools. Many codes that permit several types of construction for such occupancies apply different restrictions to the respective types in point of height and area. It is apparent that buildings housing hazardous occupancies should be restricted to some extent in point of permissible type of construction, although

other considerations—such as spacing from other buildings, height and area of building, and the provision of adequate exits—may be more important.

The largest loss of life in burning buildings occurs in those housing occupancies of the residential type, including hotels, apartment buildings, and other types of multifamily dwellings as well as private dwellings. Although associated with the lower range in combustible contents and concentration of occupants, there is apparently a considerable hazard at night when the occupants are asleep. The limitation in point of height for residential buildings of other than the Fireproof type has been variously placed at 3 to 6 or 7 stories. Considering that the application of firestopping to prevent communication of fire through the concealed spaces in wood framing cannot be assured, it appears that a reasonable degree of safety in the higher buildings having such framing is difficult to obtain. The increased safety with incombustible floor and other subdividing interior construction has been abundantly indicated by the fire record. Also, there would be less objection to more rigid requirements in this respect if the required fire resistance of buildings recognized as fully fireproof for the purpose were proportioned with respect to the relatively low fire severity to be expected from the occupancy.

CHAPTER III. SURVEY OF COMBUSTIBLE CONTENTS OF BUILDINGS

As an assistance in applying fire-resistance requirements, surveys were made under the auspices of the Central Housing Committee of combustible contents associated with representative types of occupancies or buildings. In tests that have been conducted to obtain information on the intensity and duration of fires in buildings, it has been indicated that there is a fairly definite relation between the amount of combustible contents and the resulting fire severity. This is applicable for the buildings having the main structural elements of incombustible materials of fire resistance sufficient to preserve their integrity in a fire consuming all the combustible contents. Considering the wide range in weight of the combustible contents to be found in buildings, it appears logical to proportion the fire resistance of structural members with reference to the severity of fires that can occur within them.

In the surveys (see tables 7 to 17) the weights were obtained by weighing furniture and other contents in sufficient number to enable the total weight within an area to be computed. The weight of the combustible flooring and trim was determined from the thickness and area, which method was also applied for fixed furniture and other contents that could not be weighed.

For a given room the doors, windows, frames, and trim are included in general at one-half their total weight. The combustible contents and area of closets have been averaged with those of the room served by the closet. The total weight of the combustible contents of metal lockers, filing cabinets, etc., is included. No weight is included for possible escaping illuminating gas. In school surveys the contents of the storage rooms represent the maximum weight ordinarily stored therein. Pupils' desks are assumed to be empty. The weight of pupils' wearing apparel is not included.

In small areas, such as closets in residential buildings, concentrations considerably higher than the average were found, this being reflected to some extent in the average for the rooms which they served. A summary of combustible contents of such closets is given in table 8. Considering the small areas and the fact that closet doors if not open are generally of type that will burn through inside of 10 minutes, it is apparent that their contents should be averaged with that of the adjoining room or hall. It is seen that the greater portion of the combustibles is in trim, lining, and shelving.

These surveys indicate the range in combustibles associated with the occupancies covered. Thus, for residential buildings, the weight of combustible contents is uniformly light. The same applies for school and office buildings except for areas used for filing or storage, which generally constitute only a small percentage of the total area. For warehouses the range is wider, although the concentration has some relation to the type of

TABLE 7.—*Summary data for apartments and residences*

Survey No.	Floor area	Combustible contents			
		Movable property	Floor	Exposed woodwork other than floor	Total
Entire apartment or residence					
	ft²	*lb/ft²*	*lb/ft²*	*lb/ft²*	*lb/ft²*
A–1	695	3.1	3	3.6	9.7
A–2	670.5	2.5	3	2.8	8.2
A–3	544	2.4	2.7	3.4	8.5
A–4	604.5	2.7	3	2.6	8.2
A–6	519	3.4	3	2.9	9.3
A–7	647	4.0	3	2.7	9.7
A–8	431	3.4	3	3.6	10
A–9	514	3.5	3.	2.9	9.4
A–10	734	3.7	1.9	2.9	8.5
A–11	734	2.9	1.9	2.8	7.6
A–12	748	4.9	0	2.7	7.6
A–13	529	4.6	3	1.5	9.1
A–17	796	3.1	3	2.2	8.3
Average		3.4	2.6	2.8	8.8
Basement					
A–1	783	0.8	0.0	0.2	1.0
Bathroom					
A–1	58	1.2	3.0	1.0	5.2
A–2	60	0.4	2.2	7.4	10.0
A–3	35	.1	0.0	1.9	2.0
A–6	42	1.2	.5	7.1	8.8
A–7	35	0.5	3.0	3.0	6.5
A–8	35	.8	3.0	3.0	6.8
A–9	35	1.1	3.0	3.0	7.1
A–10	42	1.5	3.0	2.8	7.3
A–11	42	1.5	3.0	2.8	7.3
A–17	47	1.6	3.0	4.5	9.1
Average		1.0		3.7	7.0
Bedroom and bedroom closets combined					
A–1	110	3.7	3.0	3.1	9.8
A–1	136	5.4	3.0	4.6	13.0
A–2[a]	86	3.9	3.0	1.9	8.8
A–3	188	4.1	3.0	2.3	9.4
A–6	133	7.3	3.0	2.5	12.8
A–7	128	6.5	3.0	2.2	11.7
A–7	145	6.7	3.0	2.0	11.7
A–8[b]	133	5.0	3.0	3.2	11.2
A–9	138	6.2	3.0	4.0	13.2
A–10	112	4.8	3.0	2.6	10.4
A–10[b]	161	3.8	3.0	3.1	9.9
A–11	112	6.6	3.0	2.6	12.2
A–11[b]	161	4.3	3.0	2.2	9.5
A–12	154	3.8	0.0	3.0	6.8
A–13[a]	144	4.4	3.0	1.6	9.0
A–13[a]	80	7.2	3.0	1.5	11.7
A–17	126	4.2	3.0	1.8	9.0
A–17	126	2.5	3.0	1.8	7.3
Average		5.0		2.6	10.4
Dining room					
A–2	132	2.9	3.0	1.9	7.8
A–4	137.5	3.6	3.0	0.7	7.3
A–12	224	3.0	0.0	3.5	6.5
Average		3.2		2.0	7.2

TABLE 7.—*Summary data for apartments and residences*—Continued

Survey No.	Floor area	Combustible contents			
		Movable property	Floor	Exposed woodwork other than floor	Total
Hallway					
	ft²	*lb/ft²*	*lb/ft²*	*lb/ft²*	*lb/ft²*
A–1	21	2.6	3.0	6.5	12.1
A–1	11	1.0	3.0	9.7	13.7
A–2	86	2.1	3.0	2.4	7.5
A–3	25	1.0	3.0	7.4	11.4
A–4	81	5.4	3.0	0.6	9.0
A–6	52	0.0	3.0	6.8	9.8
A–7	67	.0	3.0	5.8	8.8
A–8	42	.0	3.0	8.1	11.1
A–9	28	.0	3.0	5.5	8.5
A–10	27	.0	3.0	7.7	10.7
A–11	27	.0	3.0	7.7	10.7
A–17	20	.0	3.0	9.5	12.5
Average		1.0		6.5	10.5
Kitchen					
A–1	109	1.6	3.0	6.1	10.7
A–2	152	0.7	3.0	2.4	6.1
A–3	47.5	.2	0.5	4.0	4.7
A–4	148.5	.7	3.0	4.2	7.9
A–6	96	1.0	3.0	2.6	6.6
A–7	90	2.1	3.0	3.2	8.3
A–9	137	0.5	3.0	3.0	6.5
A–10	171	.5	1.0	1.4	2.9
A–11	171	1.8	1.0	1.7	4.5
A–13	103	3.8	3.0	1.4	8.2
A–17	87	0.7	3.0	4.5	8.2
Average		1.2		3.1	6.8
Library					
A–12	146	10.6		2.4	13.0
Living room					
A–1	250	3.3	3.0	1.9	8.2
A–2	132	4.8	3.0	2.6	10.4
A–3	233	3.3	3.0	2.0	8.3
A–4	237.5	4.3	3.0	1.3	8.6
A–6	175	3.5	3.0	0.6	7.1
A–7	167	3.0	3.0	.7	6.7
A–8	213	3.6	3.0	1.9	8.5
A–9	167	4.6	3.0	1.1	8.7
A–10	217	6.8	0.0	3.5	10.3
A–11	217	1.4	.9	3.4	5.7
A–12	224	4.4	.0	2.1	6.5
A–13	202.5	4.3	3.0	1.6	8.9
A–17	283	3.9	3.0	0.9	7.8
Average		3.9		1.8	8.1
Storeroom (apartment house)					
A–5	264	6.2	0.0	0.0	6.2
A–5	301	2.4	.0	.0	2.4
A–14	432	8.8	.0	.2	9.0
A–15	1,221	8.0	.0	.0	8.0
A–16	1,446	10.0	.0	.0	10.0
A–17	98	2.8	3.0	1.8	7.6
Average		6.4		0.3	7.2
Vestibule					
A–2	22.5	2.2	3.0	4.4	9.6

[a] No closets.
[b] Two closets.

materials that are stored. It is probable that similar conditions obtain for stores, manufacturing establishments, and other commercial occupancies.

In the summary tables are given the areas, and in some cases the percentages of the total area, over which a given concentration or range in combustibles was found. The concentration is expressed in pounds per square foot of floor area, assumed uniformly distributed, and applicable for materials, such as wood and paper, that have calorific values in the general range 7,000 to 8,000 Btu/lb for the dry material. Where combustibles differing markedly in calorific value from the above were present, their weights were modified to give the equivalent weight of a material having a calorific value of 8,000 Btu/lb.

TABLE 8.—*Summary for closets in residential buildings*

Closets		Average floor area	Movable property	Floor	Other woodwork	Total		
Type	Number					Average	Maximum	Minimum
		ft^2	lb/ft^2	lb/ft^2	lb/ft^2	lb/ft^2	lb/ft^2	lb/ft^2
Clothes	28	8.75	5.1	2.7	11.6	19.4	30.2	10.2
Linen	9	4.77	11.7	3.0	21.4	36.1	49.3	26.2
Kitchen	1	5.00	4.0	3.0	23.2	39.2		

TABLE 9.—*Summary data for offices*

Survey No.	Floor area	Combustible contents			
		Movable property	Floor	Exposed woodwork other than floor	Total
			Office (only)		
	ft^2	lb/ft^2	lb/ft^2	lb/ft^2	lb/ft^2
0–17	285	3.8	3.3	1.7	8.8
0–28	122	4.9	0	2.1	7
Average		4.4		1.9	7.9
			Office and reception room		
0–6	289	2.6	0	1.7	4.3
0–21	292	2.4	3.3	3.1	8.8
Average		2.5		2.4	6.6

TABLE 9.—*Summary data for offices*—Continued

Survey No.	Floor area	Combustible contents			
		Movable property	Floor	Exposed woodwork other than floor	Total
			Office and light files		
	ft^2	lb/ft^2	lb/ft^2	lb/ft^2	lb/ft^2
0–1	656	10.7	0.0	1.2	11.9
0–2	336	8.6	.0	2.1	10.7
0–3	336	9.9	.0	2.7	12.6
0–4	1,321	3.8	.0	2.9	6.7
0–5	467	10.2	3.3	2.2	15.7
0–7	739.5	5.7	.0	1.8	7.5
0–8	739.5	8.1	.0	0.8	8.9
0–10	742.5	2.9	.0	.9	3.8
0–11	775.5	8	.0	.9	8.9
0–13	448	6.4	3.3	1.4	11.1
0–15	323	4.6	3.3	1.5	9.4
0–16	170	11.5	3.3	1.9	16.7
0–18	388	3.9	3.3	4.8	12
0–19	233	5	3.3	1.7	12
0–20	263	9.5	3.3	2.4	15.2
0–22	304	4.1	3.3	3.7	11.1
0–23	199	9.7	3.3	2.9	15.9
0–29	1,284	6.7	.0	0.1	6.8
0–34	2,031	5.9	.0	.1	6
0–36	104	9.8	3.0	2.8	15.6
Average		7.3		1.9	10.9
			Files (heavy)		
0–9	1,508	30.3	.0	0.5	30.8
0–12	855	85.9	.0	.0	85.9
0–14	1,064	23.9	3.3	.9	28.1
0–25	225	23.6	3.3	1.7	28.6
0–30	9,550	33.1	.0	0.1	33.2
0–31	7,742	28.9	.0	.1	29
0–32	4,220	37.2	.0	.1	37.3
0–33	2,041	48.4	.0	.1	48.5
0–37	226	61.8	3.0	.5	65.3
Average		41.5		.4	42.9
			Law office and library		
0–26	369	16	0	1.9	17.9
0–27	187	17.7	0	1.9	19.6
Average		16.9		1.9	18.8
			Library		
0–24	459	30.4	3.3	1.6	35.3
0–35	2,533	19.7	0	0	19.7
Average		25.1		0.8	27.5

TABLE 10.—*The percentage of usable floor area in office buildings having combustible contents within given limits*

Combustible contents for usable floor area	Building 1	Building 2	Building 3	Building 4	Building 5	Building 6
lb/ft^2	Percent	Percent	Percent	Percent	Percent	Percent
0 to 6	65					
6 to 10	10					
10 to 30	0					
30 or more	25					
0 to 8			0			
8 to 10			16			
10 to 15			74			
15 or more			10			
0 to 10		12.5		11.4	36	72.5
10 to 20		75		83	61	8
20 to 30				1.6	1	3
20 or more		12.5				
30 to 50				4	2	
30 or more						16.5
Total	100	100	100	100	100	100

TABLE 11.—*Summary data for rooms in school buildings in the District of Columbia, Chevy Chase, Md., and Bethesda, Md.*

Room	Survey no.	Room area	Combustible contents: Movable property	Floor	Exposed woodwork other than floor [a]	Total
		ft²	*lb/ft²*	*lb/ft²*	*lb/ft²*	*lb/ft²*
Auditorium	46–W [b]	8,245	0.46	2.6	0.6	3.66
Do	44–R [c]	6,300	1.75	2.6	.6	4.95
Do	49–CC [d]	2,250	0.6	6.2	1.2	8.0
Average		5,598	0.94	3.8	0.8	5.54
Art room	36–R	880	7.1	2.6	2.5	12.2
Do	55–B [e]	1,024	5.8	1.0	0.5	7.3
Average		952	6.5	1.8	1.5	9.8
Bookkeeping	34–R	704	7.2	2.6	2.2	12.0
Mechanical drawing	37–R	1,364	6.0	2.6	2.0	10.6
Typewriting	33–R	704	6.2	2.6	2.2	11.0
Average		924	6.5	2.6	2.1	11.2
Geography	35–R	704	2.7	2.6	2.2	7.5
Music	47–CC	782	1.5	2.6	2.6	6.7
Physics lecture	30–R	736	3.0	6.0	2.0	11.4
Average		741	2.4	3.7	2.3	8.5
Typical classroom	4–C [f]	765	3.2	2.6	1.3	7.1
Do	14–W	770	2.8	2.6	1.1	6.5
Do	26–R	704	1.7	2.6	2.0	6.3
Do	41–M [g]	788	3.7	2.6	2.0	8.3
Do	48–CC	828	2.8	1.0	4.4	8.2
Do	50–B	759	2.1	1.0	1.9	5.0
Average		769	2.7	2.1	2.1	6.9
Gymnasium	45–R	9,350	0.3	6.9	2.5	9.7
Gymnasium auditorium.	51–B	4,428	.35	2.6	2.1	5.1
Average		6,889	0.33	4.8	2.6	7.4
Biology laboratory	1–C	1,020	8.0	2.6	1.5	12.1
Do	20–W	1,232	1.4	2.6	1.0	5.0
Do	27–R	891	6.1	2.6	2.0	10.7
Do	53–B	1,024	4.5	1.0	0.4	5.9
Average		1,042	5.0	2.2	1.2	8.4
Chemistry laboratory	3–C	980	4.8	2.6	1.5	8.9
Do	28–R	828	6.9	2.6	1.4	10.9
Do	54–B	1,024	3.5	1.0	0.8	5.3
Average		944	5.1	2.1	1.2	8.4
Clothing laboratory	25–W	1,170	5.2	2.6	1.0	8.8
Foods and clothing laboratory.	52–B	1,542	3.5	1.0	3.3	7.8
Average		1,356	4.4	1.8	2.2	8.3
Physics laboratory	22–W	880	1.3	2.6	1.2	5.1
Do	29–R	828	5.4	2.6	1.5	9.5
Average		854	3.35	2.6	1.4	7.3
Library reading room	11–C	3,180	4.2	2.6	3.4	10.2
Do	23–W	1,653	7.7	1.0	1.7	10.4
Do	31–R	1,736	9.8	2.6	2.5	14.9
Do	56–B	1,265	7.4	1.0	0.3	8.7
Average		1,959	7.3	1.8	2.0	11.1
Library stack room	12–C	528	32.8	2.6	1.2	36.6
Do	24–W	132	25.8	1.0	13.6	40.4
Do	32–R	132	26.7	2.6	1.5	30.8
Average		264	28.4	2.1	5.4	35.9
Lunch room	43–M	587	2.6	2.6	1.5	6.7
Office, and file room	38–R	276	36.3	2.6	0.1	39.0
Office, home economics	21–W	253	12.5	3.6	1.2	17.3
Office, publications	10–C	272	6.9	3.6	6.0	16.5
Office, teachers	2–C	500	6.4	2.6	2.5	11.5
Average		325	15.5	3.1	2.5	21.1
Storeroom, janitor's	19–W	529	16.8	0	0.2	17.0
Do	39–R	445	41.6	0	1.2	42.8
Do	42–M	86	49.2	2.6	3.2	55
Average		353	35.9	0.87	1.5	38.3
Storeroom, lumber	6–C	684	24.9	0	0.3	25.2
Do	16–W	276	62.5	2.6	1.1	66.2
Average		480	43.7	1.3	0.7	45.7
Storeroom, paint	7–C	115	1.1	2.6	23.6	27.3
Do	17–W	253	6.9	2.6	2.5	12.0
Average		184	4.0	2.6	13.1	19.7
Storeroom, paper	8–C	720	92.2	0	0.8	93.0
Do	13–W	129	112.7	0	.6	103.3
Average		425	97.5	0	0.7	98.2
Storeroom, textbook	9–C	560	227.0	0	1.0	228.0
Do	18–W	945	42.5	0	0.3	42.8
Do	40–R	794	164.1	2.6	.9	167.6
Do	57–B	60	255.8	0	0	255.8
Average		590	172.3	0.7	0.6	173.6
Woodworking shop	5–C	1,917	4.8	2.6	0.4	7.8
Do	15–W	851	7.4	2.6	1.0	11.0
Average		1,384	6.1	2.6	0.7	9.4

[a] Doors, windows, baseboard, moulding, etc.
[b] W—Woodrow Wilson High School.
[c] R—Theodore Roosevelt High School.
[d] CC—Chevy Chase Elementary School.
[e] B—Bethesda Chevy Chase High School.
[f] C—Central High School.
[g] M—Ben W. Murch Grade School.

TABLE 12.—*Data taken from certain schools in Washington, D. C., and vicinity showing the percentage of usable floor area having combustible contents, between certain limits, in pounds per square foot, and the area of each floor*

Combustible contents for usable floor area	Basement	Ground floor	First floor	Second floor	Third floor	Entire building
Bethesda-Chevy Chase Senior High School (Main Building), Bethesda, Md.						
lb/ft²	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
0 to 4.9			34.14	31.10		32.62
5 to 9.9			62.83	65.35		64.08
10 to 14.9			3.03	3.06		3.04
255.7 (text book storeroom)				0.49		.26
Total			100	100		100
Usable floor area [a]	*ft²*	*ft²*	*ft²* 13,138	*ft²* 12,039	*ft²*	*ft²* 24,177

See footnotes at end of table.

TABLE 12.—*Data taken from certain schools in Washington, D. C., and vicinity showing the percentage of usable floor area having combustible contents, between certain limits, in pounds per square foot and the area of each floor*—Continued

Combustible contents for usable floor area	Basement	Ground floor	First floor	Second floor	Third floor	Entire building
Central High School, Washington, D. C.						
lb/ft²	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*
0 to 4.9	88.34	72.61	67.20	44.20	55.87	66.39
5 to 9.9	9.16	16.38	25.19	42.15	38.85	25.37
10 to 14.9	------	4.98	7.14	9.95	4.06	5.29
15 to 19.9	------	.29	------	.66	------	0.19
25 (storerooms)	2.50	3.65	0.47	1.77	1.22	2.00
36.6 (book stack room)	------	------	------	1.27	------	0.21
93 (paper storage)	------	1.26	------	------	------	.33
288 (text book storage)	------	.83	------	------	------	.22
Total	100	100	100	100	100	100
	ft²	*ft²*	*ft²*	*ft²*	*ft²*	*ft²*
Usable floor area	42,298	67,813	57,814	41,600	45,094	254,619
Theodore Roosevelt High School (Main Building), Washington, D. C						
lb/ft²	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*
0 to 4.9	71.97	------	47.81	39.33	36.80	50.34
5 to 9.9	24.68	------	25.47	42.81	32.81	31.03
10 to 14.9	------	------	25.32	15.80	28.16	16.21
15 to 19.9	------	------	------	------	1.32	0.26
25 (storerooms)	------	------	0.55	1.23	1.57	.77
30.8 (book stack room)	------	------	------	0.83	------	.21
39 (office and files)	------	------	0.85	------	------	.22
42.8 (storeroom)	1.20	------	------	------	------	.34
167.6 (text book storeroom)	2.15	------	------	------	------	.62
Total	100	------	100	100	100	100
	ft²	*ft²*	*ft²*	*ft²*	*ft²*	*ft²*
Usable floor area	35,970	------	32,420	32,245	25,154	125,790
Woodrow Wilson High School (Main Building), Washington, D. C.						
lb/ft²	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*
0 to 4.9	69.12	------	62.46	49.67	35.81	54.60
5 to 9.9	21.31	------	24.93	38.96	53.82	34.41
10 to 14.9	------	------	7.52	7.38	9.96	6.17
15 to 19.9	------	------	1.64	2.13	------	0.95
25 (storerooms)	6.51	------	1.40	0.96	0.41	2.35
40 (text book storage)	------	------	0.90	.90	------	0.24
40.4 (book stack room)	------	------	------	------	------	.22
42.8 (text book storage)	3.06	------	------	------	------	.76
66.2 (wood storage)	------	------	0.77	------	------	.20
103.3 (paper storage)	------	------	.38	------	------	.10
Total	100	------	100	100	100	100
	ft²		*ft²*	*ft²*	*ft²*	*ft²*
Usable floor area	35,165	------	34,249	31,959	31,600	130,973
Chevy Chase Elementary School, Chevy Chase, Md.						
lb/ft²	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*
0 to 4.9	82.68	------	36.57	34.60	------	50.83
5 to 9.9	17.32	------	57.15	65.40	------	47.11
10 to 14.9	------	------	6.28	------	------	2.06
Total	100	------	100	100	------	100
	ft²	*ft²*	*ft²*	*ft²*	*ft²*	*ft²*
Usable floor area [b]	12,992	------	13,179	13,927	------	40,098
Ben W. Murch Grade School, Washington, D. C.						
lb/ft²	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*
0 to 4.9	------	------	36.96	39.32	------	38.14
5 to 9.9	------	------	57.98	59.08	------	58.53
10 to 14.9	------	------	5.06	------	------	2.53
55 (janitor's storeroom)	------	------	------	1.60	------	0.80
Total	------	------	100	100	------	100
	ft²	*ft²*	*ft²*	*ft²*	*ft²*	*ft²*
Usable floor area [c]	------	------	15,670	15,639	------	31,309

[a] Excludes attic, and basement, which latter contains boiler room only.
[b] Exclusive of a temporary wooden corridor.
[c] Exclusive of basement, which contains boiler room only.

TABLE 13.—*Summary data for Medical and Surgical Building, St. Elizabeths Hospital*

Occupancy	Number of rooms or units	Total floor area	Combustible contents				
			Movable property	Woodwork and floor covering [a]	Total		
					Average	Maximum	Minimum
Administrative							
		ft²	*lb/ft²*	*lb/ft²*	*lb/ft²*	*lb/ft²*	*lb/ft²*
Administrative office	6	915	6.30	1.80	8.10	13.40	2.40
Doctors' office	3	945	5.70	2.90	8.60	14.40	5.10
Waiting rooms	3	495	1.40	1.80	3.20	4.10	2.10
Nurses' offices and rooms	13	1,728	3.10	1.90	5.00	12.50	3.10
Nurses' training school	12	3,613	2.20	1.80	4.00	14.50	1.10
Nurses' infirmary	11	1,599	0.85	2.15	3.00	3.45	2.50
Library and conference	1	704	5.20	2.50	7.70	------	------
Service							
Corridors	26	15,103	------	2.60	2.65	3.20	0.80
Heating and mechanical services	4	1,009	0.14	0.43	0.51	1.70	0.30
Refrigeration	5	775	1.90	1.85	3.75	12.70	0.0
Kitchen	7	3,259	0.20	0.33	0.53	4.65	0.10
Laundry	2	336	4.40	0.60	5.00	12.40	3.80
Janitors' closets and supplies	10	989	1.00	1.40	2.40	7.75	0.90
Stores	14	11,675	1.70	4.00	5.70	19.40	1.50
Lockers and toilets	8	1,766	0.90	0.50	1.40	2.90	1.20
Clinical							
Surgery	13	4,307	0.70	1.10	1.80	10.60	0.20
Minor surgery and casts	2	390	2.10	1.10	3.20	3.80	2.20
Therapy and laboratories	4	978	2.80	1.60	4.40	7.30	2.50
Clinics	33	7,421	2.00	1.90	3.90	21.60	0.50
Dormitories	32	11,223	0.90	1.60	2.50	3.60	1.70
Rooms, single	28	3,511	0.80	1.50	2.30	3.20	1.80
Rooms, disturbed patients'	8	1,016	0.40	2.50	2.90	3.20	2.20
Day and waiting rooms	3	720	0.80	2.40	3.20	3.80	2.50
Porches, patients'	6	3,566	0.90	0.40	1.30	2.30	0.90
Sterilizers and clothing stores	4	545	1.40	4.00	5.40	5.80	5.00
Pharmacy, dispensary and stores	5	1,172	5.80	1.90	7.70	11.50	6.80
Diet kitchens and patients' dining rooms	9	1,755	1.20	2.40	3.60	5.20	2.70
Lavatories, etc	22	2,304	0.50	1.40	1.90	5.40	0.30

[a] Combustible floor finish where present was ¼-in. thick linoleum, assumed to give equivalent of 1 lb/ft² combustible material.

TABLE 14.—*Summary of part of data for Neuro-psychiatric Continued Treatment Building, St. Elizabeths Hospital*

Occupancy	Number of rooms or units	Total floor area	Combustible contents				
			Movable property	Woodwork and floor covering [a]	Total		
					Average	Maximum	Minimum
Administrative [b]							
		ft²	*lb/ft²*	*lb/ft²*	*lb/ft²*	*lb/ft²*	*lb/ft²*
Administrative offices and records	2	218	3.4	1.6	5.0	7.3	2.7
Waiting room	1	128	1.7	1.5	3.2	3.2	3.2

[a] Combustible floor finish where present was ¼-in. thick linoleum, assumed to give equivalent of 1 lb/ft² of combustible material.
[b] Two office rooms temporarily vacant having 604 ft² area are not included.

TABLE 14.—*Summary of part of data for Neuro-psychiatric Continued Treatment Building, St. Elizabeths Hospital*—Continued

Occupancy	Number of rooms or units	Total floor area	Combustible contents				
			Movable property	Woodwork and floor covering[a]	Total		
					Average	Maximum	Minimum
Service							
	ft²	*lb/ft²*	*lb/ft²*	*lb/ft²*	*lb/ft²*	*lb/ft²*	*lb/ft²*
Corridors	9	8,176	0.0	2.4	2.4	3.2	0.2
Heating and mechanical services	2	612	.7	0.3	1.0	3.3	.8
Laundry rooms and clothes storage	12	916	12.5	.6	13.1	23.0	1.3
Janitors' closets and supplies	1	32	2.9	1.4	4.3	4.3	4.3
Storage room	1	1,320	2.1	0.0	2.1	2.1	2.1
Lockers, toilets, and barber shop	9	2,605	0.1	0.1	.2	1.4	0.0
Clinical							
Treatment room	5	4,976	2.4	0.1	2.5	7.5	0.3
Dormitories	13	7,197	0.7	.8	1.5	4.1	.5
Single rooms	23	2,093	.5	1.6	2.1	2.5	1.1
Sitting rooms and porches	8	7,680	.7	0.1	0.8	3.1	0.7
Patients' clothing	1	594	.5	.0	.5	0.5	.5
Lavatories, baths, etc	1	360	.0	.1	.1	.1	.1

TABLE 15.—*Summary data for Tuberculosis Infirmary, St. Elizabeths Hospital*

Occupancy	Number of rooms or units	Total floor area	Combustible contents				
			Movable property	Woodwork and floor covering[a]	Total		
					Average	Maximum	Minimum
Administrative							
	ft²	*lb/ft²*	*lb/ft²*	*lb/ft²*	*lb/ft²*	*lb/ft²*	*lb/ft²*
Administrative office and records	2	264	0.5	3.0	3.5	3.5	3.5
Doctors' offices	2	344	.9	2.0	2.9	3.5	2.3
Attendants' offices	2	248	.3	3.4	3.7	4.4	2.9
Waiting rooms	2	560	.1	1.3	1.4	1.4	1.4
Service							
Corridors	2	3,440	0.0	1.2	1.2	1.2	1.2
Mecbanical services and incinerator	3	720	.3	0.2	0.5	0.8	0.3
Kitchens and dining rooms	3	1,436	.7	1.0	1.7	2.4	.3
Janitors' closets and supplies	7	476	3.1	3.4	6.5	15.8	4.1
Barber shops, lockers, and toilets	2	624	0.2	1.2	1.4	1.7	1.3
Clinical							
Treatment room and medical supplies	2	188	0.7	1.0	1.7	2.0	1.5
Dormitories	17	4,535	.8	2.0	2.8	4.0	1.9
Single bed rooms	22	2,312	.5	3.2	3.7	4.0	2.6
Rooms for disturbed patients	2	272	.4	3.3	3.7	3.7	3.7
Porches, patients	4	4,656	.0	1.3	1.3	1.3	1.3
Sterilizers and clotbing	7	1,542	1.7	2.3	4.0	12.7	0.8
Lavatories, baths, etc	8	1,437	0.0	0.5	0.5	0.6	.4

[a] Combustible floor finish wben present was ¼-in.-thick linoleum, assumed to give equivalent of 1 lb/ft² combustible material.

TABLE 16.—*Distribution of combustible contents, St. Elizabeths Hospital*

Combustible contents for usable floor area	Medical and Surgical Building	Continued Treatment Building	Tuberculosis Infirmary
lb/ft²	*Percent*	*Percent*	*Percent*
0 to 4.9	82.1	91.0	93.2
5 to 9.9	15.4	7.6	0.3
10 to 14.9	1.6	0.7	1.8
15 to 19.9	0.5		4.4
20 or more	.4	.7	0.3
Usable floor area	*ft²* 84,535	*ft²* 36,964	*ft²* 23,928

TABLE 17.—*Summary data for three warehouses*

Survey No.	Portion of building	Floor area	Combustible contents			
			Movable property	Floor	Exposed woodwork other than floor	Total
		ft²	*lb/ft²*	*lb/ft²*	*lb/ft²*	*lb/ft²*
W-1[a]	Basement	33,890	172.9	6.2	0	179.1
	1st floor	34,900	223.7	9.7	0	233.4
	2d floor	32,592	105.8	10	[b] 0.4	116.2
	3d floor	23,448	204.0	6.2	0	210.2
	3d floor	10,225	61.6	0	0	61.6
	3d floor (total)	33,673	160.8	4.3	0	165.1
	Entire building	135,055	166.8	7.5	[b] 0.1	174.4
W-2[c]	1st floor	46,158	6.8	0	0	6.8
	2d floor	44,957	13.6	0	1	14.6
	3d floor	45,677	4	0	1.2	5.2
	4th floor	45,677	12.7	0	2.2	14.9
	5tb floor	45,677	8.4	0	1.9	10.3
	6th floor	45,677	12.2	0	3.8	16.0
	Entire building	273,823	9.6	0	1.5	11.1
W-3[d]	1st floor	17,442	0	0	0	0
	2d floor	17,442	16.2	0	0.8	17
	3d floor	17,442	16.0	0	2.3	18.3
	4tb floor	17,442	10.6	0	2.1	12.7
	Entire building	[e] 52,326	14.3	0	1.7	16

[a] W-1—Warehouse for printing department.
[b] Wood partition of 3,360 fbm.
[c] W-2—Warehouse for department store.
[d] W-3—Warebouse for department store.
[e] Not including first floor wbich is used only for merchandise in transit.

CHAPTER IV. FIRE-RESISTANCE RATINGS FOR BUILDING CONSTRUCTION AND MATERIALS

1. Fire-Resistance Ratings for Load-Bearing Masonry Walls

(a) *Test Conditions*

The fire tests cited below were conducted in substantial accord with the Standard Specifications for Fire Tests of Building Construction and Materials, ASA No. A2–1934. According to this specification, average indicated furnace temperatures are required to conform to the

following values within allowable tolerance limits:

1,000° F at 5 min,
1,300° F at 10 min,
1,550° F at 30 min,
1,700° F at 1 hr,
1,850° F at 2 hr,
2,000° F at 4 hr,
2,300° F at 8 hr,
and continues at 2,300° F.

The fire-resistance period is taken to be reached if:

(1) An average temperature rise of 250° F or a maximum rise of 325° F, measured with thermocouples under asbestos pads, is attained on the unexposed side of the wall.

(2) Passage of heat, flame, or gases hot enough to ignite cotton waste occurs.

(3) Failure under the design load occurs (load-bearing constructions only).

Walls must also stand the fire and hose-stream test and, for load-bearing construction, the loading test within 72 hr after the completion of the fire-and-hose test.

Most of the brick test walls were laid up in 1:1:6 portland cement-lime mortar. Some solid walls were laid up in 1:3 portland cement or 1:3 lime mortar, these proportions being based on volume of cementing materials to that of damp sand. They were tested restrained within the panel frame, unrestrained with freedom for expansion and deflection at sides and top, or under a constant working load of 160 lb/in.^{2} of gross area, except that the 4-in. walls without pilasters were loaded to 80 lb/in.^{2} The ratings for 8-in. or heavier solid walls can be taken to apply if laid in any of these mortars. For 4-in. solid walls and all hollow walls the mortar mix should be not leaner than 1:1:6 proportion.

The structural tile walls were laid in 1:1:4 and those of concrete blocks in 1:1:6 portland cement-lime mortar. The respective ratings given should be taken as applying where mortar mixes not leaner than these are used. The walls were loaded during the fire test to 80 lb/in.^{2} of gross area.

The hollow brick walls with 70 percent of solid material were loaded to 120 lb/in.^{2} and with 87 percent of solid material to 160 lb/in.^{2} of gross area. The brick cavity wall made up of 2 wythes of brick laid flat with a ¼ in. metal tie between them for each 3 ft^2 of surface is rated for an average working load of 40 lb/in.^{2} of gross area which may be applied eccentrically to give a maximum stress at the fire-exposed surface of 80 lb./in.^{2}

(b) Sources of Data

(1) *Fire resistance of hollow load-bearing wall tile*, BS J. Research **2**, 1 (1929) RP37.

(2) *"Fire resistance of concrete masonry units"* by Carl A. Menzel, Portland Cement Association, January 1934.

(3) Original data from National Bureau of Standards tests of brick and heavy structural tile (clay or shale) walls, partly summarized in Letter Circulars LC 228 and 229.

(4) Underwriters' Laboratories tests of concrete masonry walls.

(5) Unpublished results of recent tests of concrete masonry walls at the National Bureau of Standards.

(c) Extension and Interpolation of Test Results

When the test data were directly applicable, the ratings were taken generally at a little below the average of the test results where there was an appreciable variation. A few ratings are based on limited interpolation and extension of a line of related test data made by the method given in section 1 of appendix B.

(d) Effect of Plaster

The constants for use in the formula for determining the fire resistance of plastered walls given near the end of section 1 of appendix B were derived from available test results, and all the ratings for plastered walls were made by the use of this formula. The average thickness of plaster applied in the different series of tests ranged from ½ to ¾ in. The thickness for which ratings are given are those most likely to obtain in building construction considering what must be done to obtain a true surface. Thus ratings for plastered brick and concrete block walls are for ½-in. plaster thickness and in the case of structural clay tile for ⅝-in. thickness. Ratings for other thicknesses can be obtained by substituting the appropriate constants in the formula.

Tests of four hollow concrete-unit walls show the effect of one coat of plaster on the fire-exposed side to be about the same as for one

coat of plaster on the unexposed side. No tests have been made with plaster on the unexposed side only of clay hollow-tile walls. However, the ratings given in the table for plaster on one side are believed to have sufficient margin of safety to be applicable for either condition.

(e) *Combustible Members Framed into Wall*

The fire-resistance period, when combustible members are framed into the wall, is taken to be reached when an average temperature rise of 325° F, or a maximum rise of 422° F, is attained at a point 3½ to 4 in. from the side not exposed to fire.

Average test results show that the ratings for unplastered walls into which combustible members project will be the following parts of the rating for the same unplastered walls not thus modified. These factors may be applied where definite test data are lacking.

(1) All walls with 1 cell in wall thickness	two-fifths.
(2) 8-in. walls with 3 cells in wall thickness	two-fifths.
(3) 8-in. walls with 2 units in wall thickness	two-fifths.
(4) 8-in. solid walls	two-fifths.
(5) All walls with 2 cells in wall thickness	one-half.
(6) All 12-in. walls (except walls with 1 or 2 cells in wall thickness)	two-thirds.

If such walls are plastered with ½-in. 1:3 sanded gypsum plaster on the side opposite the framing, add ½ hr if the rating for combustible members framed into the unplastered walls is 2½ hr or less, and add 1 hr if the rating is 3 hr or more. For ⅝-in. plaster thickness these increments are somewhat greater, as indicated in the ratings for walls of clay or shale structural tile. For plaster on the same side as the framing and for plaster on one side of walls with combustible members entering from both sides, no increase in fire resistance due to the plaster can be assumed, since the wall may be exposed to fire on the unplastered side.

If hollow spaces (cells) surrounding the ends of combustible members are filled solidly with masonry the rating will be the same as for incombustible or no members framed into the wall, except that the rating cannot exceed the rating for solid walls of the same thickness with combustible framing. These limits can be taken as follows:

8-in. walls unplastered	2 hr.
8-in. walls plastered on fire-exposed side or both sides	2½ hr.
12-in. walls unplastered	7 hr.
12-in. walls plastered on fire-exposed side or both sides	8 hr.

(f) *Fire-Resistance Ratings*

Fire-resistance ratings for masonry walls are given in tables 18 to 23, inclusive. All are rated as load-bearing unless otherwise noted.

TABLE 18.—*Load-bearing brick walls*

Nominal wall thickness	Type of wall	Material	Ultimate fire-resistance period				
			Incombustible members framed into wall or no framed-in members			Combustible members framed into wall	
			No plaster	Plaster on one side	Plaster on two sides	No plaster	Plaster on exposed side
in.			*hr*	*hr*	*hr*	*hr*	*hr*
4	Solid	Clay or shale	1¼	1¾	2½		
8	do	do	5	6	7	2	2½
12	do	do	[a] 10	[a] 10	[a] 12	8	9
8	Hollow Rolok	do	2½	3	4	1	1½
12	do	do	5	6	7	3	4
8	Hollow Rolok Bak	do	4	5			
12	do	do	10	10			
9 to 10	Cavity	do	5	6	7	2	2½
4	Solid	Concrete	1½	2	3		
8	do	do	6	7	8	2½	3
12	do	do	13	14	16	8	9
4	do	Sand-lime	1¾	2½	3		
8	do	do	7	8	9	2½	3
12	do	do	[b] 10	[b] 10	[b] 12	9	10

[a] Based on load failure. If based on temperature rise, the fire-resistance period would be 12 hr for the unplastered wall, 13 hr for plaster on one side, and 15 hr for plaster on both sides.

[b] Based on wall failure at 10 hr. If based on temperature rise, the fire-resistance period would be 14 hr for the unplastered wall, 15 hr for plaster on one side, and 17 hr for plaster on both sides.

NOTE.—Not less than ½-in. 1:3 sanded gypsum plaster is required to develop the above ratings for plastered walls.

TABLE 19.—*Load-bearing walls of clay, or shale, cored bricks*

Nominal wall thickness	Units in wall thickness	Cells in wall thickness	Minimum percentage of solid materials in units	Ultimate fire-resistance period				
				Incombustible members framed into wall or no framed-in members			Combustible members framed into wall	
				No plaster	Plaster on one side	Plaster on two sides	No plaster	Plaster on exposed side
in.				*hr*	*hr*	*hr*	*hr*	*hr*
8	1	1	70	2½	3	4	1	1½
12	1	2	70	5	6	7	3	4
8	2	2	87	5	6	7	2	2½
12	3	3	87	[a] 10	[a] 10	[a] 12	8	9

[a] Based on load failure. If based on temperature rise, the fire-resistance period would be 11 hr for the unplastered wall, 12 hr for plaster on one side, and 14 hr for plaster on both sides.

NOTE.—Not less than ½ in. of 1:3 sanded gypsum plaster is required to develop the above ratings for plastered walls.

TABLE 20.—*Load-bearing walls of clay, or shale, structural tile*

Nominal wall thickness	Units in wall thickness	Cells in wall thickness	Minimum percentage of solid materials in units [a]	Ultimate fire-resistance period				
				Incombustible members framed into wall or no framed-in members			Combustible members framed into wall	
				No plaster	Plaster on one side	Plaster on two sides	No plaster	Plaster on exposed side
in.				*hr*	*hr*	*hr*	*hr*	*hr*
8	1	2	40	1¼	2	3	¾	1½
8	1	2	43	1½	2	3	¾	1½
8	1	2	46	1¾	2½	3½	1	1¾
8	1	2	49	2	3	4	1¼	2
8	1	3 or 4	40	1¾	2½	3½	¾	1½
8	1	3 or 4	43	2	3	4	¾	1½
8	1	3 or 4	48	2½	3½	4	1	1¾
8	1	3 or 4	53	3	4	5	1¼	2
12	1	3	40	2½	3½	4	2	3
12	1	3	45	3	4	5	2½	3½
12	1	3	49	3½	4	6	3	4
12	2	3 or 4	40	3½	4	6	2	3
12	2	3 or 4	45	4	5	6	2½	3½
12	2	3 or 4	53	5	6	7	3	4
16	2 or 3	4 or 5	40	5	6	8	4	5
16	2 or 3	4 or 5	43	6	7	9	4	5
16	2 or 3	4 or 5	46	7	8	10	5	6
16	2 or 3	5 or 6	49	8	9	11	5	6
16	2 or 3	5 or 6	51	9	10	12	6	7
16	2 or 3	5 or 6	53	10	11	13	7	8

[a] The percentage of solid material in units given above, in the case of walls built up of units of different designs, is to be taken as the weighted average for the units at the courses in the wall where the average percentage is the lowest.

NOTES.—All tile is to conform with ASTM specifications from the standpoint of strength and absorption.

Not less than ⅝-in. of 1:3 sanded gypsum plaster is required to develop the above ratings for plastered walls.

TABLE 21.—*Load-bearing brick-faced walls of clay, or shale, structural tile*

Nominal wall thickness	Description	Ultimate fire-resistance period	
		No plaster	Plaster inside
in.		*hr*	*hr*
8	4-in. 40 percent solid tile plus 4-in. brick face.	3½	4
12	8-in. 40 percent solid tile plus 4-in. brick face.	6	7
12	8-in. 70 percent solid tile plus 4-in. brick face.	[a] 10	[a]

[a] Based on wall failure under load. If based on temperature rise, the ultimate fire-resistance period would be 11 hr for the unplastered wall and 12 hr for the wall plastered on one side.

NOTE.—Not less than ⅝-in. of 1:3 sanded gypsum plaster required to develop the above ratings for plastered walls.

TABLE 22.—*Load-bearing furred and cavity walls of clay, or shale, structural tile*

Nominal wall thickness	Description	Ultimate fire-resistance period	
		Plaster on one side	Plaster on two sides
in.		*hr*	*hr*
8	8-in. 40 percent solid tile plus 2-in. furring tile	3½	5
10	Two 3¾-in. 40 percent solid tiles with 2-in. air space between	----	4

NOTE.—Not less than ¾-in. portland cement plaster or stucco outside and ⅝-in. gypsum plaster inside is required to develop these ratings.

TABLE 23.—*Load-bearing walls of cored concrete masonry units*

Nominal wall thickness	Units in wall thickness	Cells in wall thickness	Minimum percentage of solid material in concrete units	Ultimate fire-resistance period				
				Incombustible or no members framed into wall			Combustible members framed into wall	
				No plaster	Plaster on one side	Plaster on two sides	No plaster	Plaster on exposed side
A. Units made with expanded slag or pumice aggregates								
in.			*Percent*	*hr*	*hr*	*hr*	*hr*	*hr*
6	1	1	70	3	4	5	----	----
6	1	1	76	3½	4	5	----	----
8	1	1	55	3	4	5	1¼	1¾
8	1	1	62	4	5	6	1½	2
10	1	1	60	5	6	7	2	2½
10	2	2	62	4	5	6	1½	2
	Cavity type 2-in. air space.							

TABLE 23.—*Load-bearing walls of cored concrete masonry units*—Continued

Nominal wall thickness	Units in wall thickness	Cells in wall thickness	Minimum percentage of solid material in concrete units	Ultimate fire-resistance period				
				Incombustible or no members framed into wall			Combustible members framed into wall	
				No plaster	Plaster on one side	Plaster on two sides	No plaster	Plaster on exposed side
	B. Units made with expanded burned clay or shale, crushed limestone, air-cooled slag, or cinders							
hr				*hr*	*hr*	*hr*	*hr*	*hr*
8	1	1	52	2	2½	3½	¾	1½
8	1	1	62	2½	3	4	1	1½
8	1	1	70	3	4	5	1½	2
10	1	1	60	4	5	6	1½	2
12	1	1	55	4	5	6	1½	2
12	1	1	62	5	6	7	2	2½
8½	2	2	65	3½	4	5	1¼	1¾
13	3	3	65	7	8	9	4	5
8	2 3¾-in. brick face.	1	62	5	6	----	----	----
8½	2 2¼-in. brick face.	1	62	4	5	----	----	----
10	2 Cavity type 2-in. air space.	2	62	3½	4	5	1¼	2
	C. Units made with calcareous sand and gravel. Coarse aggregate, 60 percent or more calcite and dolomite							
10	2 Cavity type 2-in. air space.	2	62	1¼	1¼	5	1¼	1¾
	D. Units made with siliceous sand and gravel. Ninety percent or more quartz, chert, or flint							
8	1	1	54	⅛	⅛	½	⅛	½
12	1	1	57	5½	5½	6	5½	2½
12	2	2	55	5	6	7	2	2½

NOTE.—Not less than ½-in. 1:3 sanded gypsum plaster is required to develop the above ratings for plastered walls.

2. FIRE-RESISTANCE RATINGS FOR MASONRY PARTITIONS

(*a*) *Test Conditions*

The fire tests upon which the ratings are based were conducted in substantial accord with the Standard Specifications for Fire Tests of Building Construction and Materials, ASA No. A2–1934, the fire-resistance period being taken to be reached if any of the following occurs:

1. An average temperature rise of 250° F or a maximum rise of 325° F, measured with thermocouples under asbestos pads, is attained on the unexposed side of the partition.

2. Structural collapse or passage of flame or of gases hot enough to ignite cotton waste.

For a full rating the requirements of the hose-stream test also must be met. Partitions having ratings of less than 1 hr require no hose-stream test. Those having ratings of 1 hr or more require a hose-stream test after a fire exposure equal to one-half the rating period, except that for ratings of more than 2 hr the fire exposure before the hose-steam test need not be of more than 1-hr duration.

(*b*) *Sources of data*

(1) *Magnesium oxysulfate wood-fiber blocks.*—The ratings were taken directly from the results of fire tests conducted at the Underwriters' Laboratories and the National Bureau of Standards. The material is shredded wood (excelsior) bound with magnesium oxysulfate cement.

(2) *Hollow glass blocks.*—The rating was taken directly from the results of fire tests conducted at the Underwriters' Laboratories. The rating given is for glass blocks used as partition material and not as an opening protective.

(3) *Gypsum blocks.*—The ratings were based on fire tests conducted at the Underwriters' Laboratories and Ohio State University (Ohio Engineering Experiment Station Bulletin No. 104, A Study of the Fire Resistance of Building Materials, January 1940, and more recent tests), the ratings being limited by considerations of the stability of the partition when exposed to fire rather than by temperature rise on the unexposed side.

(4) *Structural clay tile.*—The ratings represent the lower averages of the results of fire tests conducted at the National Bureau of Standards and Ohio State University (Ohio Engineering Experiment Station Bulletin No. 104, A Study of the Fire Resistance of Building Materials, January 1940).

(5) *Hollow concrete units.*—The ratings represent the lower averages of the results of fire tests conducted at the National Bureau of Standards and by the Portland Cement Association (Tests of the Fire Resistance and Strength of Walls of Concrete Masonry Units, January 1934). These results, as for structural clay title, have been interpolated and extended according to the principles outlined in appendix B, section 1, chiefly for the ratings of some of the plastered constructions.

(c) *Fire-Resistance Ratings*

Fire-resistance ratings for masonry partitions are given in tables 24 to 26, inclusive. They are all rated as nonbearing.

TABLE 24.—*Miscellaneous nonbearing masonry partitions*

Description	Ultimate fire-resistance period	
	No plaster	Plaster on both sides
Magnesium oxysulfate wood-fiber blocks [a]		
	hr	*hr*
2-in. blocks laid in portland cement-lime mortar		1
3-in. blocks laid in portland cement-lime mortar		2
Hollow glass blocks		
8- by 4⅞-in. blocks 3⅞-in. thick, weight 4 lb each; portland cement-lime mortar, horizontal mortar joints reinforced with metal lath	¼	
Gypsum blocks [b]		
2-in. solid blocks	1	
3-in. blocks not less than 70-percent solid	1	2
4-in. hollow blocks		3
5-in. solid blocks	4	6

[a] Not less than ½-in. thickness of 1:3 sanded gypsum plaster is required to develop the above ratings for plastered partitions.

[b] Laid in 1:3 sanded gypsum mortar. Voids in hollow blocks to be not more than 30 percent. Not less than ½-in. thickness of 1:3 sanded gypsum plaster is required to develop the above ratings for plastered partitions.

TABLE 25.—*Structural clay tile partitions*

[Laid in portland cement-lime mortar]

Description	Ultimate fire resistance period							
	No plaster		Plaster on unexposed side		Plaster on fire-exposed side		Plaster on both sides	
	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
One cell in wall thickness								
	hr min	*hr min*	*hr min*	*hr min*	*hr min*	*hr min*	*hr min*	*hr min*
3-in. partition, units not less than 50-percent solid	0 10	0 20	0 20	0 20	0 30	0 45	0 45	1
4-in. partition, units not less than 40-percent solid	10	20	20	25	30	45	45	1
4-in. partition, units not less than 50-percent solid	15	25	25	30	45	1	1	1 15
6-in. partition, units not less than 30-percent solid	15	20	25	35	45	1	1 15	1 30
6-in. partition, units not less than 40-percent solid	20	25	30	40	1	1 05	1 15	1 30
Two cells in wall thickness								
4-in. partition, units not less than 50-percent solid	25	30	35	45	1	1 15	1 15	1 30
4-in. partition, units not less than 60-percent solid	30	35	40	1	1 15	1 30	1 30	2
6-in. partition, units not less than 45-percent solid	45	1	1	1 15	1 15	1 30	1 30	2
Double shells plus one cell in wall thickness								
4-in. partition, units not less than 45-percent solid	20	25	30	35	45	1	1 15	1 30
One cell in wall thickness, cells filled with broken tile, crushed stone, slag, cinders, or sand, mixed with mortar								
4-in. partition, units not less than 40-percent solid	1 15	1 15	1 30	1 30	1 45	1 45	2 30	2 30
6-in. partition, units not less than 30-percent solid	2	2	2 30	2 30	2 30	2 30	3 30	3 30

NOTES.—Ratings in column (A) are for dense hard-burned clay or shale tile.
Ratings in column (B) are for medium-burned clay tile. All shale tile are classed under (A).
Not less than ⅝-in. thickness of 1: 3 sanded gypsum plaster is required to develop the above ratings for plastered partitions.

TABLE 26.—*Partitions of hollow concrete units*

[Ratings based on one unit and one cell in wall thickness]

Partition	Ultimate fire-resistance period		
	No plaster	Plaster on one side	Plaster on two sides
A. Units made with expanded slag or pumice aggregates			
3-in. partition, unit not less than 73 percent solid	*hr* 1	*hr* 1½	*hr* 2
4-in. partition, units not less than 62 percent solid	1¼	1¾	2½
4-in. partition, units not less than 73 percent solid	1½	2	2½
6-in. partition, units not less than 49 percent solid	1½	2	2½
6-in. partition, units not less than 62 percent solid	2	2½	3½
6-in. partition, units not less than 73 percent solid	3	4	5
B. Units made with crushed limestone, blast furnace slag, cinders, and expanded burned clay or shale			
3-in. partition, units not less than 73 percent solid	¾	1¼	1¾
4-in. partition, units not less than 65 percent solid	1	1½	2
4-in. partition, units not less than 73 percent solid	1¼	1¾	2
6-in. partition, units not less than 49 percent solid	1¼	1¾	2
6-in. partition, units not less than 62 percent solid	1½	2	2½
6-in. partition, units not less than 73 percent solid	2½	3	4
C. Units made with calcareous sand and gravel. Coarse aggregate, 60 percent or more calcite and dolomite			
4-in. partition, units not less than 62 percent solid	⅓	½	1¾
D. Units made with siliceous sand and gravel. Ninety percent or more quartz, chert, or flint			
4-in. partition, units not less than 73 percent solid	¼	⅓	1

NOTE.—Not less than ½-in. thickness of 1:3 sanded gypsum plaster is required to develop the above ratings for plastered partitions.

3. FIRE-RESISTANCE RATINGS FOR STEEL-FRAMED PARTITIONS AND STEEL-FRAMED BRICK-VENEERED WALLS

(*a*) *Test Conditions*

The fire tests upon which the ratings are based were conducted in substantial accord with the Standard Specifications for Fire Tests of Building Construction and Materials, ASA No. A2–1934. (See under section 1 (a), "Fire-Resistance Ratings for Load-Bearing Masonry Walls," or under section 4 (a), "Fire-Resistance Ratings for Wood- and Metal-Framed Partitions.")

(*b*) *Source of Data*

The ratings given herein were taken directly from the results of fire tests conducted at the National Bureau of Standards.

(*c*) *Plaster*

Plaster proportions are given in the tables as weight of dry plaster to dry sand. The ratings can be taken to apply if a finish coat is included in the given plaster thickness. See "Fire-Resistance Ratings for Wood- and Metal-Frame Partitions," page 33, for the method of measuring plaster thickness. The plaster thickness is taken from the back of flat lath and the back of the flat portion of ribbed lath. Plaster noted as "neat" is to taken as unsanded wood-fiber gypsum plaster.

(*d*) *Fire-Resistance Ratings*

The ratings given in tables 27 and 28 are for the indicated facings secured to lightweight steel studs not less than 3 in. in depth. The spacing of the studs will be governed by the loading, the ratings being for loads developing a stress of not more than 7,270 lb/in.² of the net area of the steel studs for the partitions and 5,120 lb/in.² for the brick-veneered walls. The spacing of the studs is to be such as to afford adequate rigidity to the metal-lath or gypsum-plaster base. All constructions are rated as load-bearing and designated as "combustible" only when noted.

TABLE 27.—*Steel-framed partitions*

Partitions faced on both sides with—	Ultimate fire-resistance period
	hr
¾-in. sanded gypsum plaster, 1:2 for scratch coat and 1:3 for brown coat, on metal lath	¾
¾-in. sanded gypsum plaster, 1:2 for scratch and brown coats	1
⅞-in. sanded gypsum plaster, 1:2 for scratch coat and 1:3 for brown coat, on metal lath	1
⅞-in. sanded gypsum plaster, 1:2 for scratch and brown coats, on metal lath	1¼
¾-in. neat gypsum plaster on metal lath	1½
1-in. neat gypsum plaster on metal lath	[a] 2

[a] For partitions loaded not to exceed 5,120 lb/in.² of stud area the rating is 2½ hr.

TABLE 28.—*Steel-framed brick-veneered walls*

Brick-veneered walls faced as indicated	Ultimate fire-resistance period	
	Plaster side exposed	Brick-faced side exposed
	hr	*hr*
On one side, of 1-in. magnesium oxysulfate wood fiberboard sheathing attached to studs, 1-in. air space, and 3¾-in. brick secured with metal ties to steel frame every fifth course. Inside facing of ⅞-in. 1:2 sanded gypsum plaster on metal lath secured directly to studs	1¾	4
Same as above except with ⅞-in. vermiculite plaster for inside facing	2	4
On one side, of ½-in. wood fiberboard sheathing next to studs, ¾-in. air space formed with ¾- by 1⅝-in. wood strips placed over the fiberboard and secured to the studs; paper-backed wire lath nailed to these strips, 3¾-in. brick veneer held in place by filling a ¾-in. space between the brick and paper-backed lath with mortar. Inside facing of ¾-in. neat gypsum plaster on metal lath attached to 5/16-in. plywood strips secured to edges of the studs. Rated as "combustible" on account of the sheathing	1½	4
On one side, of paper-backed wire lath attached to studs and 3¾-in. brick veneer held in place by filling a 1-in. space between the brick and the lath with mortar. Inside facing of 1-in. paper-enclosed mineral-wool blanket weighing 0.6 lb/ft² attached to studs, metal lath or paper-backed wire lath laid over the blanket and attached to the studs, and ¾-in. sanded gypsum plaster, 1:2 for the scratch and 1:3 for the brown coat	4	5

4. Fire-Resistance Ratings for Wood- and Metal-Framed Partitions

(*a*) *Test Conditions*

The fire tests upon which the ratings are based were conducted in substantial accord with the Standard Specifications for Fire Tests of Building Constructions and Materials, ASA No. A2–1934, the fire-resistance period being taken to be reached if:

(1) An average temperature rise of 250° F or a maximum rise of 325° F, measured with thermocouples under asbestos pads, is attained on the unexposed side of the partition.

(2) Passage of heat, flame, or gases hot enough to ignite cotton waste occurs.

(3) Failure under the design load occurs (load-bearing constructions only).

For a full rating the requirements of the hose-stream test must be met. Partitions having ratings less than 1 hr require no hose-stream test. Those having rating of 1 hr or more require a hose-stream test after a fire exposure equal to one-half the time of the rating, except that for ratings of more than 2 hr the fire exposure before the hose-stream test need not be of more than 1-hr duration.

Partitions involving material which burns freely during the fire test or continues to flame after the furnace fire is shut off are rated as "combustible."

Only wood-stud partitions were tested under load, the loading being on the basis of 360 lb/in.^{2} of the net area of the studs.

(*b*) *Sources of Data*

Results of fire tests of 147 wood- and metal-framed partitions conducted at the National Bureau of Standards (see Building Materials and Structures Report BMS71) and 9 fire tests of wood frame partitions conducted at the Underwriters' Laboratories were used as a basis for the ratings given herein.

(*c*) *Interpolation of Test Results*

Most of the ratings were taken directly from the test results and represent the lower averages of results of tests in the case of duplicate or similar partition tests. Some of the ratings for partitions having facings of sanded gypsum plaster on metal lath were interpolated according to the method given in appendix B, section 1. Partitions which were not subjected to the hose-stream test have been given ratings on the basis of comparisons made with similar partitions that have qualified under the hose-stream test. Accordingly, all partitions rated can be taken as having met such requirements.

(*d*) *Framing*

(1) *Wood framing.*—Ratings are for 2- by 4-in. (nominal size) wood studs (No. 1 Common or better) set edgewise and having 2- by 4-in. wood plates at top and bottom and stayed transversely at midheight with wood blocking.

(2) *Metal-Framed, Hollow Partitions.*—Ratings are for any usual type of nonbearing metal framing providing not less than 2-in. air space.

(3) *Metal-Framed, Solid Partitions.*—Ratings are for ¾-in. channel framing or, in the case of sprayed-on portland cement mortar, reinforcement of 4-in. square mesh of No. 6 gage wire welded at intersections (no channels).

(e) *Firestopping*

The actual protection given by a partition construction may be less than the rated fire resistance because of passage of fire around the borders of the partition. To prevent this occurrence the spaces in the wood framing adjoining the partition must be closed or filled, preferably with incombustible material.

(f) *Mineral-Wool Fill*

For the ratings here given "mineral-wool fill" can be taken as rock-wool bats weighing not less than 1.0 lb/ft^2 of wall surface, glass-wool bats at 0.6 lb/ft^2, or rock wool blown in and weighing not less than 2.0 lb/ft^2 of wall surface. "Wall surface" above applies only to surface of filled space. Where particular methods of securing the fill in place are required, this is noted in the tables.

(g) *Board Facings and Plaster Bases*

"Fiberboard" can be taken as wood or cane fiberboard of light or medium density, the minimum weights being as given in the tables. "Metal lath" can be taken as expanded metal, wire lath, or paper-backed expanded metal or wire lath, the weights to be as usually specified for the different types of construction. Other types of board facings and plaster bases are as given in the tables.

(h) *Plaster*

Plaster measurements are taken from the face of the plaster base except that for metal lath the thickness is measured from the back of the lath. For corrugated or ribbed plaster bases the thickness is taken as the average thickness of plaster applied to the base. Plaster proportions are given in the tables as weights of dry plaster to dry sand, the first ratio being for the scratch coat and the second for the brown coat. The ratings can be taken to apply if a finish coat is included in the given plaster thickness. Mixtures richer in plaster can be substituted for those given. Where other aggregates than sand are used, these are indicated, the last figure in the combination being for the sand. Plaster noted as "neat" is to be taken as unsanded wood-fiber gypsum plaster.

Volumes of loose damp sand corresponding to the required weights of dry sand, assuming dry sand to weigh 100 lb/ft^3, are given in table 29, which is arranged for convenient use with half bags and full bags of gypsum plaster, Keene's cement, hydrated lime, and portland cement as plaster components of the mix.

TABLE 29.—*Required volumes of damp sand, assumed shoveled in, for given weights of dry sand*

Percentage of moisture in sand	Weights of dry sand								
	25 lb	50 lb	100 lb	200 lb	300 lb	94 lb	188 lb	282 lb	376 lb
	ft^3	*ft*^{3}	*ft*^{3}	*ft*^{3}	*ft*^{3}	*ft*^{3}	*ft*^{3}	*ft*^{3}	*ft*^{3}
0	0.25	0.50	1.00	2.00	3.00	0.94	1.88	2.82	3.76
1	.28	.56	1.12	2.24	3.36	1.05	2.10	3.16	4.21
2	.30	.60	1.20	2.40	3.60	1.13	2.26	3.38	4.51
4	.31	.63	1.26	2.52	3.78	1.18	2.37	3.55	4.74
6	.32	.64	1.28	2.56	3.84	1.20	2.40	3.61	4.81
8	.31	.63	1.26	2.52	3.78	1.18	2.37	3.55	4.74
10	.30	.61	1.22	2.44	3.66	1.15	2.30	3.44	4.59
12	.29	.58	1.16	2.32	3.48	1.09	2.18	3.27	4.36
Average, 2 to 10	.31	.62	1.25	2.50	3.75	1.17	2.35	3.52	4.70

The percentage of moisture is obtained by dividing the loss of weight on drying at a temperature above 212° F by the dry weight of the sample. Where the moisture content of the sand is not known but it is damp, although not so wet that water comes out of it, the values given in the last line of the table can be used with a fair degree of approximation.

The volume in cubic feet of containers used for measuring sand may be determined by dividing the increase in weight due to filling with water by 62.4.

(i) *Fire-Resistance Ratings*

All partitions, the ratings for which are given in table 30, are assumed to have identical facings on both sides and are rated as load-bearing unless otherwise noted. They are designated as "combustible" according to the test specifications on account of the wood framing.

TABLE 30.—*Wood-framed partitions*

[Rated as load-bearing except as noted]

Description	Ultimate fire-resistance period				
Thickness of board or plaster in facing	⅜-in.	½-in.	¾-in.	⅞-in.	1-in.
Facings of Boards Without Plaster					
	hr min	*hr min*	*hr min*	*hr min*	*hr min*
Fiberboard weighing 0.7 lb/ft²		10			
Fiberboard weighing 1.1 lb/ft²		15			
Flameproofed fiberboard weighing 1.6 lb/ft² as treated		30			
Tongue-and-grooved wood boards			20		
Tongue-and-grooved wood boards with mineral-wool fill			35		
Tongue-and-grooved wood boards with asbestos paper weighing 30 lb/100 ft² between boards and studs			45		
Gypsum wallboard	25	40			
Gypsum wallboard with mineral-wool fill		45			
Gypsum wallboard with mineral-wool fill, rated as nonbearing		1			
Gypsum wallboard with mineral-wool bats nailed to studs		1			
Facings of Plaster on Wood Lath					
1:2, 1:3 gypsum plaster		30			
1:2, 1:3 gypsum plaster with mineral-wool fill		1			
1:5, 1:7.5 lime plaster		30			
1:5, 1:7.5 lime plaster with mineral-wool fill		45			
Facings of Plaster on Board Plaster Bases					
1:2, 1:2 gypsum plaster on ½-in. fiberboard weighing 0.7 lb/ft²		35			
1:2, 1:2 gypsum plaster on ⅞-in. flame-proofed fiberboard weighing 2.8 lb/ft² as treated		1			
1:3, 1:3 gypsum plaster on 1-in. magnesium oxysulfate wood fiberboard		45			
Neat gypsum plaster on ⅜-in. plain gypsum lath		1			
1:2, 1:2 gypsum plaster on ⅜-in. plain gypsum lath with 1¾- by 1¾-in. metal lath pads nailed 8-in. centers vertically, 16-in. centers horizontally		1			
1:2, 1:2 gypsum plaster on ⅜-in. perforated gypsum lath, one ¾-in. diameter hole or larger per not more than 16 in.² of lath surface		1			
1:2, 1:2 gypsum plaster on ⅜-in. gypsum lath, plain, indented, or perforated other than as above		45			
Facings of Plaster on Metal Lath					
1:2, 1:3 gypsum plaster			45	1	
1:2, 1:3 gypsum plaster with mineral-wool fill			1 15	1 30	
1:2, 1:2 gypsum plaster			1		
1:2, 1:2 gypsum plaster with mineral-wool fill			1 30		
Neat gypsum plaster			1 30		
Neat gypsum plaster rated as nonbearing			1 30	1 45	2
1:2, 1:3 portland cement plaster			30	45	
1:1/30:2, 1:1/30:3 portland cement and asbestos fiber plaster			45	1	
1:5, 1:7.5 lime plaster			30		
2:1:8, 2:1:10 lime and portland cement plaster			30		
2:1:8, 2:1:12 lime and Keene's cement plaster			45		

The steel-framed hollow partitions listed in table 31 have facings on both sides of plaster on metal lath. They are rated as nonbearing partitions on account of the nonbearing types of framing used.

TABLE 31.—*Steel-framed hollow partitions, nonbearing*

[Facings of plaster on metal lath]

Thickness of plaster	¾-in.	⅞-in.	1-in.
	Ultimate fire-resistauce period		
	hr	*hr*	*hr*
1:2, 1:3 gypsum plaster	¾	1	1¼
1:2, 1:2 gypsum plaster	1	1¼	
1:½, 1:½ gypsum plaster	1¼	1½	2
Neat gypsum plaster	1½	2	2½
1:2, 1:3 portland cement	½	¾	
1:1/30:2, 1:1/30:3 portland cement and asbestos fiber plaster	¾	1	

The steel-framed solid partitions covered in table 32 are also rated as nonbearing on account of the framing used, which was of ¾- or 1-in. hot-rolled or strip-steel channels.

TABLE 32.—*Steel-framed solid partitions, nonbearing*

[Body and facings of plaster on metal lath]

Thickness of plaster	2 in.	2¼ in.	2½ in.
	Ultimate fire-resistance period		
	hr	*hr*	*hr*
1:2½, 1:2½ gypsum plaster on 1 in. magnesium oxysulfate wood fiberboard			1
1:2, 1:2 gypsum on ¾ asbestos lath (soft)	¾		
1:2, 1:3 gypsum plaster on metal lath	¾		1
1:2, 1:2 gypsum plaster on metal lath	¾	1	1
1:1, 1:1 gypsum plaster on metal lath	1	1¼	1½
1:½, 1:½ gypsum plaster on metal lath	1½	1¾	2
Neat gypsum plaster on metal lath	1¾	2	2½
1:2, 1:3 portland cement on metal lath	½	½	½
1:4, 1:4 portland cement sprayed on wire mesh			⅓
4.5:1:7, 4.5:1:7 portland cement, sawdust, and sand sprayed on wire mesh			1

(j) *Partition Facings as Fire-Protective Finishes over Wood Framing*

Temperature measurements taken on the face of the studs during tests of partitions in which the framing was of wood indicated the effectiveness of the facings in affording protection to combustible members. In conformity with the tests specifications, the limit of protection is assumed to be reached when an average temperature rise of 250° F above the initial occurs on the face of the wood supports, or a rise at any one thermocouple location of 325° F. The ratings for this condition are given in table 33.

TABLE 33.—*Fire-protective finishes over wood framing*

Facings	Limit of protection
	min
½-in. fiberboard	5
½-in. fiberboard flameproofed	10
½-in. fiberboard with ½-in. 1:2, 1:2 gypsum plaster	15
⅞-in. flameproofed fiberboard with ½-in. 1:2, 1:2 gypsum plaster	30
⅜-in. gypsum wallboard	10
½-in. gypsum wallboard	15
⅜-in. plain or indented gypsum lath with ½-in. 1:2, 1:2 gypsum plaster	20
⅜-in. perforated gypsum lath with ½-in. 1:2, 1:2 gypsum plaster	30
Wood lath with ½-in. 1:2, 1:3 gypsum plaster	15
Wood lath with ½-in. 1:5, 1:7.5 lime plaster	15
Metal lath (no paper backing) with ¾-in. 1:2, 1:2 gypsum plaster	15
Metal lath (no paper backing) with ¾-in. neat gypsum plaster	30
Metal lath (no paper backing) with 1-in. neat gypsum plaster	35
Metal lath (no paper backing) with ¾-in. 1:5, 1:7.5 lime plaster	10
Metal lath (no paper backing) with ¾-in. portland cement plaster	10
Paper-backed metal lath with ¾-in. 1:2, 1:3 gypsum plaster	20
1-in. magnesium oxysulfate woodfiberboard with ½-in. 1:3, 1:3 gypsum plaster	20

5. Fire-Resistance Ratings for Walls and Partitions With Cement-Asbestos Facings

(a) *Test Conditions*

The fire tests upon which the ratings are based were conducted in substantial accord with the Standard Specifications for Fire Tests of Building Construction and Materials, ASA No. A2–1934. (See (a) under section 1, "Fire-Resistance Ratings for Load-Bearing Masonry Walls", or (a) under section 4, "Fire-Resistance Ratings for Wood- and Metal-Framed Partitions.")

(b) *Source of Data*

The ratings given herein were taken directly from the results of fire tests conducted at the National Bureau of Standards.

(c) *Firestopping*

The actual protection given by a wall or partition construction may be less than the rated fire resistance because of passage of fire around its borders. To prevent this occurrence, the spaces in any wood framing adjoining the wall or partition must be suitably closed or filled, preferably with incombustible material.

(d) *Fire-Resistance Ratings*

The ratings given in table 34 are for the indicated facings applied to 2- by 4-in. wood studs of No. 1 Common or better grade, set edgewise, spaced 16 in. on centers, having wood plates at top and bottom, and stayed transversely with wood blocking located to form support at the horizontal joints of the board facings. The loading is not to be in excess of 360 lb/in.^{2} of the net area of the studs. When the cement-asbestos boards or shingles are secured by countersunk nails, the holes drilled for the nails should be 0.02 to 0.03 in. smaller than the nail head and care should be taken that the nails are driven so as not to injure the cement-asbestos material. For the boards in the test partitions, 6d casing nails were found to be the most suitable, particularly if the heads are to be countersunk. The weights of mineral-wool bats per square foot refer to the net area of the filled space and are to be taken as the minimum. All ratings are as load-bearing constructions, except as noted, and the "combustible" designation applies to all on account of the wood supports.

(e) *Facings as Fire-Protective Finishes Over Wood Framing*

Temperature measurements taken on the face of the studs during the tests indicate the effectiveness of the facings in affording protection to combustible members. In conformity with the test specifications, the limit of protection is assumed to be reached when an average temperature rise of 250° F above the initial occurs on the face of the wood supports, or a rise of 325° F at any one thermocouple location. The protection periods found for this general type of partition are given in the last column of table 34.

TABLE 34.—*Cement-asbestos facings*

Facings	Ultimate fire resistance period	Protection period for wood framing
(A) Partitions faced on both sides with—		
	hr min	*hr min*
3/16-in. cement-asbestos board	10	5
Same as above filled with full-thick mineral-wool bats weighing 1 lb/ft²	40	5
4-in. strips of 3/8-in. gypsum boards over edges of studs under facings of 3/16-in. cement-asbestos boards, filling of mineral-wool bats weighing 2 lb/ft²	1	10
Same as above rated as nonbearing	1 15	10
3/16-in. cement-asbestos boards over 3/8-in. gypsum wallboard	1	15
3/16-in. cement-asbestos boards over 1/2-in. gypsum sheathing	1 15	20
Same as above rated as nonbearing	1 30	20
(B) Exterior walls faced as indicated		
Outside facing of 3/4-in. wood sheathing, asbestos felt weighing 14 lb/100 ft² and 3/12-in. cement-asbestos shingles. Inside facing of 9/16-in. board consisting of 7/16-in. wood fiber faced with 1/8-in. cement-asbestos. Outside facing to fire	30	20
Same as above with inside facing to fire	30	15
Outside facing same as above. Inside facing of 4-in. strips of 3/8-in. gypsum board over the edges of the studs under facing of 3/16-in. cement-asbestos board. Filled with full-thick mineral-wool bats weighing 1 lb/ft². Outside facing to fire	45	20
Same as above with inside facing to fire	40	15
Same as above except gypsum board strips were 1/2-in. thick and mineral-wool bats weighed 1 3/4 lb/ft². For fire exposure on either side	1 15	20

6. Fire-Resistance Ratings for Prefabricated and Built-up Partitions

(*a*) *Test Conditions*

The fire tests upon which the ratings are based were conducted in substantial accord with the Standard Specifications for Fire Tests of Building Construction and Materials, ASA No. A2–1934. (See (a) under section 1, "Fire-Resistance Ratings for Load-Bearing Masonry Walls," or (a) under section 4, "Fire-Resistance Ratings for Wood- and Metal-Framed Partitions.")

(*b*) *Sources of Data*

Ratings given under (d) in table 35 are based on recommendations of the Forest Products Laboratory of the U. S. Department of Agriculture. All other ratings are based on fire tests conducted at the National Bureau of Standards (see BMS71, and Research Paper RP1076). The ratings are taken directly from the test results without interpolation or extension.

(*c*) *Assembly of Prefabricated Wood Panels*

Joining of panels may be accomplished by the use of wood splines over which the panel facings are extended, leaving 1/8-in. space between facings of adjacent panels for calking, the facings being secured to the splines by nailing, or battens of suitable thickness may be nailed over the joints. The assembled partitions may be secured in a similar or equivalent manner to wood plates at the floor and ceiling, all spaces to be solidly filled. Ratings are based on phenolic resin glue being used for gluing facings to wood frames. If other types of glue are used for this purpose, the ratings can be taken to apply if the facings are nailed to the frames in addition to being glued.

(*d*) *Flameproofing*

The test results on which the ratings are based indicate that treating the wood with flameproofing chemicals will not materially increase the ultimate fire-resistance period. Hence, the ratings can be taken to apply for either flameproofed or untreated wood. Pending further tests, this should be taken as applying only for the types of treatment and construction details represented in the tests.

(*e*) *Load-Carrying Ability of Built-Up and Prefabricated Wood or Steel Partitions*

No load was applied during the fire tests on which the ratings in tables 35, 36, and 37 are based and, accordingly, they are rated as nonbearing constructions. The condition of the solid partitions at the end of the test indicated that at this time they would support at the most only a small part of a full working load as computed by generally accepted formulas. Hollow partitions that failed by temperature rise or flame penetration of the facings had somewhat greater strength, and mineral-wool fill in the hollow space further served to protect the studs as load-bearing members. For hollow partitions the estimated fire-resistance rating as bearing constructions is in the range one-half to three-fourths of the rating for nonbearing members, and for the solid partitions and the steel partition, from one-fourth to one-half of the rating periods given below. Where the loads actually applied are lower

than the maximum permitted by accepted design formulas, the fire endurance under load will be greater than as estimated above.

TABLE 35.—*Built-up and prefabricated wood partitions all rated as nonbearing, combustible*

Partitions	Ultimate fire-resistance period
(a) Solid partitions of 1 11/16 by 3¼-in. T&G beaded wood boards nailed together, the board joints being vertical and staggered	
	min
Two board layers	15
Two board layers with asbestos paper weighing 30 lb/100 ft² between layers	25
(b) Solid panels of ¾-in. wood boards, 2½ to 6 in. wide, grooved and joined with wood splines, nailed together, boards placed vertically with staggered joints except as noted	
One board layer	10
Two board layers	25
Three board layers	40
Three board layers with center boards not vertical	35
(c) Solid panels with 3/16-in. plywood facings glued to 1¾-in. solid wood core of glued T&G construction for both sides and ends of core pieces with T&G rails in the core about 2½ ft apart	
2⅛-in.-thick panels	60
(d) Hollow panels with facings on both sides of plywood glued to wood frame. Thickness of framing not less than 1¾ in.	
¼-in. plywood faces	10
⅜-in. plywood faces	15
½-in. plywood faces	20
⅝-in. plywood faces	25
(e) Hollow panels of plywood, ¼ in. thick on one side and ⅜ in. thick on the other side, glued to 2⅜- by ¾-in. wood studs, set edgewise, and filled with mineral wool bats weighing 2 lb/ft² of filled space	
3 in. thick panel	45

TABLE 36.—*Prefabricated steel partitions rated as nonbearing*

Partitions	Ultimate fire-resistance period
	min
Hollow panels with 18 gage steel facings spot-welded to steel channels having 3 rows of 4- by ⅛-in. staggered slots in the web, hollow space filled with heat-expanded vermiculite weighing 1.5 lb/ft² of wall surface, over-all thickness of panel 3 in	25
Same as above but with vermiculite fill weighing 2 lb/ft² of wall surface	30

TABLE 37.—*Partitions of prefabricated reinforced concrete units rated as load-bearing*

Partitions	Ultimate fire-resistance period
	hr
Prefabricated metal-reinforced concrete wall units, separate units for each face, connected with wood splines and metal pins, the assembly forming a 5-in. masonry wall with 1-in. faces and 3- by 13-in. continuous vertical air spaces. The rating is for loads not in excess of 2,250 lb/linear ft	¾
Same as above with all spaces filled with "nodulated" mineral wool weighing not less than 10 lb/ft³	2

7. Fire-Resistance Ratings for Columns

(a) *Test Conditions*

The fire tests cited below were conducted in substantial accord with the Standard Specifications for Fire Tests of Building Construction and Materials, ASA No. A2–1934. The columns were tested under working loads corresponding approximately with those computed by commonly accepted formulas, the criterion of failure being collapse under such load. No portion of the protection is computed as carrying load, although inevitably some types of protections will sustain a part of the load, particularly near failure.

(b) *Effect of Plaster*

The fire-resistance period for columns having ratings of less than 2½ hr, from 2½ hr to 4 hr, and 4 hr or more will be increased by at least 1 hr, 1½ hr, and 2 hr, respectively, by the application of ¾ in. of 1:3 sanded gypsum or 1 in. of 1:2½ portland cement plaster, the latter being held in place with wire mesh weighing 2 lb/yd², the plaster proportions being by weight of cementing material to that of dry sand. Plaster may develop more than its normal protective value if it adds to the stability of the protection to which it is applied.

(c) *Sources of Data*

(1) *Timber columns.*—Data taken from *Fire tests of building columns*, Tech. Pap. BS **15** (1921) T184; and Fire Exposure Tests of Loaded Timber Columns, Underwriters' Bulletin of Research No. 13, November 1939.

(2) *Round cast iron columns.*—Data taken from NBS Tech. Pap. T184.

(3) *Steel pipe columns.*—Data taken from NBS Tech. Pap. T184.

(4) *Structural steel columns (unprotected).*—Data taken from NBS Tech. Pap. T184.

(5) *Structural steel (solid section) partly protected with concrete.*—Data taken from NBS Tech. Pap. T184.

(6) *Structural steel (latticed) partly protected with concrete.*—Data taken from NBS Tech. Pap. T184. Concrete mix not leaner than 1:8 by volume of portland cement to aggregates.

(7) *Structural steel solidly protected with concrete.*—Data taken from NBS Tech. Pap. T184,

with due consideration of the influence of mineral composition of aggregates on fire resistance of concrete, Proc. Am. Soc. Testing Materials **29**, pt. 2, 824 (1929). Concrete mix not leaner than 1:8 by volume of portland cement to aggregates.

(8) *Structural steel protected with hollow tile and concrete.*—Data taken from NBS Tech. Pap. T184. Ratings are average values taken from test results.

(9) *Structural steel protected with hollow tile.*—Data taken from NBS Tech. Pap. T184.

(10) *Structural steel protected with brick.*—Data taken from NBS Tech. Pap. T184.

(11) *Structural steel protected with hollow cinder concrete blocks.*—Data taken from "Test of column for Philadelphia Board of Education," unpublished report, National Bureau of Standards (1938).

(12) *Structural steel protected with plaster.*—Data taken from NBS Tech. Pap. T184.

(13) *Structural steel protected with gypsum.*—Data taken from NBS Tech. Pap. T184; and *Fire tests of columns protected with gypsum*, BS J. Research **10**, 737 (1933) RP563.

(14) *Reinforced concrete columns.*—Data taken from NBS Tech. Pap. T184; and *Fire resistance of concrete columns*, Tech. Pap. BS **18**, 635 (1924–25) T272. Concrete mix not leaner than 1:6 by volume of portland cement to aggregates.

(*d*) *Fire-Resistance Ratings*

Ratings for various columns are given in tables 38 to 41, inclusive. The ratings for structural steel solidly protected with concrete, table 39, are based on the test reports cited with interpolations and extensions made by the method given in appendix B, section 2 (a), to include 6- by 6-in. to 12- by 12-in. structural steel sections having 2-, 3-, and 4-in. outside protection. Formula 4 was applied for the purpose with the following values for the constant *c:* For group I aggregates, 0.135; for group II, 0.095; for group III, 0.075; for group IV, 0.045. The above constants give the fire resistance in hours when D and d are taken in inches. The higher computed values were reduced somewhat on account of possible spalling and fusion effects.

The ratings for reinforced concrete columns, table 41, have been derived in part from interpolations and extensions made by the method given in the appendix B, section 2 (b). The values given under columns (A) were derived with formula 4 and those under columns (B) with formula 5. The higher computed values were reduced for the reason indicated above in the case of structural steel protected with concrete.

It is to be understood that the classifications for the aggregates apply to the coarse aggregate only. The fine aggregate can be of any type meeting accepted specifications for use in concrete.

TABLE 38.—*Timber columns and unprotected or partly protected cast iron, steel pipe, and structural steel columns*

Type of column	Ultimate fire-resistance period
	hr
Timber (long leaf pine or Douglas fir) minimum area 120 in.²	
With unprotected, steel plate cap	½
With unprotected, cast iron cap and pintle	¾
With concrete or protected steel or cast iron cap	1¼
With ⅜-in. gypsum wallboard over column and over cast iron or steel cap	1¼
With 1-in. portland cement plaster on wire lath over column and over cast iron or steel cap, ¾-in. air space	2
Round cast iron columns (7 in. outside diameter) minimum thickness of metal 0.6 in.	
Unprotected	½
Concrete filled, outside unprotected	¾
1 ½-in. portland cement plaster on high ribbed metal lath, ½-in. broken air space	3
2-in. concrete (other than siliceous aggregate)	2½
2-in. porous hollow tile, ¾-in. mortar between tile and column, outside wire ties	3
Steel pipe (minimum thickness of metal 3/10 in.)	
7-in. inside diameter, concrete filled, outside unprotected	½
8-in. inside diameter, concrete filled, reinforced with four 3 ½- by 3 ½- by ⅜-in. angles, in fill, outside unprotected	1
Structural steel, unprotected	
Minimum area of steel 10 in.²	¼
Structural steel (solid section) partly protected with concrete	
Reentrant space filled, outside unprotected, group I, II, or III aggregates, minimum area of solid materials 36 in.²	½
Same as above, group II or III aggregates, minimum area of solid materials 64 in.²	¾
Same as above, group I aggregate, minimum area of solid materials 64 in.²	1
Structural steel (lattice section) partly protected with concrete (no ties)	
Interior filled, lattice and main members covered, concrete extending to outside of rivets, group II aggregates, minimum area of solid material 130 in.²	3
Same as above, group I aggregate, minimum area of solid material 130 in.²	5

TABLE 39.—*Structural steel columns solidly protected with concrete*

Type of column and protection	Ultimate fire-resistance period; grouping by aggregates and ties			
	I	II	III	IV
	hr	*hr*	*hr*	*hr*
6- by 6-in. steel columns, 2-in. outside protection	5	3½	2½	1¾
6- by 6-in. steel columns, 3-in. outside protection	7	5	3½	2½
6- by 6-in. steel columns, 4-in. outside protection	9	7	5	3½
8- by 8-in. steel columns, 2-in. outside protection	6	4	3	2
8- by 8-in. steel columns, 3-in. outside protection	8	6	4	3
8- by 8-in. steel columns, 4-in. outside protection	11	8	6	4
10- by 10-in. steel columns, 2-in. outside protection	7	5	4	2½
10- by 10-in. steel columns, 3-in. outside protection	10	7	5	3½
10- by 10-in. steel columns, 4-in. outside protection	12	9	7	5
12- by 12-in. steel columns, 2-in. outside protection	8	6	5	3
12- by 12-in. steel columns, 3-in. outside protection	11	8	6	4
12- by 12-in. steel columns, 4-in. outside protection	14	10	8	5

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/yd², 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 gage 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/yd², 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 gage steel wire, wound spirally over the column section on a pitch of 8 in., or equivalent ties.

TABLE 40.—*Structural steel columns protected with hollow tile, brick, cinder block, plaster on metal lath, or gypsum*

Type of column and protection	Minimum area of solid material	Ultimate fire-resistance period
Structural steel protected with clay or shale hollow tile		
	*in.*²	*hr*
2-, 3-, or 4-in. tile, wire mesh in horizontal joints (two pieces in each joint placed on opposite sides and at right angles with respect to joints above or below), flanges covered with mortar or concrete, reentrant space filled with concrete	80	1½
Do	110	2
Do	145	2½
Do	180	3
Do	220	3½
Do	225	4
Same as above except reentrant space not filled	70	1½
Same as above except with two wythes of 2-in. tile outside, reentrant space filled with tile and mortar	250	4
Same as above except with outside wire ties instead of mesh in joints	250	1½

TABLE 40.—*Structural steel columns protected with hollow tile, brick, cinder block, plaster on metal lath, or gypsum*—Continued.

Type of column and protection	Minimum area of solid material	Ultimate fire-resistance period
Structural steel protected with brick (clay or shale)		
	*in.*²	*hr*
2¼-in. thick reentrant space filled with brick and mortar	180	1¾
3¾-in. thick reentrant space filled with brick and mortar	270	7
Structural steel protected with hollow cinder concrete blocks		
3-in. hollow block, space between block and steel and reentrant space filled with broken block and mortar, ¾-in. 1:3 sanded gypsum plaster	240	7
Structural steel protected with ¾-in. 1:3 sanded gypsum or 1-in. 1:2½ portland cement plaster on wire or metal lath		
One layer		1
Two layers with ¾-in. air space between		2½
Structural steel protected with gypsum		
2-in. solid blocks with wire mesh in horizontal joints, 1-in. mortar on flange, reentrant space filled with block and mortar	130	2
Same as above with ½-in. sanded gypsum plaster	150	5
2-in. solid blocks with wire mesh in horizontal joints, 1-in. mortar on flange, reentrant space filled with gypsum concrete	130	2½
Same as above with ½-in. sanded gypsum plaster	150	5
4-in. solid blocks with wire mesh in horizontal joints, 1-in. mortar on flange, reentrant space filled with block and mortar	300	4
Same as above with reentrant space filled with gypsum concrete	300	5
2-in. solid blocks with cramps at horizontal joints, mortar on flange only at horizontal joints, reentrant space not filled	85	2½
Same as above with ½-in. sanded gypsum plaster	105	4
3-in. hollow blocks with cramps at horizontal joints, mortar on flange only at horizontal joints, reentrant space not filled	95	2½
Same as above with ½-in. sanded gypsum plaster	120	5
2-in. neat fibered gypsum, reentrant space filled, poured solid and reinforced with 4- by 4-in. wire mesh, ½-in. sanded gypsum plaster	130	7

TABLE 41.—*Reinforced concrete columns*

Type of column	Ultimate fire-resistance period, grouping by aggregates and ties [a]							
	I		II		III		IV	
	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
Reinforced concrete columns with 1½ in. of concrete outside of reinforcing steel:								
Outside diameter of round columns or side of square columns, including outside protection:	*hr*	*hr*	*hr*	*hr*	*hr*	*hr*	*hr*	*hr*
12 in	6	4	4	2½	3	2	2	1¼
14 in	7	5	5	3½	4	2½	2½	1½
16 in	9	6	6	4	5	3½	3	2
18 in	11	8	7	5	6	4	3½	2½
20 in	12	9	9	6	7	5	4	3

[a] 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.

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

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

8. Fire-Resistance Ratings for Floor Constructions

(a) *Test Conditions*

The fire tests upon which the ratings are based were conducted in substantial accord with the Standard Specifications for Fire Tests of Building Construction and Materials, ASA No. A2–1934. This specification contemplates fire exposure to the under side of the construction and the fire-resistance period is taken to be reached if:

(1) An average temperature rise of 250° F or a maximum rise of 325° F, measured with thermocouples under asbestos pads, is attained on the unexposed side (upper side) of the construction.

(2) Passage of heat, flame, or gases hot enough to ignite cotton waste occurs.

(3) Structural collapse under the design load occurs.

For a full rating the requirements of the hose-stream test must be met. Floor constructions having ratings of less than 1 hr require no hose-stream test. Those having ratings of 1 hr or more require a hose-stream test after a fire exposure equal to one-half the time of the rating, except that for ratings of more than 2 hr the fire exposure before the hose-stream test need not be of more than 1-hr duration.

Floor constructions involving material which burns freely during the fire test or continues to burn after the furnace is shut off are rated as "combustible."

Where any information is available on the resistance of floor constructions to fire from above, this is given under the respective types.

(b) *Source of Data*

The results of fire tests conducted at the National Bureau of Standards were used as a basis for the ratings given herein. The ratings in general were taken directly from the test results and represent the lower averages of results in the case of tests on similar constructions.

(c) *Plaster*

Measurements of plaster thickness are taken from the face of the plaster base except that for metal lath the thickness is measured from the back of the lath. See section 4, Fire-Resistance Ratings for Wood- and Metal-Framed Partitions, for further information concerning plaster.

(d) *Fire-Resistance Ratings for Wood-Joist Floors*

The ratings given in table 42 are for the indicated ceilings applied to the following construction: Joists of 2- by 10-in. southern pine or Douglas fir of No. 1 Common or better grade, subfloor of ¾-in. wood sheathing, diaphragm of asbestos paper, and finish of tongue-and-groove wood flooring. The diaphragm can be of ordinary building paper if tongue-and-groove subflooring is used. The ratings apply for loadings developing not more than 1,000 lb/in.^{2} maximum fiber stress in the joists. The dimensions and spacings of nails given for supporting ceilings are to be taken as the minimum required. Larger nails and closer spacings can be substituted. The perforations in the gypsum lath are to be of not less than ¾-in. diameter, with one perforation for not more than 16 in.^{2} of lath surface.

All constructions are rated as "combustible" on account of the wood supports and floor boards.

The criteria for the limit of protection given the wood joists by the ceiling finish are the same as given above (par. 4, a–1) for partition facings over wood studs.

Table 42.—*Wood-joist floors*

Description of ceiling	Ultimate fire-resistance period	Protection period for the wood joists
Exposed wood joists		
	hr min	*min*
No ceiling	15	None
Gypsum wallboard, unplastered		
Gypsum wallboard ⅜- or ½-in. thick secured with 1½-in. No. 15 gage nails having 9/16-in. heads, spaced 6 in. centers, covered with asbestos paper applied with paperhangers' paste and finished with casein paint	25	15
Gypsum wallboard ½-in. thick secured with 1¾-in. No. 12 gage nails having ½-in. heads, spaced 6 in. centers, and finished with casein paint	25	15
Gypsum wallboard ½-in. thick secured with 1½-in. No. 12 gage nails having ½-in. heads and spaced 18 in. centers, covered with asbestos paper applied with paperhangers' paste and secured with 1½-in. No. 15 gage nails having 9/16-in. heads, and finished with casein paint (combined spacing of nails, 6 in. on centers)	30	18
Two layers of ⅜-in. gypsum wallboard secured with 1½-in. No. 15 gage nails having 9/16-in. heads, the combined spacing of the nails being 6 in. on centers	30	20

TABLE 42.—*Wood-joist floors*—Continued

Description of ceiling	Ultimate fire-resistance period	Protection period for the wood joists
	hr min	*min*
Perforated gypsum lath, ⅜ in. thick, plastered		
Perforated gypsum lath secured with 1⅛ in. No. 13 gage nails having 5/16-in. heads spaced 4 in. on centers, ½-in. 1:2 sanded gypsum plaster	30	8
Same as above except nailed with 1⅛-in. No. 13 gage nails having ⅜-in. heads and spaced 4 in. on centers	45	20
Perforated gypsum lath nailed with 1⅛-in. No. 13 gage nails having ⅜-in. heads and spaced 4 in. on centers, joints covered with 3-in. strips of metal lath nailed with 1¾-in. No. 12 gage nails having ½-in. heads (2 nails to each joist for strips perpendicular to joists, and spaced 5 in. on centers for strips over joists), ½-in. 1:2 sanded gypsum plaster	1	20
Two layers of gypsum lath, plastered		
One layer of ⅜-in. plain gypsum lath and lower layer of ⅜-in. perforated gypsum lath (joints broken) nailed with 1 ¾-in. No. 13 gage nails having 5/16-in. heads and spaced 4 in. on centers, ½-in. 1:2 sanded gypsum plaster or ½-in. 1:3 portland cement plaster	45	25
Metal lath and plaster		
The thickness of plaster is to be taken as the average measured from the back of the lath. Metal lath nailed with 1 ¼-in. No. 11 gage nails having ⅜-in. heads or 6d common wire nails driven 1 in. and bent over, spaced 6 in. on centers, ¾-in. sanded gypsum plaster 1:2 for scratch and 1:3 for brown coat	45	12
Same as above except nailed with 1 ½-in. No. 11 gage barbed roofers' nails having 7/16-in. heads and spaced 6 in. on centers	1	12
Either of the above with the lath nailed to joists as given and with additional supports for the lath, placed 27 in. on centers, attached to alternate joists and consisting of two nails driven 1¼ in., 2 in. above bottom on opposite sides of the joists, one loop of No. 18 gage wire slipped over each nail and the ends of these loops twisted together below the lath	1 15	15
Metal lath nailed with 1½-in. No. 11 gage barbed roofers' nails having 7/16-in. heads and spaced 6 in. on centers, ¾-in. portland cement plaster 1:2 for scratch and 1:3 for brown coat, plus 3 lb of asbestos fiber and 15 lb of hydrated lime per 94-lb bag of cement	1	10
Metal lath nailed with 8d, 11½ gage barbed box nails 2½ in. long, driven 1¼ in. on slant and bent over, spaced 6 in. on centers, ¾-in. sanded gypsum plaster 1:2 for scratch coat and 1:3 for brown coat	1	10

(e) *Fire-Resistance Ratings for Steel-Joist Floors*

The ratings given in table 43 apply to the floor constructions indicated when supported on open-web steel joists, pressed steel joists, or rolled steel beams, which are not stressed beyond 18,000 lb/in.^{2} in flexure for open-web or pressed or light rolled steel joists and 20,000 lb/in.^{2} for American standard or heavier rolled beams, and are bridged in accordance with accepted requirements. The ratio of weight of portland cement to that of fine and coarse aggregates combined for the floor slab shall not be less than 1:6½. The plaster for the ceiling shall be applied on metal lath (expanded metal, woven wire, or paper-backed wire lath) of appropriate weight for the spacing of the supports. The lath shall be tied to the supports to give the equivalent of single No. 18-gage steel-wire ties on 5-in. centers. The thickness of plaster shall be the depth from the back side of flat lath and to the back of the flat portion of ribbed lath.

The slab thicknesses are measured from the top flange of the joists and unless otherwise indicated are for monolithic poured construction. To obtain the fire-resistance ratings herein given, the average thickness of the slabs cast in place should be ¼ in. greater than at the joists. This greater average thickness usually results from the sag of metal lath forming or the placing of the more rigid forms under the top flange of the joists.

TABLE 43.—*Steel-joist floors*

[All plaster proportions are by dry weight of materials]

Construction	Ultimate fire-resistance period
	hr
Floor: 2-in. reinforced concrete, or 2-in. precast reinforced gypsum tile. *Ceiling:* ¾-in. portland cement sand plaster 1:2 for scratch and 1:3 for brown coat with 15 lb of hydrated lime and 3 lb of short asbestos fiber per bag of portland cement, or ¾-in. sanded gypsum plaster 1:2 for scratch coat and 1:3 for brown coat.	1½
Floor: 2¼-in. reinforced concrete or 2-in. reinforced gypsum tile, the latter with ¼-in. mortar finish. *Ceiling:* ¾-in. sanded gypsum plaster 1:2 for scratch coat and 1:3 for brown coat.	2
Floor: 2-in. reinforced concrete, or 2-in. reinforced gypsum tile, the latter with ¼-in. mortar finish. *Ceiling:* 1-in. neat gypsum plaster or ¾-in. gypsum-vermiculite plaster, ratio of weight of gypsum to fine heat-expanded vermiculite in the range 2:1 to 3:1.	2½
Floor: 2½-in. reinforced concrete, or 2-in. reinforced gypsum tile, the latter with ½-in. mortar finish. *Ceiling:* 1-in. neat gypsum plaster or ¾-in. gypsum-vermiculite plaster, ratio of weight of gypsum to fine heat-expanded vermiculite in the range 2:1 to 3:1.	3
Floor: 2½-in. reinforced concrete, or 2-in. reinforced gypsum slabs, the latter with ½-in. mortar finish. *Ceiling:* 1-in. gypsum-vermiculite plaster applied on metal lath and proportioned in the range 2:1 to 3:1 gypsum o heat-expanded vermiculite by weight.	4
Floor: 2-in. reinforced concrete, or 2-in. precast reinforced portland cement concrete or gypsum slabs, the precast slabs to be finished with top coating of mortar ¼-in. thick. *Ceiling:* 2-in. precast reinforced gypsum tile, well anchored into beams with metal ties or clips and covered with ½-in. 1:3 sanded gypsum plaster.	4

(f) *Fire-Resistance Ratings for Steel-Plate Floors*

The ratings given in table 44 are for the indicated finished floors and ceilings applied to steel construction that provides a steel-plate base on which the finished flooring may be applied directly. The ratings are predicated upon the following conditions:

(1) The rolled-steel supporting beams and the steel-plate base shall not be stressed beyond 20,000 lb/in.^{2} in flexure except for formed steel (wide upper flange) construction, in which case stresses are limited to 16,000 lb/in.^{2} The steel-plate base may be designed either as a flexural or suspension member carrying the load between the main supporting members. In either case the portion of the load carried by the concrete or other flooring material can be considered in the stress determinations as being carried separately or in combination with the steel plate as a structural member. In the latter case topping material such as concrete must be properly bonded to the steel plate.

(2) To prevent cracking of concrete flooring, some type of expanded metal or woven wire should be embedded near the middepth of the concrete. This reinforcing should preferably be welded to the plate.

(3) Plaster for ceilings is to be on metal lath wired to rods or channels which are clipped or welded to the under side of the steel construction. All wiring of lath shall be with steel wire not smaller than 18 gage and spaced not more than 7 in. apart, preferably with double ties for the higher ratings or for the wider spacings. The securing of the rods or channels to the steel construction shall be accomplished in a positive manner at least as effective as the following: Single 3/16-in. iron rods with 1 in. of their length bent over the lower flanges of beams with the rods or channels tied to this clip with 14 gage iron wire ties. In lieu of the above the plaster may be on ribbed or reinforced metal lath wired directly to the clips, the clips being as indicated above. The weights of metal lath and the weights and spacing of rods or channels can be according to usual specifications.

(4) The ratings are based on tests in which the back of the lath was located within an inch or two or in contact with the lower flange of the supporting steel beams, an air space of at least 3 in. being thus formed between the ceiling and the floor plate. However, the ratings can be taken to apply for suspended ceilings in which the back of the lath may be at some distance below the steel construction, provided the supporting system for the ceiling achieves a strength at least equivalent to that outlined under (3).

(5) While the ratings given are based on fire exposure from beneath, tests of this type of floor construction indicate that with the floors required for these ratings, the resistance to fire exposure from above is fully equal to that herein given for fire exposure below the floor.

TABLE 44.—*Steel-plate floors*

Construction	Ultimate fire-resistance period
	hr
Wood floor and plaster ceiling, rated as combustible	
Floor: Asbestos paper weighing 14 lb/100 ft^2 cemented to steel deck with waterproof linoleum cement, wood screeds and 7/8 in. wood floor. *Ceiling:* 3/4-in. sanded gypsum plaster 1:2 for scratch and 1:3 for brown coat.	1
Concrete floor and plaster ceiling	
Floor: 1½-in. 1:2:4 portland cement concrete. *Ceiling:* 3/4-in. sanded gypsum plaster 1:2 for scratch and 1:3 for brown coat.	1½
Floor: 2-in. 1:2:4 portland cement concrete. *Ceiling:* 3/4-in. sanded gypsum plaster 1:2 for scratch and 1:3 for brown coat.	2
Floor: 2-in. 1:2:4 portland cement concrete. *Ceiling:* 1-in. portland cement-sand plaster with 10 lb of hydrated lime added for each bag of cement 1:2 for scratch and 1:2½ for brown coat.	2
Floor: 2-in. 1:2:4 portland cement concrete. *Ceiling:* 1½-in. 1:2 sanded gypsum plaster on ribbed metal lath.	2½
Floor: 2-in. 1:2:4 portland cement concrete. *Ceiling:* 1½-in. 1:1 sanded gypsum plaster.	2½
Floor: 2½-in. 1:2:4 portland cement concrete. *Ceiling:* 1-in. 1:2 sanded gypsum plaster.	2½
Floor: 2½-in. 1:2:4 portland cement concrete. *Ceiling:* 1-in. neat gypsum plaster, or 3/4-in. gypsum-vermiculite plaster (ratio of weight of gypsum to fine heat-expanded vermiculite to be in the range of 2:1 to 3:1).	3
Floor: 2½-in. 1:2:4 portland cement, sand, and cinder concrete, plus ½-in. 1:2½ cement-sand finish. Total thickness, 3 in. *Ceiling:* 1½-in. 1:1 sanded gypsum plaster.	3
Floor: 2½-in. gas-expanded portland cement-sand concrete, plus ½-in. 1:2½ cement-sand finish. Total thickness, 3 in. *Ceiling:* 1½-in. 1:1 sanded gypsum plaster.	3½
Floor: 2½-in. 1:2:4 portland cement concrete. *Ceiling:* 1-in. gypsum-vermiculite plaster (ratio of weight of gypsum to fine heat-expanded vermiculite to be in the range of 2:1 to 3:1).	4
Concrete floors and gypsum tile ceiling	
Floor: 2-in. 1:2:4 portland cement concrete. *Ceiling:* 2-in. interlocking unreinforced gypsum tile supported on upper face of lower beam flange, ½-in. 1:3 sanded gypsum plaster.	2
Floor: 2-in. 1:2:4 portland cement concrete. *Ceiling:* 2-in. precast metal-reinforced gypsum tile, ½-in. 1:3 sanded gypsum plaster (tile clipped to channels which are clipped to lower flange of beams).	4

(*g*) *Fire-Resistance Ratings for Cellular Steel Floors*

The ratings given in table 45 are for the indicated finished floors and ceilings applied in

the manner noted to the following construction: Prefabricated units 2 ft wide, with the length equal to the span, composed of two pieces of No. 18 gage formed steel welded together to give four longitudinal cells, the depth being not less than 3 in. and the distance between cells not less than 2 in. For these ratings the maximum fiber stress in the steel is not to be in excess of 16,000 lb/in^2.

TABLE 45.—*Cellular-steel floors*

Construction	Ultimate fire-resistance period
	hr
Floor: 1:3:6 portland cement, sand, and gravel concrete applied directly to the top of the steel units and 1½-in. thick at top of cells, plus ½-in. 1:2 ½ cement-sand finish, total thickness at top of cells, 2 in. *Ceiling:* Plaster on metal lath tied to furring channels secured to runner channels hung from the cellular steel panel. The details of the supporting system for the plaster ceiling are assumed to conform with usual specifications.	
(a) With 1-in. neat gypsum plaster, the back of the lath being located 2 in. or more from the under side of the cellular steel panel	3
(b) With 1-in. gypsum vermiculite plaster (ratio of weight of gypsum to fine expanded vermiculite to be in the range of 2 : 1 to 3 : 1), the back of the lath being 2 in. or more from the under side of the cellular steel panel	4
(c) With 1-in., neat gypsum plaster, the back of the lath being located 9 in. or more from the under side of the cellular steel panel	4
(d) With 1-in. gypsum vermiculite plaster (ratio of weight of gypsum to fine expanded vermiculite to be in the range of 2 : 1 to 3 : 1), the back of the lath being 9 in. or more from the under side of the cellular steel panel	5

g. Fire-Resistance Classification of Roof Coverings

(*a*) *Basis of Classification*

The requirements for roofing materials from the standpoint of the public interest can be based on (1) the protection required for the individual building that is covered and (2) the fire hazard presented by the building with its roofing to the surrounding construction. Building codes have emphasized one or both of these considerations.

The classification is based largely on the degree to which the material resists sustained ignition from flame and flaming brands, the degree to which the fire will spread over the surface and give off dangerous brands, the protection against ignition and sustained flaming of combustible roof sheathing on which the roofing is applied, and the protection against exterior fire exposure given to incombustible roof sheathing and roof construction.

Brand, flame-exposure, and flame-spread tests are applied to roofings to determine their properties from the above standpoints. The lists of acceptable materials include those that have been subjected to such fire tests. Classes 1 and 2 are parallel with classes A and B of the Underwriters' Laboratories and class 3 is similar to their class C except that the asphalt rag-felt roll roofings laid in single thickness are not included. Class 4 covers the latter type of roofing as well as some wood-shingle constructions.

(*b*) *Sources of Data*

The classifications are based on the results of fire tests which have been conducted at the Underwriters' Laboratories and the National Bureau of Standards. All of the tests on built-up roofings were conducted at the Underwriters' Laboratories. Information on the weight of cementing material in built-up roofings was obtained from the old Federal specifications for the different types of built-up roofing, no longer issued, and the Navy Department "Specification for Roofing, Siding, and Sheet Metal Work; Dampproofing and Membrane Water-proofing" No. 7Yg, as well as manufacturers' specifications. The weights given represent minima used in good practice.

Of the prepared roofing materials, fire tests of asphalt-rag felt and asphalt-asbestos felt roofings, cement-asbestos shingles, and some metal roofings and coated wood shingles were conducted at the Underwriters' Laboratories. Tests of slate, cement-asbestos shingles; clay and cement tile; galvanized steel, tinned steel, copper, and zinc shingles and sheet roofing; asphalt-saturated asbestos-felt and asphalt-saturated rag-felt roll roofing and shingles, new and after weathering up to 12 years; and wood shingles untreated, chemically treated, and painted, new and after weathering up to 30 years, were conducted at the National Bureau of Standards.

(*c*) *General Requirements*

Class 1 roofing materials shall be effective against severe fire exposures, shall not carry or communicate fire, afford a relatively high degree of protection against fire to any combustible roof deck on which they may be placed, not

slip from position, possess no flying-brand hazard, and shall not require frequent repairs to maintain their fire-protective properties.

Class 2 roofing materials shall be effective against moderate fire exposures, shall not be readily flammable or carry or communicate fire. They shall afford a moderate degree of protection to the roof deck, shall not slip from position, shall possess no flying-brand hazard, and shall require only infrequent repairs in order to maintain the above properties.

Class 3 roof coverings under light fire exposures shall not be readily flammable or carry or communicate fire under such light fire exposures, afford some degree of protection to the roof deck, shall not slip from position nor possess any flying-brand hazard, and shall maintain these properties with only occasional repairs.

Class 4 roof coverings present less resistance to ignition from sources such as flying brands than the class 3 coverings but give at least a slight degree of protection to the roof deck. In burning they will give off flying brands. Their susceptibility to ignition from brands will increase with time in service. As applied by accepted methods they will not slip from position.

Class 5 comprises wood shingles that on account of thickness, length, treatment, coatings, underlay, or supporting sheathing are not included in classes 3 or 4. It also includes very readily ignitable and hazardous roofing materials, such as light asphalt or tar impregnated paper or straw thatch.

(*d*) *Lists of Acceptable Roof Coverings*

The above general requirements are exemplified by the following lists of roof coverings of which a sufficient number have been tested to indicate acceptability for the different classes. Pending the establishment of definite performance requirements for various classes of roof coverings, additional coverings not included herein can be classified by comparison under recognized tests with roof coverings herein classified.

(1) *Built-up Roof Coverings.*—A classification of built-up roof coverings is given in tables 46 to 48. The roof coverings are assumed to be applied according to accepted good practice. The minimum combined weight of bonding and coating materials required per 100 ft² of roof surface, for coverings nailed to deck and coverings held in place by cementing material applied directly to deck, are given. In the case of roof coverings nailed to deck, weights are based on designs which permit the least number of felt layers to be bonded with cementing material. The weights of felt given are minima.

Roofs surfaced with gravel or slag require not less than 400 lb of roofing gravel or crushed stone or 300 lb of crushed slag per 100 ft² of roof surface.

TABLE 46.—*Class 1 built-up roof coverings*

Description	Minimum weight of cementing material per 100 ft²	
	Roofing nailed to deck	Roofing cemented to deck
	lb	*lb*
Asbestos-felt saturated with asphalt bonded and surfaced with asphalt cement		
(1) 4 layers of 14-lb felt (18 lb if coated)	60	110
(2) 2 layers of 28-lb felt (each of 2-ply 14-lb felt)	40	70
(3) 1 layer of 35-lb felt (55 lb if coated) and 2 layers of 14-lb felt (18 lb if coated)	60	90
(4) 3 layers of 14-lb felt (18 lb if coated) limited to incombustible decks	40	90
(5) 2 layers of 35-lb felt (55 lb if coated) limited to incombustible decks	40	70
Rag-felt saturated with asphalt, bonded with asphalt cement and surfaced with gravel or slag on asphalt cement		
(1) 4 layers of 14-lb felt	100	150
(2) 1 layer of 28-lb felt and 2 layers of 14-lb felt	100	130
(3) 1 layer of 14-lb felt and 2 layers of 20-lb or heavier cap or base sheets	100	130
(4) 3 layers of 20-lb or heavier cap or base sheets	100	130
(5) 3 layers of 14-lb felt. Limited to incombustible decks	80	130
Asbestos-felt saturated with asphalt and rag-felt saturated with asphalt bonded and surfaced with asphalt cement		
(1) 1 layer of 28-lb rag-felt and 2 layers of 14-lb asbestos felt (18 lb if coated) limited to incombustible decks	60	90
Asbestos-felt or rag-felt saturated with tar, bonded with tar and surfaced with gravel or slag on tar		
(1) 4 layers of 14-lb felt	120	185
(2) 3 layers of 14-lb felt. Limited to incombustible decks	95	160
Rag-felt saturated with asphalt, bonded with asphalt cement and surfaced with ½-in. asphalt impregnated fibrous board applied with asphalt mastic.		
(1) 3 layers of 14-lb felt or other class 3 built-up roofing	40	90

TABLE 47.—*Class 2 built-up roof coverings*

Description	Minimum weight of cementing material per 100 ft²	
	Roofing nailed to deck	Roofing cemented to deck
	lb	*lb*
Asbestos-felt saturated with asphalt, bonded and surfaced with asphalt cement		
(1) 3 layers of 14-lb felt (18 lb if coated)	40	90
(2) 2 layers of 35-lb felt (55 lb if coated)	40	70
(3) 1 layer of 35-lb felt (55 lb if coated) and 1 layer of 14-lb felt (18 lb if coated)	40	70
Rag-felt saturated with asphalt, bonded with asphalt cement and surfaced with gravel or slag on asphalt cement		
(1) 3 layers of 14-lb felt	80	130
(2) 2 layers of 30-lb or heavier cap or base sheets	80	110
Asbestos-felt or rag-felt saturated with tar, bonded with tar and surfaced with gravel or slag on tar		
(1) 3 layers of 14-lb felt	95	160

TABLE 48.—*Class 3 built-up roof coverings*

Description	Minimum weight of cementing material per 100 ft²	
	Roofing nailed to deck	Roofing cemented to deck
	lb	*lb*
Rag-felt saturated with asphalt, bonded and surfaced with asphalt cement:		
(1) 3 layers of 14-lb felt	40	90
(2) 1 layer of 28-lb felt and 1 layer of 14-lb felt	40	70
(3) 2 layers of 20-lb or heavier cap or base sheets	40	70
(4) 2 layers of 14-lb felt and 1 layer 14-lb or heavier cap or base sheet	40	90

(2) *Prepared Roof Coverings.*—Prepared roof coverings are assumed to be applied according to accepted good practice. Where rag felt is indicated, asbestos felt of equal weight can be substituted. The coverings are all classified as applied over wood sheating of 1-in. nominal thickness.

From the standpoint of relative effectiveness of the different types of wood roof sheathing, the tongue-and-groove boards gave the best results in the brand-and-flame tests and the square-edge sheathing with boards spaced about ¼ in. apart were indicated as better than slat decks of 3-in. strips spaced 5 or more inches on centers. Accordingly for classifications based on slat supporting construction, square-edge or tongue-and-groove sheathing can be substituted and the latter can be substituted fort he square-edge sheathing.

By end lap is meant the overlapping length of two units, one placed over the other. Head lap is the distance that the lower of three superimposed units overlaps the upper unit.

Where the coverings are applied over concrete or other masonry roof slabs of 1 in. or greater thickness, the thickness of the roof covering is not a consideration as far as fire resistance is concerned.

Class 1. Prepared roof coverings

Brick 2¼ in. thick.

Reinforced portland cement concrete 1 in. thick.

Concrete or clay floor or deck tile 1 in. thick.

Flat or French-type clay or concrete roof tile, ⅜ in. thick with 1½ in. or more end lap and head lock, spacing body of tile ½ in. or more above roof sheathing, with underlay of asphalt-saturated rag-felt in one or two layers of total weight not less than 24 lb per 100 ft² or one layer of asphalt-saturated asbestos-felt weighing not less than 14 lb per 100 ft².

Clay or concrete roof tile, Spanish or Mission pattern, 7/16 in. thick, 3-in. end lap, same underlay as above.

Slate 3/16 in. thick, 3-in. head lap.

Cement-asbestos shingles laid American method, 3/16 in. or greater average thickness, 2-in. head lap.

Corrugated sheet steel, 24-gage metal or heavier, covered on both sides with asbestos felt weighing not less than 9 lb per 100 ft², cemented to the steel and saturated and coated with asphalt weighing not less than 18 lb per 100 ft² for each side. Sheets are to have not less than 3-in. side lap and 6-in. end lap. Over metal roof decks the underlay is not required from the standpoint of fire resistance.

Asphalt-saturated asbestos sheet roofing, 4-ply, with an unsaturated asbestos top sheet, weight not less than 80 lb per 100 ft² of roof surface, laid in single thickness with 2-in. end lap and side edges butted, with 6-in. wide strip beneath.

Class 2. Prepared roof coverings

Cement-asbestos shingles of 3/16-in. or greater thickness laid with not less than than 2 in. side, end, or combined side and end lap, according to the French, Dutch, or Scotch method, with underlay of asphalt-saturated rag-felt in one or two layers of total weight not less than 24 lb per 100 ft^2 or one layer of asphalt-saturated asbestos-felt weighing not less than 14 lb per 100 ft^2.

Asphalt-asbestos smooth surfaced sheet roofing, 3-ply, laid in single thickness, weight not less than 60 lb per 100 ft^2 of roof surface with 2-in. end lap and side edges butted, with 6-in. wide strip beneath.

Asphalt-asbestos felt smooth surfaced sheet roofing, 3-ply, with an unsaturated asbestos top sheet, weight not less than 55 lb per 100 ft^2 of roof surface, laid in single thickness with 2-in. or more end and side laps.

Asphalt-asbestos felt shingles made of asbestos felt saturated and coated with asphalt, surfaced with mineral granules, and weighing not less than 80 lb per 108 ft^2 and as laid on the roof with 2-in. or more head lap, weight not less than 180 lb per 100 ft^2 of roof surface.

Asphalt mastic shingles composed of asphalt and fibrous and granular materials of which not less than 45 percent by weight is incombustible, laid with not less than 2-in. head lap, total weight not less than 425 lb per 100 ft^2 of roof surface.

Copper, galvanized iron, or tin-coated iron standing seam or flat seam sheet roofings, underlaid with 14-lb saturated or unsaturated asbestos felt or asphalt-saturated rag-felt in one or two layers of total weight not less than 24 lb per 100 ft^2 of roof surface.

Copper or galvanized iron tile or shingle pattern roofings with same underlay as above.

Class 3. Prepared roof coverings

Copper, galvanized iron, or tin-coated standing-seam or flat-seam sheet roofing either without underlay or with underlay of rosin-sized paper.

Copper or galvanized iron tile or shingle-pattern roofings without underlay or with underlay of rosin-sized paper.

Asphalt rag-felt individual or strip shingles made of rag-felt saturated and coated with asphalt, surfaced with mineral granules and weighing not less than 80 lb per 108 ft^2 and as laid on the roof with 2-in. or more head lap, weight not less than 180 lb per 100 ft^2 of roof surface.

Asphalt-asbestos felt-roll roofing surfaced with mineral granules and laid in single thickness with 2-in. or more side and end lap, weight not less than 85 lb per 100 ft^2 of roof surface.

Asphalt-asbestos felt smooth-surfaced sheet or roll roofing laid in single thickness with 2-in. or more end and side lap, weight not less than 50 lb per 100 ft^2 of roof surface.

Zinc sheet or shingle roofings with underlay of 24-lb asphalt-saturated rag-felt in one or two thicknesses or 14-lb unsaturated or asphalt-saturated asbestos felt.

Wood shingles with butt thickness not less than 3/8 in. laid with not less than 6-in. head lap, coated on bottom with asphalt emulsion weighing not less than 4 lb per 100 ft^2 of roof surface except for upper 2 in., and on top and three edges with asphalt weighing not less than 60 lb per 100 ft^2 of roof surface, into which are embedded granules of crushed slate weighing not less than 100 lb per 100 ft^2 of roof surface. Shingles are to be laid over slat or close 3/4-in. wood sheathing.

Class 4. Roof coverings

Asphalt rag-felt mineral-surfaced roll roofing laid in single thickness with 2-in. or more end and side laps, weight not less than 75 lb per 100 ft^2 of roof surface.

Asphalt rag-felt smooth-surfaced roll roofing laid in single thickness with 2-in. or more end and side laps, weight not less than 35 lb per 100 ft^2 of roof surface.

Wood shingles of not less than 3/8-in. butt thickness chemically treated under pressure with double treatment of sodium borate, and zinc chloride with evacuation and drying between treatments laid with 6-in. or more head lap.

Edge-grain red-cedar, redwood, and No. 1 pine shingles, 7/16-in. butt thickness, 18 in. long, laid with 5-in. weather exposure on 3/4-in. square-edge wood sheathing with boards spaced not more than 1/4 in. apart.

Edge-grain red-cedar and redwood shingles, ⅜-in. butt thickness, 16 in. long, laid with 5-in. weather exposure on ¾-in. tongue-and-groove wood sheathing.

Edge-grain red-cedar and redwood shingles, ⅜-in. butt thickness, 16 in. long laid with 5-in. weather exposure on ¾-in. square-edge wood sheathing with boards spaced not more than ¼ in. apart and asphalt or tar-saturated rag felt between shingles and sheathing.

Wood shingles of any species ⅜-in. or greater butt thickness, 16-in. or greater length, laid with not less than 6-in. head lap on ¾-in. square-edge or tongue-and-groove wood sheathing, spaces between boards not more than ¼ in. and underlay between boards and shingles of asphalt-saturated rag-felt in one or two layers weighing not less than 24 lb per 100 ft² or asphalt-saturated asbestos-felt weighing not less than 14 lb per 100 ft².

Red-cedar, redwood, or No. 1 pine shingles, butt thickness not less than ⅜ in., 16-in. or greater length, laid with not less than 6-in. head lap on ¾-in. square-edge or tongue-and-groove wood sheathing, space between boards not more than ¼ in., shingles before application to be dipped to within 2 in. of the top in mineral oxide paint thinned so that the weight of pigment is not less than 30 percent of the weight of the prepared paint, and a brush coat of the unthinned paint applied over the exposed length after application on the roof.

Class 5. Roof coverings

Roof coverings possessing greater fire hazard than those included in class 4.

APPENDIX A. SUMMARY OF RESTRICTIONS AND LIMITATIONS IN SIX TYPICAL BUILDING CODES BASED ON TYPES OF CONSTRUCTION

This study is based upon an analysis of building codes to determine the nature and extent of the restrictions imposed by them according to types of construction. The following codes were used:

New York City, 1938;
Boston, (Proposed, 1938);
Minneapolis, 1935;
Atlanta, 1924;
Denver, 1935;
Seattle, 1937.

The restrictions in each of the codes were studied under the following general headings supplemented with a brief discussion:

I. Classifications.
II. Location with respect to fire zones.
III. Permissible spacing from adjacent construction or property lines.
IV. Permissible heights and areas of buildings.
V. Permissible materials.
VI. Required degrees of fire resistance of structural members.
VII. Permissible occupancies.
VIII. Discussion.

The study covers substantially the requirements of the codes on the topics under consideration, but necessarily presented in abbreviated form rather than in the original wording. For information regarding specific cases reference should be made directly to the codes.

For convenience, the classifications of construction by type and occupancy are included in the study at the beginning. When encountered later in the detailed requirements, they may be identified by turning back to the first section. Permissible heights and areas are given as combined limitations where they are so expressed in the codes.

These requirements are presented as typical of those applied in building codes of American cities at the present time. A discussion thereof in relation to the classifications of building construction presented in this report is given at the end of this summary.

I. CLASSIFICATIONS

1. New York

(a) Classification of Structures by Type of Construction

Class 1. Fireproof structures.
Class 2. Fire-protected structures.
Class 3. Nonfireproof structures.
Class 4. Wood frame structures.
Class 5. Metal structures.
Class 6. Heavy timber structures.

(b) Classification by Occupancy

Public Buildings.—Structures for civic, political, educational, religious, or recreational purposes, or in which persons are harbored for medical, charitable or other care or treatment.

Residence Buildings.—Structures in which sleeping accommodations are provided (unless otherwise classed as public buildings), including multiple dwellings.

Commercial Buildings.—Structures which are neither public nor residence buildings, but which include office buildings, factories, sales rooms, markets, restaurants, warehouses, garages, etc.

2. Boston

(a) Types of Construction

Type I. Fireproof.
Type II. Semifireproof.
Type III. Heavy timber and masonry.
Type IV. Light wood and masonry.
Type V. Metal frame.
Type VI. Wooden frame.

(b) Occupancies Classified

Group A. Theaters.
Group B. Halls.
Group C. Schools.
Group D. Hospitals and detention buildings.
Group E. Commercial buildings of hazardous occupancy.
Group F. Offices and commercial buildings.
Group G. Commercial buildings of nonhazardous occupancy.
Group H. Dwellings, large.
Group I. Dwellings, small.
Group J. Miscellaneous structures.

3. Minneapolis

(a) Types of Construction

Type 1. Fireproof.
Type 2. Slow burning.
Type 3. Skeleton and all-steel.
Type 4. Ordinary.
Type 5. Frame.

(*b*) *Classification of Buildings*

Class A–1.—Bakeries, chemical works, crane sheds, flour mills, foundries, ice-storage houses, laundries, machine shops, manufacturing buildings, power houses, sheds, warehouses, wholesale stores, woodworking shops.

Class A–2.—Baths, business colleges, department stores, markets, office buildings, places of assembly for not over 100, public convenience stations, recreation buildings, restaurants, retail stores, telephone exchanges.

Class B–1.—Garages, motorboat houses, hangars, paint shops, enameling shops, rag shops, buildings for the manufacture, storage, use or sale of inflammable liquids and other inflammable substances, including calcium carbide.

Class B–2.—Dry-cleaning establishments, buildings used for storage or manufacture of celluloids, buildings for storage of explosives and for generating acetylene.

Class B–3.—Stables.

Class C.—Public buildings: Armories, auditoriums, churches, administrative buildings, courthouses, dance halls, post offices, schools, etc.

Class D.—Theaters.

Class E–1.—Multiple dwellings, hotels, lodging houses, dormitories, monasteries, convents, boarding schools, clubhouses, more than 10 sleeping rooms.

Class E–2.—Hospitals, sanitariums.

Class E–3.—Prisons, reformatories, jails, asylums.

Class F.—Single and two-family dwellings, lodging houses, dormitories, monasteries, not more than 10 sleeping rooms.

4. Atlanta

(*a*) *Classification of Buildings by Construction*

I. Frame construction.
II. Non-fire-resistive construction.
  a. Ordinary construction.
  b. Mill construction.
III. Fire-resistive construction.

(*b*) *Classification of Buildings by Occupancy*

I. Public Buildings.
Class A.—Armories, asylums, bath houses (with sleeping accommodations other than those required for janitor), city halls, colleges, court houses, detention buildings, police stations, hospitals, libraries, museums, nurseries, railway passenger stations, schools and theaters.
Class B.—Amusement halls, churches, exhibition buildings, lodge rooms, public halls.

II. Residence Buildings.
Class C.—Bachelor apartments, club houses and studios with more than 15 sleeping rooms, dormitories, hotels, and lodging houses.
Class D.—Dwellings, apartment houses, and all other residence buildings not specified in Class C.

III. Business Buildings.
Class E.—Factories, lofts, office buildings, printing houses, restaurants, stores, warehouses, and workshops.
Class F.—Car barns, foundries, light and power plants, railroad freight stations, ice houses; special industry buildings such as coffee roasters, cooperage shops, dry-cleaning establishments, grain elevators, ice-making plants, laboratories, malt houses, oil houses, oil refineries, refrigerating plants, rendering plants, soap factories, sugar refineries, smoke houses, slaughter houses, wharf buildings, garages accommodating more than three cars.

5. Denver

(*a*) *Types of Construction*

Type I. Fire-resistive construction.
Type II. Heavy timber construction.
Type III. Ordinary masonry construction.
Type IV. Metal frame construction.
Type V. Wood frame construction.

(*b*) *Occupancy Classification*

Group A–1.—Major theaters with stage loft and equipment.
A–2.—Moving picture theaters seating 1,000 or more.
A–3.—Places of public assemblage seating 1,000 or more in any one room.

Group B–1.—Theaters seating less than 1,000.
B–2.—Places of public assemblage seating less than 1,000 in any one room.

Group C.— Public and parochial schools.

Group D–1.—Jails, prisons, reformatories, asylums.
D–2.—Hospitals, sanitariums, orphanages, nurseries accommodating more than 6 patients.

Group E–1.—Public garages, gasoline stations, spray paint shops.
E–2.—Planing mills, box factories, woodworking and mattress factories.
E–3.—Storage of highly inflammable or explosive materials.

Group F–1.—Wholesale and retail stores, office buildings, restaurants, undertaking parlors, printing plants, police and fire stations.
F–2.—Factories and workshops using materials not highly inflammable or explosive.
F–3.—Storage and sales rooms for combustible goods.

Group G–1.—Ice plants, power plants, pumping plants, cold storage, creameries.
G–2.—Factories and workshops using incombustible or non-explosive materials.

Group G–3.—Storage and sales rooms for incombustible or non-explosive goods.
Group H–1.—Hotels, apartment houses, dormitories, lodging houses.
H–2.—Convents, monasteries, accommodating 10 or more.
Group I.— Dwellings.
Group J–1.—Private garages.
J–2.—Accessory buildings and structures such as sheds, fences, water tanks, towers.
J–3.—Stadiums, reviewing stands, amusement park structures.

6. Seattle

(*a*) *Types of Construction*

There shall be five general classes of buildings as follows: Fireproof, steel joist, mill, ordinary masonry, frame, and such other special classes as are elsewhere herein permitted for special uses.

(*b*) *Occupancy Classification*

No occupancy classifications are given.

II. LOCATION WITH RESPECT TO FIRE ZONES

1. Number of Zones, Including an Unrestricted Area

New York	3
Boston	3
Minneapolis	3
Atlanta	2
Denver	4
Seattle	4

2. Restrictions and Limitations

(*a*) *New York*

Frame construction forbidden within fire limits.

With certain limitations frame residences occupied by not more than two families, and one-story stables and garages 600 ft² or less in area on the same lot or plot, are permitted outside fire limits.

In the Borough of Richmond, frame structures of two stories in height, not over 3,000 ft² in area, are permitted for business purposes other than garages, motor-vehicle repair shops, or gasoline service stations.

Certain other frame structures are permitted outside the fire limits provided they are not used for industrial or commercial purposes or as a place of public assembly, and do not exceed 40 ft or three stories and basement in height, or 5,500 ft² in area.

(*b*) *Boston*

Wooden frame construction is prohibited within first fire zone.

Wooden frame dwellings for one or two families are permitted in second fire zone.

Garages for more than four cars in the first and second fire zones shall be of fireproof or semifireproof construction and if more than one story in height shall be of fireproof construction.

Metal-frame buildings for use as garages are prohibited in the first fire zone. In the second fire zone, metal-frame buildings for use as garages are permitted if one story in height and not more than 600 ft² in area.

Schools in the first and second fire zones shall be of fireproof or semifireproof construction.

Wooden frame buildings not over 27 ft high on wharves, and for the storage and handling of coal or grain in bulk, are permitted in the first and second fire zones if the exteriors are covered with slate, tile, sheet metal, or other equally fire-resistive materials.

(*c*) *Minneapolis*

Within the Fireproof District, one-story buildings of slow-burning or ordinary construction, or skeleton and all-steel construction when having masonry exterior walls, and one-story sheds of all-steel construction not over 400 ft² in area or 12 ft high may be erected. All other construction in the Fireproof District is required to be fireproof.

Within the fire limits, fireproof, slow-burning, skeleton and all-steel, and ordinary constructions are permitted. Masonry exterior walls are required.

(*d*) *Atlanta*

No frame building except temporary buildings may be erected within the fire limits.

(*e*) *Denver*

Wood-frame construction is prohibited in fire zones Nos. 1, 2, and 3.

Ordinary masonry and metal-frame constructions in fire zone No. 1 are limited to 400 ft² in area and one story or 20 ft in height.

Temporary structures, such as reviewing stands, are permitted in fire zones Nos. 1 and 2.

In fire zone No. 3 frame sheds and chicken houses are permitted.

There are no restrictions in fire zone No. 4.

(*f*) *Seattle*

Buildings in the First Building District are required to be of fireproof, steel-joist, or mill construction. Ordinary masonry construction not higher than one story is permitted.

The requirements for the Second Building District are the same as those for the First Building District except that ordinary masonry construction may be two stories high.

In the Third Building District ordinary masonry construction may be four stories high. Frame residences of two stories or other frame buildings of one story if roofed with shingles or of three stories if roofed with three-ply roofing or roofing as for mill buildings are permitted.

There are no restrictions in the Fourth Building District.

III. PERMISSIBLE SPACING FROM ADJACENT CONSTRUCTION OR PROPERTY LINES

1. New York

The restrictions given below apply to structures located outside of fire limits:

Frame residence, not more than two families, eight livable rooms per family, when covering 80 percent or less of the area of the lot:

Distances between buildings across side lot lines, 6 ft.

Distance from a side lot line, 2 ft.

Four double dwellings with party wall:

Distance from opposite side lot line, 4 ft.

When width of plot is 30 ft or less, single-family dwelling:

Distance from lot line on one side, 3 ft.

Distance from other lot line if not contiguous with building on adjoining lot, 2 ft.

Frame residence, maximum 10 livable rooms per family, when covering not more than 50 percent of the area of the lot and 60 percent of the width of the lot:

Distance from nearest lot line, 25 ft.

Frame residence, maximum 12 livable rooms per family, when not covering more than 50 percent of the width of the lot:

Distance from nearest lot line, 50 ft.

One-story stables or garages, 600 ft² or less in area, 15 ft or less in height; on same plot with one- or two-family residence structures:

Frame.—Distance from lot line, 3 ft.

Masonry exterior walls, masonry-veneered or stud spaces filled:

Distance from lot line may be less than 3 ft.

Frame business structures in the Borough of Richmond other than garages, motor vehicle repair shops, or gasoline stations, not over 2 stories in height or 300 ft² in area or 80 percent of width of lot:

Distance from side lot line, 4 ft.

Other frame structures, except commercial, industrial, or places of assembly:

Distance from nearest boundary line, 30 ft.

Distance from nearest other structure between it and boundary line, 30 ft.

Frame structures, except as otherwise provided:

Clearance from other frame structures on same plot, 6 ft.

Frame structures, used for manufacturing purposes or for storage of inflammable materials:

Distance from lot line, 15 ft.

Other business structures of class 5:

Distance from lot line, 4 ft.

2. Boston

Halls, Schools, Hospitals, Detention Buildings, Commercial Buildings, Hazardous Occupancies:

Exterior walls less than 5 ft from property line are required to be of 4-hr fire-resistive construction.

Exterior walls more than 5 ft but less than 10 ft from property line are required to be of 2-hr fire-resistive construction.

Office and Commercial Buildings, Commercial Buildings of Nonhazardous Occupancy:

Large dwellings:

Exterior walls less than 10 ft from property line are required to be of 2-hr fire-resistive construction.

Small dwellings:

Exterior walls less than 5 ft from a property line are required to be of 2-hr fire-resistive construction.

Miscellaneous Structures:

Exterior walls less than 5 ft from a property line or less than 10 ft from another building on the same lot are required to be of 1-hr fire-resistive construction; less than 3 ft from a property line or less than 6 ft from another building on the same lot are required to be of 2-hr fire-resistive construction.

3. Minneapolis

Exterior walls of Class A buildings required to be of masonry if nearer than 5 ft to property line or 10 ft to another building on the same property. (Class A includes shops, warehouses, stores, office buildings, and certain places of assembly.)

Exterior walls of Class B–1 and B–3 buildings required to be of masonry if within 10 ft of property line or other building on the same property.

No Class B–2 buildings shall be built less than 10 ft from property line or any other building on the same property.

Dry-cleaning establishments are required to be not less than 15 ft from any other building on the same premises and from any property line.

No private garage shall be erected within 15 ft of any Class E–1 building (multiple dwellings, hotels, etc.) without permit from the City Council.

Walls of garages are required to be of masonry if within 4 ft of any dwelling already erected or within 1 ft of the side lot line. Double private garages may be erected on the lot line by mutual consent without masonry separating walls.

Airplane hangars may be of frame construction when 40 ft from any adjacent property line or other building and 20 ft from any other hangar.

Walls of Class C (Public) buildings are required to be of masonry if nearer than 5 ft from a property line or other building on the same property.

Class D (Theaters) No applicable requirement.

Sanitariums (Included in Class E–2) one story, 15 ft in height may be of frame construction if at least 5 ft from any property line or 10 ft from any other frame building.

Walls of Class F buildings are required to be of

masonry if nearer than 3 ft from any property line or any other building on the same property. (Class F includes dwellings and lodging houses, dormitories, etc. of not more than 10 sleeping rooms.)

Coal pockets, etc., may be of wood if not less than 10 ft from any property line.

Gas holders are required to be 100 ft from any private property held under separate ownership.

Grandstands of wood may not be closer than 10 ft to property line or 20 ft from other frame buildings.

Roller coasters of wood are required to be at least 20 ft from property line or other frame structures on the same property. If steel or concrete, not limited as to location.

Other amusement devices of wood shall not be nearer than 20 ft to adjacent property lines.

4. Atlanta

Frame buildings of Class F (various industrial buildings) and frame buildings of other classes exceeding 5,000 ft² without sprinklers are required to be 35 ft from side or rear lot lines; if the area exceeds 7,500 ft², 100 ft from side or rear lot lines.

The minimum permissible distance of a frame building from a lot line is 3 ft and from another building on the same lot, 10 ft. These distances may be reduced to 3 ft and 5 ft, respectively, if the spaces between the studs are properly filled and the walls protected as required.

If the adjacent walls of two buildings have no openings, and are protected in the prescribed manner, there is no limitation as to distance between them.

5. Denver

Walls of Group E buildings are required to be of masonry if within 10 ft from adjacent property lines. (Group E includes public garages, shops and factories working with inflammable materials, and places storing inflammable or explosive materials.)

Exterior walls of Group F buildings are required to be of masonry if within 4 ft from adjacent property lines. (Group F includes stores, office buildings, factories, and storage places for combustible goods.)

Location with reference to property lines of buildings of Group I (private dwellings) is governed only by zoning ordinances.

6. Seattle

Frame residences are required to be 18 in. from the lot lines of adjacent property.

Frame buildings other than residences are required to be 3 ft from the lot lines of adjacent property.

These restrictions are removed if the walls are of fireproof material or otherwise built as required by the code.

Frame buildings not over 400 ft² in area may, under certain conditions, be constructed up to the lot line.

Walls of incombustible service stations in the First and Second Building Districts are required to be of masonry if nearer than 6 ft from adjacent property lines.

Incombustible shelters on auto parking lots in the First and Second Building Districts are required to be 3 ft from the lot lines of adjacent property.

IV. PERMISSIBLE HEIGHTS AND AREAS OF BUILDINGS

1. New York

The maximum height and area limits of buildings as applied in the New York City building code are given in table 49, but subject to the following qualifications.

Table 49.—*Maximum heights and areas of buildings, New York City building code*

Use classification	Construction classification									
	Class I, Fireproof		Class II, Fire-protected				Class III, Nonfireproof			
	Height	Area	Height		Area	Street fronts	Height		Area	Street fronts
	ft	*ft²*	*ft*	*Stories*	*ft²*	*No.*	*ft*	*Stories*	*ft²*	*No.*
(1) Public [a] (churches only)										4
(2) Public [a] (other than churches, hospitals, asylums and places of incarceration or amusement)										
(3) Public (other than (1) and (2))	Unlimited	Unlimited	40	3	7,500	1	20		5,000	
			40	3	12,000	2				
			40	3	15,000	3				
(4) Commercial (other than garages, motor vehicle repair, shops and gasoline selling stations)	do	do	75	6	7,500	1	50	4	7,500	1
			75	6	12,000	2	50	4	12,000	2
			75	6	15,000	3	50	4	15,000	3
			50	4	10,000	1	30	2	10,000	1
			50	4	14,500	2	30	2	14,500	2
			50	4	17,500	3	30	2	17,500	3
(5) Garages, motor vehicle repair shops and gasoline selling stations.	do	do		2	7,500	1		1	7,500	1
				2	12,000	2		1	12,000	2
				2	15,000	3		1	15,000	3
(6) Residence	do	do	100	9	12,000	1	75	6	3,000	
			100	9	15,000	2				
			100	9	20,000	3				

[a] See under Class VI.

TABLE 49.—*Maximum heights and areas of buildings, New York City building code*—Continued

Use classification	Construction classification									
	Class IV, Wood frame			Class V, Metal			Class VI, Heavy timber			
	Height		Area	Height		Area	Height		Area	Street fronts
	ft	*Stories*	*ft²*	*ft*	*Stories*	*ft²*	*ft*	*Stories*	*ft²*	*No.*
(1) Public [a] (churches only)							40	2	6,000	1
								2	8,000	2 or 3
(2) Public [a] (other than churches, hospitals, asylums and places of incarceration or amusement)							35	2	6,000	1
								2	8,000	2 or 3
(3) Public (other than (1) and (2))		1	600				20		6,000	
(4) Commercial (other than garages, motor vehicle repair shops and gasoline selling stations)				30	1	15,000	65	5	7,500	1
							65	5	12,000	2
							65	5	15,000	3
							40	3	10,000	1
							40	3	14,500	2
							40	3	17,500	3
(5) Garages, motor vehicle repair shops and gasoline selling stations				20	1	5,000		1	10,000	1
								1	15,000	2
								1	18,000	3
(6) Residence	35	[b] 2	2,500 (single family occupancy).				75	6	3,000	
	40	3								

[a] See under Class VI.
[b] Unoccupied attic permitted.

The limits of area for business and garage structures (except Class V Metal structures) may be increased 100 percent when approved sprinkler systems are installed.

Class II, Class III, and Class VI, business and garage structures of greater total area may be constructed, provided they are divided by fire walls into areas within the tabular limits.

Public buildings of Class III construction, whose tabular height limitation is 20 ft, may be erected to a height of 35 ft if having only one occupied story.

Class III residence structures of greater area than 3,000 ft² may be constructed provided they are divided into units of area of 3,000 ft² or less, by walls or partitions having a fire-resistance rating of at least 3 hr.

Coal pockets and grain elevators, within the fire limits, shall be Class I Fireproof structures, or Class II Fire-protected structures.

Class VI Heavy timber construction or structures used exclusively for the storage or handling of building construction materials may, in the discretion of the Superintendent, exceed 40 ft or 3 stories in height.

2. Boston

The permissible heights and areas of buildings according to the 1938 proposed code are given in table 50, subject to the following qualifications and further restrictions.

Buildings on wooden wharves shall not exceed 20,000 ft² in area.

Group B.—The maximum area provided may be increased 50 percent if the entire floor area is protected by automatic sprinklers.

Group C.—Same as Group B.

Group D.—Division 1. Jails, prisons, reformatories and similar buildings.

Division 2. Hospitals, sanitariums, orphanages, etc.

Division 1 buildings shall be of Type I throughout. The ceilings and partitions of Division 2 buildings more than one story in height shall be of not less than 1-hr fire-resistive construction, and the first floor of such buildings more than two stories in height shall be of Type I construction.

The basements, cellars, store rooms, corridors, and stairways of Group D buildings of other than Type I or Type II construction shall be protected by automatic sprinklers.

Group E.—Division 1. Garages of more than six cars capacity and hangars.

Division 2. Planing mills, box factories, wood-working plants, mattress factories, paint shops, dry-cleaning plants.

Division 3. Buildings for the storage of hazardous, highly flammable, or explosive material or liquids.

TABLE 50.—*Maximum heights and areas of buildings, Boston, 1938 proposed code*

Types of buildings	Sides accessible	I Fireproof			II Semifireproof			III Heavy timber and masonry			IV Light wood and masonry			V Metal frame			VI Wood frame		
		Height		Area	Height		Area	Height		Area	Height		Area	Height		Area	Height		Area
		ft	*Stories*	*ft²*	*ft*	*Stories*	*ft²*	*ft*	*Stories*	*ft²*	*ft*	*Stories*	*ft²*	*ft*	*Stories*	*ft²*	*ft*	*Stories*	*ft²*
A, theatres		Unlimited																	
B, halls		do			55	4	18,000	55	4	17,000	45	3	12,000	45	1	12,000	35	1	5,000
					55	1	24,000	55	1	20,000	45	1	18,000						
C, schools		do			55	4	18,000	35	2	17,000	35	2	12,000	35	1	10,000	35	1	5,000
					55	1	24,000	35	1	20,000	35	1	18,000						
D, hospitals, etc		do			55	4	17,000	45	3	12,000	45	3	10,000	35	1	7,500	35	1	2,500
					55	1	20,000	35	1	18,000	35	1	15,000						
E, commercial, hazardous	1	150	15	10,000	50	4	8,000	50	4	8,000	40	3	4,000	20	1	6,000	20	1	3,000
	2	150	15	15,000	50	4	10,000	50	4	10,000	40	3	6,000	20	1	8,000	20	1	4,000
	3	150	15	20,000	50	4	12,000	50	4	12,000	40	3	8,000	20	1	10,000	20	1	5,000
	1										20	1	6,000						
	2										20	1	8,000						
	3										20	1	10,000						
F, offices and commercial buildings	1	Unlimited			80	7	10,000	75	6	9,000	55	5	4,000	35	2	6,000	30	2	3,000
	2				80	7	12,000	75	6	10,000	55	5	6,000	35	2	8,000	30	2	4,000
	3				80	7	15,000	75	6	12,000	55	5	8,000	35	2	10,000	30	2	5,000
	1										35	3	6,000						
	2										35	3	8,000						
	3										35	3	10,000						
G, commercial, nonhazardous	1	Unlimited			80	7	15,000	75	6	15,000	55	5	8,000	35	2	10,000	30	2	3,000
	2				80	7	18,000	75	6	18,000	55	5	10,000	35	2	12,000	30	2	4,000
	3				80	7	20,000	75	6	20,000	55	5	12,000	35	2	14,000	30	2	5,000
	1										40	3	10,000						
	2										40	3	12,000						
	3										40	3	14,000						
H, dwellings, large		Unlimited			100	10	12,000	65	5	8,000	65	5	6,000	(a)	(a)	(a)	40	3	2,400
I, dwellings, small		do			100	10	12,000	65	5	8,000	65	5	6,000	40	3	5,000	40	3	5,000
J, miscellaneous amusement		do			75	4	15,000	55	3	10,000	35	2	10,000	35	2	5,000	35	2	5,000
F, buildings on wharves		do			50–80	3–7	15,000	50–75	3–6	12,000	50–55	3–5	10,000	35	2	60,000	30	2	30,000
					50	2	120,000	50	2	60,000	50	2	60,000						

[a] Not permitted.

The limits in area shall not apply to buildings one story high of Group E Division 1 of Type I construction. These may be 15,000, 20,000 and 25,000 ft² for one, two, and three sides accessible, respectively.

Every unit of Group E occupancy higher than two stories or having an aggregate floor area greater than 10,000 ft² shall be equipped throughout with automatic sprinklers.

Group F.—Division 1. Office buildings, restaurants, police and fire stations, museums, and libraries.

Division 2. Wholesale and retail stores, printing plants, factories and work shops using materials not highly flammable.

Division 3. Buildings for storage and sale of goods not highly flammable, stables and buildings not on wharves, for storing or handling transient freight.

Division 4. Wharf buildings for storage and handling of transient freight.

Group F.—Buildings of Divisions 2 and 3, six or more stories in height shall be equipped with automatic sprinklers.

The maximum areas for buildings of Division 1, and for buildings of Divisions 2 and 3 less than six stories in height may be increased fifty percent if the entire floor area is protected by automatic sprinklers.

Group J.—The maximum areas provided may be increased 50 percent if the entire floor area is protected by automatic sprinklers.

3. Minneapolis

(a) *Height Limitations*

Type 1. Fireproof.—This type of construction shall not be limited in height.

Type 2. Slow-Burning.—Limited to six stories, 75 ft. or less in height and not permitted in Fireproof District except for special cases noted in the code.

Type 3. Skeleton and All-Steel.—Limited to one story and one mezzanine or 75 ft except when roof purlins or roof boards are of wood, in which case such buildings shall not exceed 45 ft. Not permitted in Fireproof District except for special cases noted in the code. Permitted in fire limits when interior walls are of masonry and buildings are limited in area and located on a lot as given under class of building.

Type 4. Ordinary.—Limited to four stories, 55 ft. Not permitted in Fireproof District when exceeding one story.

Type 5. Frame.—Limited in height to two stories and attic or 35 ft. Not permitted in Fireproof District or fire limits.

Exceptions.—Buildings not exceeding one story in height of Types 2 or 4, and of Type 3 when having masonry exterior walls, may be constructed in the Fireproof District.

Class A buildings shall be built of one of the following types of construction:

If not over one story or 20 ft, of any type.

If not over four stories or 55 ft, of Types 1, 2, or 4.

If not over six stories or 75 ft, of Types 1 or 2.

If over six stories or 75 ft, of Type 1.

Class A–2 buildings may be built of Type 5 construction if not over two stories or 25-ft height.

(b) *Area or Combined Height and Area Limitations*

General area limitations are given in table 51, which however, are qualified by building height and occupancy as indicated below.

Table 51.—*General height and area limitations, Minneapolis code*

Type of construction	Number of stories	Maximum floor area		
		One streets	Two streets	Three streets
		ft²	ft²	ft²
Type 1	1 story	No limit		
	2 stories or over	30,000	40,000	55,000
	When sprinklered	50,000	66,000	83,000
Type 2	1 story	20,000	25,000	30,000
	When sprinklered	33,000	42,000	50,000
	2 stories or over	12,000	14,000	16,000
	When sprinklered	20,000	24,000	27,000
Type 3	1 story and mezzanine	15,000	18,000	20,000
	When sprinklered	25,000	30,000	34,000
Type 4	1 story	12,000	15,000	18,000
	When sprinklered	20,000	25,000	30,000
	2 stories or over	7,500	10,000	12,500
	When sprinklered	12,500	17,000	21,000
Type 5	1 story	5,000	7,000	9,000
	When sprinklered	8,500	11,750	15,000
	2 stories or over	3,000	4,000	5,000
	When sprinklered	5,000	6,750	8,500

All Class A buildings except office buildings of Type 1 shall be divided into areas not exceeding those given in table 51.

Buildings of Types 1 and 3 for storage or manufacture of incombustible materials may be unlimited in area.

Class B buildings shall be constructed of one of the following types of construction:

Sub-Class B–1

If not over one story or 20 ft, 600 ft², any type.

If not over one story or 20 ft, over 600 ft², types 1, 2, 3, or 4.

If not over two stories or 30 ft, Types 1 or 2.

If over two stories or 30 ft, Type 1.

Airplane hangars may be Type 5. The height may be more than 20 ft but not more than 30 ft. Area, 10,000 ft²; if sprinklered, 25,000 ft².

Class B–1 buildings shall be divided into areas not exceeding those for class A.

Class B–2 buildings shall be Type 1.

Class B–2 buildings shall be divided by fire walls into areas not exceeding 3,000 ft², openings guarded by Type A fire doors. In buildings for films, area on one floor shall not exceed 7,500 ft².

Private garages, etc., not exceeding 600 ft² may be erected with walls of frame construction.

Class B–3

If not over one story or 20 ft, 600 ft², any type.

If not over one story or 30 ft, over 600 ft², Types 1, 2, 3, or 4.

If over one story or 30 ft, Type 1.

Class B–3 buildings shall be divided into areas not exceeding those for Class A buildings.

Class C buildings shall be one of the following types, except schools over one story shall be Type 1. The area may be increased 50 percent when sprinklered.

If not over one story or 20 ft, 5,000 ft², any type.

If not over one story or 40 ft, 20,000 ft², roof and balcony may be Types 1, 2, or 3; first floor shall be Type 1, exterior of masonry.

If not over two stories or 40 ft, 5,000 ft², Types 1, 2, or 4.

If not over two stories or 40 ft, 10,000 ft², Types 1 or 2.

If over two stories or 40 ft, 10,000 ft², Type 1.

Class D buildings

Seating capacity not over 600, Type 1 or 2.

Seating capacity over 600, Type 1.

Class E buildings shall be constructed of one of the following types:

Class E–1

If not over two stories or 35 ft, 5,000 ft², Types 1, 2, 4, or 5.

If not over three stories or 45 ft, Types 1, 2, or 4.

If over three stories or 45 ft, Type 1.

Class E–2

If not over two stories or 35 ft, Types 1, 2, or 4.

If over two stories or 35 ft, Type 1.

Sanitariums not over one story or 15 ft, no basement, 1,500 ft², may be Type 5.

Class E–3. No height limitations, Type 1 required.

Class E buildings other than Type 1 shall be divided into fire areas not to exceed 5,000 ft².

Class F buildings shall be built of one of the following types of construction:

If not over two stories or 35 ft, Types 1, 2, 4, or 5, except that single- or two-family dwellings only may be built of frame construction of not over two and one-half stories high.

If not over three stories or 45 ft, Types 1, 2, or 4.

Class F buildings other than Type 1 construction shall be divided into fire areas of 5,000 ft².

Miscellaneous Structures

Grandstands of wood, 5,000 ft². The highest level of seats shall not be more than 20 ft above ground level and no part of canopy shall exceed 30 ft above ground level.

4. Atlanta

(a) *Heights of Buildings*

No building or structure hereafter erected, except church spires, water towers, smoke stacks or chimneys, shall exceed the limits given in table 52 with the following qualifications:

Table 52.—*Height limitations of buildings, Atlanta code*

Type of buildings	Height	
	Feet	*Stories*
Frame buildings other than dwellings or apartments	30	2
Frame dwellings and apartments not more than two families	30	2½
Buildings having bearing walls of hollow terra cotta or concrete blocks	40	3
Non-fire-resistive buildings, ordinary construction	55	4
Non-fire-resistive buildings, mill construction or metal joist construction:		
Without sprinklers	65	5
With sprinklers	75	6
Fire-resistive buildings	150	14

Group I, Public Buildings, Class B.—Buildings of this class over three stories or 40 ft high, shall be of fire-resistive construction, except that church spires need not be fire resistive unless they exceed 75 ft in height.

Group III, Business Buildings, Class F.—Outside of fire limits for isolated buildings or plants of a character not usual to city industries, such as cotton mills, the height in feet may be increased 50 percent over that permitted in table 52, but not to exceed 125 ft, and the area may be increased 60 percent over that permitted under Allowable Floor Areas, table 54(c), "with sprinklers."

(b) *Allowable Floor Areas*

In every building of the character named in this section the maximum area of any floor between fire walls or exterior walls, either without or with a full equipment of automatic sprinklers shall be as given in tables 53 and 54, unless otherwise qualified.

Unless all floor openings are protected, areas in buildings equipped with automatic sprinklers shall not exceed 50 percent greater than that allowed for similar buildings not so equipped but occupying similar location as to streets.

Table 53.—*Allowable areas for buildings of non-fire-resistive construction, Atlanta code*

Fronting on—	Without sprinklers	With sprinklers (increase 100 percent)
(a) Apartment houses, 3,000 ft²		
(b) All other ordinary non-fire-resistive buildings, heights not exceeding 55 ft		
	ft²	*ft²*
One street	5,000	10,000
Two streets	6,000	12,000
Three or more streets	7,500	15,000
(c) Mill-construction buildings, height limit 65 and 75 ft		
One street	6,500	13,000
Two streets	8,000	16,000
Three or more streets	10,000	20,000

TABLE 54.—*Allowable areas for buildings of fire-resistive construction, Atlanta code*

Fronting on—	Without sprinklers	With sprinklers (increase 100 percent)
(a) All buildings of class A, B, C, and D; Light and power stations; Office buildings	No restrictions as to area	
(b) All other buildings not exceeding 65 ft in height		
	ft^2	ft^2
One street	10,000	20,000
Two streets	12,000	24,000
Three or more streets	15,000	30,000
(c) Stores, warehouses, factories, and workshops		
One street	7,500	15,000
Two streets	10,000	20,000
Three or more streets	12,500	25,000

(d) The first floor only of any fire-resistive building occupied as a store may have an area of 20,000 ft^2, and if fully protected by approved automatic sprinklers may be increased 100 percent or have a maximum area of 40,000 ft^2.

(*c*) *Frame Buildings Outside of Fire Limits*

1. No frame building shall exceed two stories or 35 ft. in height, except that dwellings may have two-and one-half stories, provided they do not exceed 35 ft. in height or 3,000 ft^2 in area.

2. No frame building, erected for any occupancy other than buildings of Class F, shall cover a ground area exceeding 5,000 ft^2, except as modified in paragraph 4 below; except also that a frame building equipped with an approved system of automatic sprinklers may have an increase in area of 66⅔ percent, or a total of 8,333 ft^2.

3. Frame buildings of Class F, and frame buildings of other classes having an area exceeding 5,000 ft^2 without sprinklers, shall not be placed within 35 ft of any side or rear lot line; 7,500 ft^2, 100 ft.

4. The combined area of frame buildings, sheds, and outhouses located on any lot shall not exceed 80 percent of the lot area.

5. Outside of fire limits for isolated buildings or plants of a character not usual to city industries, such as cotton mills, the area may be increased 60 percent over that permitted in non-fire-resistive construction given in table 53 (c), "with sprinklers."

5. DENVER

(*a*) *Restrictions Based on Types of Construction*

Type I. The height of Type I buildings shall not be limited.

Type II. Buildings shall not exceed a height of 65 ft. Floor areas are limited by occupancy requirements.

Type III. Buildings shall not exceed a height of 45 ft in which height there shall be not more than three stories. Floor areas are limited by occupancy requirements.

Type IV. Buildings shall not exceed a height of one story and a mezzanine floor, except that buildings of Group I occupancy may be two stories in height. Floor areas are limited by occupancy requirements.

Type V. Buildings shall not exceed a height of 25 ft, in which height there shall be not more than two stories.

(*b*) *Restrictions Based on Occupancy*

Group A.—Type I construction required, otherwise no restrictions.

Group B.—Heights and areas to be limited according to table 55.

TABLE 55.—*Height and area limitations for Group B buildings, Denver code*

Type of construction	Maximum height for corresponding areas		Maximum floor areas: Building front on— One street	Two streets	Three streets	Increase for complete sprinkling
	ft [a]	*Stories* [a]	ft^2	ft^2	ft^2	*Percent*
I	65	5	6,500	9,500	12,000	100
II	65	1	12,500	16,000	20,000	
III	45	3	5,000	6,500	9,500	100
	35	1	7,500	9,500	12,500	
IV	[a]	1	16,000	19,000	22,000	100

[a] No restrictions.

Group C.—Type I construction required with certain exceptions, otherwise no restrictions.

Group D.—Type I construction required, otherwise no restrictions.

Group E.—Heights and areas to be limited according to table 56.

TABLE 56.—*Height and area limitations for Group E buildings, Denver code*

Type of construction	Maximum height for corresponding areas		Maximum floor areas: Building front on— One street	Two streets	Three streets	Increase for complete sprinkling
	ft [a]	*Stories* [a]	ft^2	ft^2	ft^2	*Percent*
I	65	5	5,000	6,500	9,500	100
II	65	1	9,500	12,500	16,000	
III	45	3	5,000	6,500	9,500	100
	35	1	7,500	9,500	12,500	
IV	45	1	9,500	12,500	16,000	100

[a] No restrictions.

Group F.—Same as Group B.

Group G.—Types I, II, III, same as Group B. Type IV, no restrictions.

Group H.—Same as Group B except Type IV is limited to 45 ft height.

Group I.—No restrictions except as limited in height by type of construction.

Group J.—The floor area of Types I and II construction shall not be limited, the floor area of Types III and IV shall be limited to 10,000 ft² and buildings of Type V construction shall not exceed 1,000 ft.² The latter shall not apply to amusement-park structures of the open skeleton-framed type or to stadiums or reviewing stands for temporary use only.

6. Seattle

(*a*) *Maximum Building Heights*

No building shall exceed a height of two and a half times the width of the widest street on which the building abuts, except that towers for occupany may be erected above said height if they are at least 25 ft from any lot line other than a street line; if they do not exceed an area of 25 percent of the lot area; and if they do not exceed 50 ft in length and breadth.

Work shops and factories other than feed and flour mills, shall not exceed a height of 85 ft. Stores, warehouses, and storage garages shall not exceed a height of 100 ft.

Height of Fireproof Buildings.—No fireproof building shall exceed a height of two and a half times the width of the widest street on which the building abuts, except that towers for occupany may be erected above said height if they are at least 25 ft from any lot line other than a street line, if they do not exceed an area of 25 percent of the lot area, and if they do not exceed 60 ft in length or breadth.

Fireproof workshops and factories, including feed mills and flour mills, shall not exceed 200 ft in height. Fireproof stores, warehouses, and storage garages shall not exceed a height of 125 ft.

Steel-Joist Construction.—Steel-joist construction may be used wherever mill, ordinary masonry, or frame construction is permitted by this code.

In addition, a building of this class may be built to a greater height than permitted for a mill building, provided that the occupany is that of an office building fireproof through the third floor; place of habitation or place of refuge fireproof through the second floor.

Steel-joist construction in which the joists have a web thickness of 0.2 in. or less shall not be used in the construction of any story of a building below the top 10 stories nor in any building which exceeds 15 stories in height.

Steel-joist construction in which the minimum thickness of web is greater than 0.2 in. may be used at greater heights, but shall not be used in the construction of any story of a building below the top 15, nor in any building which exceeds 20 stories in height.

Height of Mill Buildings.—No mill-construction building shall exceed a height of six stories or 75 ft, nor shall it be higher than 85 ft at any point.

Height of Ordinary Masonry Buildings.—No ordinary masonry building shall exceed a height of four stories or 50 ft, nor shall it be higher than 60 ft at any point.

Height of Frame Buildings.—No frame building shall exceed a height of three stories or 35 ft, nor shall it be higher than 45 ft at any point.

(*b*) *Maximum Building Areas*

In any building, a floor occupied as a place of habitation, refuge, or detention shall, except as hereinafter provided, be divided by fire walls, so located that the area of the floor shall not exceed the number of square feet indicated below:

Mill buildings	12,000
Ordinary masonry buildings	8,000
Frame buildings	6,000

In any building, a floor occupied by one or more stores, offices, factories, workshops, garages, warehouses, stables, hangars, or for purposes producing equivalent fire hazard, shall except as hereinafter provided, be divided by fire walls so located that the area of no floor shall exceed the number of square feet indicated in table 57, except that fireproof office buildings are not limited as to the area of any floor used exclusively for office purposes.

Table 57.—*Permissible areas of commercial buildings, Seattle code*

Location	Fireproof buildings	Mill buildings	Ordinary masonry buildings	Frame buildings
	ft²	*ft²*	*ft²*	*ft²*
On lots with more than one street frontage	20,000	15,000	10,000	8,000
On lots with only one street frontage	18,000	14,000	9,000	7,200

Buildings Housing Incombustible Materials.—In the Fourth Building District, one-story factory buildings manufacturing exclusively products which are mainly composed of incombustible materials, and one-story warehouses used entirely for the storage of incombustible materials, are not restricted as to the undivided floor area of the first story if the building is constructed of fireproof, mill, or ordinary masonry construction, or frame construction having floor, roof, and wall sheathing of 2- by 6-in. tongue-and-groove lumber, etc., or when the building is constructed of equally fire-resistive material.

If located in the Fourth Building District, two-story fireproof, mill, ordinary masonry, or frame buildings, providing the latter are constructed as specified in this section for one-story frame buildings, may, if used exclusively for the manufacturing therein of products which are composed mainly of incombustible materials, have undivided first- and second-floor areas one-third greater than indicated in the above table.

In the Second and Third Building Districts, either one-story fireproof warehouse buildings or one-story warehouse buildings built entirely of incombustible materials may be constructed and may have unlimited undivided areas, provided such warehouses are used for the storage and handling of nothing but incombustible materials, and are not nearer than 15 ft to any frame building, except where separated by masonry division walls.

Provided further, that any building having floor

areas increased as permitted above shall be equipped in each story with one or more 2-in. standpipes, etc.

Allowable Floor Areas with Sprinklers.—A store building of fireproof construction having all floor openings not specifically exempted enclosed with fireproof construction and fire doors, is not restricted as to its undivided floor area, provided such building is equipped throughout with an automatic sprinkler system constructed as specified.

The allowable floor area of any building having its stairways, elevator shafts, and other floor openings enclosed as required by this code, and having its means of egress complying in all respects with this code, may be increased 100 percent if the building is equipped throughout with an automatic sprinker system.

Attic Division.—In nonfireproof buildings, all attics or unfinished spaces between the ceilings and roofs must be divided into compartments having areas not to exceed 3,600 ft².

In fireproof buildings the attic space shall not be used where temporary wood roofs are permitted. Such attic shall be divided into areas not to exceed 1,800 ft².

Incombustible Service Stations and Auto Parking Lot Shelters.—Incombustible service stations may comprise more than one building. All such buildings . . . shall be included in computing the allowable area . . . An incombustible service station shall not be larger than 3,000 ft² in area.

Incombustible shelters on auto parking lots shall have no greater area than 50 ft.²

V. PERMISSIBLE MATERIALS

1. New York

Class I. Fireproof Structures

Walls.—Masonry or reinforced concrete or masonry in combination with fireproofed iron or steel.

Structural Members.—Steel, iron, or reinforced concrete.

Floors.—Reinforced concrete, brick, or hollow-tile arches, reinforced poured gypsum or precast units.

Roofs.—Same as floors except protection may be omitted from roof trusses: (1) in one-story structures, (2) in multistory structures if supporting roof loads only and there is a clear height of 20 ft below lower chord of trusses, (3) if a continuous ceiling having a fire-resistance rating of 3 hr is provided below lower chord of truss and space above ceiling is completely enclosed and firestopped, and contains no passageways or apparatus of any kind.

Trim and Finish Floors.—May be of wood in buildings 150 ft or less in height. No height limitation if wood is treated to make it fire resistive.

Doors, Frame, and Sash.—May be of wood in buildings 150 ft or less in height, with no height limitation if wood is treated to make it fire resistive, except that exterior window frames and sash to be of incombustible materials throughout full height in buildings over 150 ft in height.

Subdividing Partitions.—To be of incombustible materials or wood treated to render it fire resistive, except that in spaces without combustible occupancies, such as require a permit from the fire commissioner, partitions may be of a single thickness of wood, or wood and glass may be used in structures 150 ft or less in height to subdivide rooms or spaces 5,000 ft² or less in area, if separated from adjoining rooms or spaces, corridors, elevators, and stair enclosures by fireproof partitions or walls made of incombustible materials.

Roof Coverings.—Required to pass specified tests.

Class II.—Fire-protected Structures

Walls.—Masonry or reinforced concrete or masonry in combination with fireproofed steel or iron.

Structural Members.—Steel, iron, or reinforced concrete.

Floors.—Reinforced concrete slabs, brick, or hollow-tile arches, reinforced poured gypsum or precast units.

Roofs.—Same as for Class I, Fireproof Structures.

Trim and Finish Floors.—Interior doors and sash with their frames, trim and casings and finish floors may be of wood.

Roof Coverings.—Required to pass specified test.

Class III. Nonfireproof Structures

Exterior and Fire Walls.—Masonry or reinforced concrete.

Structural Framework.—Wood or unprotected steel or iron.

Floors.—May be of wood except in residence structures more than three stories and basement in height and in other structures four stories or more in height, the floor above cellar or basement and columns below such floors are to be of masonry, reinforced concrete or fireproofed steel or iron.

Roofs.—Wood sheathing.

Trim, Doors and Finish Floors.—May be of wood.

Stair Enclosures and Shafts.—Incombustible materials.

Roof Coverings.—Required to pass specified test.

Class IV. Wood Frame Structures

Footings, foundations and columns or other supports of first-floor framing to be of incombustible materials.

Exterior and interior construction and finish may be of wood.

Roof Coverings.—Required to pass specified test.

Class V. Metal Structures

Exterior Walls.—Metal, flat or corrugated, cement-asbestos composition sheets, or of incombustible material other than masonry.

Structural Framework.—Metal.

Roofs.—Same as for exterior walls.

Roof Coverings.—Required to pass specified test.

Class VI. Heavy Timber Structures

Exterior Walls.—Masonry or reinforced concrete.

Structural Framework.—Wood. Beam and girders not less than 6- by 10-in. Posts or columns not less than 8 in. If steel is used, it must be protected as for Class II construction.

Floors.—Splined or T & G plank 3 in. thick covered with 1-in. flooring laid crosswise or diagonally or planks set on edge, floor 4 in. thick.

Floor immediately over basement or cellar and all construction below it, including columns, same as for Class II construction.

Roof.—Planks 2½ in. thick and beams supporting roof not less than 6 in. in smallest dimension.

Shafts and Stairways.—Enclosed in materials or assemblies having a fire-resistance rating of at least 2 hr.

Roof Coverings.—As required by zoning.

2. Boston

Type I. Fireproof Construction

Shall be of incombustible materials in all structural parts.

Walls.—(4 hr) Reinforced concrete, masonry, or steel frame. May be finished except on the outside of exterior walls and within enclosures of vertical openings with wooden or other combustible wainscoting, insulating, or acoustical material.

Columns and Framing.—(4 hr) Structural steel or reinforced concrete.

Floors.—(3 hr) Steel, reinforced concrete, brick or structural clay tile arches, reinforced gypsum, or combinations of these materials or other approved systems.

Roofs.—(3 hr) Steel, reinforced concrete, brick or structural clay tile arches, reinforced gypsum, or combinations of these materials or other approved systems.

Partitions.—Reinforced concrete, masonry, steel frame, except that within one tenancy nonbearing partitions may be of wood.

Flooring, Trim, and Decorative Wall, and Ceiling Finish.—May be wood or other combustible but not highly inflammable material.

Doors, Frames and Sash.—May be of wood except where fire doors or fire windows are required.

Roof Coverings.—Fire retardant (Class A or B) or Ordinary (Class C).

Type II. Semifireproof Construction

Shall be of incombustible materials in all structural parts.

Walls.—(4 hr) Reinforced concrete, masonry, or steel frame. May be finished, except on the outside of exterior walls and within enclosures of vertical openings with wooden or other combustible wainscoting, insulating or acoustical material.

Columns and Framing.—(2 hr) Structural steel or reinforced concrete.

Floors.—(1 hr) Incombustible materials.

Roofs.—(1 hr) Incombustible materials.

Partitions.—Reinforced concrete, masonry, steel frame, except that within one tenancy nonbearing partitions may be of wood.

Flooring, Trim, and Decorative Wall and Ceiling Finish.—May be wood or other combustible but not highly inflammable material.

Doors, Frames and Sash.—May be of wood except where fire doors or fire windows are required.

Roof Covering.—Fire-retardant (Class A or B) or Ordinary (Class C).

Type III. Heavy Timber and Masonry Construction

Exterior Walls.—(4 hr) Masonry or other incombustible materials. Interior face may be finished with wood or other combustible wainscoting or acoustical material with no concealed spaces between finish and wall.

Structural Frame.—Heavy timber or protected steel (1 hr), or steel pipe columns filled with concrete.

Floors.—Heavy timber without concealed spaces, or protected steel (1 hr).

Roofs.—Heavy timber without concealed spaces.

Partitions.—Solid wood, or hollow wood filled with incombustible material.

Doors, Frames and Sash.—May be of wood except where fire doors or fire windows are required. Fire doors shall have incombustible thresholds.

Roof Coverings.—Fire-retardant (Class A or B).

Type IV. Light Wood and Masonry Construction

Exterior Bearing Walls.—(4 hr) Masonry or other incombustible materials.

Other Walls.—Wood except party or fire walls.

Structural Frame.—Wood or structural steel.

Floors.—Wood.

Roofs.—Wood.

Partitions.—Wood.

Flooring.—Wood, tile, concrete.

Doors, Frames and Sash.—May be of wood except where fire doors or fire windows are required. Fire doors shall have incombustible thresholds.

Roof Coverings.—Fire-retardant (Class A or B).

Type V. Metal Frame Construction

Walls.—Unprotected metal or other incombustible materials.

Structural Frame.—Unprotected metal or other incombustible materials.

Floors.—Unprotected metal or other incombustible materials.

Roofs.—Unprotected metal or other incombustible materials.

Doors, Frames and Sash.—May be of wood, except where fire doors or fire windows are required.

Roof Covering.—Fire-retardant (Class A or B) or Ordinary (Class C).

Type VI. Wooden Frame Construction

Walls.—Wood.

Structural Frame.—Wood, structural steel, cast iron, or reinforced concrete.

Floors.—Wood.
Roofs.—Wood.
Partitions.—Wood.
Flooring.—Wood, tile, concrete.
Roof Coverings.—Fire-retardant (Class A or B).

3. Minneapolis

Type I. Fireproof

Bearing Walls.—Masonry.
Nonbearing Partitions.—Brick, concrete, concrete block, structural clay tile, plaster on gypsum or metal lath on metal studs.
Vertical Members.—Masonry, concrete, reinforced concrete, or fireproofed ferric materials.
Horizontal Members.—Reinforced concrete beams or lintels, fireproofed steel beams and girders.
Floors.—Any fire-resistant material properly fireproofed, 2-hr rating required. Wood sleepers may be embedded when protected underneath by minimum of 2-in. concrete or gypsum. Floor finish may be of wood not exceeding 1⅛ in. thick.
Roofs.—Any material permitted for floors. Formed steel roofs protected with ceiling not less than ¾ in. permitted in buildings not exceeding three stories in height, but in one-story buildings regardless of height. Roof coverings, incombustible material.
Wood Permitted.—Mezzanine floors to be 1⅝ in. thick. Window frames and aprons, 1st floor. Partitions around cashier's cages, wash stands, lockers, closets. Partitions separating offices within space occupied by same tenant may be wood panel construction. (Wood stud and lath prohibited.) Nailing blocks brick size permitted. Wood trim permitted. Wood doors permitted except to stairs, elevators or other shaft enclosures, fire division walls, closets for gas meters, electric closets communicating with open shaft to other parts of building.

Type II. Slow Burning

Bearing Walls.—Masonry.
Partition Walls.—Fireproof or wood stud, with expanded metal lath and plaster on both sides or any other partition which will withstand a 1-hr fire test. Wood furring and lath prohibited.
Enclosures.—Area over 9 ft², masonry bearing walls, or partition walls of brick, tile, concrete or gypsum 6 in. thick. Under 9 ft², metal lath and plaster on metal studs, supported on steel frame. Enclosures shall be continuous and no wood floor members shall project into or through enclosure partitions.
Vertical Members.—Fireproof or wood posts not less than 56 in.² in cross-sectional area.
Horizontal Members.—Concrete, steel, or wood not less than 52 in.² in section area. Wood joists less than 70 in.² in cross-sectional area solid. Over 70 in.² in cross-sectional area may be built up.
Floors.—Type I, or wood subfloor minimum 1⅝ in. thick covered with waterproof paper and not less than ⅞-in. floor covering. If subfloor is less than 3½ in. thick, it shall be matched. Under side of floor joists shall not be scaled except when sealed with metal lath and plaster. Floors permitted with joists not less than 2 in. thick and having floor as required and protected with a ceiling of metal lath and plaster of ¾-in. minimum thickness.
Roofs.—Similar to floors except 1⅝-in. matched roof, covered with incombustible roofing. One- and two-story buildings only may have ⅞-in. roof boards. Where attic space is used, ¾-in. fireproof protection required. Solid or built up wood roof trusses permitted if compression members exceed 52 in.² with tension members similar or protected with ¾-in. metal lath and plaster.
Stairs.—Fireproof or 1⅝-in. wood flooring, stringers and joists protected on soffits with ¾-in. protection. No wooden stairs or landings shall be in contact with wood floors.
Windows.—May have wood frames except where required to be fire windows.
Bays, Oriels, Porches, Balconies Incombustible.—Cornices, eaves and gutters not extending over lot line on buildings not over three stories or 40 ft may be wood protected with metal. All others incombustible.
Roof Structures.—Towers, dormers, spires and cupolas not over 200 ft² and not nearer than 20 ft to lot line may be wood covered with incombustible material, if not over 30 ft in height from supporting masonry or roof and not over 100 ft from grade. All other structures, incombustible but steel members not fireproofed. Such structures not of incombustible construction sealed at bottom by fire doors or metal-covered doors.
Studies and Dormers.—When less than 200 ft² and not over one story or 16 ft measured from roof on buildings not over three stories or 40 ft may have wood walls metal covered, (No. 26 U. S. gage) and roof as on remainder of structure.

Type III.—Skeleton and All Steel

Walls and Partitions.—Enclosing walls of masonry, or under specified conditions of metal lath and 2-in. plaster, and interior bearing walls of masonry. Interior nonbearing walls, any material permitted in Type II.
Enclosures.—No enclosure required around stairs and shafts except that where there is a basement the stairwell and other openings through first floor shall be enclosed with 8-in. masonry and provided with a self-closing fire door of Type B.
Vertical Bearing Members.—Masonry or cast iron and steel unprotected.
Horizontal Members.—Reinforced concrete, unprotected steel, and wood of sizes permitted in Type II.
Floors.—Where basement is provided, first floor over and walls around and stairs leading to heating-plant room, fireproof construction.
Roof.—Concrete, or steel trusses, or beams with wood purlins with 1⅝-in. thick sheathing for buildings up

to 45 ft in height. Concrete, unprotected steel, with reinforced concrete or gypsum roofs for buildings up to 75 ft in height.

Roofing.—Incombustible.

Windows.—Wood frames except where required to be fire windows.

Trim.—Wood.

Type IV. Ordinary Construction

Enclosing Walls.—Masonry.

Partitions.—Wood studs with wood lath or ⅜-in. gypsum lath plastered or ⅜-in. gypsum wallboard permitted except for fire or division walls, stair, elevator, or shaft enclosures, which shall be brick, structural clay tile, gypsum, or concrete blocks.

Vertical and Horizontal Members.—Below first-floor line: metal, masonry or wood. All other vertical and horizontal members, any material not more combustible than wood.

Floors and Roofs.—Any material not more combustible than wood.

Roof Covering.—Incombustible material.

Bays and Oriels.—Wood covered with No. 26 U. S. gage metal or other material of equal fire rating. Up to two stories.

Porches and Balconies.—When 3 ft from property line and not above third story, wood porches. Above third story, incombustible.

Type V. Buildings of Wood Construction

Foundations.—Masonry.

Structural Members.—Below first floor, girders shall be masonry or metal. Wooden columns may be used in buildings with basements if foundations or footings under posts extend 2 in. above basement floor. Wood and other combustible materials may be used throughout, if fire-stopped at each floor, and the other materials meet same fire rating as pine.

4. Atlanta

I. Frame Construction

May be of wood throughout, except as follows:

Residence Row Houses.—Dividing walls of incombustible materials, or wood studs with spaces filled solidly with incombustible materials and having metal lath and plaster or plasterboard, and, where there are more than 3 houses, alternate division wall of masonry to above roof.

Stairways and Shaft Enclosures.—Wood covered with plaster on metal lath or fiber plasterboard, or with plasterboard covered with metal.

Roof Coverings.—Standard asphalt rag-felt prepared roofings and shingles or equivalent approved and labeled by Underwriters' Laboratories.

II. Non-Fire-Resistive Construction

Exterior and Party Walls:

Ordinary and mill.—Incombustible, except as follows: Wood lintels for openings less than 4 ft, wood nailing blocks, and wood furring fire-stopped with masonry.

Floor and Roof Framing Members:

Ordinary and mill.—Wood or steel; 6-in. minimum wood or steel protected as for Type III in Mill Construction.

Columns or Interior Supporting Walls or Partitions:

Ordinary and mill.—Masonry, protected steel, or 8-in. minimum wood, except in dwellings and other ordinary construction not more than one story in height, wood-stud partitions may be used; steel protected as for Type III in Mill construction.

Walls and Ceilings:

Ordinary.—No limitations except that wood wainscot must have plaster behind it.

Mill.—Wood exposed or protected steel with no concealed spaces.

Partitions:

Ordinary.—No limitations.

Mill.—Incombustible, unless less than four stories, or if sprinklered may be 2-in. solid wood.

Floor and Roof Sheathing:

Ordinary.—No limitations.

Mill.—Floors, 3 in. wood, splined or T & G and covered with 1-in. flooring diagonal or crossways. Roofs, 2½ in. wood, splined or T & G.

Stairways or Shaft Enclosures:

Ordinary.—Except for dwellings same as for Type III, except if not over two stories, walls may be masonry partitions; woodwork other than guides and elevator cars, exposed on inside of shaft, to be covered with metal lath and plaster.

Mill.—Masonry walls except in buildings not over three stories sprinklered or two stories not sprinklered, wood or metal studs with spaces filled with incombustible material and plastered on metal lath; openings to have approved fire doors.

Roof Coverings.—For dwellings and buildings not over two stories or 30 ft high, and 2,500 ft² area, not used for factories, warehouses, or mercantile purposes, may be standard asphalt rag-felt prepared roofing and shingles.

All other buildings shall have roof covering of standard quality, such as brick or concrete surface, clay or cement tile, tin or slate, asbestos shingles ⅛-in. minimum thickness, four-ply built-up pitch and felt with gravel or slag surface, four-ply asbestos-asphalt built up smooth or grit surface, or equivalent approved and labeled by Underwriters Laboratories.

III. Fire-Resistive Construction

Exterior and Party Walls.—Masonry or incombustible.

Floor and Roof Framing.—Masonry or protected structural steel.

Partitions.—Incombustible, masonry or protected steel.

Wall and Ceiling Surfaces.—Incombustible except wood wainscot not more than 3 ft high.

Floor Surfaces.—Wood or other.

Floor sleepers, grounds, bucks, nailing blocks entirely embedded in incombustible materials, may be wood.

Interior windows, doors, with frames, trim and casings, and interior finish.—When backed up solidly with fire-resistive materials, except as otherwise limited, may be of wood.

Stairway and shaft Enclosures.—Masonry walls or partitions with floor surfaces and trim of approved incombustible material.

Roof Coverings.—Same as for Type II.

5. Denver

Type I. Fire-Resistive Construction

Foundations.—Solid masonry or reinforced concrete.

Exterior, Fire, and Court Walls.—Masonry or reinforced concrete.

Structural Framework.—Steel, iron, or reinforced concrete.

Floors.—Reinforced concrete, brick or hollow-tile arches or reinforced gypsum.

Roofs.—Same as floor except that roof members in buildings not over 65 ft high, having 2-hr fire-resistive ceiling beneath, may be of wood.

Partitions.—Incombustible materials except that within one tenancy they may be wood or wood and glass.

Trim and Finish Floors.—May be of wood.

Doors, Frames, and Sash.—May be of wood, except for openings required to be protected.

Insulation.—If in board form and backed with walls and ceilings of 1-hr fire-resistive construction, may be combustible, except in attic and concealed spaces.

Roof Coverings.—Fire retardant.

Type II. Heavy Timber Construction

Foundations.—Solid masonry or reinforced concrete.

Exterior, Fire, and Court Walls.—Masonry or reinforced concrete.

Shaft Enclosures.—Masonry or reinforced concrete except they may be of wood in buildings not over three stories and completely sprinklered.

Structural Framework.—Reinforced concrete, steel, or solid wood.

Floors.—Same as Type I or solid wood.

Roofs.—Same as floors.

Partitions.—One-hour fire-resistive or solid wood.

Trim, Finish Floors.—May be of wood.

Doors, Frames, and Sash.—May be of wood except in openings required to be protected.

Insulation.—If in board form and backed with walls and ceilings of 1-hr fire-resistive construction or applied without air space to under side of floors and roof sheathing may be combustible except in attic and concealed spaces.

Roof Coverings.—Fire retardant.

Type III. Ordinary Masonry Construction

Foundations.—Solid masonry or reinforced concrete.

Exterior, Fire, and Court Walls.—Masonry or reinforced concrete except that gables of Group I (dwellings) and Group J (garages, etc.) may be of wood or unprotected metal frame above the plate line.

Structural Framework.—Steel, iron, reinforced concrete, masonry, or wood.

Floors.—Reinforced concrete, masonry, steel, iron, or wood.

Roofs.—Same as floors.

Partitions and Shaft Enclosure.—May be of wood.

Trim, Finish Floors.—May be of wood.

Doors, Frames, and Sash.—May be of wood except in openings required to be protected.

Insulation.—Combustible insulating materials must be treated to render them slow-burning if placed in concealed spaces.

Roof Coverings.—Fire retardant except in fire zones 3 and 4 where wood shingles and the lighter combustible roofings can be used.

Type IV. Metal Frame Construction

Foundations.—Masonry or reinforced concrete.

Exterior Walls.—Metal or other incombustible materials.

Partitions.—Metal or other incombustible materials.

Structural Framework.—Steel, iron, masonry or reinforced concrete.

Floors.—Incombustible materials or wood planks or blocks laid directly on the earth. In Group I (dwellings) and Group J (garages, etc.), floors may be of wood on metal joists.

Roofs.—Metal or other incombustible materials except that 4-in. or larger wood purlins may be used. For Types I and J occupancies wood sheathing may be used on metal rafters.

Doors, Frames, and Sash.—May be of wood except in openings required to be protected. No opening protection required for Groups I and J occupancies.

Insulation and Linings.—Incombustible except that combustible insulating materials in board form may be used in buildings of Groups I and J occupancies.

Roof Coverings.—To be metal or "Fire Retardant" except that for Groups I and J occupancies "Ordinary" roof coverings including wood shingles may be used in fire zones 3 and 4.

Type V. Wood Frame Construction

Foundations.—Masonry, reinforced concrete, or post and girder. Footings, masonry or concrete.

Exterior and Interior Construction and Finish.—May be of wood.

Insulation.—If in loose form and placed in joist or stud spaces, combustible insulation must be treated to render it slow-burning.

Roof Coverings.—All accepted coverings, except "Fire Retardant" coverings are required in fire zones 1 and 2.

6. Seattle

Fireproof Buildings and Steel Joist Buildings

Except as otherwise provided, these buildings must be constructed entirely of fireproof or incombustible material.

Walls.—Masonry or masonry in combination with fireproofed iron or steel.

Structural Framework.—Masonry, reinforced concrete, or fireproofed steel, for columns, beams, and girders. Where permitted, steel joists having webs more than 0.2 in. thick may be used in buildings not over 20 stories high for the top 15 stories; steel joists having webs 0.2 in. thick or less may be used in buildings not over 15 stories high for the top 10 stories; protected by 1 in. of plaster on metal furring in either case.

Floors.—Concrete or masonry arches.

Roofs.—Same as floors except buildings designed for additional stories may have temporary flat roofs of wood supported on top slab.

Trim.—Wood, when backed without intervening space by incombustible material, except for wainscot in public halls.

Finish Floors.—Wood except in public corridors and enclosures.

Doors, Frames, and Sash.—Wood except where fireproof openings are specifically required.

Roof Coverings.—Coverings corresponding to classes 1 and 2 of this report.

Mill Buildings

Exterior and Court Walls, Piers, and Columns.—Masonry or masonry in combination with fireproofed iron or steel.

Interior Columns.—Wood, not smaller than 10 in.; iron or steel, fireproofed, if carrying masonry walls or floors.

Interior Beams, Girders, Joists, and Stair Stringers.—Structural steel, wood, or fireproof construction. Minimum dimensions of wood, 8 in. for girders and beams, 6 in. for joists, 4 in. for stair stringers. Steel beams in cellars and basements fireproofed or protected with 1-in. plaster on metal lath.

Floors.—Solid wood lower layer and board upper layer. Any space between layers must be filled with incombustile material or firestopped into areas not exceeding 32 ft².

Roofs.—Same as under layer of floor. May be 2-in. tongue-and-groove plank on 4-in. minimum timbers if protected by a suspended plaster ceiling.

Ceilings.—Metal lath and plaster on steel supports if ceiling space is firestopped into areas not exceeding 1,800 ft². Same on wood supports if space is firestopped into areas not exceeding 32 ft².

Partitions.—Fireproof; incombustile; or (a) double plank; (b) single plank plastered both sides; (c) laminated of 2- by 4-in. wood and covered both sides with plaster, 1-in. wood sheathing, plasterboard, ¼-in. asbestos, or galvanized metal with joints locked or lapped 1½ in., (d) 2¼ in. plaster on flat wood studs and lath.

Stairway Enclosures.—In warehouses, factories, and workshops over three stories high, fireproof; three stories or less, two thicknesses of vertically placed matched 1⅜-in. lumber with 30-lb asbestos paper between and joints broken. If stairway leads to place of assembly, habitation, refuge, or detention through first story used for a different purpose, over three stories high, fireproof up to top of second-floor level; three stories or less, two thicknesses of vertically placed 1⅜-in. lumber with 30-lb asbestos paper between and joints broken or a mill building partition. In buildings containing places of assembly or where basements are used for storage or sale of combustible goods or contain a boiler in operation or equivalent hazard, fireproof up to top of ground floor. In buildings over three stories, required enclosure includes halls connecting successive runs of stairs.

Elevator Shaft Enclosures.—In all basements, within 20 ft of stairway, or in buildings used as places of habitation, refuge, or detention; fireproof. Passenger elevator shafts elsewhere, fireproof. If not more than four stories and basement high, solid stud or approved laminated plank construction 3¾ in. thick, in either case lined with tin as for fire doors or plastered both sides. Freight elevator shafts elsewhere 6-ft high solid or open wood or metal wainscot at all floors; in stores, factories, and workshops housing more than 25 employees per freight elevator per floor or more than 100 employees per freight elevator, fireproof or approved laminated plank as for passenger elevators.

Other Shaft Enclosures.—Mill building partitions the solid wood portion of which shall be not less than 4 in. thick, protected on the inside by lath and plaster, two thicknesses of plasterboard or plasterboard covered by sheet metal either lock jointed or lapped at least 1½ in.

Roof Coverings.—Coverings corresponding to classes 1 and 2 of this report.

Ordinary Masonry Buildings

Exterior and Court Walls and Piers.—Masonry or masonry in combination with iron or steel, fireproofed except in first story of one-story buildings.

Interior Framework.—May be wood.

Floors.—At least two thicknesses of wood.

Roof Sheathing.—Tight single thickness of wood.

Partitions and Ceilings.—Plastered if of wood. Metal lath or plasterboard required on all ceilings of basements and cellars except apartments and sleeping rooms, and on the sides and ceilings of public corridors, stair halls, and soffits of public stairs.

Stairway Enclosures.—Same as for mill buildings.

Elevator Shaft Enclosures.—Same as for mill buildings.

Other Shaft Enclosures.—In buildings over three stories high, same as for mill buildings. In buildings of three stories or less, mill building partitions or single 2- by 6-in. lumber, tongue-and-groove, protected on the inside by lath and plaster, two thicknesses of plasterboard, or plasterboard covered with sheet metal either lock-jointed or lapped at least 1½ in.

Roof Coverings.—Coverings corresponding to classes 1 and 2 of this report.

Frame Buildings

May be of wood throughout except as noted.

Plaster.—Required on all frame walls, partitions, and ceilings in places of assembly, detention, or habitation other than a detached one-family residence. Not required in basement of two-family apartment except on ceilings of furnace and habitable rooms. Detached one-family residences over one story high, must have plaster or plasterboard in habitable rooms, bath rooms, halls, and corridors.

Shaft Enclosures.—Same as for ordinary masonry buildings.

VI. REQUIRED DEGREE OF FIRE RESISTANCE OF STRUCTURAL MEMBERS

1. New York

Class 1. Fireproof Structures

	Fire-resistance ratings hr
Exterior walls, fire walls, party walls, piers, columns, and interior structural members which carry walls	4
Other girders, fire partitions, floors including beams and girders, beams, roofs, and floor fillings, required stairway enclosures	3
Required stairway enclosures in schools	2
Permanent interior partitions	1

Class 2. Fire-Protected Structures

Exterior walls, shafts; required stairway enclosures in structures more than 50 ft in height	3
Required stairway enclosures in structures 50 ft or less in height	2
Protection of structural members in exterior walls, those which support walls, shafts, and interior columns in public and commercial buildings	3
Protection of interior columns in residence structures	2
Floor above cellar or basement	3
Other floors and roof	1½
Other walls and partitions	1

Class 3. Nonfireproof Structures

Exterior walls	3
Floor above cellar or basement and columns below such floors (except in residence buildings three stories and basement or less in height and other structures not over four stories or 40 ft in height)	3
Shafts and required stairway enclosures except as below	2
Shafts and required stairway enclosures in residence buildings, three stories and basement or less in height and in other structures not over four stories or 40 ft in height	1

VI. REQUIRED DEGREE OF FREE RESISTANCE OF STRUCTURAL MEMBERS—Con.

1. New York—Continued

Class 6. Heavy Timber Construction

	Fire-resistance ratings hr
Exterior walls	3
Shafts and required stairway enclosures	2

2. Boston

Type I. Fireproof

Exterior bearing walls and frames	4
Floors and roofs	3

Type II. Semifireproof

Exterior bearing walls	4
Columns and frames	2
Floors and roofs	1

Type III. Heavy Timber and Masonry

Exterior bearing walls	4

Type IV. Light Wood and Masonry

Exterior bearing walls	4

3. Minneapolis

Requirements are not expressed in degree of fire resistance.

4. Atlanta

Requirements are not expressed in degree of fire resistance.

5. Denver

Type I. Fire-Resistive Construction

Exterior bearing walls, firewalls, and fire-division walls	4
Other exterior walls and inner court walls	3
Partitions (except that partitions within 1 tenancy can be ¾-in. wood or wood and glass)	1
Enclosure of vertical openings	2
Structural members (buildings more than 8 stories, 85 ft)	4
(buildings 8 stories, 85 ft or less)	3
Floors (buildings more than 8 stories, 85 ft)	3
(buildings 8 stories, 85 ft or less)	2
Roofs, same as floors except (a) that the framing may be unprotected if there is a 3-hr ceiling separating it from the top story, and (b) that the roof construction may be of non-fire-resistive construction if the building is not over 65 ft in height and there is a 2-hr self-supporting ceiling separating it from the top story.	

VI. REQUIRED DEGREE OF FIRE RESISTANCE OF STRUCTURAL MEMBERS—Con.

5. Denver

Type II. Heavy Timber Construction

	Fire-resistance ratings hr
Exterior and inner court walls and fire walls	4
Partitions	1
Partitions may be of 2 layers of 1-in. matched boards.	
Enclosure of vertical openings	2
For completely sprinklered buildings not over 3 stories in height the enclosures may be of wood.	
Structural members—	
Columns, steel or reinforced concrete	3
Columns, 8 in. wood minimum are permitted.	
Beams and girders, steel or reinforced concrete	2
Beams, 6 in. wood minimum are permitted.	
Floors, steel or concrete	2
4 in. solid wood floors are permitted.	
Roofs, 2½ in. solid roof sheathing is permitted.	

Type III. Ordinary Masonry Construction

Exterior and inner court walls and fire walls	4
Partitions (bearing) except Groups I and J occupancy	1
Enclosure of vertical openings	1

Type IV. Metal Frame Construction

No requirements except fire walls	4

Type V. Wood Frame Construction

No requirements except fire walls	4

6. Seattle

Requirements are not expressed in degree of fire resistance.

VII. PERMISSIBLE OCCUPANCIES

1. New York

Class 1. Fireproof Structures.—All occupancies.

Class 2. Fire-Protected Structures.—All except certain public occupancies.

Class 3. Nonfireproof Structures.—All except special occupancies.

Class 4. Wood Frame Structures.—Residence, public, and certain business occupancies.

Class 5. Metal Structures.—Commercial occupancies.

Class 6. Heavy Timber Structures.—All except certain public occupancies.

2. Boston

Type I. Fireproof.—All occupancies.

Type II. Semifireproof.—All occupancies except theaters and detention buildings.

Type III. Heavy Timber and Masonry.—All occupancies except theaters and detention buildings, and in first and second zones, schools.

Type IV. Light Wood and Masonry.—All occupancies except theaters, schools in the first and second zones, detention buildings, and public garages and dry-cleaning establishments more than two stories or 600 ft².

Type V. Metal Frame.—All occupancies except theaters, schools in the first and second zones, detention buildings, and large dwellings.

Type VI. Wooden Frame.—All occupancies except theaters, schools in the first and second zones, detention buildings, public garages, dry-cleaning establishments, and certain garages for six cars or less.

3. Minneapolis

Type I. Fireproof.—All occupancies.

Type II. Slow Burning.—All occupancies except theaters seating more than 600, Class B–2 and E–3.

Type III. Skeleton and All-Steel.—Class A, B–1, B–3, and C, permitted; other occupancies prohibited.

Type IV. Ordinary.—All occupancies except Clsas B–2, E–3 and theaters.

Type V. Frame.—Class A, B–1, B–3, C, E–1, and F occupancies permitted.

4. Atlanta

Frame Construction.—Class B, C, D, and E occupancies permitted.

Non-Fire-Resistive Construction:

Ordinary Construction.—Certain schools of Class A occupancy, and Class B, C, D, and E occupancies permitted.

Mill Construction.—Certain Schools of Class A occupancy, Class B, C, D, and E, and Class F except garages, oil houses, oil refineries, rendering plants, smoke houses, varnish works, etc., permitted.

Fire-Resistive Construction.—All occupancies permitted.

5. Denver

Type I. Fire-Resistive Construction.—All occupancies.

Type II. Heavy Timber Construction.—All occupancies except Groups A, C, and D permitted. However, one-story schools with not over four classrooms and private schools having not more than 25 students are permitted under this construction.

Type III. Ordinary Masonry Construction.—All occupancies except Groups A, C, and D permitted. Same exceptions as for Type II.

Type IV. Metal Frame Construction.—All occupancies except Groups A, C, and D permitted. Same exceptions as for Type II.

Type V. Wood Frame Construction.—Groups I and J occupancies permitted.

6. Seattle

Fireproof Construction.—All occupancies.

Steel Joist Construction.—All occupancies.

Mill Construction.—Churches, capacity up to 1,750; assembly halls, capacity up to 1,500; assembly halls used exclusively for dancing, seating capacity up to 3,000; theaters outside First and Second Building Districts, capacity less than 750; theaters outside First Building District, one story, capacity not over 1,000; schools, three stories and basement, capacity 1,000; places of refuge and detention, three stories.

Ordinary Masonry.—Churches, capacity 750; theaters outside First and Second Building Districts, capacity less than 750; schools, capacity 300 or less, not over two stories; garages, not more than 550 ft².

Frame Construction.—Churches, capacity 750; schools not over two stories and basement, capacity 300; garages, 550 ft².

VIII. DISCUSSION OF CURRENT BUILDING CODE RESTRICTIONS IN THEIR RELATION TO TYPES OF CONSTRUCTION

1. Classification of Buildings by Type of Construction

A review of the classifications in the six codes cited above indicates that the types defined could be placed in four groups, as recommended in the present report, as far as the application of restrictions related to fire safety is concerned. Thus, if the Fireproof type is taken to comprise a range in fire resistance of structural members, it can include also the Fire-protected type (New York), and Semifireproof type (Boston). The Incombustible type defined in this report would include Metal, Metal Frame, and All-Steel structures as defined in the different codes, although the present report contemplates a wider application of this type in point of permissible number of stories and occupancies, and degrees of fire resistance are specified considerably above those of unprotected metal members.

As has been previously indicated, light wood interior construction, by the application of firestopping and suitable finishes, can be made fully as fire resistive as heavy timber construction. Hence, buildings having exterior masonry walls and light or heavy interior wood or other non-fire-resistive framing (Classes 3 and 6, New York; Types III and IV, Boston and Denver; Types 2 and 4, Minneapolis; Types IIa and IIb, Atlanta; and Mill and Ordinary Masonry, Seattle) can be placed in one group defined herein as Exterior-Protected. This leaves structures defined as Frame or Wood Frame comprising those classified in this report under Wood Construction.

2. Occupancy Classifications

In the Seattle code there are no occupany classifications and in the other codes there are from three to ten with two or three subdivisions within some of them. It appears that if an occupancy classification is to serve its purpose, each class should not cover too wide a range in conditions otherwise general requirements applied from the occupancy standpoint may not be equitable for the whole range. There can be little objection to the more detailed classifications from the standpoint of clarity and enforcement, since the name of the occupancy serves in large part as a definition and other defining conditions can be readily applied.

In the present report, data are given by means of which the fire hazard as it concerns fire effects on structural members can be defined in terms of the combustible content of buildings, and this is indicated as having a general relation to the kind of occupancy involved. However, the hazard to occupants is not thus as well defined since this depends in part on the flammability as well as the amount of combustibles and on the number, distribution, age, and physical condition of the occupants. Hence, it is believed that restrictions can be best applied in relation to occupancy when the latter is defined in as much detail as is deemed practical for building code purposes.

3. Fire Zoning

While up to four fire zones, including the unrestricted area, are established by these codes, in no case do the restrictions on construction for the first fire zone go as far as justified for the congested high-value districts in our large cities, where Fireproof construction might be required except for small buildings of types herein defined as Incombustible or Exterior-Protected. For other than the larger cities, such rigid restrictions may not be justified, any distinction between requirements for the first and second fire zone, as exemplified in these codes, being in the extent to which unprotected metal and wood construction are permitted. Except as may be deemed necessary on account of variations in the geographic or other features of the area covered, there appears to be little need for establishing more than three fire zones, inclusive of the outer or unrestricted area.

4. Spacing from Adjacent Construction or Property Line

It is noted that restrictions of this type while differing widely are based on both type of construction and occupancy. In some cases the location of small buildings, such as private garages, is less restricted than of large buildings.

5. Height and Area Limitations

Only in the Atlanta code is there a general height limitation (150 ft) applied to buildings of the Fireproof type where also areas are limited to 10,000 to 40,000 ft² for some occupancies. In Seattle the height except for towers is limited to two and one-half times the width of the widest street on which the building abuts and for some commercial occupancies further height limitations and also area limitations are applied. In Boston the height of hazardous commercial buildings of the Fireproof type is limited to 150 ft and the area to 15,000 to 20,000 ft². In Minneapolis the floor areas in Fireproof buildings over one story in height are limited to

30,000 to 83,000 ft², depending on the number of street frontages and installation of automatic sprinklers. In New York and Denver no height or area restrictions are applied for this type of construction except as may be required by zoning regulations.

The limitations applied to the Incombustible (Metal, Metal Frame, All Steel) type present a wider range and in general are more restrictive than might be considered necessary, particularly if some degree of protection is applied to the metal members. For the other types the requirements are more uniform due apparently in part to more definite type definitions. The heights and areas permitted in some codes for buildings of the Exterior-Protected type appear excessive, and considering available materials and constructions such concessions can hardly be regarded as necessary under normal conditions.

6. Permissible Materials

While for the Fireproof type the structural members are required to be of incombustible materials, there is a wide range in materials permitted for trim, finish, and partitions. According to some of the codes these can be of combustible materials to an extent that offsets largely the basic safety features of the construction. There are notable deviations as concerns the other types of construction although here also differences in permissible materials and their method of application materially affect the status of the building type in its relation to fire safety. Without doubt, practical considerations and the prevailing building practices keep these variations within closer limits than indicated by comparison of the codes.

7. Required Fire Resistance

Whether given in the form of thickness of protecting materials or as periods of fire resistance referenced to the standard furnace test, the code requirements are the same for a given type of construction without reference to the occupancy or associated amounts of combustibles. The 4-hr requirement for exterior walls can be regarded as excessive as a general restriction, and the same holds for party and fire walls for all but certain commercial occupancies, for which without further provisions it may be insufficient. The fire resistance required for incombustible members in buildings permitted to have interior wood framing is generally in excess of that obtainable with the latter. In some of the codes the requirement for protection of shafts and exit ways is far in excess of that required for safe exit of occupants in point of fire resistance, but not necessarily as concerns smoke-tightness.

8. Permissible Occupancies

The restrictions as to permissible types of construction to accommodate given occupancies are supplemented by height and area limitations, also partly based on occupancy. Distinctions are necessarily largely based on judgment aided by such experience as is applicable. The general limitation of the larger places of public assembly and of detention buildings to those of Fireproof construction appears warranted by the fire record.

APPENDIX B. METHODS OF ESTIMATING FIRE-RESISTANCE PERIODS

Section 1. General Method of Estimating the Ultimate Fire-Resistance Periods of Walls and Partitions

In most cases the fire-resistance period will be determined by the temperature rise on the unexposed side of the wall, and it is on this criterion that the following method of interpolation and extension is based.

According to the general theory of heat transmission, if walls of the same material are exposed to a heat source that maintains a constant temperature of the surface of the exposed side, and the unexposed side is protected against heat loss, the time at which a given temperature will be attained on the unexposed side will vary as the square of the wall thickness. (See "Heat Transmission" by Wm. H. McAdams (1933) and "Mathematical Theory of Heat Conduction" by Ingersoll and Zobel (1913).)

In the standard fire test, which involves specified conditions of temperature measurement and a fire that increases the temperature at the exposed surface of the wall as the test proceeds, the time required to attain a given temperature rise on the unexposed side will be different from where the temperature on the exposed side remains constant at the initial exposure temperature for any period. It has been found that comparisons fairly consistent with test results can be obtained by assuming the variation to be according to some lower power of n than the second. The fire resistance of the wall can be then expressed by the formula

$$R=(cV)^n,$$

where R=fire-resistance period,

c=coefficient depending on the material, design of wall, and the units of measurement of R and V,

V=volume of solid material per unit area of wall surface, and

n=exponent depending on the rate of increase of temperature at the exposed face of the wall.

For walls of a given material and design it was found that an increase of 50 percent in volume of solid material per unit area of wall surface resulted in a 100-percent increase in the fire-resistance period.[1] This relation gives a value of 1.7 for n. The lower value for n as compared with 2 for the theoretical condition of constant temperature of the exposed surface is to be expected as the rising temperature at the exposed surface would tend to shorten the fire-resistance period of walls qualifying for relatively higher ratings.

The fire-resistance period of a wall may be expressed in terms of the fire-resistance periods of the conjoined wythes or laminae of the wall as follows:

If R_1, R_2, R_3, etc.=fire-resistance periods of walls (or component laminae of walls) having volumes of solid material per unit area of wall surface of V_1, V_2, V_3, etc., respectively, also letting c and n be as defined above, then for walls in general,

$$R_1=(c_1V_1)^n,\ R_2=(c_2V_2)^n,\text{ and } R_3=(c_3V_3)^n.$$

The fire-resistance period of the composite wall will be

$$R=(cV)^n,$$

where $V=V_1+V_2+V_3$

and $$c=\left(\frac{c_1V_1+c_2V_2+c_3V_3}{V}\right).$$

Therefore, $$R=(c_1V_1+c_2V_2+c_3V_3)^n$$
$$=(R_1^{1/n}+R_2^{1/n}+R_3^{1/n})^n.$$

Substituting 1.7 for n and 0.59 for $1/n$, the general formula becomes

$$R=(R_1^{0.59}+R_2^{0.59}+R_3^{0.59}\ .\ .\ .\ etc.)^{1.7}$$

It will be noted that the fire-resistance period has been expressed in terms of the fire-resistance periods of the component laminae of the wall, which need not be of the same material and design.

For walls otherwise similar but of different thickness the general formula takes the following form:

$$R_2=R_1\left(\frac{V_2}{V_1}\right)^{1.7},$$

where V_1 and V_2 are the respective volumes of solid materials per unit area of wall surface, and R_2 and R_1 the corresponding fire-resistance periods.

If the fire-resistance period of a wall is known and if it is desired to find the fire-resistance period when one coat of ½-in. 1:3 sanded gypsum plaster is added, the solution is as follows:

$$R=(R_1^{0.59}+0.3)^{1.7}.$$

R_1=fire-resistance period of the unplastered wall in hours;

R =fire-resistance period of the plastered wall in hours;

0.3=an average value derived from tests (use 0.6 if plastered on both sides).

Use 0.37 for one coat of 5/8-in. 1:3 sanded gypsum plaster and 0.75 if plastered on both sides. For ¾-in. thickness of this plaster, use 0.45 for application on one side and 0.90 for plaster on both sides. The value of the constant is directly proportional to the thickness of plaster.

In like manner, it was found that the effect of continuous air spaces separating wythes, or laminae of a wall by distances of ½ to 3½ in. may be estimated by the use of the values 0.3 and 0.6 for one and two spaces, respectively.

Section 2. General Method of Estimating the Ultimate Fire-Resistance Periods of Columns

According to theory, if similar homogeneous columns of the same material are exposed to a heat source that maintains a constant temperature at the surface of the column, the time at which a given temperature at the center of the column is attained will vary as the square of the distance from the surface to the center, or directly as the transverse area of the section. Although

[1] This also corresponds with findings of Menzel, see page 26.

the temperature at the center of the column is not the criterion for determining its ultimate fire resistance, the above theoretical consideration lends support to the conclusion that a substantial increase in fire resistance is to be expected, when the total area of solid material in the transverse section is increased.

(*a*) *Protected Metal Columns*

The fire resistance of protected metal columns, by analogy with the principles applied above for walls, can be expressed approximately by the following formula:

$$R=(F^{1/n}+f^{1/n})^n, \tag{1}$$

where R is the fire resistance of the column, F is the fire resistance attributable to the portion of the protection outside of the lines circumscribing the metal section (outside section), and f is that attributable to the portion within the lines circumscribing the metal section (inside section).

The fire resistance of columns as for walls can be assumed to be a function of the volume of solid material per unit area of outside or fire-exposed surface. The constants for the "outside" and "inside" sections of protected metal columns can, however, not be taken to be the same, and accordingly on the above basis, formula 1 may be written in the form:

$$R=c\left[\left(\frac{D^2-d^2}{D}\right)+(1-a)\frac{d^2}{D}\right]^n \tag{2}$$

or

$$R=c\left(D-a\frac{d^2}{D}\right)^n, \tag{3}$$

where c and a are constants, and D and d are sides or diameters of "outside" and "inside" sections, respectively. As concerns results from fire exposure in the standard furnace test, n can be taken as 1.7. The other two constants can be obtained by solution of one or more pairs of simultaneous equations obtained from results of fire tests of two or more columns of the same material and of similar but unequal sections. With constants thus derived, the formula can be used to interpolate and extend within moderate limits the results of fire tests with a given type of column and protection. It will be used only in the case of structural steel columns with solid concrete protections and all reentrant spaces filled with the concrete. For this condition, a, was found to be 0.4, and c varied with the coarse aggregate used. Accordingly, for structural steel columns with solid protections of concrete, formula 3 becomes:

$$R=c\left(D-0.4\frac{d^2}{D}\right)^{1.7} \tag{4}$$

(*b*) *Reinforced Concrete Columns*

Tests to failure of reinforced concrete columns were limited to columns having fire-resistance periods of less than 4 hr for concrete made with siliceous aggregate and about 7 hr for trap-rock concrete. The columns made with calcareous aggregate concrete and some made with trap-rock aggregate were not tested to failure under the working load and fire exposure, the tests being terminated at 4 or 8 hr. It was found that formula 3, using the same values of c and a as determined for structural steel protected solidly with concrete, could be applied consistently to the results of fire tests of concrete columns. For this purpose d was taken as the diameter or side of the column core. Accordingly, in the case of working loads computed as carried by the core area (which was the method used for the columns tested), the interpolations and extensions were made by the use of formula 4 above.

However, according to present practice, except as it concerns columns heavily reinforced with bands or spiral hooping, the working load is generally computed on the basis of the gross area of the column. This will have the effect of increasing the permissible load on a column of a given size with consequent decrease in its fire resistance. An approximate allowance for this can be made by assuming d to be equal to D.

Accordingly, formula 4 for this condition becomes:

$$R=c(0.6D)^{1.7}. \tag{5}$$

Section 3. Applications Made in the Present Report

Some applications were made of the above methods as limited interpolation and extension of related test data, which are noted under ratings for load-bearing masonry walls (p. 26), masonry partitions of structural clay tile and hollow concrete units (p. 30), plaster partitions (p. 32), and columns (p. 38). Many of them involve increases in fire resistance due to plaster, allowances for which have been generally made in other compilations of fire-resistance ratings. By the present method the constant representing the increment is added to the 1.7 root of the rating for the unplastered construction and the sum raised to the 1.7 power to give the rating for the plastered construction. This represents a more rational method than a fixed addition to the rating for the unplastered condition and conforms with results of fire tests that indicate quite uniformly an increase in the increment due to plaster with increase in fire rating of the unplastered construction.

In general, the limit to which applications of the methods were made was set by average variations to be expected in results of fire tests of nominally comparable constructions. Accordingly, conservative extension and interpolation of a related line of test data are considered as giving reliability at least comparable to that obtaining for results of individual fire tests. Variability for the latter has been indicated to be as high as 40- to 50-percent deviation from average values, with 5- to 15-percent deviation representing more nearly the average experience. The variability is caused by variations in material, workmanship, and seasoning conditions, such as quality, set, and seasoning of plaster and cement, varying imperfections of joints in masonry, and amount of free water present in the construction at the time of test. The latter is a frequent cause of variation, depending as it does, not only on surface volume-relations and seasoning conditions, but also on the moisture-retentive properties of the materials.

Washington, June 9, 1942.

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