B. S. HANDBOOK SER. No. 19

U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

MANUAL OF FIRE-LOSS PREVENTION OF THE FEDERAL FIRE COUNCIL

NATIONAL BUREAU OF STANDARDS HANDBOOK No. 19

U.S. DEPARTMENT OF COMMERCE
DANIEL C. ROPER, Secretary

NATIONAL BUREAU OF STANDARDS
LYMAN J. BRIGGS, Director

NATIONAL BUREAU OF STANDARDS HANDBOOK No. 19

MANUAL OF FIRE-LOSS PREVENTION

OF THE

FEDERAL FIRE COUNCIL

(Issued November 5, 1934)

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1934

For sale by the Superintendent of Documents, Washington, D.C. - Price 20 cents

PREFACE

In the present manual it is aimed to present concisely the principles on which fire-resistance classifications of building types and building materials are based, general methods for controlling the spread of fire by structural provisions and application of appropriate types of fire-extinguishing equipment, and general fire-prevention measures that can be introduced in the management routine for services and properties.

This manual has been prepared under the auspices of the Federal Fire Council which was organized to serve as a medium of contact between Federal Government Departments and Establishments on matters pertaining to fire prevention and protection. The Council consists of about 60 representatives organized into 4 main committees concerned with different aspects of fire-loss prevention. In addition, the minutes of meetings and formal reports are sent to the chiefs of Federal Government bureaus and also to State and city fire marshals.

By committee activities such as inspections of typical properties and occupancies, meetings of the main group, and dissemination of reports and other informative material, it is hoped to create a continuing interest that will result in materially decreasing the loss from fire. The general means for accomplishing this object include the proper design and construction of buildings, installation of fire-protection equipment to an extent justifiable by the prospective saving in fire loss, and systematic inspection of properties under the direction of those in responsible charge thereof.

LYMAN J. BRIGGS,
Director, National Bureau of Standards;
Chairman, Federal Fire Council.

JUNE 18, 1934.

CONTENTS

MANUAL OF FIRE-LOSS PREVENTION OF THE FEDERAL FIRE COUNCIL

I. INTRODUCTION

1. SCOPE

It is aimed to present herein the essentials relating to design, materials of construction, and equipment and operation of buildings, that effectively prevent or abate loss by fire.

In determining the extent of the treatment under the different subjects, consideration has been given to the degree to which information thereon is extant, particularly as incorporated into the sources on which the designer relies for guidance. Where the knowledge on a subject is not in organized form it is aimed to present it to an extent that will enable decision to be made as to the type and degree of the protection that should be provided. Further information can be obtained from the references listed at the end of the manual, the index numbers of which are given in parentheses in the text dealing with the respective subjects.

2. ARRANGEMENT

An initial discussion is given of justifiable outlay for fire-loss prevention, considering the values and the degree of hazard present. Sections III to VI, inclusive, deal with the fire resistance of building materials, assemblies, and types, control of spread of fire by structural means, and design and arrangement of buildings to secure exit facilities for occupants in case of fire.

In sections VII and VIII, structural and equipment features having a bearing on safeguarding hazards incidental to heating, lighting, and power supply are discussed as also those pertaining to lightning protection, fire hazards during construction, and special occupancy hazards. In section IX protection of records is treated from the standpoint of construction and equipment and in section XIII from the standpoint of business routine and general fire prevention. Sections X and XI deal with equipment for detecting and extinguishing fire.

In section XII general methods for decreasing the ease of origin and initial spread of fire are outlined, and in sections XIV to XVI inclusive, the effective use of equipment in case of fire by prior training for emergency, and the systematic inspection of property to enable unnecessary fire hazards to be promptly eliminated and defects in construction and equipment remedied.

Two general subdivisions of the manual may be noted, namely, construction and equipment up to and including section XI, and fire prevention and maintenance covered in the subsequent sections.

II. CONDITIONS DETERMINING OUTLAY FOR LOSS PREVENTION

1. FIRE-LOSS RATIOS

The general ratio of annual fire loss to value of buildings and contents subject to fire loss is near 0.002, or 20¢ per $100 value, for the range of property insured by stock fire-insurance companies, most of which would have the benefit of public fire protection in addition to some degree of private protection. Farmers' mutual fire-insurance companies have experienced a similar loss ratio on farm and town property having in general little public fire-department protection and practically no protection supplied by the owner. Compared with this, the loss ratio on industrial property, all but a small portion of which is under automatic-sprinkler protection combined with other fire-prevention measures of comparatively high degree of effectiveness, has been only about 0.1 of this figure or near 0.0002, or 2¢ per $100 value subject to loss by fire. It is apparent that at least a part of the saving represented by this difference in loss ratio is offset by the cost of the protection measures employed.

The loss ratio is not known as well for Government property as it is for private property, but considering construction generally of good types from the fire-resistance standpoint, the presence in general of at least fair public and inside protection, good housekeeping conditions, and occupancies generally presenting only light or moderate fire hazard, it apparently should be lower than the general average. Since differences such as those indicated above have a decided effect on the fire loss, it may be justifiable to assume a loss ratio on Government property of no more than 0.001 and it may even be considerably lower than this figure, to judge from the incomplete available data.

2. JUSTIFIABLE EXPENSE FOR PROTECTION

The expense incurred for protection should be proportioned with respect to the reduction in the fire loss that can be produced thereby, and where property loss alone is concerned, it should not exceed the expected saving. While safety to life and uninterrupted functioning of the activities concerned may justify a higher cost, its comparison with a conservative estimate of the property loss to be prevented is of value in such cases also. The annual cost of loss-prevention measures can be taken as the sum of annually recurring items not included under cost of equipment, such as for fire-brigade and watchman service, plus approximately 10 percent of the total initial investment in equipment.

The 10 percent annual charge against equipment can be distributed as 4 percent interest on investment, 4 percent depreciation, and 2 percent for maintenance. In estimating possible reductions in fire loss, consideration must be given to the degree of effectiveness of the measures provided and an annual expense equal to the fire loss expected if the protection were not provided, is justified on the score of property value, only if these measures can be relied upon to reduce the loss to a relatively small amount.

The expense that can, with economy, be incurred depends on the physical value of the property, its value from the standpoint of continuous use and occupancy, and the degree of fire hazard presented, the latter as represented by the loss ratio. High values and hazards may justify an outlay not otherwise warranted. The increase or decrease in hazard with type of occupancy, character of materials, and method of housing are quite marked and the probability of loss can vary from twice to one-half of the general average for no very outstanding differences in such conditions.

As an example, take a four-story and basement fire-resistive building having a contract or present value of $1,000,000 exclusive of ground value. The height above basement slab is 65 ft and the area within exterior walls 40,000 ft^2. The value of contents, including uninventoried values such as records, is $800,000. An additional value of building and contents of $400,000 is added as representing loss in productive value of the activities housed and increase in cost of accommodations that would result in case all portions of the building and contents suffer the maximum expected fire damage. This gives a total for the purpose of determining justifiable cost of fire protection of $2,200,000.

The contents, taken in conjunction with the building design, finish, and occupancy, are deemed to present a low fire hazard. The property has the benefit of good public fire protection with hydrants and alarm boxes located near the building. Under the circumstances a loss ratio without any inside protection, of 0.001 might be assumed, which gives a justifiable annual expense of $2,200 for fire-loss prevention, if the measures provided are such that they will reduce the loss to only a small portion of what would otherwise occur. The portion of the watchman service chargeable to fire protection is taken at $1,000 leaving $1,200 for the annual charge against equipment, which is 10 percent of an initial investment of $12,000. A watchman's clock with key stations, a manual fire-alarm system of the general-alarm type, hand fire extinguishers, and standpipe system with small hose might be installed for about one-fourth of this amount. Neither automatic-sprinkler protection nor automatic fire-alarm equipment can be installed over the whole building for the balance. Some of it may be profitably applied to protect hazardous areas of minor extent, such as by wet-pipe automatic sprinklers where applicable. While a considerable decrease in fire loss can be effected with the protection applied, some loss should be expected and, accordingly, the total annual expense incurred should in general be somewhat less than the fire loss that would be experienced with no inside protection.

As another example, take a building of the same size and cost intended for the handling and storage of combustible stocks, the value of which will be taken as $1,500,000. There will in general be an increase in fire hazard because of larger accumulations and a fire-loss ratio of 0.002 for this property without inside fire protection will be assumed. On this basis for a total value of $2,900,000 the average expected annual fire loss without inside protection would be $5,800. Taking cost of watchman service chargeable to fire protection at $1,500, the maximum justifiable investment for fire-protection equipment would be $43,000. This will usually be found more than sufficient to cover the cost of fire-alarm and watchman's supervisory equipment, hand fire extinguishers, standpipe or other connections for small hose, and automatic-sprinkler protection for the whole building.

3. COORDINATION OF PROTECTION MEASURES

By combining elements of protection entering into the design and materials of construction of buildings and their equipment and management, a high degree of protection can be obtained at lower outlay than if attempted with one of them alone. Nor is it necessary to charge the full cost of all measures effecting a decrease in the fire hazard to fire-loss prevention. The fire-resistive type of building construction meets a number of other requirements than resistance to fire, including relatively low depreciation, greater strength for given sizes of members, and greater resistance to wind and earthquake shock. Inclosure of vertical and horizontal openings and subdivision of large areas to limit the spread of fire do not introduce a large added element of cost. A decided increase in fire resistance of building members can be attained by proper choice of materials and methods of application at little or no additional cost. Water-supply systems both inside and outside of buildings can in many cases be designed to meet the combined demand from domestic consumption and fire service at a considerable saving as compared with the cost of separate systems. In equipping buildings, incombustible filing equipment, furniture, and shelving, while effecting a decided increase in fire safety, cost little more than equipment of combustible materials. Other examples of equipment serving the dual demands of ordinary service and protection against fire will be given in subsequent sections.

Measures under the general designation of fire prevention, intended to prevent or decrease the frequency of occurrence of fire and restricting initial spread thereof, are known to be effective if consistently applied. While dependent on the human element with possibility of lapses, they form an important and necessary part of any fire-loss-prevention program. Establishing conditions that are not conducive to the origin and rapid spread of fire, may not be more difficult than continually contending with a less satisfactory state of affairs and added advantages accrue in greater orderliness and better general maintenance of property.

The relative importance of type of building construction, interior arrangements of building and occupancy, and of protection measures, will vary considerably with occupancy conditions and environment. In a light-hazard occupancy such as an office building, arrangement and construction are clearly of prime importance. For places of public assembly and institutional buildings, arrangement to afford ready means of exit and to prevent initial spread of fire and smoke should receive first consideration. In buildings housing hazardous processes and storage, effective means for discovering and extinguishing fire must be applied if large losses are to be avoided. Next in importance may be proper subdivision of the building, with inclosure of vertical and horizontal communications. The fire-resistive type of building construction usually affords a basis for subdivision into areas restricting spread of fire and smoke, does not itself contribute materially to the spread of fire, and prevents the spread of fire to neighboring construction.

An appreciation of the value of fire-prevention measures and sustained interest therein is essential, beginning with the inception of a building project and extending through the planning, construction, and subsequent use periods. Protection measures are best incorporated integrally into the building and its general equipment with special fire-protection equipment provided where necessary. However, such measures cannot be even moderately effective unless supplemented by subsequent management to give conditions favorable to preventing fire origin and promptly extinguishing any fire that does originate, with well-maintained equipment, automatically actuated or effectively handled by personnel instructed and trained in its use.

III. FIRE-RESISTANCE CLASSIFICATION OF BUILDING MATERIALS, MEMBERS, AND ASSEMBLIES

1. FIRE-TESTING PROCEDURE

There has been developed during the past 3 or 4 decades a basis for classifying, from the fire-resistance standpoint, component construction parts such as floors, walls, partitions, columns, and fire doors, fire windows, insulated safes, and other protection devices (1).[1] The classification is based on resistance to exposure from a furnace fire of controlled intensity, the time limit of performance being determined by criteria such as failure to support applied working load, transmission of flame or of hot gases or temperatures hazardous to combustibles in contact with or near the unexposed side or within the inclosure defined by the assembly. The fire exposure is regulated to obtain as nearly as possible the furnace-temperature indications given in table 1, as determined by prescribed methods.

[1] Figures in parentheses here and elsewhere in the text refer to the references given on pp. 133 to 137.

TABLE 1.—*Furnace temperature control schedule for fire tests*

Time after start	Temperature ° *F*	Temperature ° *C* (*approximately*)
5 min	1,000	538
10 min	1,300	704
30 min	1,550	843
1 hr	1,700	927
2 hr	1,850	1,010
4 hr	2,000	1,093
8 hr or over	2,300	1,260

An average temperature rise above initial of 250° F, 139° C, or a maximum rise at any point of 325° F, 181° C, as measured under asbestos pads placed on the side not exposed to fire, determines the ultimate fire-resistance period for floors, walls, and partitions and for finish protecting combustible members. Qualification based on the hazard created by burning of contained combustible materials is a part of the classification. Somewhat higher temperature limits are taken to apply for fire doors, vault doors, and other opening protectives. For insulated safes a temperature in specified locations on the inside of 350° F, 177° C, must not be exceeded.

Ability to resist the impact and eroding effects of hose streams is also required for floors, walls, partitions, and opening protectives. The pressure at the hose nozzle and duration of water application is varied with the fire-resistance classification of the assembly, the more severe requirements applying for the higher classifications.

Materials such as those used in roof coverings and in sound and heat insulations are subjected to special tests to determine susceptibility to ignition from flame or brands, and the hazard to the surroundings when burning.

2. FIRE-RESISTANCE CLASSIFICATIONS

Based on procedure outlined above, classifications expressed as ultimate resistance in time, to the conditions of the fire test have been established for some types of building constructions in a range of design and materials. As tested according to the latest, 1926, revision of the testing procedure, considerable information is available on columns (2, 3, 4) and on walls and partitions (5, 6, 7, 8, 9). Results of fire tests conducted largely according to earlier American procedure or that used abroad are also informative (7, 8, 10, 11). Fire tests made according to the later procedure and covering the whole field of building constructions have, however, not been made and the fire resistance for some types and materials must be estimated, using the best information available.

Summaries of classifications based on results of tests, supplemented by estimates where test data are lacking, have been made (12, 13). While the publications to which reference is made (see titles in appendix corresponding to numbers given above) should be consulted for the necessary information on fire-resistance ratings, the following is given as indicative of the range in protection obtainable. All values given are based directly on results of tests.

(a) COLUMNS

Unprotected structural-steel columns of section corresponding to that required to support a design load of a little over 100,000 lb fail under load after 10 to 20 min as subjected to the fire test (2). Cast-iron columns of comparable load capacity will withstand the same test for about 30 min. The fire endurance, however, is greatly increased by the application of suitable coverings. In thickness of 2 in., portland cement concrete coverings will give increase to the range 1½ to 7 hr. The lower results are obtained if highly siliceous (quartz, chert) aggregates are used for the concrete, on account of the cracking induced by them as subjected to the sudden temperature rise, effects that can be offset to some extent by embedding metal mesh in the covering. Progressively better results obtain with sandstone, granite, cinders, and trap rock. The highest fire resistance obtains with crushed limestone or calcareous pebbles. Almost any fire resistance required can be obtained by increase in thickness within practical limits, combined with proper choice of aggregates and details of application.

68770—34——2

The fire resistance of reinforced-concrete columns depends also largely upon the mineral composition of the aggregates used. With the more unfavorable aggregate combinations a fire endurance of between 3 and 4 hr obtains for columns of 18 in. outside diameter including a 1½-in. concrete thickness outside of the steel. By the use of metal mesh near the surface, application of plaster, or choice in aggregates, any needed fire resistance can be obtained with very moderate thickness of material as protection for the portion assumed to carry the load (3). Metal binder for concrete protections should have 2- to 4-in. wide mesh and weigh not less than 1½ lb/yd^2 of fabric. With the given sizes of mesh, no considerable obstruction to the placement of the concrete is presented.

With hollow-clay tile applied to steel and cast-iron columns, fire-endurance limits from 1½ to 4 hr obtain, the degree of protection depending more on the type of clay, anchorage of tile, filling of the interior, and other details of application than on the gross thickness of the tile (2). Metal mesh in the horizontal joints holds the tile in place much more effectively when exposed to fire than ties around the outside of the covering. Plaster that remains in place during fire exposure increases the effectiveness of all types of fire-protective coverings by giving added heat insulation and decreasing the disruptive fire effects. Lime plaster generally falls off soon after exposure to fire. Such spalling of gypsum plaster occurs occasionaly but can generally be traced to improper preparation of base or plaster of unduly long time of set. Positive anchorage, such as by **U**-shaped cramps, spanning between holes in ends of adjacent blocks, and embedded in the horizontal mortar joints, is needed for unplastered gypsum-block coverings if their full fire resistance is to be developed. So applied to steel columns, unfilled coverings of 2-in. solid or 3-in. hollow gypsum blocks give ultimate fire-endurance limits of 2½ to 2¾ hr and if plastered, between 4 and 5 hr. Similarly, plastered protection of 2-in. gypsum wood-fibered concrete gives ultimate fire resistance of 7 hr (4).

For fire-resistive buildings unlimited as to height and unsubdivided area, fire resistance for columns of not less than 4 hr has been recommended and where height and area limitations are imposed, not less than 2 or 3 hr. It is, however, generally advisable to design the protection for the severity of fire to be expected as outlined herein in a subsequent paragraph. By proper choice of materials and details this can usually be effected with moderate thickness of protective coverings.

Unprotected timber columns (12 by 12 in.) with exposed steel or cast-iron caps fail under load as exposed to the fire test after 35 to 50 min, the immediate cause of failure being softening of the wood in contact with the metal bearing (2). With caps of reinforced concrete the fire-resistive value of the 12-in. column shaft of about 1½ hr is developed, the wood species included in the tests being longleaf pine and Douglas fir (14).

(b) WALLS AND PARTITIONS

The fire resistance given by walls built of brick, structural (hollow) clay tile, and concrete blocks ranges from a little over 1 hr for 4-in. brick walls to 10 hr or more for 12-in. brick walls or 16-in. walls built of heavy structural clay tile (5, 6, 9). The fire-endurance limit as determined by temperatures developed on the unexposed side, varies approximately with the square of the wall thickness, not including air spaces (law of times) (16). Plaster on one or both sides adds more to the fire endurance than would be expected from the increase in thickness.

Solid plaster partitions 2-in. thick built on metal studs and lath give fire-endurance limits from ½ hr for 1:2½ portland-cement plaster, to 2 hr for neat wood-fibered gypsum plaster, with intermediate values depending on the ratio of cementing materials to sand in the mix (15). Hollow partitions of metal or wood studs covered with plaster on metal lath or perforated plaster board classify as 1 hr or better, depending on the thickness and proportions of the plaster (7, 15). Partitions of hollow gypsum block 3-in. thick, plastered, apparently qualify for the 2-hr rating (7, 11). Other classifications can be determined with fair reliability from tests made according to the earlier testing methods (7, 8, 10), or calculated from results with the same material in a different thickness, applying the "law of times."

Fire and party walls are generally required to have an ultimate fire resistance of not less than 4 hr and inclosures for stair and elevator shafts or partitions with openings that are a part of the exit requirements, 2 to 3 hr, with reduction in some instances for light-hazard occupancies. It is desirable to design fire and party walls for the full severity of the fire to be expected with the building contents. Room and corridor partitions in fire-resistive buildings subdividing areas of 5,000 ft^2 or more, are usually required to have fire resistance of not less than 1 hr as an aid in restricting the spread of fire.

(c) FLOOR BEAMS, GIRDERS, AND SLABS

Classifications for floors must be based largely on tests conducted here and abroad before the latest, 1926, revision of the testing procedure (8, 10, 17). Estimates based on performance of similar materials applied for walls and columns can be made if material subject to cracking and spalling on exposure to fire is adequately anchored. Fire resistance as limited by temperature on the upper surface can be increased by increasing the thickness of fill over the floor as well as by adding to the protection beneath.

For use in fire-resistive buildings, particularly if no limitations on height or unsubdivided area are imposed, 2½- to 3-hr fire resistance is generally recommended for floor beams and slabs (12, 13, 19). This can be attained with 1½- to 2-in. protection thickness on the steel shapes or bars in the beams with portland-cement concrete floor slab 5- to 6-in. thick, depending on the aggregates used, or a poured-gypsum slab 4-in. thick, plastered. For protections placed under and above steel or concrete beams or joists, a suitably anchored soffit covering 1½- to 2-in. thick, combined with a concrete slab over the beams not less than 2 in., and for the thinner soffit coverings, not less than 2½-in. thick, will give the required fire resistance. Little information is extant on the fire resistance of brick and hollow-tile arches, but with a concrete fill above and plaster beneath the given fire resistance should obtain with the thickness of arch required to support the floor load. It is, however, desirable and generally feasible to design for the full severity of the fire to be expected in the given location.

For another type of fire-resistive building, limited as to height and floor area, fire resistance of floor members of 1½ to 2 hr has been recommended. This can be attained with a portland-cement concrete slab 3½- to 4½-in. thick or ¾ to 1 in. of plaster on metal lath beneath steel or concrete joists combined with a top reinforced-concrete or gypsum slab not less than 2-in. thick.

(d) OPENING PROTECTIVES

Classifications up to the present have been based most generally on the requirements for different types of openings (18). These comprise mainly, A, openings in fire or party walls; B, openings in shafts; C, openings in corridor and room partitions; and D, E, F, openings in exterior walls subject, respectively, to severe, moderate, and light fire exposure. Fire doors, windows, and shutters are classified according to performance in tests indicating suitability for the different types of openings (7, 8, 10). Fire doors to be effective as fire barriers should be self-closing and normally remain in the closed position. Where doors, windows or shutters must be open continually or for portions of the day, means should be provided for closure in case of fire, with heat-actuated devices. The following classifications and requirements follow those used by the fire underwriters.

1. *Class A openings.*—For class A openings the protectives are required to be mounted on both sides of the opening with hardware and other fastenings found satisfactory in tests. The general limitations in size depend on the type of door and are given as 8 to 12 ft in height and in width, 4 to 6 ft for swinging single doors, 8 to 12 ft for swinging double doors or sliding doors, and 12 ft for rolling doors. The types listed as satisfactory include hollow metal especially designed for this use, sheet metal, steel rolling, and tin-clad, 3-ply wood-core doors. The openings in fire walls

should be as few as is consistent with the requirements of the occupancy.

2. *Class B openings.*—For class B openings the protectives are mounted on one side of the opening, the limitation in dimensions of openings being within the range indicated for class A openings. The same type of doors adapted for the particular purpose can be used, the tin-clad door being required to have only a 2-ply wood core. Others listed as satisfactory for this type of location are metal-clad paneled doors and steel counterbalanced elevator doors.

3. *Class C openings.*—The protectives for class C openings are mounted in the opening and may be of the general type listed for class B openings, adapted for the purpose and subject to approximately the same limitations in size. Doors may have panels of ¼-in wire glass, individual glass lights not to exceed 1,296 in.^{2} in area.

4. *Class D openings.*—For class D openings in exterior walls, swinging doors and shutters, single or in pairs, of the hollow metal, metal-clad with panels, sheet metal, and tin-clad, 2-ply core types, are regarded as satisfactory, as also the rolling steel shutter. Sliding shutters are not recommended for installation on the outside of buildings since snow and ice may accumulate on the track. At least 1 shutter in 3 above the first story and below the seventh must be hung so it can be operated from both inside and outside and marked for identification by the fire department.

5. *Class E and F openings.*—For classes E and F openings in outside walls subject to moderate or light fire exposure, the same types are recommended as for class D openings, with the addition of hollow-metal window casements. The limit of size for metal frames containing glass or sash is given as 7 by 12 ft, the area of any wire glass light not to exceed 720 in.^{2} for class E openings and for both this class and class F openings the maximum dimension of glass recommended is 54 inches.

6. *Openings into vaults and record rooms.*—Doors in openings into fire-resistive vaults are rated as 2-, 4-, or 6-hr doors as based on performance in fire tests (20). In order

to qualify for these ratings insulation thicknesses from 2 to 5 in. are required in addition to proper details of door jambs and frames. A lighter door qualifying for a ½-to-1-hr rating is recommended for openings into record rooms. The uninsulated type plate steel vault door that was used almost exclusively until within the past 10 yr, has in a fire test given a performance qualifying it for a ½-hr rating.

(e) ROOFING MATERIALS

The classification of roofing materials is based on performance in tests designed to determine resistance to ignition from flying brands, flames, and radiated heat, and the extent to which fire will spread over the surface of the roofing. Whether or not flying brands are given off when burning is also a criterion. The classes recognized, A, B, and C, give a range in fire resistance as defined by the testing procedure.

Under class A roofings are included the heavier (4- or 5-ply) built-up asphalt and asbestos, asphalt and rag felt, and tar rag-felt roofings, surfaced with slag, crushed stone, or pebbles. Of the prepared roofings it includes slate, clay and cement roofing tile, and rigid cement-asbestos shingles laid with suitable head lap.

Under class B are included medium weight (3-ply) built-up asphalt and asbestos, asphalt and rag felt, and tar rag-felt roofings, surfacings with slag, etc., being required for the rag-felt roofings only. Under prepared roofings are included cement-asbestos shingles laid according to the diagonal or French method, heavy asphalt-saturated asbestos felt sheets, and copper, steel, and tin-coated steel sheet roofings and shingles suitably designed and applied.

Under class C roofings are included the lighter built-up asphalt and rag-felt roofings (2-or 3-ply) on which top surfacing of slag, pebbles, etc., is not required. Among prepared roofings, the medium weights of asphalt-saturated asbestos felt sheets, and all but the lighter weights of asphalt-saturated rag felt sheets and shingles, are included in this class. The sheet roofings may be either smooth-surfaced or covered with mineral granules. The shingles are all granular surfaced. Class C also includes zinc sheets and zinc shingles and sheet-steel roofing not qualifying for class B.

It may be noted that the requirements for roofing materials outlined above are concerned largely with the protection needed for a combustible roof deck beneath them. Where the roof deck is incombustible, any exposed covering material applied should be incombustible or fire retardant and if burning under severe exposure no brands should be given off. The location of the building with reference to other buildings and the spacing of the construction in the district concerned are also factors that may determine the choice in roofing materials. State and city buildings codes generally require greater fire resistance for roofing in the congested districts than in the outlying sections where buildings are lower and less closely spaced.

3. SEVERITY OF BUILDING FIRES

In order that building members, protections, and equipment, may be designed to have fire resistance adequate for the location, information on the severity of fire to be expected with given amounts of combustibles in the building and contents is required.

(a) FIRE SEVERITY IN FIRE-RESISTIVE BUILDINGS

As concerns buildings with fire resistance such that a complete burning-out of combustibles will not result in collapse of main structural members, the severity in temperature and duration of fires in combustible contents can be related to the amount of combustibles present, assumed distributed uniformly over the included floor area (22). For ordinary combustibles such as wood and paper having calorific values in the range 8,500 to 6,500 Btu/lb the equivalents in hours of exposure to the furnace test defined above can be taken as given in table 2.

TABLE 2.—*Equivalent durations for fires in fire-resistive buildings with calorific value of combustibles assumed in the range for wood and paper*

Combustibles		Equivalent fire duration	
lb/ft²	*Btu/ft²*	*hr*	*min*
10	80,000	1	00
15	120,000	1	30
20	160,000	2	00
30	240,000	3	00
40	320,000	4	30
50	380,000	6	00
60	432,000	7	30

The periods contain an addition for increase in severity due to fires in adjacent buildings that may be sufficient to cover all but exceptional cases.

In computing combustible contents the calorific value of cotton, wool, silk, straw, grain, sugar, and similar organic materials can be taken as coming within the range for wood and paper. Considering their higher heating values, the weight of animal and vegetable oils, fats, and waxes, petroleum oils and other petroleum products, asphalt, bitumen, paraffin, pitch, and alcohol, should be multiplied by 2 to determine combustible contents.

Little difficulty is involved in estimating combustible contents for a given building or even a given occupancy. Typical pieces of furniture and units of contents can be weighed and the weight of finish, flooring, and trim computed. The total weight for a given or typical floor bay divided by the pertaining floor area gives the measure of the distributed combustible contents. Office and residential occupancies give the lighter combustible contents, the average for a building even with a combustible finish floor being seldom more than 10 to 15 lb/ft² although spaces given to storage of records or other material will generally be more heavily loaded. Where such concentrations occupy only one floor bay or less that is not partitioned off, the dissipation of heat to the surrounding space would decrease the fire severity. For concentrations covering greater areas, the general building design would have to take them into account if they may occur anywhere within the building. If segregated to given portions thereof, the necessary protection can be applied at relatively low expense. If such concentrations are housed in fully enclosed incombustible containers, such as filing cabinets, enclosed shelving and similar equipment, the hazard is reduced to a point where it would require no greater protection than the general average for the building.

Stores and storage present in general the heaviest combustible contents. While the average for such a building may not exceed 20 or 30 lb/ft^2 in a considerable portion thereof, concentrations of 60 or more lb/ft^2 may be present. Some building codes set a maximum of 3- or 4-hr fire resistance beyond which building members need not be designed, partly on the assumption that fire extinguishment will keep the fire severity within limits. It is, however, preferable and generally feasible to design the building or portions thereof for the full severity to be expected. Also, all main members such as columns, floors, walls, should be designed to have the required fire resistance since the effects on them of the exposing fire and their relative importance from the standpoint of prevention of building collapse are approximately the same.

(b) FIRE-EXPOSURE CONDITIONS IN NON-FIRE-RESISTIVE BUILDINGS

The fire exposure to be expected in buildings with combustible or unprotected interior construction is less determinate than for the fire-resistive type nor does it have equal interest from the standpoint of design. Collapse of interior construction is expected from an uncontrolled fire. Masonry walls are required from the standpoint of stability to be of thickness such that fire-resistance demands are generally met even where combustible building members project into them from one or both sides. The main interest concerns exposure conditions for safes and vaults which may be buried in the hot debris. An approximate measure of the hazard is represented by the sum of the weights of combustible building members and contents within the outside walls in all stories (21). Where this is less than 25 lb/ft^2 of ground area of building, indications are that 1-hr safes may preserve their contents if impacts are not severe. Otherwise, 2-hr safes or vaults should be used. These are required where combustibles exceed the above limit, and above 50 lb/ft^2 4-hr safes and vaults are required, except that above the basement or ground story 2-hr vaults may be sufficient. For contained combustibles over 100 lb/ft^2 6-hr vaults are required in the basement or ground story, with possible decrease to 4 hr for the story next above and to 2 hr for other stories. For combustibles over 150 lb/ft^2 it is preferable to avoid the basement location for the vault on account of possibility of prolonged heat exposure from the hot debris.

IV. FIRE-RESISTANCE CLASSIFICATION OF BUILDING TYPES

By fire resistance in the present connection is meant the ability to withstand fire exposure from without and within, with no collapse of structural members and minimum amount of fire damage. It also pertains to such properties of the different building types as tend to prevent the origin and spread of fire within and also such as will make the building a fire barrier in case of a general conflagration.

1. FIRE RESISTIVE

The fire-resistive type includes buildings, the essential structural members of which consist wholly or mainly of incombustible materials, so proportioned or protected as to resist without collapse the whole or a considerable portion of the severity of an uncontrolled fire consuming combustible building contents, finish, and trim.

(a) CLASSES

The 2 main classes from the structural standpoint are skeleton and bearing wall construction. For the former the loads from the stories above the ground story are supported on columns or on beams or girders supported on columns. For the latter the floor loads are supported wholly or partly on bearing walls. From the standpoint of fire resistance there is no preference as between the 2 classes.

(b) RANGE IN FIRE RESISTANCE ATTAINABLE

Features of general design, such as subdivision of large areas and protection of vertical and horizontal openings, have a decided effect on restriction of fire spread as outlined in a subsequent section.

By proper design and choice of materials for structural members a fire resistance sufficient to withstand a complete burning-out of combustible contents can usually be attained with moderate proportions of members and protective coverings. By the same means the fire damage can be greatly decreased. This refers to choice of aggregates for concrete, type of clay and design of units for clay products, and methods of application. Plaster can be chosen of types likely to remain in place as exposed to fire, and thus increase the fire resistance of the member and decrease the fire damage. Plaster furred out from the surface of members such as walls and columns has been found particularly effective in preventing fire damage. All other factors being equal, hollow members suffer more damage from fire exposure than solid members, the damage extends farther in from the surface and is more difficult to repair. Hollow members of building units may, however, be preferable in sufficient degree from other standponts, such as heat insulation and lower weight and cost, as to offset any disadvantage from the standpoint of resistance to fire.

The amount of combustible materials in exterior and interior finish and trim has an influence on the ease with which fires can originate and spread. Incombustible or fire-retardant material for frames and sash is an aid in preventing communication of fire from floor to floor at exterior openings. They should be glazed with wire glass where needed from the standpoint of exposure from other buildings, other portions of the same buildings, or storage in the open of combustible materials in sufficient amount to create a hazard to the building. Increase in fire resistance for the building is obtainable with incombustible or fire-retardant-finish flooring, wainscoting, partitions, doors, frames, and sash. If wood is used, a considerable gain in fire safety is obtainable, particularly for interior use, by impregnation with chemicals to decrease flammability (23, 24). Incombustible or fire-retardant heat-insulating and sound-absorbing materials applied as boards, felts, or loosely as fills, are obtainable and should be preferred to the combustible types in locations where the latter would add appreciably to the general fire hazard otherwise created by the building and its occupancy.

2. MASONRY WALLS WITH INTERIOR WOOD OR UNPROTECTED-METAL FRAMING

(a) CLASSES

Subdivision within this type is based on difference in interior floor, column, and partition construction. In heavy timber or mill construction, floors consist of solid planking, tongued and grooved, splined, or laminated, not less than 3 in. in nominal thickness with a finish wearing floor of 1 in. or thicker boards. Roof planking is required to be not less than 2½-in. thick. Beams, girders, and columns must have minimum nominal thickness of 6 in. (25). In this as in other classes within this type, suitable means must be provided for anchoring floor beams into exterior masonry walls with provision for release when collapsing in fires. The main feature for this class is solid wood construction with absence of hollow spaces, this applying also for wood partitions. Portions thereof may have metal or reinforced-concrete framing for which a fire resistance of not less than 1 hr is generally required.

Interior unprotected metal framing will in general collapse sooner as subjected to comparable fire exposure than timber framing with members of 12-in. minimum dimensions, although cast-iron columns failed in tests only a few minutes earlier than timber columns with unprotected steel bearings. Filling reentrant portions of structural-steel columns with concrete will increase the fire resistance to the range obtaining for wood members of comparable strength.

Wood-joist interior construction affords in general lower fire resistance than the heavy timber framing on account of the smaller size of members and the presence of hollow spaces that contribute to fire spread and make extinguishment more difficult.

(b) EFFECT OF DETAILS OF DESIGN AND FINISH

Subdivision of areas by means of self-supporting fire walls extended a few feet above combustible roof construction is one of the most effective means for restricting fire spread. Protection of vertical and horizontal openings is also effective, particularly during the initial stages of the fire. Finishes such as plaster on metal lath, plaster board, or wood lath, and plaster wall board are effective in retarding fire in approximately the order named. Asbestos paper placed between the finish and base wood flooring will act as a smoke and fire stop. Filling hollow spaces at intersections of floors, roofs, partitions and walls, with incombustible materials, assists in checking the spread of fire through the hollow spaces in the framing. Protection to metal bearings in timber construction or substitution of bearing details of materials of lower heat conductivity will increase the time before collapse of heavy timber construction occurs in fires.

3. UNPROTECTED METAL

While the fire resistance obtainable with this type of building is not large as gaged by the fire-testing procedure, it is adaptable for situations involving normally low stresses in the materials and light fire exposure.

(a) CLASSES

With incombustible exterior siding and roof sheathing, metal sash, and wire glass, this type of building gives fair resistance against exterior exposure, particularly with light interior contents not stored against the walls. Subdividing partitions and floors should be of incombustible materials.

Combustible siding, roof sheathing, and insulation decreases the fire resistance since collapse can occur from fire in them alone and they augment the damage from fires in the building contents. Resistance against exterior exposure is also decidedly less than with incombustible exterior construction.

(b) EFFECT OF SPAN LENGTH, HEIGHT, AND LOADING

As used in roof construction on spans of not over 30 or 40 ft, the dead-load stress will not be large in comparison with the total design stress, which usually includes provision for resisting wind and snow loads. Since at the time of a fire the latter may not be present in significant amounts, the stress will be relatively low and the members can attain a higher temperature without collapse, than if loaded to have the full design stress. For the longer span lengths, the dead-load stress will constitute a larger part of the total design stress. Hence the adaptability of this type for 1-story buildings with roof supported on moderate spans. Where combustible contents are light and heights above floor relatively large, such as in auditoriums, gymnasiums, and hangars, such roof construction using incombustible roof sheathing or slab, may withstand considerable fire in the contents without collapse. Height of unprotected members decreases the possibility of collapse from fire although not to the extent reflected in some building regulations that permit omission of protection on trusses with lower chord 20 ft or more above the floor below. Such protection should be applied to structural members in multi-story buildings, irrespective of height above floor.

4. WOOD FRAME

In this building type, the supports for the exterior wall construction, as well as those for the interior, are of wood.

(a) CLASSES

Different degrees of resistance against exterior fire exposure can be obtained, depending on the exterior facing used, the range being defined by brick or masonry veneer, stucco on metal or wood lath, cement-asbestos sheets or shingles, sheet-metal facing, and exterior wood board or shingle facing. When the building itself burns, however, the hazard to the surroundings is not greatly different for the several classes.

(b) EFFECT OF MATERIALS AND DETAILS

As for type 3, a considerable increase in fire safety is obtainable with incombustible fire-resistive finishes for partitions and ceilings and fire stopping of hollow spaces (26). The fire-resistive properties of the roof coverings used are also important for this as for buildings of similar type, in protecting against exterior exposure and preventing undue hazard to neighboring construction if the building burns.

V. STRUCTURAL CONTROL OF FIRE SPREAD

1. HEIGHT LIMITATIONS

From the standpoint of fire hazard, no height limitations are generally applied to buildings of construction sufficiently fire resistive to withstand a fire consuming combustible building contents and trim, with a fixed requirement according to some building codes of not less than 3 to 4 hours fire resistance. In New York City such buildings over 150 ft in height are required to have incombustible or fire-retardant finish floors and interior trim. For buildings of this type having fire resistance in the range 1½ to 2 hr for the floor construction, height limitations ranging from 50 to 100 ft have been applied depending on the occupancy and occasionally on the area (12, 13, 19). Buildings housing occupancies deemed to have the higher fire hazards are limited to lower heights than those presenting lower hazard.

For buildings of non-fire-resistive interior construction, height limits are lower since the building constitutes a greater hazard when it burns, fire-fighting operations must be conducted largely from the ground, and less-dependable measures can be realized for the exit of occupants in case of fire. For heavy timber interior, height limits up to 80 ft have been recommended for business and residential buildings. For public buildings, height limits have been placed in the range 20 to 55 ft or 1 to 3 stories, mainly to enable proper provision for exit to be made. For wood joist interior construction, limits ranging from 20 to 65 ft or 1 to 4 stories, depending mainly on occupancy, have been applied, and for buildings with exterior and interior framing of wood, limits from 20 to 35 ft or 1 to 2 stories. Unprotected metal buildings are generally limited to 1 story. Mezzanine floors or galleries not exceeding in aggregate area 25 percent of the area of the building, have been allowed.

While reflecting a considerable variation due to differences in judgment as also possibly in local conditions, the above can be taken as indicative of the range in restrictions on height imposed with the object of attaining greater fire safety. Height limitations are also imposed on the score of city planning and zoning, requirements for light, and resistance to earthquake shock.

2. AREA LIMITATIONS

While the building having fire resistance for structural members of 3 to 4 hr or more is generally unrestricted as to area from the standpoint of State and municipal regulations, subdivision to the practical limits dictated by occupancy requirements and cost is desirable. For buildings of the fire-resistive type but with no more than 1½- to 2 hr fire resistance for interior construction, area limitations of 7,500 to 25,000 ft^2 have been applied or recommended for buildings facing on 1 street. For interior heavy timber or wood joist construction, these limits have been placed in the range 3,000 to 20,000 ft^2, depending on occupancy and also on building, height, and for wood frame construction, in the range 2,500 to 5,000 ft^2 (12, 13, 19).

The area limitations apply to sections sub-divided by fire walls or to the building as a whole if no fire division is present. For business buildings, garages, and hangars protected by automatic sprinklers, the area limits are generally increased by 100 percent. Increases in permissible area of 50 percent are generally allowed if the building fronts on

68770—34——3

2 streets and up to 100 percent if fronting on 3 or more streets. The same allowances are made for buildings not located on a street line but directly accessible to fire apparatus on 2 or more sides.

3. PROTECTION OF VERTICAL AND HORIZONTAL COMMUNICATIONS

The inclosure of stair and elevator shafts and other vertical communications is a recognized means for restricting the vertical travel of fire and protecting avenues for egress of occupants. The inclosure can be directly at the shaft opening or by means of a room or lobby in front of the opening or openings. Stairs should preferably be continuous from first or street exit floor to roof. Where this is not the case, connecting hallways or passages should be inclosed in walls or partitions which with their supports through the structural frame of the building, should have fire resistance at least equal to that of the stair inclosure. For other than fire resistive buildings, the inclosing walls should be self-supporting from the ground up. In case of main entrances, objection is frequently made to the inclosure of stairs and sometimes elevators on the street-entrance floor. If the interior communicating openings to the entrance lobby on the same floor and to the floor below are fully protected, no considerable objection exists to the omission of such inclosure.

To reduce the ease with which fire can be communicated from floor to floor on outside of light-court walls, a minimum distance of 3 ft vertically between windows is desirable. For this and closer spacings, metal frames and sash preferably glazed with wire glass will give added protection.

Information relating to the protection of vertical communications and openings in walls and partitions is given in a previous section on opening protections. Emphasis might be placed on the desirability of utilizing as a fire barrier any wall in a favorable location by providing suitable doors at the openings, which can be done at the time the building is constructed or when existing door assemblies are due for replacement, at moderate added cost.

4. PROTECTION AGAINST EXTERIOR EXPOSURE

(a) SPACING OF BUILDINGS

As an aid in preventing communication of fire, building regulations are requiring wood frame buildings to be spaced not less than a distance of 3 to 10 ft from the lot line or 10 to 20 ft from the nearest building. Some codes permit closer spacing if the wall is filled with brick or similar material, finished with plaster on metal lath, or both. Such construction is generally allowed for the party wall in double frame dwellings although some codes require all party walls to be of masonry. For fire-resistive buildings and those with exterior masonry walls and interior wood framing (types 1 and 2), no restrictions are imposed and an exterior wall may be built on the lot line if conforming to the requirement for party walls. From the standpoint of code requirements, type 3 or unprotected metal buildings are in some codes unrestricted and according to others restricted in locations the same as wood frame buildings. Considering height restrictions for this building type, it appears that no greater fire hazard is presented than for type 2 buildings. Party walls should, however, be of masonry.

According to the Public Buildings Act of May 25, 1926, Federal buildings constructed under the supervision of the U.S. Treasury Department are required to be spaced 40 ft from any line upon which other construction can be built, this distance to include bordering streets or alleys, unless by ruling of the Secretary of the Treasury a closer spacing is deemed safe and permissible in specific cases.

Other spacing restrictions may be imposed because of needed light, ventilation, hazardous occupancies, and means for egress. The spacing required from the standpoint of fire protection to the structure cannot be assumed as assuring that communication of fire will not take place. They should rather be regarded as aids in preventing spread of fire from building to building and make less probable a general conflagration, considering the fire-fighting facilities available.

(b) PROTECTION OF EXTERIOR OPENINGS

Building regulations require openings in exterior walls of incombustible construction to be protected where within 30 to 50 ft from a wood frame building or an opening in any other building. Private dwellings and garages, churches, and show windows in the first and occasionally in the second story, are as a rule exempt from such requirements. Openings in walls in the same plane, or in parallel planes and facing in the same direction, are not regarded as mutually exposing. Protection is also required for openings distant not more than 50 ft above a roof of combustible construction. As in the case of spacing of buildings, such requirements cannot be considered as assuring that fire will not be communicated to buildings with unprotected wall openings spaced more than the 30 or 50 ft away from the exposing source. Fire has been communicated to fire-resistive buildings located 100 ft from burning non-fire-resistive construction of considerable height and area. The hot blast created by a conflagration may create a hazard at much greater distances. With the protections required and the spacings for unprotected openings, it may be possible with available fire fighting within and without the exposed building to prevent fire from entering under other than conflagration conditions. The type of construction of the exposing buildings is important as determining the degree of hazard as also their height and indidivdual or aggregate area. The fully fire-resistive building with moderate size of wall openings presents a mild hazard compared with buildings of combustible interior, or interior and exterior construction. Full or partial collapse of exterior masonry walls may occur when interior construction is consumed and in any case the volume of flame and heated gas is not restrained by floor and roof construction that remains in place throughout the fire. The exposure is more severe to the portion of the exposed building a few stories above ground than to the lower stories.

The designer should, therefore, not be guided solely by current building-code requirements in providing opening protection. Tabulations, necessarily based largely on judgment, have been prepared, giving recommended protections for spacings from buildings within given height and area ranges of the different construction types, that might be considered as approximating full protecton, particularly if some degree of fire fighting can be assumed within the exposed building. (See appendix to reference 27.)

The types of window protection include automatic-rolling shutters, swinging shutters, and metal window frames and sash glazed with wired glass. Where the exposure is very severe it may be necessary to supplement wired-glass window protection with some form of shutter. Outside sprinklers might also be used under some conditions to supplement other opening protectives. If the wall area to be protected is large the outside sprinkler will require a heavy draft of water that may at the time be needed for other extinguishing purposes within or outside of the building. Also the exterior details must be such as to direct the water over the window sash. Exterior sprinklers appear, however, well adapted for the protection of buildings of moderate height and area with wood exterior, the details of which have been designed and the sprinklers located to obtain flow of water over the whole exposed surface.

The cost of exterior window protection can be reduced for the larger openings where occupancy and location permit, by glazing marginal panels with obscure wire glass, using the clear glass only in the central panels. The cost of the combination would be little if any more than plate glass. The heavier frames and wire glass would have a longer life and offer greater resistance to high winds, hailstorms, and also to intrusion, than plain-glass windows.

VI. MEANS FOR EGRESS

The source material for the following recommendations relating to egress requirements consists mainly of the building-exits code sponsored by the National Fire Protection Association (28) and results of studies on the same subject by the National Bureau of Standards.

Means for prompt egress may be required because of smoke or of panic not attributable to the presence of fire or actual peril therefrom. Hence such means should be provided even where the building and its contents may present only a very low degree of combustibility or fire hazard.

1. GENERAL REQUIREMENTS AND ASSUMPTIONS

(a) DETERMINATION OF POPULATION

The capacity of exits for different occupancies should be based on the actual number of persons to be evacuated and the allowance of time that may be given them to reach an area of refuge without being subjected to too great hazard. A guide to the minimum number of persons to be accommodated in different occupancies is given in table 3. In many buildings provision must be made for larger numbers.

TABLE 3.—*Assumed population density for typical occupancies*

Occupancy	Gross floor area per person
	ft ^{2}
Places of public assembly	15
Places of public assembly, seating space	6
Stores, street floors and sales basements	30
Stores, other floors	60
Schools, court rooms, restaurants, etc	40
Office, factory, and workrooms	100
Hotel and apartment	125
Institutional	150
Warehouse, storage, and garage	300

(b) NUMBER OF EXITS

Every floor area or room should have not less than 2 exits as remote from each other as practicable except rooms occupied by less than 100 persons. Places of assembly or areas therein accommodating 600 persons or less should have not less than 2 exits. Those accommodating from 600 to 1,000 should have not less than 3 exits and above 1,000, not less than 4 exits.

The maximum area that may be safely served by a given type of exit will depend upon the fire safety of the building, its occupancy, and the course traveled before reaching a place of refuge. At least 2 exits should in general be provided from all floors. More will be required for large areas.

Floor areas of 3,000 ft² or less in buildings of fire-resistive construction and used for residential or business purposes or as garages, hangars or barns may under some conditions be safe with only 1 exit, although some requirements call for not less than 2. The same applies for area limits of 6,000 ft² in fire-resistive buildings devoted to office occupancy and in which the maximum distance to an exit does not exceed 50 ft. This presupposes in multi-storied buildings, fully-inclosed stairways and adequate elevator service. The same rule would apply to areas in manufacturing buildings of the same class only when the building is fully equipped with automatic sprinklers.

(c) LOCATION OF EXITS

Exits should be located so that no point in a floor area, room, or space is more than 100 ft distant from an exit, measured along the course of travel, except that in fire-resistive office buildings and in buildings fully equipped with automatic sprinklers the distance may be 150 ft. Areas subdivided into small rooms and having corridors leading to exits, as in hotels and apartments, may have the exits located so that the travel distance from the room or apartment door along the corridor to an exit does not exceed the distance specified.

Every area or room housing a steam boiler, gas generator, or apparatus using gas or steam likely to be dangerous to the occupants should have not less than 2 exits, 1 leading directly to the outside.

(d) UNIT OF EXIT WIDTH

The width required for the free movement of a file of persons is 22 inches and has been chosen as the unit of exit width. Exit ways with widths exceeding 22 in. or multiples thereof by 12 in. or more may have such excess counted as half a unit.

Doorways used for exits should be not less than 30 in. wide and stairs, enclosed passages, or hallways, not less than

36 in., except that for the use of not more than 15 persons stairs of 30-in. width may be used. The width of stairways should not decrease in the direction of exit travel.

2. DOORS AND DOORWAYS

(a) EXIT CAPACITY OF DOORS

The capacity of doors for exit purposes for alert and able-bodied persons may be considered as 60 per min per 22-in. unit of width. A limit of 100 persons per unit for the period of evacuation seems justified, since part of the exits may not be available in an emergency. If only half are available this would correspond to an exit time of $3\frac{1}{3}$ min. The capacity of exit doors from sleeping quarters and for institutions housing incapacitated persons may be considered as half that for alert and able-bodied persons, or a total of 50 per unit of width. All doors should be open in the direction of exit travel.

Narrow doors are readily congested in emergency and very wide doors appear to have lower capacity rates than those of 4 units or less width. Doorways 2 to 4 units in width are to be preferred to those outside this range where likely to be utilized to their capacity.

(b) MOUNTING AND HARDWARE FOR DOORS

Outward-swinging hinged doors are to be preferred for outside exits. Revolving doors, although used for outside exits, are given credit for not more than one-half of a 22-in. unit of width. They should be supplemented by swinging doors adjacent to them. Rolling doors cannot be credited as exits and sliding doors only as entrances to elevators and at other locations with attendance.

Two doors at the same location in an exit, such as an inner door and a screen door or a detention grill and an outer door, should be provided with a vestibule or sufficient space between them so both can be hung to swing in direction of exit travel.

For interior doorways preference should be given to hinged doors swinging with exit travel in all exits used by by more than a few persons. Doors entering stair shafts should swing with exit travel and should be located so as not to interfere with those using the stairway for exit. Doors to elevator shafts, whether serving as means of exit or not, should be reasonably smoketight and fire resistive.

The fastenings of exit doors should be such that egress of occupants is not prevented or unduly impeded. Exit doors from places of assembly accommodating 500 or more persons should be equipped with exit bolts (panic hardware).

For types and fire resistance of doors for the different locations see section III 2(d).

(c) HORIZONTAL EXITS

Horizontal exits consist of swinging doors through or around fire division walls or partitions. Horizontal exits through fire walls should have vestibules with 2 class A doors in the line of egress. Doors leading to balconies for passage around fire walls may be class B doors.

Horizontal exits are credited with the same capacity for exit purposes as other doors, but augment by 50 percent the credits allowed other exits leading from protected areas on the side of the wall to which exit is made.

3. STAIRWAYS, RAMPS, AND ELEVATORS

(a) EXIT CAPACITIES

Stairways for buildings housing institutional or residential occupancies are considered as affording egress for 30 persons per 22-in. unit of width and for other ordinary occupancy, 60 persons per unit of width. The required number of units of stair width is determined by dividing the greatest number of occupants on a tributary area on any floor above the stairway by this figure. Winding and spiral stairs are not desirable for general exit purposes and should be credited with not more than half the capacity of straight run stairs of the same width. Ramps are credited with 50 percent greater capacity than stairs. Elevators are given little direct credit as exits, and in the aggregate may serve for not more than 10 percent of the required exit capacity. However, the capacity allowed for stairs is set somewhat higher than it would be if elevators were not assumed present to carry a considerable portion of the exit load in high buildings.

(b) CONSTRUCTION OF STAIRS

The risers of stairs should not exceed 7¾ in. in height and the treads should have not less than 9-in.-width exclusive of nosings, and should be proportioned so that the sum of the height of 2 risers and the width of 1 tread exclusive of nosing is not less than 24 and not more than 25 in. Stairs less than 2 units in width require a hand rail on 1 side only, other stairs require hand rails on each side and if more than 88-in. wide, intermediate hand rails are required so that the spacing of rails is not more than 88 in. Preferably there should be not more than a 3-unit or 66-in. width between hand rails.

Runs of stairs should have not less than 3 risers and should have a total rise between landings of not more than 8 ft in public buildings and 12 ft elsewhere. Antislip wearing surfaces should be provided for stairs or ramps exposed to the weather or slippery from other causes.

(c) EXITS FROM STAIRS

The exits from stair enclosures should be planned and marked so as to be unmistakable and should lead either directly to the outside or have short well-protected passages leading to the outside. It is allowable to have half of the required number and width of stairways empty into first-floor areas of stores and office buildings. Floor areas into which stairways discharge shall have exit doors of aggregate width not less than three-fourths the aggregate width of such stairways in addition to the doors required for the population of such floor area. The exit capacity of the stairs will not be appreciably decreased by this narrower aggregate width of the doors.

4. OUTSIDE STAIRS, FIRE ESCAPES, LADDERS, AND CHUTES

(a) LOCATION AND LIMITATIONS

Outside stairs and fire escapes in protected locations and under favorable climatic conditions form acceptable means of egress, otherwise they are looked upon as inferior to enclosed stairways and fire towers. Ladders are acceptable only as means of egress for the use of not more than 3 or 4 able-bodied men from boiler rooms or similar locations, and as means for firemen to retreat from the roof of a burning building to the top landing of outside stairs or fire escapes. Chutes or slide escapes are acceptable as 1 of 2 or more required means of egress from elevated floors or areas of industrial works housing processes of high hazard and under some conditions from institutions whose occupants are under constant supervision and control, such as school buildings, orphan asylums, hospitals, sanitariums, and corrective institutions. This assumes that they are regularly used in drills to familiarize the occupants with this method of exit and to maintain the surface of the chute in proper condition. Chutes together with entrance ways and discharge areas should be protected from fire and accumulations of snow and ice.

(b) EXIT CAPACITY

With favorable design and location, the exit capacity of outside stairs can be computed on the same basis as for inside stairs. The capacity of chutes or slide escapes can be taken as 30 persons per min for each slideway, except that for schools, orphanages, etc., the inmates of which are under close supervision and where fire drills are practiced frequently, 50 percent additional credit may be allowed. If a required exit time of 2½ min is taken, the latter figure would require 1 slideway for each 112 occupants. For hazardous occupancies exit time of less than 1 min may be required.

(c) CONSTRUCTION

Outside stairs, fire escapes, ladders, and chutes should be of incombustible materials and fire resistive to the degree suitable for the service intended. The limiting general proportions, height and width of stair and fire-escape runs, risers, and treads should be the same as for inside stairs. Chutes should be designed to retard acceleration and to avoid congestion or interference at the discharge outlet. Openings in walls should have class E or better protectives where within 10 ft of an outside exit way and be of fixed type or automatically closed.

5. LIGHTING AND MARKING OF EXITS

Buildings of public character or occupied by persons not ordinarily familiar with the exits should have lighted exit ways and exit signs visible from the exit approach. Exit ways, the direction of egress in which is not readily apparent should have direction signs. Luminous or well-illuminated signs should be provided for the exit of places of public assembly.

Green to correspond with other traffic signals is suggested for exit ways rather than red which in most signal systems indicates " danger " or " stop ".

Story designations should be marked inside of stair and elevator shafts and the landing at the exit leading to the outside should be marked in such a manner that persons cannot inadvertently pass it.

The floors of exit ways from places of public assembly should be illuminated at intensities of not less than 1 ft-c at principal points, such as corridor intersections and angles, passageways, stairways, stair landings and exit doorways, and at other points to intensities of not less than 0.5 ft-c. The latter intensity should be used for exit ways of buildings of other occupancies.

6. ENCLOSURE OF EXIT WAYS

Inside of buildings, stairs, elevators, ramps, and exit corridors should be inclosed with constructions having fire resistance as outlined in section III 2(b), and the openings in the enclosures suitably protected (sec. III 2(d). Ramps, bridges, stairs, and chutes outside of buildings are generally not required to be enclosed if exposing adjacent openings are protected.

VII. SAFEGUARDING COMMON HAZARDS

1. HEATING AND VENTILATION

In fire-resistive buildings fire hazards from heating equipment can generally be safeguarded with little added detail. Fire-resistive inclosure for the heating equipment and fuel storage is usually required with protectives in the openings. Rooms housing oil or gas heating equipment or storage should, in addition be vented to the outside and the enclosure should be as fully gas-tight as can be practically attained. Fires have been communicated through fire-resistive floors unduly exposed from beneath by heating equipment. Proper insulation of furnaces and boilers decreases not only heat loss but also the fire hazard. Where furnaces are supported on a floor not directly on the ground, an air space should be provided between the equipment and the floor, as materials such as mortar and concrete are disintegrated by prolonged heat exposure even if of moderate degree. Wood piling in dry soil under concrete slabs 3-ft thick has been charred from a boiler setting supported on it without an air space. Wood forms left in place under concrete basement slabs or arches under fireplaces have been ignited in a similar manner.

Exhaust ventilating systems present little possibility of causing spread of fire or smoke. Plenum systems are best safeguarded by locating inlets and unprotected ducts at points where fire or smoke is unlikely to enter. The fire shutters actuated by fusible links that are installed in the ducts may not function until after communication of a considerable volume of smoke and heated gases. Fan rooms should be designed to accommodate no other materials or equipment and provision should be made to prevent accumulation of oil and dust.

Combustible interior and exterior building construction must be safeguarded by proper protections and spacings for heating equipment and accessories. A 4-in. thickness of brick plus flue lining or equivalent, is generally considered the safe minimum for chimney walls (29). Ceilings above furnaces and fuel rooms generally need protection with incombustible finishes. Smoke pipes should not pass through combustible floors or roofs and if passing through partitions, ventilated thimbles of 8-in. larger diameter than the pipe should be used or of 4-in. larger diameter if filled with incombustible insulating material. Long runs of horizontal metal pipe are undesirable unless of heavy gage with riveted joints. Stoves and uninsulated furnaces of the size used in residences generally require a spacing of not less than 24 in. from combustible walls or partitions unless protections are applied (26).

High-pressure steam should be reduced to the low pressures required for heating before the pipes are passed through combustible constructions and metal sleeves provided around the pipes passing through floors and partitions. Proper pressure-relief valves and fusible plugs are required for heating boilers. In installations where a check valve is placed in the water supply line to prevent back flow through the water meter, all heater equipments, such as water heaters, supplied through the connection should be equipped with pressure-releasing devices. In addition there should be provided a separate connection from the heater with a check valve in it set to release into the supply line at a point sufficiently remote to prevent damage to the meter from the back flow of hot water.

2. ELECTRIC LIGHTING AND POWER

The electric circuits and equipment of a building present a possible hazard that on account of the extent of their distribution and continuous presence of potential, justifies safeguards that otherwise might be considered excessive. The fire and life or accident hazard are in general inseparable and the electric installation should be designed to safeguard them. General requirements covering both have been formulated (30, 31).

(a) CONDUCTORS AND THEIR PROTECTION

Safe current-carrying capacities of conductors are given in table 1 of reference (30) and the fuse or other overcurrent protection should be of the same rating as the rated capacity for the given size of wire unless otherwise provided for equipments such as motors that may be connected. Ordinarily nos. 14, 12, or 10 AWG wires are used for lighting or small appliance branch circuits, fused with 15, 20, and 25-amp fuses, respectively. Regardless of the size of wire, lighting circuits with fixtures wired with no. 18 or 16 should be fused for no more than 15 amp. The rules of the Supervising Architect of the U.S. Treasury Department require not smaller than no. 12 AWG gage for lighting branch circuits and where the distance from the lighting panel to the first outlet exceeds 75 ft, no. 10 wire is to be used to the first outlet. Careful consideration must be given the power demands of equipment such as banks of elevators.

Rubber wire insulation conforming with Federal specification no. HH–I–531 (57) is preferable to "30 percent grade rubber insulation" as the small difference in cost, if any, is more than compensated for by longer life and greater safety. Requirements for lead-sheath and for weather-resistant rubber insulation are covered by Federal specifications nos. J–C–101 and HH–I–531, respectively. Requirements for the conductor and braiding are given in Federal specification no. J–C–101 (58). Portable cord with rubber outer sheath of type POSJ is designed for light duty, type SJ for hard usage, and type S for extra hard usage (30). Slow-burning insulation, type SB and type A (30), should be used in hot, dry places and where wires are bunched as on the back of a large switchboard or in a wire tower. Where dampness may occur, a rubber-covered wire having a braid with flame-retardant rating is preferable for such locations.

Circuit-breaker or plug-fuse panels are best adapted for circuits of less than 30 amp and cartridge fuses or circuit breakers with a thermal element for currents above this limit. Renewable type cartridge fuzes are generally limited to buildings where a competent electrician is employed. Fused switches or circuit breakers should be provided for all branches of smaller size than the main from which they are tapped. Isolated switches should be of inclosed type operative from the outside. Switches controlling circuits and subdivisions of building wiring should preferably be grouped within a metal cabinet. The use of switchboards supporting exposed switches and conductors is being abandoned in favor of dead-front switchboards having all current-carrying parts enclosed in steel.

(b) OIL-FILLED APPARATUS

Oil-filled apparatus comprises in general transformers, oil switches, and induction regulators. Transformers and oil switches for important buildings should be installed preferably outside. If located within buildings they should preferably be on the ground floor (basement), structurally segregated from the rest of the building and from each other, with vents to the outside. Curbs at door openings and floor drains with traps serve to carry away spilled oil to a suitable location. Fire extinguishment of suitable type, preferably automatic, provided for the enclosure, will increase the safety of the installation. In the case of oil switches protection must be provided against scattered burning oil. No wiring not essential to the transformer installation and the space occupied, nor pipes for water, steam, gas, sewers, or other purposes, accessories such as faucets and sprinkler heads, and ducts for ventilating other parts of the building, should be installed in transformer vaults, even if concealed in furred ceilings. Conduits housing the power leads to transformers should be sealed to prevent entrance of water and gases. While precautions along the lines indicated above should be taken, it should not be inferred therefrom that transformers present any extreme fire hazard as this is not warranted by their comparatively good fire record.

(c) MOTORS

Motors, motor bearings, resistors and reactors for starting, and the bearings of motor-driven machines should be treated as sources of heat in their installation and separation from flammable material. This applies especially to motors which start or stop automatically or which may operate while unattended. Unless the motor is of a fully enclosed type, fire in the windings augmented by electric arcs may emit sufficient radiant heat to ignite exposed flammable material at considerable distances.

(d) GROUNDING

When alternating current is used the comparatively low-voltage supply of the building is usually derived through transformers from much higher potential transmission circuits. By connecting one of the low-voltage circuit conductors to ground through a low-resistance, high-current-carrying path, the potential of the ungrounded conductor may be fixed with respect to ground so that accidental crosses between the low-voltage circuit and high-voltage circuits outside of the building cannot increase the life and fire hazard by increasing the potential impressed on circuits and appliances within the building.

The combination of grounding one conductor of the building circuit and the non-current-carrying parts of electrical equipment will insure the immediate disconnection of a faulty circuit from the supply by the operation of an automatic over-current protective device in case a breakdown of insulation occurs between an ungrounded conductor of the circuit and an exterior metallic part. Portable appliances should, where practicable, operate on 110 to 120 v and preferably have outside surfaces either of insulating material or connected to ground if of metal. The grounding may be obtained by the use of a three-wire portable cord, one wire being used for the grounding conductor. This will require a special form of receptacle and plug.

(e) HAZARDOUS LOCATIONS

Any location in which the atmosphere may be explosive because of flammable gases or vapors, the suspension of flammable dusts or flyings or where it is impracticable to prevent combustible dusts from collecting on motors or other electrical devices in such quantities as to interfere with normal heat radiation, or any location where ignitable fibers or materials producing combustible dust are handled, is classified as a hazardous location. In such locations, sparks and heating, that may be harmless in ordinary locations, must be avoided. This is possible by the use of electrical equipment designed for use in hazardous locations properly installed (30, 31).

68770—34——4

Electric-light sockets less than 8 ft above the floor in damp locations or in those where persons can contact them and grounded building parts, fixtures or equipment, should be of porcelain or other nonabsorptive insulating material, or grounded if of metal. Droplights should not be used in such locations. Currents of 0.01 amp or more passing through the human body are considered dangerous. The dry skin gives contacts a resistance from 5,000 to 100,000 ohms, but when moist this may be reduced to less than 1,000 ohms.

3. GAS INSTALLATIONS

As in the case of electrical installations, in safeguarding against the fire hazard, life and accident hazards from asphyxiation, burns, and explosion must also be considered. Venting through a fire-resistive flue to the outside is generally required for manually controlled gas appliances, except domestic gas ranges, using in excess of 50,000 Btu/hr, or if all equipment within a room consumes 30 or more Btu/hr/ft^3 of room space. Automatically controlled appliances are required to be vented unless equipped to shut off the gas supply if the pilot light is extinguished and the gas consumption is less than 5,000 Btu/hr. Recommendations covering general requirements for safe installation are available (32, 33). For appliances such as domestic gas ranges, spacing from a combustible wall or partition of 6 in. has been found sufficient. In appliance installations, flexible tubing should be avoided and in lighting installations, swinging gas fixtures.

Liquefied gases present inherently greater hazard in transportation, storage, and use than gases at ordinary pressures and most flammable liquids. The boiling point at atmospheric pressure being below ordinary room or outside temperatures, evaporation of the free liquid will take place rapidly with formation of explosive mixtures with air. Where large quantities are involved, spacing within reasonable limits, of storage or operations from other buildings and occupancies does not afford a sufficient safeguard, and dependence must be placed on containers constructed and protected to prevent rupture, and valves and other safety devices arranged to prevent accidental discharge. Those handled in large quantities comprise mainly liquefied petroleum gases.

Fixtures and burners must be adapted to burn the gas concerned. Care need be taken to prevent deterioration at joints, metal-to-metal contact being preferred. Scenting the gas to enable detection of leaks is advantageous.

4. LIGHTNING PROTECTION

The principal damage done by lightning arises when it traverses nonconductors, in which case it may cause fire and may do mechanical injury. The type of building, therefore, is of major importance in determining the need for protection against lightning and the type of protection, although the nature of the contents must also be considered. Wherever the building or its contents are highly combustible, special attention should be given to protection against lightning.

Buildings which are metal-covered or which have a steel or metal-reinforced frame need attention at points where the discharge of lightning may enter or leave the building. Such buildings sometimes have terra cotta or other embellishment or superstructure, which, being nonconductors, should be provided with metal air terminals bonded to the steel frame, if considered of sufficient value to require protection. The steel frame should also be thoroughly grounded, preferably to buried water-supply piping outside of the water meter. Metal roofing which is electrically continuous (not discrete metal shingles), grounded through downspouts or other metal having adequate joints and ground electrodes, serves acceptably as lightning protection.

Buildings of stone, brick, or frame construction can be protected by a complete system of lightning rods. Detailed specifications for such a system are available (37). It has been general experience that where buildings that do not differ greatly in height are spaced closely over a considerable area, such as in the built-up portions of cities, there is less probability of lightning striking than for isolated buildings. Monumental buildings, because of their character and sometimes also because of their height and isolated location, are in special need of protection against lightning.

Steel flagpoles on buildings should be grounded on the steel of the building by a structural connection or by means of a copper conductor large enough to withstand mechanical damage and corrosion that may affect it. Wooden flagpoles should be provided with a bare copper conductor, fastened directly against the wood extending from the top of the pole to an effective junction with the structural steel or the ground connection.

VIII. SAFEGUARDING SPECIAL HAZARDS

Among special hazards can be named packing and shipping operations, storage of hazardous liquids, chemicals, or oil-propelled vehicles, woodworking, painting, and similar hazardous processes, and showing, handling, or storage in quantity of nitrocellulose photographic, X-ray, and motion-picture film.

1. GENERAL PROTECTION MEASURES

Where located in the same building with other occupancies, special hazards are generally safeguarded by structural subdivision, automatic fire-extinguishing equipment, or both. Where the activity or storage is of considerable extent or extra hazardous, a separate building may be required. In any large building designed for general office, residential, or institutional occupancy it may be desirable to provide one or more ventilated vaults for the storage of hazardous materials, not including flammable liquids other than in small containers. Such vaults should preferably be located on the roof or in the upper story to enable ready venting to the outside (34, 35). If located in lower stories the vent should preferably be placed so that no windows, doors, or other wall openings are within 50 ft. Storage such as of flammable film in quantities up to about 1,000 lb can be made in vented cabinets each containing not more than 250 lb.

2. HAZARDS DURING CONSTRUCTION, DEMOLITION, AND ALTERATION

Many disasters have occurred during the construction or alteration of buildings due to fires in combustible false work and building materials (36). The Fall River, Mass., conflagration of 1928 started in a building that was being demolished and from which automatic-sprinkler protection had been removed.

The use of incombustible materials as far as possible in form work, or of wood treated to reduce flammability, would assist materially in decreasing construction hazards. The fire protection of structural members should follow erection as closely as practicable and some stairs, elevators, and standpipes should be carried up with the construction. Heating during construction should preferably be by steam or by other method less hazardous than stoves or open fires. The permanent heating plant might be installed and utilized at an early stage of the construction for this purpose.

3. STRUCTURAL PROVISIONS AGAINST THE EXPLOSION HAZARD

For the storage of high explosives, underground magazines are best adapted, the required depth underground depending on the amount and character of the explosive. Not only are the destructive effects on the surface of the ground from the explosion wave greatly reduced by such location but the probability of sympathetic detonation of nearby magazines in similar subsurface locations is also greatly reduced. This assumes soil, sand, or soft clay formations with absence of rock or hard pan. If manufacture, handling, and storage of explosives in large amount must be conducted above ground, the preferable building type would be one of light construction that affords a minimum resistance to outward pressure. The materials and their assembly should be such that their scattering by the explosion will cause the least destructive effects. Practically, it will be found that considerable weight and resistance must be incorporated into the structure to attain the necessary strength and resistance to the elements. In a group of structures housing such hazards, the light construction presents moreover greater vulnerability to destructive effects from explosions in other structures in the group unless protected by barricades. The air-pressure wave set up by the detonation of as large an amount of high explosive as 1,000,000 lb TNT has caused destruction or major structural damage to buildings located up to 2 miles distant. Fire-resistant construction with walls and partitions well bonded to the floor and roof construction have been found more resistive to such pressure than ordinary frame or brick-walled buildings with interior wood framing.

Barricades of earth-filled timber cribs or retaining walls built around buildings housing explosive manufacturing or storage will decrease the hazard from explosions outside of the barricade and by blanketing flying debris and directing the explosion wave upward, will decrease the damage to neighboring construction from explosion within the barricade. With such protections the distances to inhabited buildings, public railways, and public highways may be decreased by one half according to the American Table of Distances (39).

Location in deep narrow valleys has an effect similar to that obtained with barricades. Heavy timber also will decrease the range of flying debris and assist in breaking up the pressure wave caused by the explosion.

If the explosion effect is of so moderate degree that the assembly of major structural members can be built to resist it, there is considerable advantage in designing the building so that collapse will not occur. This is accomplished by incorporating the maximum strength practicable into the construction and providing openings, such as windows of large area with filling that presents the least resistance to outward pressure consistent with proper resistance to the elements. The class of explosions coming within this range of intensity include minor amounts of explosives and those depending on the combination of a gas or dust with the oxygen of the air. If the maximum rate of propagation of the flame front for the type of explosion concerned is known, the maximum rate of pressure increase within a room of given dimensions can be determined and area of openings and the weight and resistance of opening protections proportioned so the ultimate pressure resistance of the structure will not be exceeded. Reinforced-concrete wall, floor, and roof construction can, with little added cost over that designed with the usual details, be built to resist pressures of 500 to 1,000 lb/ft.^{2} Large steel-frame windows will buckle and be forced out of their openings at pressures not exceeding 10 percent of the resistance that can be thus built into the structure. The venting afforded by windows can be augmented by hanging portions of them to open automatically under pressure.

For the milder types of explosions such as some types of dust explosions, relief can be given by vents of moderate area even with building construction that presents comparatively low resistance to outward pressure. Area of vents of not less than 1 ft^2 per 80 ft^3 of room volume or not less than 10 percent of the outside wall area have been recommended (38).

Buildings within which hazards from explosions exist require special precautions appropriate to each type of hazard in the types of mechanical and electrical equipment installed with the object that dust accumulations, presence of dust clouds, or ignition thereof, may be prevented. Studies relative thereto as well as general fire-prevention precautions, applicable to a range in hazardous occupancies have been made and recommendations for promoting safety are available (38, 39).

IX. CONSTRUCTION AND EQUIPMENT FOR PROTECTION OF RECORDS

1. BUILDING CONSTRUCTION AND FINISH

The prospective content of records of some buildings, particularly Government and office buildings, is of such volume and value as to justify special consideration in the design and finish of the building. This will require fully fire-resistive construction, well protected against exterior exposure with little or no combustible interior finish, floors, doors, and trim. Undivided areas should be moderate, preferably less than 10,000 ft^2, and vertical and horizontal communications well protected. Combined with proper equipment for housing the records and good housekeeping, a good degree of protection is attainable by this method (40). It is well adapted for conditions involving a large volume of records of value high enough to require special protection measures.

2. RECORD VAULTS

In non-fire-resistive buildings and in fire-resistive buildings where structural and occupancy conditions are not favorable, excellent protection can be obtained for records in suitably constructed vaults having fire resistive doors. This type of protection is particularly adaptable for records not in frequent use.

Record vaults have been classified as 2, 4, and 6 hr (20) but should be constructed to withstand the fire conditions in the location concerned, some general information relative to which is extant (21). In non-fire-resistive buildings they must be supported on the ground independent of the building but in fire-resistive buildings, designed to withstand any fires that can occur within them, may be supported on the structure. The most severe fire exposure conditions occur in the lower stories of non-fire-resistive buildings where the vault may be covered with hot debris for a considerable period after the fire has subsided. The wall and floor thicknesses required can be judged from the fire-resistance ratings for the types of wall and floor assemblies that are to be used. The openings into record vaults should be restricted to those required for entry and ventilation.

3. RECORD ROOMS

In fire-resistive buildings records in considerable volume but not of the highest value can be given protection by segragation in rooms enclosed by walls and floors of fire resistance proportioned for the severity of fire to be expected, but not less than about 2 hr. The finish floors, and trim of record rooms should be of incombustible materials and all interior and exterior openings properly protected (20).

4. RECORD STORAGE BUILDINGS

For large volumes of records that need be consulted only occasionally, considerations of economy as well as fire protection indicate that storage can best be made in buildings constructed and equipped for the purpose. Such buildings can have incorporated in their construction, finish, opening protection, and equipment, the elements most conducive to fire safety, and with proper operation and maintenance, a high degree of protection is attainable.

5. EQUIPMENT

(a) FURNITURE

For record vaults, record rooms, record-storage buildings, and general-occupancy buildings designed to afford the best protection, all shelving and other record containers should be of incombustible materials and preferably afford full enclosure. For open shelving, that with solid backs and partitions is preferable. Metal shelving open on all sides gives very little more protection than wooden shelving. In shelving open at the front, the rate at which fire spreads decreases with the size of compartments. Metal filing cabinets supported on incombustible structural and finish floors afford good protection. The contents may, however, be ignited and destroyed by a fire in a finish floor of 1-inch boards (40).

No definite decree of protection can be given by incombustible uninsulated record containers in non-fire-resistive buildings or fire-resistive buildings where fires can attain volume in freely exposed combustible contents, equipment, and trim. For such condition valuable records should be protected in vaults, record rooms, or insulated safes.

(b) PORTABLE RECORD CONTAINERS

Insulated safes and other portable insulated record containers are adapted for protection of relatively small volumes of records that are in frequent use. Only a small percentage of the records originating in connection with many activities have high value and these can be given protection in portable insulated record containers or, if the fire exposure to be expected is severe, in record vaults, the fire resistance of which is adequate for the locations concerned.

The current classifications of insulated safes, A, B, and C, correspond to fire-endurance limits of 1, 2, and 4 hr (50). The most severe fire exposure for safes also result from contact with the hot ruins of non-fire-resistive buildings and for some conditions the highest fire resistance afforded by this type of container may be inadequate. For fire-resistive buildings it is generally possible to select safes of classes designed to resist the full severity of the fire that can occur in the locations concerned.

X. FIRE-ALARM AND WATCHMAN'S SUPERVISORY EQUIPMENT

The general functions of fire-alarm equipment within buildings are to summon those who will extinguish the fire and protect property exposed to fire and water damage and to warn occupants so exit can be made if necessary. To properly perform its function the fire-alarm system must provide: 1, a reliable means continuously present for transmitting the signal; 2, the signal must reach those trained to respond; 3, it should compel immediate attention and mean "fire" with no possibility of misinterpretation; 4, it should carry with it an approximate location of the fire, and 5, if transmitted by personal intervention the means for transmission must be readily accessible and require only the most elementary performance on the part of the sender with a minimum opportunity for delay or error due to sender's distraction or unfamiliarity with the equipment.

To warn building occupants, means must be available for sounding a compelling alarm that may be heard anywhere within the building or fire area and be of sufficient intensity to awaken those who may be asleep. Whether or not a general alarm is needed will depend on the type of construction, size of building, and occupancy. For non-fire-resistive interior construction a general alarm may be needed even in a large building. For fire-resistive construction, particularly if horizontal openings and stair and elevator shafts are well protected, a general alarm in large buildings would be needed only for the more hazardous occupancies.

Equipment for supervision of watchmen's rounds increases the reliability of this service which would increase the probability of preventing conditions conducive to origin of fires and make more likely their discovery in the early stages. While fires in some materials gain headway rapidly, in furniture and ordinary building contents fires progress more slowly, particularly if no accumulations of loose combustibles are present and the materials in the building do not contribute fuel for the fire.

1. MANUAL FIRE-ALARM SYSTEMS

In these systems the alarm is transmitted to a central point by the pulling of a lever in a fire-alarm box. This may sound a general alarm, or only at certain designated locations from which alarms in the whole or given portions of the building can be initiated. The location of the box pulled is indicated by the ringing code and by the record on the register. If desired it may be indicated by lamps on an annunciator board. Equipment recording the alarm by perforation of a paper tape or printing of a number can be supplied as also a stamp to record the time it is received.

The minimum size of building in which such equipment should be installed will vary with the occupancy conditions. In hotels, dormitories, and apartment houses, some State and city regulations require bells for sounding a general alarm as a means of notifying the occupants. This type of alarm, particularly if coded, is also of assistance in summoning any one within hearing to fight the fire. There appears to be no object in providing for reception and recording of signals at one or more central points (presignal feature), unless some one is on duty at one or more of them at all times of the day and night. In new buildings for the U.S. Post Office Department, costing $500,000 to

$1,000,000 a fire-alarm system is provided of a general alarm, closed-circuit, coded, electrically supervised type. For larger buildings the presignal feature is added with switch to transfer from presignal to general alarm and vice versa, also recording equipment, and when specified, the time stamp. Other recommendations (51) limit the installation of systems having a central receiving point for signals, to buildings of 2,500,000 ft^3 capacity or more with 30 or more fire-alarm stations or groups of smaller buildings requiring 25 or more stations.

(a) TYPES AND SPECIFICATIONS

Two general types of manual fire-alarm systems both serving nearly the same purpose can be recognized. One covered by Federal specification no. W–F–391 (51) is termed the "PNI" or "positive non-interfering type." In this system the first box pulled on a circuit sends its signal and the pulling of any other box or boxes while the signal is being transmitted will not interfere with the transmission. The operation of other boxes during this period (average of about 50 sec) will not result in alarms from such operation. This system is designed for operation by storage battery, the gongs being of the electro-mechanical type operated by a hand-wound spring enabling 250 powerful strokes to be made, or sufficient for about 5 complete fire signals.

The "shunt" type system described in Federal specification no. W–F–396 (52) is designed either for operation by storage battery or by power from the electrical supply for the building. In this system when two or more boxes are pulled at the same time, the box on the circuit electrically nearest to the source of energy will send its signals without interference. When there is a short time interval between the pulling of several boxes, fragmentary records of signals from other boxes will be given either before or after the complete signal from the box electrically nearest to the source of power. In case of electrical discontinuity, short-circuiting, or grounding of the circuit, by the operation of a switch an auxiliary circuit is established over which fire alarms may be received pending the clearing of the trouble on the primary circuit.

In both types, continuity of all important electrical circuits and source of electrical power is insured by electrical supervision, and an electrical disarrangement is announced by a trouble bell which may be silenced by transfer of the signal to a trouble lamp.

(b) LOCATION OF STATIONS

Manual fire-alarm stations should be located in the path of escape from fire at readily accessible points which are not likely to be obstructed and preferably so that the distance of travel to reach a box will not average more than 100 ft. Locations will also depend on the subdivision of the building as determining access to box locations. Some advantage is presented by locating fire-alarm stations, standpipes for hand hose, and hand fire extinguishers near together, since the location will thus become better known to the occupants and the sender of an alarm will be in position to use the extinguishing equipment with the least delay.

2. AUTOMATIC FIRE-ALARM SYSTEMS

(a) TYPES AND OPERATING DETAILS

Fire alarms may be initiated automatically by the fusion of an alloy, expansion of air within a partially closed system, expansion of liquid within a frangible bulb, and action of temperature on bimetallic strips, thermopiles, or mercury bulbs. One type seldom used in buildings but extensively used to detect fires in cargo holds of ships, involves a pipe system for sampling the air from the different compartments and means for detecting by eye any smoke present.

The fire signal from a zone circuit, which may include as many as from 50 to 100 thermostats, 1,000 ft of pneumatic tubing, or 1,500 ft of thermostatic wire, is given at one or more central points by the ringing of a bell, and the zone is indicated by a lighted lamp on an annunciator board. Generally the bell alarm is not coded. Not less than one manual break-glass box is usually provided for each zone. For such boxes the signal is initiated by the breaking of the glass, whereas with most manual fire-alarm systems both the opening of the box and pulling of a lever is necessary, a difference that may cause confusion if both types are used in the same building or building group. Provision for electrical supervision of circuits up to the thermosensitive elements is made with all automatic systems, the contacts for most types of thermosensitive elements being normally open. For closed-circuit systems the contacts can also be thus supervised.

The protection given by automatic fire-alarm systems is adapted for conditions presenting hazard of a degree that would not require automatic-extinguishing equipment and yet such that more protection than can be given by manual fire alarm and extinguishing equipment is necessary. As for manual systems the effectiveness of the protection depends upon the certainty of reception of the signal by someone always in attendance at one or more points at which the alarm is given and the degree to which such person is in position to act on the alarm, summon aid, or initiate fire extinguishment with suitable equipment, which should include hand fire extinguishers and fire hose.

The effectiveness of the unit-type alarm device in which the detecting element and alarm are combined in one assembly depends entirely on whether the alarm sounded will be heard. It has little or no application in buildings not occupied at all hours. In residence buildings an alarm unit located at a point such as the basement, to be effective, should rouse sleeping occupants on upper floors.

(b) SPECIFICATIONS AND INSTALLATION DETAILS

While no general specifications are extant, requirements for installations in buildings and ships have been issued that are informative (53, 54, 55). Fixed-temperature thermosensitive elements, considerably more sensitive than the fusion-type automatic-sprinkler head, are in general required to be spaced so that no point on smooth ceilings is more than 10 ft distant. Closer spacings are required for less sensitive elements and for greater sensitivity such as is presented by the rate-of-rise elements, somewhat wider spacings. On ceilings with beams over 12 in. deep it is usual to treat the inclosed space as a separate ceiling.

Electrical supervision is provided not only for the circuits but also the energy supply and at least one fire-gong circuit. The energy should be supplied preferably from storage batteries charged automatically or directly from a reliable source of electrical-current supply. In case the latter type of source is used the energy for the trouble circuits should be taken from a separate source.

3. WATCHMAN'S SUPERVISORY SYSTEMS

For buildings or groups of buildings in which no central watch station continuously occupied is present, the watchmen's portable clock and key stations afford a simple means for checking the watchmen's rounds. A system for recording the signal at a central point can be justified for these conditions only on the score of greater ease of checking the record and a convenience for the watchmen in being relieved from carrying the clock.

Larger buildings or groups of buildings in which a central watch office is maintained are best adapted for systems of supervisory equipment. In postal buildings such systems are required where the cost of the building exceeds $2,000,000. One type with which the signal is transmitted by plugging in of a portable telephone at each station is covered in Federal specification no. W–W–101 (56). Federal specifications for other types are being developed. General requirements for the systems have been formulated (53, 54). In some systems watch stations are placed on the same circuit with manual fire-alarm stations. Electrical supervision over watchmen's supervisory circuits, while desirable, is not considered as necessary as for fire-alarm circuits, since the frequency of watchmen's signals serves in a measure to discover promptly any circuit trouble. The reporting stations should be located so that, as nearly as possible, all portions of the building to be supervised will be covered by the watchmen's routes.

4. ADAPTATION OF INTERIOR AUTOMATIC-TELEPHONE EXCHANGES FOR TRANSMISSION OF FIRE ALARMS AND SUPERVISION OF WATCHMEN

Interior automatic-telephone exchanges can be adapted for the transmission of fire alarms and supervision of watchmen by introducing modifications employing equipment and installation details in common use in telephone and signalling practice. While the telephone circuits are not electrically supervised to check their operative condition, this does not introduce a serious element of the unreliability since they are supervised by normal use.

For transmission of fire alarms or other emergency calls, a call number such as 22 or 222 is assigned for the purpose, instructions for sending such calls being posted at each telephone. This call rings special telephones having loud bells at designated locations, such as the office of the superintendent or warden, the fire-brigade headquarters, and the hospital. These telephones are equipped to receive incoming calls only. In addition, the fire call lights a lamp on an annunciator board, giving by number and label the location of the call, which lamp remains connected until manually released at the receiving end.

For transmitting watchmen's calls another call number such as 33 or 333 is used which rings a special one-way telephone at the annunciator board and lights the location lamp. The lamp circuit is, however, broken when the sender completes the call.

This method of transmitting fire, emergency, and watchman's signals is adapted for conditions where the telephones are not spaced much closer or greatly exceed in number those required for covering the area concerned for the given purpose. If an insufficient number for the purpose is present, additional telephones can with economy, be provided at required locations, since the added cost of the modification compared with the cost of separate signaling systems is small.

5. GENERAL INSTALLATION REQUIREMENTS

The central station for all emergency signaling systems and switching equipment of automatic-telephone exchanges used for similar purposes should be located in a fire-resistive building or at least the fire hazard in the location chosen should be the minimum possible under the conditions. The equipment should be fully enclosed, and where conditions warrant, the enclosure as well as terminal boxes locked to prevent tampering. Damp locations should be avoided as unfavorable to reliable functioning of the central station equipment.

All wiring within buildings should be in rigid conduits preferably concealed, and outside of buildings, underground in tunnels or terra-cotta conduits. Wires should be copper, rubber covered, in lead-sheathed cables, otherwise with protective or weather-proof braid, the length of exposed wiring between all outlets and instruments to be kept at a minimum.

6. MUNICIPAL FIRE ALARMS

Means for transmitting fire calls to the headquarters of the public fire brigade include the public telephone and the municipal fire-alarm system where present. For the larger fire-resistive buildings, one or more public fire-alarm boxes might be located at suitable points within the building. Some cities prohibit placing them within buildings and in any case, where this type of protection is present, a box should be located adjacent to or at least within a few hundred feet from important buildings. A preferable location is just outside of the main entrance.

Some cities permit operation of public fire-alarm boxes by the alarms from manual or automatic fire-alarm systems or sprinkler alarms. Whether this is desirable depends on the freedom of the systems from false alarms and other disarrangements and whether it is desired that those in charge within the building shall ascertain the reason for the alarm and the degree of emergency before calling the public brigade. Where a central watch office is continuously attended, such connection with the public fire-alarm system is not usually made. A public box or a manually-operated switch by means of which a public box can be operated, located at such central point, would best serve the purpose for this condition.

68770—34——5

Telephones connected with private manual switchboards that are not attended for the full 24 hr cannot thus connected be depended upon for transmitting fire and emergency calls. With such installations, some of the branch lines should be left connected with the public exchange for the periods when the private switchboard is not attended, the location of the connected telephones to be known to the watch force or other personnel on duty.

XI. FIRE EXTINGUISHMENT

1. GENERAL METHODS OF EXTINGUISHMENT

The means to be provided for attack on fires depend on the amount, value, and fire hazard of the materials involved, temperatures obtaining where the extinguishing equipment is to be located, and the personnel by whom it will be maintained and operated.

(a) CLASSES OF FIRES

From the standpoint of extinguishment fires can be divided into three general groups that will be designated as classes A, B, and C.

1. *Class A fires.*—Fires in ligneous or cellulosic materials like wood, paper, textiles, and animal and vegetable fibers generally, come in this class, as well as those in solid carbonaceous materials such as coal, coke, starch, sugar, cereals, and in bitumen, asphalts, and waxes that do not melt readily under heat. Fires in materials containing nitrocellulose, such as photographic, X-ray, and motion-picture film and pyroxylin products generally, can be placed in this class.

2. *Class B fires.*—Class B fires are those occurring in mineral, vegetable, and animal oils. Petroleum oils in the form of crude oil, gasoline, kerosene, fuel oil, transformer oil, lubricating oil and grease, and coal-tar oils such as benzol, constitute the bulk of mineral-oil products. Among vegetable oils are the alcohols, acetone, turpentine, linseed oil, coconut oil, palm oil, olive oil, cottonseed oil, tung oil, and soybean oil. Some of them are contained in paints,

varnishes, and lacquers. Animal oils include lard oil, oleo oil, red oil, menhaden oil, and whale oil.

3. *Class C fires.*—Class C fires are fires in electrical equipment for which the extinguishing medium should be a nonconductor of electricity if applied before the equipment is disconnected from the source of energy supply. Fires in insulation of motors, generators, transformers, switchboards, and electrical wiring generally, are included in this class. Fires in the oil of oil-cooled electrical equipment should be regarded as class C fires while the equipment is energized, but after it is disconnected they can be regarded as class B fires.

(b) EXTINGUISHING AGENTS

1. *Water.*—The extinguishing effects obtainable from water consist mainly in cooling the burning material to a temperature at which it will not support combustion or re-ignite, wetting it and surrounding material to reduce the rate of combustion and spread of fire, exclusion of oxygen by surface films of water or steam or by immersion, and, as applied to some flammable liquids, dilution to a point where combustion is inhibited.

Water is well adapted for the extinguishment of class A fires, and to a limited extent for class B and class C fires. It can be used for extinguishing fires by dilution of liquids that mix readily with it, such as alcohol and acetone. Water-alcohol mixtures containing less than 25 percent alcohol will not burn. Properly applied, preferably as a spray covering the whole surface, water has a limited application in extinguishing fires in some petroleum oils, including refined distillates, viscous oils, and oils that froth, such as asphalt, fuel, crude, and lubricating oils. Water from automatic sprinklers or hose streams can be used to extinguish fires in relatively small containers of flammable liquids such as in paint rooms and other minor storages of similar materials.

Water should in general be applied to class C fires only after the equipment is disconnected from the power source. While pure water is a poor conductor of electricity, the impurities normally present materially impair its electrical insulation properties. Damage to the equipment and shock to the operator must also be considered in the use of water on live electrical equipment. The possibility of the latter is confined to the presence of high voltages or application at close range and is eliminated entirely if the equipment is disconnected manually or by the operation of automatic circuit-breaking devices.

After a fire in freely exposed materials is well past the initial stage, extinguishment with water is in general the only practical method. Exceptions include fires in large containers of flammable oils. The limitations of water as an extinguishing medium include its relatively high freezing point, making special precautions necessary where temeratures below 32° F obtain. As applied to hot fires of considerable extent water may vaporize before it reaches the burning materials, to prevent which it should be applied progressively in large volume to relatively small areas.

2. *Soda-acid.*—In some types of portable fire-extinguishing equipment and in a few of those of the fixed type, a solution of sodium bicarbonate is employed that, in the operation of the equipment to extinguish fire, is mixed with sulphuric acid. This results in the formation of sodium sulphate, water, and carbon dioxide gas, the chemicals being proportioned to give an acid-free discharge. As held within a closed container, the gas serves to expel the liquid solution under a pressure calculated to give the desired range and duration of stream without rupture of the container.

The extinguishing effect is almost wholly from the water in the solution applied in a stream that can be directed at the seat of the fire. It is accordingly adapted for the extinguishment of class A fires. It has lower electrical resistivity than water and should not be applied to charged electrical equipment. The damage from staining, etc., is somewhat greater than for water. The freezing point of the bicarbonate solution is about −2° C, 28° F.

3. *Foam.*—Foam for extinguishing fire is produced by mixture of solutions of aluminum sulphate and sodium bicarbonate to which a foam stabilizing ingredient has been added, and consists mainly of bubbles of carbon dioxide. In

some foam systems the materials in powder form are mixed with water in a foam generator.

Foam is best adapted for the extinguishment of class B fires. It should be applied gently from a point near the surface of the oil and in sufficient quantity to form a continuous blanket over the whole surface. Foam extinguishes oil fires partly by the cooling from the water it contains but more by cutting off the oil surface from the air, flames, and radiant heat. This inhibits or retards the formation of oil vapor necessary for the continuance of the fire. If the oil for a considerable depth below the surface is up to a temperature where vapor is given off freely, the vapor will penetrate the foam and burn above it. Foam is broken down by solvents such as alcohols, acetone, and ether, and is accordingly not effective for extinguishing fires in them. Carbon disulphide is so volatile that the vapor will continue to be given off and burn above the foam. Water or carbon dioxide are preferred fire-extinguishing agents for such fluids.

Foam is as effective, weight for weight, on some class A fires as water. However, as applied to finely divided material it will not penerate the burning mass to the extent obtainable with water. The greater cost, more limited general availability, and lower range of the applied stream of foam must also be considered. It is a good conductor of electricity and causes somewhat more damage to electrical equipment and materials generally than water. The freezing points of the foam solutions are not greatly below 0° C, 32° F, and even below 5° C, 40° F, the quantity of foam produced for given weights of dry chemicals is materially less than for higher temperatures.

4. *Carbon tetrachloride.*—Carbon tetrachloride is a heavy volatile liquid with boiling point near 77° C, 170° F, and freezing point near −23° C, −9° F. At 38° C, 100° F, the carbon tetrachloride would constitute 25 percent by volume of the saturated gas-air mixture and at 55° C, 131° F, 50 percent. This would reduce the oxygen content of the air to 15.75 and 10.5 percent, respectively. However, so many conditions enter in case of fire extinguishment, such as the time required for evaporation, the quantity applied in rela-

tion to the room space, and the distribution of the concentration at different levels, that such relations should be taken as only indicative. The vapor is heavier than air, which assists in smothering a fire particularly within a closed space, although retarding evaporation at temperatures below the boiling point.

The pure form used in fire extinguishers is free from water, and together with the other liquids added to depress its freezing point, is a poor conductor of electricity. It can break an electric arc. Hence it is adaptable for class C fires although it is moderately effective for small class B fires. Its effectiveness on large oil fires is limited since it would in part dissolve in the oil. Any undissolved or unevaporated portion would not float on the surface on account of higher specific gravity.

Carbon tetrachloride is in general less damaging to ordinary materials and equipment than water or foam. On account of its solvent properties it will damage some electrical insulations and the liquid and condensed fumes produce corrosion of metals. The gas is irritating and toxic and on application to fires the decomposition products contain hydrochloric-acid gas, carbon monoxide, chlorine, and under some conditions, particularly as applied to hot metal, small amounts of phosgene, a highly toxic gas. Hence, manual extinguishment with it in closed spaces should be conducted with caution and rooms within which it has been applied should be well ventilated before being entered.

5. *Carbon dioxide.*—Carbon dioxide is at normal pressures and temperatures a colorless, odorless, inert gas which extinguishes fire by smothering. It is nondamaging to most materials, noncorrosive, leaves no residue, is an electrical insulator, and does not deteriorate with age. It is suffocating in high concentrations. For fire extinguishing it is stored at high pressure in steel cylinders in liquid form. Special valves are needed to retain the carbon dioxide without leakage, and also to prevent freezing at the outlet. On emerging from the nozzle, it expands to about 425 times its stored volume. Once liberated, it cannot remain a liquid so that the amount of inert gas produced by a given quantity of liquid is independent of the fire and is governed only by

the quantity applied. The discharge is usually a combination of carbon-dioxide gas and snow at −79° C, −110° F. Although the main extinguishing effect is from smothering by the gas, the cold snow materially aids in local cooling.

Flame cannot exist in air $-CO_2$ mixtures containing more than 25 to 60 percent CO_2, depending on the material burning. This corresponds to a range in oxygen content of the air from 15.75 to 8.4 percent. The higher concentrations of carbon dioxide will also be needed for extinguishing glowing or incandescent combustible materials. Carbon dioxide has little lasting effect and care should be taken to guard against reflash, by discharging sufficient gas to prevent it.

It is recommended for classes B and C fires and is of limited value on class A fires. For other than relatively small class B and class C fires and for class A fires that are past the incipient stage, certainty of extinguishment must be premised on the presence of an enclosure that will enable an inert gas mixture to be maintained for the required period. It is used in built-in systems for flooding spaces containing special hazards, for local application on machines, tanks, etc., and in hand and wheeled extinguishers. The portable devices have a relatively short range which, however, is somewhat offset by the cold cloud of the discharge which protects the operator from the heat of the fire.

For maintaining an inert atmosphere within a room or enclosure accommodating hazardous processing or storage, flue gas or exhaust gas from internal-combustion engines is often used. This generally contains, in addition to carbon dioxide and nitrogen, minor amounts of oxygen and carbon monoxide. The latter is frequently present in amounts of 1 percent or more, which are highly toxic concentrations.

Spaces flooded with pure carbon-dioxide gas, such as is obtained from the liquid form, need ventilation to increase the oxygen content to about 18 percent before being entered. Where the oxygen concentration is below 10 percent, however, unconsciousness is likely to result within a short time. Such conditions would require oxygen helmets or air masks. Men so equipped have entered spaces flooded with inert gas and by removing hot material have extinguished the fire without the damage that would have been caused by water application.

Where carbon monoxide is present in the inert gas a greater amount of ventilation is generally necessary than for carbon dioxide alone. The maximum safe concentration of carbon monoxide if breathed for periods of over 1 hour is considered to be 0.02 percent or 20 parts per 100,000. The Davy safety lamp, while indicating the safe limit of oxygen content does not necessarily indicate the required reduction in carbon monoxide. Thus with initial oxygen content of 10 percent 2 air changes will increase the oxygen to a little over 19 percent and decrease a carbon-monoxide concentration of 1 percent to 0.12 percent, a total of about 4 air changes being required to reduce it to 0.02 percent (41). With no oxygen initially present and 2 percent of carbon monoxide, 3 air changes will increase the oxygen content to 19 percent and decrease the carbon monoxide to 0.10 percent, nearly 5 air changes being required to reduce it to 0.02 percent.

6. *Steam.*—Steam can be used for extinguishing class B fires where the surrounding space, or space above the oil, is enclosed or partly enclosed, provided the amount supplied is sufficient to reduce the oxygen content to the required degree. For fires in petroleum oils this would require raising the air temperature to near 72° C, 162° F, which corresponds to a water-vapor concentration in the air of nearly 34 percent and oxygen concentration of about 14 percent. For class A fires the vapor concentration must be higher and maintained for a longer period if glowing material is to be extinguished. For this condition an air temperature of 82°C, 180° F, corresponding to a content of saturated water vapor of 51 percent, and reduction of oxygen content to 10.3 percent, should preferably be attained.

The steam may extinguish both by smothering and by wetting. On account of the heat required to raise the temperature of the enclosure a liberal margin over the computed necessary quantity should be allowed. It will generally be advantageous to use steam for fire extinguishment only where a sufficient supply can be obtained from heating, power, or other boilers not supplying steam for equipment, the operation of which is necessary when a fire occurs. For discharge into occupied spaces, low-pressure steam, such as exhaust steam, should preferably be used and the release effected by manual means. Precautions need be taken to avoid accidental discharge and automatic discharge should be applied only for uninhabited spaces.

7. *Dry powdered material.*—Dry sand, soil, or other incombustible material in fine particles or powder form are moderately effective on small class B fires, such as oil burning on the ground or floor. Heavy material like sand is not effective for fires in oil contained in vats or tanks, but light chemicals applied by means of compressed inert gas as a dust and mixtures of sodium bicarbonate and dry sawdust applied by hand, are moderately effective where the area of the oil can be fully covered. For other than very small fires, such as grease fires in cooking utensils, a much greater quantity than that contained in the usual dry-powder hand fire extinguishers will be required. Without special equipment they must all be applied at relatively close range, which limits their usefulness for the purpose.

8. *Freezing-point depression.*—The freezing point of some fire-extinguishing media can be depressed by the addition of chemicals and thus enable their use in equipments exposed to temperatures below their normal freezing point. For water, additions of calcium chloride or sodium chloride (common salt) are usually made for this purpose. Common-salt solutions are best adapted for wood containers. If coated on the inside with pitch, asphaltum, or a mixture of paraffin and resin, they will generally also hold the calcium-chloride solution satisfactorily. Common salt has a greater corrosive effect on metal and does not depress the freezing point to the low limit obtainable with calcium chloride. One lb of lime added to each 50 gal of calcium-chloride solution will make it slightly alkaline and assist in decreasing corrosion. Table 4 gives the quantities in avoirdupois pounds required per gallon of water for depression of the freezing point of water to the degree desired. The quantities are based on pure dry sodium chloride and refrigeration grade calcium chloride. The latter is assumed to consist of 75 percent of $CaCl_2$ and 25 percent water, the quantities required being obtained by modi-

fying the values given in the International Critical Tables (vol. 4, p. 257–8) to allow for the water content assumed.

TABLE 4.—*Properties of non-freezing water solutions*

Freezing temperature of solution		75 percent calcium chloride		Sodium chloride	
Degrees F	Degrees C	Lb per gal of water	Specific gravity at 20° C	Lb per gal of water	Specific gravity at 20° C
+20	−6.7	1.39	1.090	0.95	1.072
+15	−9.4	1.82	1.116	1.30	1.097
+10	−12.2	2.23	1.136	1.62	1.118
0	−17.8	2.98	1.174	2.22	1.156
−5	−20.6	3.31	1.191	2.49	1.172
−10	−23.4	3.65	1.206	----------	----------
−20	−28.9	4.26	1.232	----------	----------
−30	−34.4	4.84	1.255	----------	----------
−40	−40.0	5.37	1.275	----------	----------

No chemicals should be applied for depressing the freezing point of sodium-bicarbonate or aluminum-sulphate solutions as used in soda-acid or foam fire-extinguishing equipment. The freezing point of stored liquid carbon dioxide is too low to require any protective measures. The freezing point of carbon-tetrachloride fire-extinguishing liquid is required according to specifications (61) to be not higher than −45.5° C, −50° F. Different chemicals are used by individual manufacturers to depress the freezing point of the carbon-tetrachloride base. The additions should not decrease appreciably the electrical insulating or fire-extinguishing properties of the liquid nor increase its toxicity.

(c) GENERAL TYPES OF FIRE-EXTINGUISHING EQUIPMENT

The general types of fire-extinguishing equipment comprise portable fire extinguishers, manually operated fixed equipments, and automatically operated fixed equipments. The choice in types will depend largely on the relation of cost of protection to the value of the property protected and the degree of fire hazard presented, as discussed in section II. It will also depend on particular structural and occupancy conditions and the environment. An occupancy unduly exposing or exposed by its surroundings may need a higher degree of protection than if its own hazards alone were considered.

Portable fire extinguishers are here taken to comprise hand and wheeled extinguishers, exclusive of motor-propelled equipment. The manually operated fixed equipments include mainly standpipe and hose systems arranged with small hose for the use of occupants or with outlets for the larger hose used by organized fire brigades, and outside systems of water mains and hydrants. Fixed equipments for discharging inert gas or foam by manual means would be included also. Automatically operated fixed equipments discharge the extinguishing fluid through the medium of heat-actuated devices and comprise automatic sprinkler systems discharging water, and automatic carbon-dioxide and foam fire-extinguishing systems.

2. STANDPIPE AND HOSE SYSTEMS

The protection given by standpipe and hose systems in buildings below a certain height is augmented by hose streams supplied by street hydrants where public protection is present. For higher buildings, the standpipe system must furnish the whole supply needed for hose streams used in fire extinguishment. This will generally involve 2 systems of standpipe or standpipe outlets, 1 for small hose to be used by the occupants of the building and the other for the larger hose employed by the public fire brigade. The building height above which standpipe supply for large hose should be provided depends in part on local conditions, such as water pressure in the street mains, fire-department equipment, and its preferred method of fighting fire. The limit can be taken to be in the approximate range 45 to 65 ft height of roof above street level.

The degree of protection that can be given by standpipe and hose designed for the use of occupants or watch force of a building depends on facilities for the discovery of fire and the organization for fire fighting. Where the hazard and values warrant, frequent rounds by watchmen of unoccupied spaces or installation of automatic fire-detecting equipment, will assist in early discovery, and an established procedure to be followed in case of fire by occupants and building personnel will help to achieve prompt extinguishment. For spaces continuously occupied the fire is likely to be discovered in its initial stages by the occupants, and unless highly flammable contents are present, standpipe and hose systems can be used to give very adequate protection.

(a) WATER SUPPLY FOR STANDPIPES

The usual sources of supply for standpipes with large hose outlets are fire-department pumpers suplying water through outside siamese connections, city high-pressure water mains, pressure tanks, gravity tanks, fire pumps, or combinations of them. For standpipes supplying small hose the sources include city service mains, house booster pumps, pressure tanks, gravity tanks, or combinations of pumps and tanks. The method of supplying water will determine some of the more important details of the systems.

1. *Water supplies for large hose.*—For standpipe systems supplying large hose (generally $2\frac{1}{2}$-in. hose with $1\frac{1}{8}$-in. nozzle) the requirements for water supply can be given as not less than 250 gal/min for each standpipe riser at a pressure of not less than 50 lb/in.^{2} at the top outlet (not including roof outlet) when discharging at the given (250 gal/min) rate (42). Allowing for friction loss in pipes of the sizes herein recommended, this will be equivalent to a static pressure at the given outlet of 55 to 60 lb/in.^{2} The minimum capacity of fire pumps used as a main source of supply should be 500 gal/min, pressure tanks 4,500 gal, gravity tank 5,000 gal, the latter with bottom elevated not less than 40 ft above top hose outlet. Gravity and pressure tanks should be considered as sources of supply only until other supplies, such as fire-department pumpers or fire pump, can be brought into service. Where water for small hose is supplied from a separate source, pressure and gravity tanks for large standpipes can be omitted if they are supplied by any of the following: A city water system of adequate capacity and pressure; fire pump with duplicate power supply; fire

pump supplemented by fire-department pumpers; or the pumpers alone if from a well-organized fire brigade, the response of which is not likely to be delayed by snow or other impediments. The quantity and pressure capacity of the separate sources is assumed adequate for the height and number of standpipes concerned. The standpipes should be kept primed by a small connection under pressure sufficient to keep them filled, with check valve against back flow provided in the connection. Dry standpipes should be used only where protection from freezing cannot be provided.

City water mains and their connections with standpipe systems should be of size and number adequate for supplying the quantity required, and connections should preferably be made outside of water meters. If made inside of the meter, the latter should be of size and type that will not introduce undue friction loss under conditions of maximum domestic and fire demand. Disk meters, while the most accurate, introduce the highest loss of head. Velocity meters of the same size as the connecting main are less objectionable. The fire-service meter is designed so that the friction loss is relatively small. Its cost is greater than that of the others and it should not be specified unless needed. Some cities permit connections for fire protection outside of the meter. A bypass should be provided around the meter in any case. It cannot, however, be premised that this will be opened in emergency to permit flow around a meter of insufficient capacity unless it is in a convenient location with building personnel and public fire brigade fully informed on the necessity of so doing.

If the source of water supply is not adequate or the connection therewith is too small or too long to supply water at the required rate, recourse must be had to gravity or pressure tanks, (43) or suction tanks or reservoirs for a fire pump. The amount of storage needed can be determined only from a study of the pertaining conditions. It will depend not only on the extent of the property to be protected but also on the type of construction, subdivision into fire areas, protection of openings, occupancy, and the exterior exposure. The quantity is determined by the number of hose streams estimated as necessary and the time they would need to be applied to control a fire under the more unfavorable conditions. Where an adequate water supply is present within reasonable distance, enlargement of the connection to the required size may be found more advantageous than provisions for storage in large amounts. It is occasionally possible to connect with a main of greater capacity or under higher pressure than that supplying the domestic demand of the building.

Where the city has a separate system of high-pressure fire-service mains, the connection to the standpipe system is made by hose from street hydrants to the fire-department connection on the outside of the building. A length of hose for the purpose might be kept within the building together with some lengths of fire hose on portable reels for use in case for any reason the response of the fire brigade is prevented or delayed.

2. *Water supplies for small hose.*—For standpipe systems supplying small hose (preferably 1½-in. linen unlined fire hose with ½- or ⅝-in. nozzle) any source giving a minimum flow of 100 gal/min at a pressure of 25 lb/in.^{2} at the highest hose outlet is considered adequate (42). Allowing for friction loss in piping this would require a minimum static pressure at the highest hose outlets of 30 to 35 lb/in.^{2} A more effective hose stream results from nozzle pressure of 40 lb/in.^{2} giving, with a ½-in. nozzle, discharge of little less than 50 gal/min. With the friction loss in 75 ft of 1½-in. unlined hose and that in the pipes added, this represents a static pressure at the hose outlet of 60 to 65 lb/in.^{2}, which it would be desirable to maintain at least as an average for the building. The supply of 100 gal/min can be taken from tanks connected with the domestic supply provided the pumps supplying them have the needed capacity for the combined demand. In this case it may be found advantageous to combine the distributing systems for the two purposes also, if the layout requires approximately the same pipe spacing. This may also assist in securing proper pressure distribution since the maximum and minimum pressures desirable for the domestic supply come within the range required for the hose streams.

If the area is covered with a wet-pipe system of automatic sprinklers, the supply for small-hose streams can be taken from the sprinkler risers, with the limitations given in the installation rules for automatic-sprinkler equipments.

For supplies that are stored as in gravity or pressure tanks, the minimum carried for all but relatively small buildings should be 3,000 gal, which allows for 2 hose streams for 30 min. If water from standpipes for large hose or from ground hydrants is also available, the above should be sufficient until extinguishment is begun with the larger hose.

3. *Location of pressure tanks.*—When the water level in pressure tanks can be maintained by the pumps under conditions of maximum demand, the tank can generally be located at the most convenient point within the building unless the latter is of such height that the basement location would require excessive pressures to be carried. For moderate heights, the cost of providing support for them above the basement may exceed the added cost for a heavier tank construction in the basement location. Where pressure tanks are used for storage, location on the roof will generally be found necessary, since for the same pressure on the upper outlets with the tank empty, those in a lower location would be required to carry an excess pressure equal to three times the head due to the difference in elevation. This assumes that when filled, the water occupies two-thirds of the tank volume.

Constant water level and pressure can be maintained by automatic regulation of air and water supply. Generally it may be sufficient to regulate only the pressure automatically by controls on either the air or the water supply. Alarm devices indicating low water level and pressure may under some conditions serve the purpose of automatic regulation.

4. *Fire pumps.*—The usual sizes are 500, 750, and 1,000 gal/min with discharge pressures from 100 to 175 lb/in.^{2}, (44) the centrifugal type being generally preferred. Any suction head from pressure in the supply main is generally neglected in rating the discharge capacity although it should be considered in providing pressure-reducing devices at hose

outlets and other points. A relief valve should be provided at the pump with drainage for the discharge.

Where there will be an immediate demand on the pump in case of fire, the pump should have a combined manual and automatic starting panel, so that it can be started by the ringing of manual or automatic fire alarms, pressure drop in the standpipe system, or by manual switches. Where the initial demand is supplied from tanks, automatic start for the pump is less necessary. The relative cost and reliability of the two methods should be considered for each installation.

5. *Inclosures.*—Fire pumps and pressure tanks should be placed within fire-resistive enclosures having curbs at door openings and floor drains.

(b) SPACING AND LOCATION OF STANDPIPES

Standpipes for large hose should be located in enclosed stairways. With adequate pressure, hose lengths of 200 ft or more can be employed, but generally the spacing of stairways required for exit of occupants will enable shorter lengths to reach all portions of the building.

Standpipes for small hose should be spaced so that all portions of the building can be reached by a stream of 25-ft range at the end of not more than 75 ft of hose. Where pressures are adequate the hose length might be increasd for isolated locations to 100 ft although this length is less easily handled.

Standpipes or standpipe outlets for small hose should be located in corridors in preference to stairway enclosures, to prevent obstruction of stairways and admission of smoke during the initial stages of the fire fighting when the stairs are used for exit of occupants. Shorter lengths of hose will also then be required. Where standpipe risers supply both small and large hose, the riser should be located in the stairway, and connections for the small hose with shut-off valve inside of stairway, taken off to points outside of the stairway enclosure. However, where no location presenting low fire hazard, such as a corridor, is present, it may be necessary to locate outlets for small hose in stairways, since otherwise it might not be possible to use them on account of fire in adjacent combustible materials. Standpipes may also have to be located with reference to protection against exterior fire exposure. Large standpipes should be extended to an outlet on the roof, portions exposed to freezing to be kept dry by means of a valve inside of the building. Standpipes outside of stairways should preferably be covered by the building construction to prevent direct exposure to fire, or be otherwise insulated.

(c) RANGE OF HOSE STREAMS OF RESTRICTED HEIGHT

The range of hose streams to be expected when the stream height is restricted, as would be the case in most locations in buildings, is given in table 5 for heights of stream of 6, 8, and 10 ft above ground or floor level. Values are given for ½-in. and 1⅛-in. nozzles. The tests on which the table is based were conducted out of doors but the results are reasonably free from wind effects.

TABLE 5.—*Range of hose streams for different heights of stream above ground*

[Tip of nozzle 2 ft 4 in. above ground]

RANGE IN FT FOR ½-IN. NOZZLE

Pressure at base of nozzle lb/in.²	Gal/min (computed)	Height											
		6 feet				8 feet				10 feet			
		A	B	C	D	A	B	C	D	A	B	C	D
10	24	16	29	34	38	17	30	35	40	17	36	39	44
15	29	17	35	40	47	19	38	43	48	18	44	48	53
20	33	19	40	46	52	21	44	49	55	20	50	54	60
25	37	20	44	50	57	23	48	54	60	22	56	60	67
30	41	22	48	54	62	25	53	58	65	24	61	64	72
35	44	23	51	57	66	27	57	62	70	27	65	68	77
40	47	25	54	60	69	29	61	66	74	30	69	72	81
45	50	27	57	63	72	31	64	70	78	32	72	76	85
50	53	28	60	65	75	32	67	73	81	35	75	79	88
60	58	31	64	69	80	35	72	77	87	38	80	84	94
70	62	33	68	73	85	37	76	81	93	41	85	89	100

TABLE 5.—*Range of hose streams for different heights of stream above ground*—Continued

[Tip of nozzle 2 ft. 4 in. above ground]

RANGE IN FT. FOR 1⅛-IN. NOZZLE

Pressure at base of nozzle lb/in.^{2}	Gal/min (computed)	Height											
		6 feet				8 feet				10 feet			
		A	B	C	D	A	B	C	D	A	B	C	D
10	118	18	32	38	43	17	35	38	41	21	39	43	50
15	145	19	39	45	51	21	42	47	53	25	51	56	62
20	167	20	45	51	58	24	48	55	63	28	60	65	72
25	187	21	50	57	64	27	55	62	71	31	67	72	80
30	205	22	56	62	69	30	61	68	77	34	73	79	88
35	221	24	61	67	74	32	67	74	83	36	78	85	95
40	237	25	65	71	79	35	73	79	90	38	84	91	102
45	251	27	69	76	83	37	79	84	96	40	89	96	109
50	265	29	71	80	87	39	85	90	102	42	94	101	115
60	290	34	75	86	94	43	94	100	113	45	102	111	126
70	313	40	78	89	99	46	100	110	123	47	108	119	135

A = Range where stream is nearly solid with little spray.
B = Range for center of stream about 4 ft above ground.
C = Range for center of stream where it hits ground.
D = Range for extreme drops.

(d) SIZE OF STANDPIPES

With the maximum demand and the water supply available known, the size of standpipes and distributing mains can be determined so that the quantity and pressures required at outlets will be obtained. Standpipes supplying large hose in buildings not over 75 ft or 6 stories high will generally be adequate if of 4-in. pipe. For higher buildings 6-in. standpipes are recommended (42). No increase in size for combined supply to large and small hose will usually be required.

For supplying small hose, standpipe risers and circulating mains should not be less than 2 in. for buildings not exceeding 4 stories or 50 ft in height and 2½ in. for higher buildings. Where the same pipe system is used as that for the domestic supply, it may be necessary to increase these sizes by ½ or 1 in. Generally, considerable economy and increased simplicity can be obtained by this combination of services. It assumes, however, that the water supply provided is adequate for both.

All standpipe risers should be connected through a gate valve with a circulating main of size not smaller than the largest riser.

(e) HOSE OUTLETS, HOSE, NOZZLES, AND VALVES

Hose valves should be of the gate or angle type and have national standard fire-hose thread. If the fire-hose thread for the locality is not according to this standard, adapters should be provided. This is recommended on the assumption that the national standard thread will eventually be adopted. Generally large hose is not provided at the outlets. Small hose should perferably be 1½ in. linen unlined (63), fittings to have 11½ threads per in. The necessary length should be stored on racks at each outlet. The discharge side of hose outlet valves and all other outlets for fire hose should have male threads. Semiautomatic or one-man hose racks can be obtained with which water from the open hose valve is prevented from entering the hose until after it is extended, but are not in general considered necessary. Racks for hose should preferably be in cabinets flush with the supporting wall and fitted with glass doors. In correctional and similar institutions, steel doors prominently marked may have to be used in place of glass.

For small hose, nozzles should preferably be ½ in. Nozzles with a shut-off device should be provided only for locations where prevention of water damage is a prime consideration. One gate valve should be provided at the base of each standpipe riser.

Where standpipes are exposed to freezing, they can be kept dry with a control valve and drain. The valve may be manually operated or remotely controlled and operated by electrical or hydraulic means. One valve may be used to admit water to several standpipes.

Where standpipe systems or pressure tanks are supplied for initial fire fighting from the domestic or other source at lower pressure than that given by the fire pump or fire-department pumpers, a check valve should be placed in the connection to the low-pressure supply. Street (siamese) inlets for pumpers or high-pressure fire-service connections, should be provided at one or more accessible points to standpipe systems where such public portection is provided. For standpipes serving large hose, one such connection must be provided for each standpipe riser where the risers are not interconnected.

(f) ALLOWABLE PRESSURES AND PRESSURE-REDUCING DEVICES

Continuous pressures exceeding 150 lb/in.^{2} are usually considered undesirable on parts of standpipe systems from which hose outlets are taken. At the hose outlets, pressure-reducing devices should be provided so that the pressure with the stream flowing will not exceed about 55 lb/in.^{2} immediately outside of the outlet. Nozzle pressures of 40 lb/in.^{2} should preferably not be exceeded. With a 1⅛-in. nozzle at the end of 100 ft of 2½-in. rubber-lined hose, or 75 ft of 1½-in. linen unlined hose with ½-in. nozzle, 55 lb/in.^{2} at the hose valve would correspond to the given nozzle pressure. Allowing for friction losses in pipe and fittings, the above rule would require reducing devices at hose outlets where the static pressure exceeds 60 to 65 lb/in.^{2}

Where the standpipe systems for small hose are combined with the domestic water-supply system, the pressure regulation required for the latter may serve the purpose for the hose outlets, depending on the range in pressure obtaining. Pressures can be reduced by the insertion of a disk outside of the hose valve with an orifice "*A*" square inches in area, that can be determined approximately from the formula,

$$A = .0425\frac{Q}{\sqrt{P_1 - P_2}},$$

where Q is the discharge in gal/min and $P_1 - P_2$ is the difference in pressure on the two sides of the disk in lb/in.^{2} The actual pressure obtaining on the outlet side of the disk should be determined in representative locations after installation.

Another method consists in placing a brass sleeve over the lower threaded portion of the valve stem immediately above the gate, about 1/16 in. thick and slightly larger than the thread on the valve stem. Its length is made so that it will stop the movement of the valve at the position giving the desired pressure. For rising-stem valves it is most conveniently determined by measuring the travel of the valve from the full open position to the position giving the desired pressure, the required length of sleeve being equal to this travel. For this type as also for the nonrising-stem type, this movement can be computed in terms of the number of turns required and gate movement per turn of wheel. (See fig. 1.)

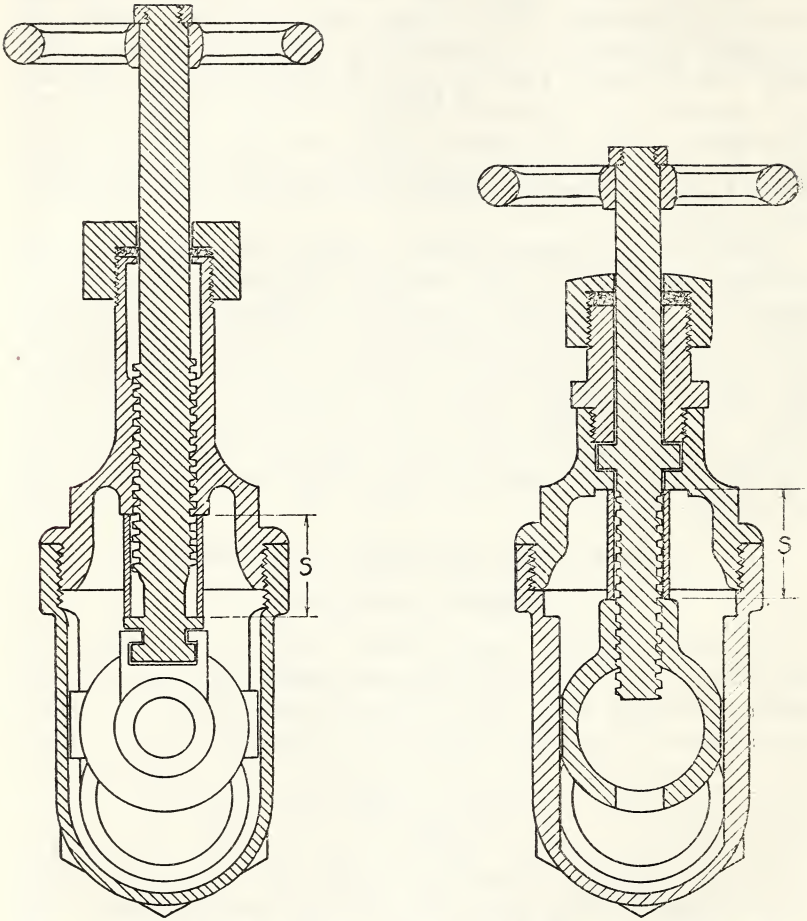
Adjustable pressure-reducing valves are obtainable involving restriction of flow through adjustable disks or diaphragms. The cost of the pressure regulation using these valves is much greater than with the devices outlined above and it should be considered whether for a given installation the added expense is warranted. One type of location in which the adjustable device has advantages is where a standpipe may have to be used to fight an exposure fire requiring water at higher pressure than fires inside of the building.

3. AUTOMATIC-SPRINKLER EQUIPMENTS

(a) SCOPE OF APPLICATION

Automatic-sprinkler protection employing water is adapted in general for occupancies presenting hazards and values such that the cost of the protection can be justified on the score of expected reduction in loss from fire, as outlined in section II. In determining the cost of protection, items such as any resulting change in the cost of the structural portion of the building, its value from the standpoint of utility, storage capacity, etc., and the expense for operation and maintenance, should also be considered. The effectiveness of this type of protection with properly installed and maintained equipments is high, so that an annual cost equal to a large portion of the average annual fire loss to which given types of property are subject as unprotected can be profitably incurred for this type of protection.

It will, in general, be found that only conditions representative of the higher values or hazards call for such pro-



RISING STEM VALVE NON-RISING STEM VALVE

FIGURE 1.—*Pressure reducing device for fire hose outlet valves.*

Length of sleeve $S=n\times p$,
Where n=turns of wheel from full open position to that giving the desired pressure,
and p=gate movement per turn of wheel.

tection. Some areas within buildings may not present values such that the protection is required on that account alone, but a fire in them may cause damage to higher values in adjacent relatively nonhazardous areas to such extent as to justify the installation. Carpenter and paint shops, shipping rooms, and waste paper and miscellaneous storage in fire-resistive public or office buildings are examples. The general types of occupancies for which the protection is adapted include manufacturing, handling, and storage, presenting moderate to high hazards and values, and subject mainly to class A fires. Fires such as those in garages and airplane hangars that come in part under class B, can generally be controlled satisfactorily also on account of the large volume of water applied. Other areas adaptable for automatic sprinkler protection include inaccessible spaces difficult to protect by other means. The absence of other forms of protection and requirements for isolation, such as in penal institutions, may also be determining factors.

The protection cannot, however, control fires in flammable liquids in large containers, in materials subject to flash fires, or those originated by explosions of gases, including vapors from flammable liquids, dusts, and explosives. Spaces subject to class C fires such as electrical generating, transforming and distributing stations, are also not adapted for this type of protection. Other materials that react with water to such extent as to preclude this type of protection where they are present in quantities, include aluminum powder, calcium carbide, calcium phosphide, metallic sodium and potassium, calcium oxide (quick lime), magnesium powder, and sodium peroxide.

Materials of high value subject to water damage might come within a similar classification although storage in suitable containers or on skids will minimize this possibility. Generally, the prospective water damage from accidental operation or opening of heads over a large area because of a localized fire, is overestimated. In some locations the exposed piping and heads may be objectionable on the score of appearance. Concealed piping and pendent heads can be used on wet-pipe systems although at some sacrifice in effectiveness.

The general advantage of sprinklers as an automatic fire-alarm and extinguishing equipment consists in that the effectiveness is independent of the human element except as concerns response for shutting off water to prevent undue water damage, and proper upkeep. With the types of protection previously discussed, it has been indicated that there must be discovery of fire at early stages and prompt response to alarms with means for initiation of fire extinguishment, if the effectiveness of the equipment provided is to be developed.

Automatic sprinklers compensate to some extent for deficiencies in construction from the standpoint of fire resistance of building members, subdivision into fire areas, and protection against exterior exposure. They cannot, however, be taken as substituting for adequate means for egress, particularly in places of public assembly, although safety to life is promoted by the extinguishment of fire in earlier stages when this equipment is present within a building.

(b) TYPES

The types of automatic-sprinkler equipments employing water include wet-pipe, dry-pipe, thermostatically operated systems with either closed or open heads, and open systems for protection against exterior exposure.

In the wet-pipe system all portions are filled with water, and without special precautions, such as maintenance of piping filled with nonfreezing solution, is is adapted only for areas not subject to freezing. Within this limitation its effectiveness, reliability, and economy, give it preference over other types except in areas over which rapid spread of fire can occur. This type can be applied at low cost to minor hazardous areas such as furnace rooms and waste paper storage. The small number of heads would often require no outlay for additional water supply.

In the dry-pipe system, adaptable for areas subject to freezing temperatures, the piping beyond the dry valve is filled with air under pressure. The operation of a head lowers the air pressure which trips the dry valve, admitting water to the system. Exhausters or accelerators are installed to hasten the action of the valve. The air in the system slightly delays the issue of water and the dry valve introduces an element of added initial cost and maintenance and a minor element of unreliability due to possible sticking of the dry value on its seat. The latter is being largely overcome in recent types of valves.

In thermostatically controlled systems with closed heads, the piping beyond the control valve is filled with air at or near atmospheric pressure. The thermosensitive elements are usually of the rate-of-rise type (see sections X 2(a) and X (b)), and are suitably distributed on the ceiling over the area to be protected. The operation of one or more thermosensitive elements from fire in the area, opens the valve and admits water to the system. No water will, however, issue until a sprinkler head opens. The thermosensitive elements being more sensitive than the sprinkler heads, will give the alarm before the latter opens, which, with prompt response may enable the fire to be extinguished with first-aid equipment before the sprinkler head opens. On opening of the heads water will issue a little more promptly than in systems controlled by dry-pipe valves because of the lower air pressure initially present in the pipes. A small difference in air pressure may be maintained between the atmosphere and the piping system as a means of detecting leaky or accidentally opened heads.

In thermostatically controlled systems with open heads, the water is admitted to the system when the control valve operates and issues through the full number of heads controlled by the valve, the heads being standard sprinkler heads with the thermosensitive element and cap removed. These are restricted by accepted regulations (45) to 75 per valve compared with 1,000 permitted for closed heads.

Both types of thermostatically controlled systems are adapted for areas subject to freezing temperatures. The type with open heads can control fires that spread rapidly better than the other types. Possibility of water damage from both accidental operation and the excess applied in case of fire, must, however, be considered. The contents of buildings such as garages and airplane hangars are not likely to be damaged by water.

Open sprinklers used for protection against exterior exposure were discussed briefly in section V 4(b). They are usually manually controlled but may be operated automatically by heat-actuated devices.

(c) HEADS FOR AUTOMATIC-SPRINKLER SYSTEMS

Heat-actuated heads for controlling the flow of water in automatic-sprinkler systems have been the subject of intense development and testing during the past 50 yr with the result that present recognized models have a high degree of reliability if properly installed.

There are three common types of sprinkler heads. One type depends for operation on the fusion of a solder in a device that controls the issue of water from the head, the temperature of operation being controlled by the characteristics of the solder. A second type depends for operation on the fusion of a solid chemical in a similar device, the temperature of operation being controlled by the use of different solid chemicals for the fusible element. The third type operates by the fracture of a liquid-filled bulb, the temperature of operation being controlled mainly by varying the relation of the volume of liquid to that of an air bubble within the bulb. All three types can be obtained in models designed to operate at various temperatures which can be recognized by the color of the frame. The temperature ratings of the various heads and the corresponding frame colors are indicated in table 6.

TABLE 6.—*Temperature ratings of automatic sprinklers*

Rated operating temperature of heads (° F)	Max permissible temp at ceiling where sprinklers to be used (° F)	Designation	Color of frame
135 to 165	80 to 100	Ordinary	Unpainted bronze.[1]
175 to 212	101 to 150	Intermediate	White.[2]
250 to 286	151 to 225	Hard	Blue.
325 to 360	226 to 300	Extra hard	Red.

[1] The 135° nonmetallic (chemical) type has partial black marking on sides of frame.
[2] The 175° chemical and silica bulb types have yellow frames.

The sensitivity of a sprinkler head, expressed in terms of the time before it operates as subjected to a given temperature rise, depends on its design and temperature of operation. The air temperature surrounding a sprinkler when it operates due to rise in temperature as from a fire, is likely to be considerably higher than its rated operating temperature, since the temperature of its thermosensitive element lags behind that of the surroundings.

For locations subject to corrosion, wax-coated heads can be obtained that afford considerable added protection. The wax melts at temperatures below that at which the sprinkler operates and hence does not materially delay operation. Heads completely enclosed in a sealed glass flask can also be obtained, but they are less sensitive than the heads with bare elements. Painting or kalsomining of heads is undesirable as it decreases sensitivity and causes sticking of moving parts.

The life of sprinkler heads as of sprinkler systems generally will vary considerably with the exposing conditions. In computing the cost of the protection, annual depreciation of 4 percent will probably cover for most conditions both deterioration and obsolescence of the equipment as such. It may not cover loss on the investment due to change in occupancy or termination of the useful life of the building. Loss on the latter score is avoided by installing automatic sprinklers in buildings that have assurance of longer life than the protection equipment.

(d) GENERAL INSTALLATION DETAILS

Installation requirements for automatic sprinkler systems have been given careful consideration and systems installed according to accepted standards (45) should give good performance. These include such details as spacing of heads for different types of buildings or ceiling constructions, clearance above heads, size of branch lines, risers, distributing mains and connections, types of fittings, types and general locations for valves, gages, drains, test pipes, and fire-department connections.

According to recommendations of the National Fire Protection Association (45), automatic-sprinkler systems are recognized in two classes, A and B. The regulations for class A systems, which are the only ones that have been recognized until within the past few years, require closer spacing of heads, larger pipe sizes, and greater capacity for the water supply than those for class B systems. The latter are recommended as suitable for light-hazard occupancies, such as apartment houses, dwellings, hotels, schools, hospitals, and office buildings, occupancies which ordinarily are not given automatic sprinkler protection. The rules of the Associated Factory Mutual Fire Insurance Companies (45) cover only class A systems.

A brief summary of requirements of interest to the designer of the building and its equipment may be pertinent. Check valves are required in connections to multiple sources of water supply to prevent back flow through one source from another source at higher pressure. A gate valve is generally required on each side of the check valve to enable inspection and repair of the valve, except in street connection for fire-department pumpers. The water supply to the whole system or portion thereof served should be controlled by one gate valve in an accessible location. Floor valves should be used for shutting off portions of the system only where areas, heights, number of building subdivisions, or number of tenants served are large or where contents are very susceptible to water damage. This is to reduce possibility of shut valves. The types of valves, their supervision, and protection should be adapted for the location. This will need special consideration where tampering or similar interference is possible in order that the protection may be in operative condition at times when it may be most needed. Provision must be made for carrying off water from drains for standpipe risers and from test pipes.

Proper structural details will assist materially in increasing the effectiveness of the installation. A clear space of 24 in. between ceiling and top of permanent equipment and 10 to 12 in. between sprinkler piping and ceiling is desirable. This should be considered in fixing story heights. While smooth ceilings give the best distribution of water from sprinkler heads, beams or draft stops 12 in. or more deep at intervals not exceeding 100 ft, assist in preventing the opening of heads beyond the area affected by a fire and increase the sensitiveness of the heads above the fire. This is particularly important where a floor or roof is supported on deep open trusses. At least some of the latter should be made solid by fireproofing or other method. For fire-resistive floor or roof construction, the best arrangement from the standpoint of class A sprinkler protection is attained by making panels 20 by 20 ft to correspond with the 10-ft spacing required for the sprinklers, with beams at all margins of the panels projecting 10 to 12 in. below the floor slab.

Vertical communications must be protected to prevent opening of heads on floors not affected by the fire and exterior openings should be protected for similar reasons. Small enclosures and concealed spaces in walls and ceilings of combustible construction are undesirable since they enable fire to originate and spread through channels that cannot be reached by the sprinklers. Segregation of portions of building not covered by the protection from those that are protected is required by the regulations. Floors should be watertight and slope on a grade of not less than 1 in. in 20 ft toward scuppers or floor drains.

(e) WATER SUPPLIES FOR SPRINKLERS

The sources of supply include public water mains, the same reinforced by booster or fire pumps, fire-department pumpers and gravity and pressure tanks. There should preferably be two sources of supply. A public main giving adequate capacity and pressure is a satisfactory source of primary supply. Hydrant tests should be made at the building site to determine the available pressure with water flowing at the required rate. A static pressure of 25 lb/in.^{2} on the top line of sprinklers or 10 to 15 lb/in.^{2} minimum at this point with water flowing at a rate representative of the consumption when all heads subject to one fire are opened, represents minimum requirements. The connection should be made outside of the meter or a meter placed in the connection that will not cause undue loss of head.

Gravity tanks are considered satisfactory primary supplies if the bottom of the tank is 20 or 25 ft above the top line of sprinklers. Capacity of tank has been recommended as not less than the consumption of 25 percent of the sprinkler heads within one undivided area for 20 minutes. Assuming 20 gal/min per sprinkler, this is equivalent to 100 gal for each sprinkler within the area. For 50 or more heads within one area the minimum capacity should be 5,000 gal. The above assumes the presence of a secondary supply such as a public main supplying water through a fire pump or fire-department pumpers. If an elevated tank supplies private hydrants also, the bottom should have an elevation above the highest buildings of not less than 25 ft and have capacity of not less than 30,000 gal.

Pressure tanks generally carry only about ½ of the water specified for gravity tanks. The static pressure on the top line of sprinklers with the tank empty should not be less than 15 lb. Unless acting merely as a cushion tank for a fire pump, the pressure tank or tanks should be placed on the roof or other elevated position to avoid excessive pressure in the basement location as explained in section XI 2(a) 3 above. A secondary supply such as was indicated for gravity tanks would be needed with the pressure tanks.

Fire pumps should preferably be provided with automatic-starting panels even where an initial supply in gravity or pressure tanks is present. Fire-department connections on outside of buildings should be made to all sprinkler equipments where public protection is present.

For further details relating to water supply and water-supply equipment, reference is made to section XI 2(a) above.

(f) FIRE-ALARM AND SUPERVISORY EQUIPMENT

Means for giving an alarm at locations where it will receive attention at all hours in case of water flow from opened sprinklers or other cause, tripping of alarm valve, low air pressure, or operation of thermosensitive elements, should be provided. Exceptions to the rule might be made for small wet-pipe systems where provisions have been made for preventing decided water damage.

Sprinkler supervisory equipments checking position of supply valves, operative condition of alarm circuits, pressures at dry-pipe valves, and water level, pressure, and temperature in supply tanks, are obtainable. The necessity for such equipment can be determined only with reference to the conditions surrounding each installation.

4. FIXED CARBON-DIOXIDE FIRE-EXTINGUISHING SYSTEMS

Fixed carbon-dioxide extinguishing equipment is adapted mainly for fires in materials and equipment in enclosed spaces that can be controlled by the reduction of the oxygen content of the air to a point where combustion will not continue. The limit varies for different materials as indicated in table 7.

TABLE 7.—*Reduced oxygen concentrations of the air required to prevent or extinguish fire in different materials*

[Taken from Proceedings of the Thirty-fifth Annual Meeting of the National Fire Protection Association, p. 123, 1931]

Material	Maximum permissible oxygen percentage	Required carbon-dioxide concentration
Pittsburgh coal dust	16	23.8
Pyrethrum flower dust	15.5	26.8
Acetone	15	28.6
Cotton lint or dust in suspension in air	15	28.6
Ethyl alcohol	15	28.6
Gasoline vapor	15	28.6
Kerosene vapor	15	28.6
Methane	14.5	31.0
Cork dust	14.1	32.9
Wheat, corn, or oat elevator dust	14	33.3
Ground oat hulls	13.7	34.8
Ether	13	38.1
Hard rubber dust	13	38.1
Wheat starch	12	43.9
White dextrine	12	43.9
Ethylene	10	52.4
Sulphur	8.5	59.5
Carbon disulphide	8	61.9
Cotton in bulk—to prevent smoldering and reignition	8	61.9
Jute	8	61.9
Carbon monoxide	5.9	71.9
Hydrogen	5.9	71.9

This method is adaptable for the prevention or extinguishment of class A, class B, or class C fires where an inclosure is present sufficient to maintain the inert gas mixture for the required period. Application of the gas locally to the fire without presence of any inclosure is confined mainly to portable equipment, although some fixed installations for direct application to machines and relatively small tanks, vats, and similar equipment have been made.

Two general conditions from the standpoint of application obtain. One condition requires the continuous presence of the gas within the space to prevent fire or explosion and for the other the gas is admitted after the fire has started. For both conditions the gas can be released by manual or automatic means (46). Provision can also be made for both immediate and delayed automatic release. Distributing valves, manually or automatically controlled, can be installed to direct the discharge to any one of several separate spaces, thus reducing the amount of inert gas that need be stored.

The carbon dioxide gas is usually contained in 50-lb cylinders, 9 ft^3 of gas at atmospheric pressure and temperature being assumed to weigh 1 pound. Flue gas and exhaust gas from internal-combustion engines have also been applied for maintaining continuously an inert atmosphere within an inclosure. Thorough ventilation of flooded spaces before entry is required, especially when the latter gases are used. When applied automatically, alarm devices actuated by the thermo-sensitive elements that release the gas or by the initial discharge should be installed to enable occupants to make exit. Openings in inclosures to be flooded, other than those needed to relieve the pressure built up, should be closed by the same means, and forced ventilation shut off. The discharge into closed spaces should be made through suitably spaced nozzles designed to prevent undue agitation that would accelerate combustion, and, also, stoppage from freezing at the point of discharge.

The room space to be allowed per pound of carbon dioxide applied as protection depends mainly on the reduction in oxygen content required for extinguishment of fire in the materials concerned. For oxygen content reduced to 15 percent, 27 ft^3 of room space per pound can be allowed, while for reduction to 10 percent, 1 lb of carbon dioxide will be needed per 12 ft^3 of room space (41). Some excess should be allowed for a further discharge by manual means if found necessary to extinguish the fire. The size of the room must also be considered, the larger rooms being allowed a greater space for a given amount of inert gas. The recommended range is from 15 $ft^3/lb\ CO_2$ for up to 800 ft room space, to 22 ft^3 for rooms of over 50,000 ft^3 (46).

5. FOAM FIRE-EXTINGUISHING SYSTEMS

Foam fire-extinguishing systems are adapted for class B fires, such as occur in storages of flammable liquids, with exceptions as noted in section XI 1(b) 3. The foam-producing materials are generally kept separated until mixed in the foam-generating equipment. The foam can be applied by either manual or automatic means. It should be applied in a manner that will produce the least agitation of the burning liquid.

The capacity of generating and distributing equipment can be determined approximately on the basis of delivery of not less than 10 ft^3 of foam per minute for each 100 ft^2 of liquid surface of the largest unit to be protected (47). The supply of foam-producing materials kept on hand should be sufficient for 5 to 10 ft^3 of foam per square foot of liquid surface of the largest unit to be protected, the amount depending on the volatility of the liquid and the method of application of the foam.

6. OUTSIDE PRIVATE PROTECTION

(a) WATER SUPPLY

Where a building or group of buildings is located beyond the range of protection from a public water supply, or where the latter is inadequate for the purpose, the installation of water mains covering the property may be necessary. The distance to the public or other supply beyond which this is necessary will depend on the extent of the property and the equipment of the public fire brigade. With good

68770—34——7

accessibility, fire engines in series can pump water through 1,000 ft or more of 2½-in. hose, rubber-lined, to deliver streams at the required pressure on the fire, although operating at a decided disadvantage. Where the property is of considerable extent and the distance of any portion thereof from public fire hydrants is more than a few hundred feet it is preferable to provide an underground distributing system.

Where a satisfactory distributing system for domestic supply is present and large extensions of the property are not expected, it may be best to make any new system for fire protection separate from other supplies. The advantage consists in fewer connections, less deterioration and obstruction within the piping, less possibility of drainage from connections broken by fire, and in some cases lower cost of water service. The latter would be true in general where no charge or only a nominal one is made for the fire-service connection. For new installations of any considerable extent, the universal practice of towns and small cities of combining all water service in one system will probably in general be found preferable. Where unpotable water must be used for fire protection, separate systems are required. While the requirements for fire protection may necessitate a larger quantity in storage than for domestic purposes, the actual amount consumed over a period of years is very small as compared to that for domestic consumption, which may make it economical to use the potable supply in preference to the construction of a separate system. The combined system has a reliability feature in its favor in that the domestic demand serves to assure open position of supply valves. However, piping could be partly obstructed by sediment and incrustation without the fact becoming apparent until the higher demand for fire extinguishment is imposed. Water systems supplying the combined domestic and fire-service demand should have supervision and maintenance comparable with that of a municipal water system, thus minimizing possible impairment of the fire service incidental to repairs or extensions of the system and its connections. No underground pipe that is a part of the system should be smaller than 6 in. and valves should be provided for shutting off the domestic connection outside of all buildings served. A separate fire-service system should be provided where the supply for fire extinguishment is from a gravity tank or other limited source or where the pressure required is in excess of that suitable for domestic use. Separate systems should be employed also where an economy results from the avoidance of a meter installation, lower annual rate, service charge or meter rental, the use of a less expensive, nonpotable water supply, or like conditions. In computing relative costs, interest on investment in the water systems, depreciation, and maintenance costs should be considered.

The amount and head of water required in storage, and capacity of connections and pumps, is determined by the maximum flow required for fire extinguishment and the length of time it would be needed under the more extreme conditions. This can be determined only from a study of local conditions. In general, the protection of an individual dwelling or a building of corresponding size requires 500 gal a min. Where dwellings are exposed within distances of 20 ft the requirement would be 1,000 gal/min, and where a district is closely built or buildings approach the dimensions of hotels, warehouses or other structures 2 and 3 stories high or of large area, approximately 3,000 gal/min is required. Densely built sections of 3-story buildings or extensive warehouses, pier sheds, and manufacturing sections, require up to 6,000 gal/min.

(b) DETAILS OF THE SYSTEM

The details of the layout should follow accepted practice, the design to be based on a full study of present and possible future requirements. A complete plan of the installation and all subsequent additions and changes should be made and filed for reference. Supply and distributing mains should be cast-iron pipe preferably not less than 6 in. Distributing mains should be looped. Where buildings in considerable size or number are involved, a minimum size of mains used for hydrant supply should be 8 in. Six-inch mains should be used only where they complete a good gridiron and their length without a cross-connection should not exceed 600 ft. Hydrants should be located to enable not less than 2 hose streams to be concentrated on any point in buildings without standpipe protection. No hose line should be required to be more than 500-ft long where streams are taken direct from hydrants nor more than 700 ft where pumpers are used (49). The average length of hose required should be much less. Hydrants in cold climates should be designed, installed, and drained to prevent freezing. Two $2\frac{1}{2}$-in. outlets, with national standard fire-hose thread are usual for private hydrants. They should be placed not nearer than 50 ft to non-fire-resistive buildings and be located on two or more sides thereof. Where supplying pumpers they should have a suction connection of size and thread to fit the suction hose used and should be located not more than 20 ft from driveways or other location accessible to the fire engine. Where hydrants are on a system of mains supplying large automatic-sprinkler or standpipe systems, no suction connection for pumpers should be provided.

(c) HOSE

The amount of hose to be carried depends on the equipment of the public fire brigade and the degree of certainty and promptness of the response. With a trained private fire brigade, an amount of hose should preferably be carried sufficient to control all but very severe fires, even where outside aid is available. Cotton rubber-lined hose, $2\frac{1}{2}$ in. with standard couplings (62), is best for the use of a trained force. Untrained personnel have difficulty in using this size of hose. The hose can be carried on portable reels, trucks, or stored in hose houses provided over the hydrants. Hose houses should be built to keep out rodents, vermin, etc., that would damage the hose, and racks should be provided to keep the hose dry. They should be arranged so two hose connections can be made readily and enable hydrant valve and hydrant to be replaced. A motor-driven hose wagon or hand-drawn reels may for many conditions be found more practical than storage of hose in hose houses, since less hose would in general be required and less difficulty encountered in maintaining it. A reserve supply of hose should be kept on hand to replace that damaged in fighting a fire. Nozzles should not exceed $1\frac{1}{8}$ in. and for many conditions a smaller size may be preferable. Detachable reducing tips or shut-off valve for nozzle will reduce the water damage incurred in extinguishing fires in the initial stage.

7. PUBLIC WATER SUPPLY

The adequacy of the public water supply is of prime importance in determining the design and cost of private protection. The best possible utilization should be made of it for any form of protection. Its capacity and reliability for any purpose can be determined by flow and pressure tests at the building site and the plan of street mains, the reservoirs, and pumping equipment, will disclose other conditions affecting reliability of the supply.

Connections with the street mains of adequate size and number can usually be made. Separate unmetered connections for fire-protection purposes are preferable. All credit that can conservatively be allowed should be given to supply of water by fire-department pumpers or high-pressure fire-service mains, to standpipe and sprinkler systems through the street (siamese) connections.

8. PUBLIC FIRE BRIGADE

The organization, equipment, location of companies, and the cooperative arrangements that can be effected with the public fire-fighting force have an important bearing on the degree and forms of private protection to be provided. That the fullest use should be made of this service is dictated by considerations of both economy and effectiveness of protection. A procedure should be established for transmitting fire alarms and directing the responding force to the fire. Where considered of mutual advantage, private emergency-signaling systems might be connected directly to the public fire-alarm headquarters.

The building personnel responsible for fire protection should be familiar in a general manner with the equipment and methods of fire fighting used by the public brigade. The latter, by inspections and contacts, can acquire a familiarity with the buildings and occupancies to be protected that will be very helpful when called to extinguish fires in them.

9. PORTABLE FIRE-EXTINGUISHING EQUIPMENT

The points in favor of portable equipments include relatively low cost, portability, which enables them to be carried to the vicinity of the fire, and ease of obtaining an extinguishing medium best adapted for particular conditions. Their effectiveness is limited by the small volume of extinguishing fluid that can be contained and the close range at which it must be applied. Hence, for all but the larger units on trucks, they must be regarded as effective only on fires in their initial stages. To serve effectively as protection, the personnel within the space covered must be informed as to the location and use of the equipment.

(a) RATING OF HAND FIRE EXTINGUISHERS

As a convenience in rating and spacing hand fire extinguishers, a "unit of first aid" has been adopted, each unit consisting of 1 to 5 duplicate appliances, depending on their effectiveness on the different classes of fires. The ratings for the more usual types, as applied by the Underwriters' Laboratories (48), together with other information, are given in table 8. The tabulation indicates the classes of fires for which given extinguishers are adapted and the number required for each unit of first aid. Information on types of fires and extinguishing action of the different media is given in section XI 1. The extinguishers listed are suitable for first-aid use generally except where women are depended on to use the extinguishers, in which case those with a weight of 30 lb or under should be available.

(b) TYPES OF PORTABLE EXTINGUISHERS

1. *Soda-acid type.*—In the loose-stopple type (59) the sulphuric acid is discharged into the solution by inverting

the extinguisher. In the break-bottle type, used mainly only by fire brigades, the top must be bumped against the floor to liberate the acid. The range of the stream is from 30 to 40 ft and the time of discharge about 1 min for the 2½-gal size. The stream should be directed at the base of the flame on the burning materials.

TABLE 8.—*Application of hand fire extinguishers*

Kind of extinguisher	Capacity	Application				Weight, each	Protect from freezing	How operated[1]
		Class of fire	Number per unit	Class of fire	Number per unit			
						Lb		
Soda-acid	1¼ or 1½ gal.	A	2			19 or 25	Yes	X
Do	2½ gal	A	1			35	Yes	X
Water, self-propelled	2½ gal	A	1			35 to 40	Yes	X
Calcium chloride	2½ gal	A	1			40	No	X
Loaded stream	1 gal	A	2				No	X
Do	1¾ gal	A	1				No	X
Pump tank	2½ gal	A	2			40	Yes[2]	P
Do	5 gal	A	1			66	Yes[2]	P
Tank containing 5 fire pails.	22 gal	A	1				Yes[2]	T
Cask with 3 pails	50 gal	A	1				Yes[2]	T
Fire pail	12 qt	A	5				Yes[2]	T
Foam	1¼ or 1½ gal.	A	2	B	2	19 to 25	Yes	X
Do	2½ or 5 gal	A	1	B	1	35 or 70	Yes	X
Carbon-tetrachloride	1, 1¼, 1½, or 2 qt.	B	2	C	2	7 for 1 qt	No	P
Carbon dioxide	7½ or 10 lb	B	2	C	1	35 for 7½ lb.	No	S
Do	15 or 20 lb	B	1	C	1	50 or 77	No	S

[1] P=hand-operated pump; S=stored pressure; X=internally-generated pressure; T=by throwing.
[2] "Yes" for plain water; "No" for nonfreezing solution.

2. *Water type* (*self-propelled*).—The charge, 2½ gal of water, is propelled by a special cartridge containing sufficient carbon dioxide to produce the necessary pressure to propel the water. It has a range of 30 to 45 ft and a discharge time of about 50 sec. It is operated by inverting and bumping.

3. *Calcium-chloride and loaded stream extinguishers.*—The method of operation is similar to that for the soda-

acid extinguisher but the solution is nonfreezing. In some makes, the liquid is expelled by carbon dioxide contained in a bulb which is fractured by bumping the extinguisher against the floor.

4. *Water tank with pump.*—These should be constructed to withstand corrosive effect of nonfreezing solution. The range and rate of discharge may not equal those for the soda-acid extinguisher, depending on the operator.

5. *Water pails, tanks, and casks.*—Five 12-qt fire pails are taken as a unit of first aid. The range and effectiveness of the application are less than for discharge by means of internal pressure or pump, but little or no training is required for fairly effective use.

6. *Foam extinguishers.*—The design and method of operation are similar in essentials to those for the soda-acid type. The extinguisher discharges a foam made up largely of carbon-dioxide bubbles, in volume about 7 times that of the original solution. This will float and spread over the surface of a burning liquid and extinguish the fire by excluding the air needed for combustion. The range is about 25 ft and the time of discharge about three-fourths of a minute for the 2½-gal size. On oil fires, to avoid agitation, direct discharge on side of container at the liquid level, not into the liquid.

7. *Carbon-tetrachloride extinguishers.*—The liquid pump type is covered by Federal specifications (60), the limit of size for other than very specialized purposes being 2 qt. The effective range of the pump type is about 20 ft and the rate of discharge about 1 qt in 45 sec. In extinguishing in oil, the discharge should be directed at the side of the container, at or a little above the liquid level, and not into the liquid. Hand grenades, usually containing colored carbon tetrachloride in a glass bulb and intended to be thrown at the fire, are not considered effective fire-extinguishing appliances.

8. *Carbon-dioxide extinguishers.*—The carbon dioxide is contained in liquid form under pressure and liberated as a gas by puncture of a disk with a hand-driven pointed tool. The effective range for the smaller sizes is about 4 ft, the

time of discharge for the 7½-lb size about 20 sec and for the 15-lb, 40 sec. Best results are obtained by directing the discharge at the edge or base of the fire, making certain that extinguishment is complete before progressing. Electric wiring and equipment to be given this type of protection should be enclosed at least in part as an aid in obtaining the needed concentration of inert gas for extinguishing a fire in them.

9. *Extinguishers on wheels.*—Wheeled extinguishers of the soda-acid and foam types can be obtained in 17- and 33-gal actual capacities, for calcium chloride, in 33-gal capacity, and for the loaded stream type, in 17-gal capacity. The possible range with the larger size is greater than for the hand extinguisher. Wheeled carbon-dioxide extinguishers are listed with capacities of 20, 50, and 100 lb.

10. *Dry-powder types.*—The ordinary dry-powder extinguisher consisting of a tube containing a few pounds of dry powder, usually cooking soda, is of too small capacity to be recognized for rating purposes. Five 12-qt pails of fine dry sand are rated as one unit of extinguishment for small fires in spilled oil. For small areas of heavy oil in vats, a soda-and-sawdust mixture has been used, a unit of first aid consisting of 8 bu of sawdust and 80 lb of soda. The material must be applied to cover the entire surface, as it will not spread like foam. All of the methods employing dry powder thrown by hand are limited in effectiveness by the close approach to the fire that must be made.

(c) RECHARGES FOR PORTABLE FIRE EXTINGUISHERS

Recharges for soda-acid extinguishers can be bought from the manufacturers or made up from the chemicals concerned. The charge for carbon-tetrachloride extinguishers consists essentially of the purified chemical to which a freezing point depressant has been added, and is covered by Federal specification O–F–380 (61). Recharges for the other types of extinguishers must in general be obtained from the manufacturer of the extinguisher. Inquiry should be made before extinguishers are purchased as to the cost and facilities for recharging as this may determine the type to be installed.

(d) SPACING OF PORTABLE EXTINGUISHERS

According to the recommendations of the National Fire Protection Association, for light-hazard occupancies such as office, residential, institutional, and public buildings, units of first-aid fire protection should be provided so that not over 100 ft of travel is required to reach the nearest unit. One unit may be required for each 5,000 ft^2 of floor area (48).

For occupancies such as stores, warehouses, and manufacturing establishments of average hazard, units are recommended to be spaced so that the travel to reach the nearest unit will not exceed 50 ft. One unit may be required for each 2,500 ft^2 of area. For extra-hazardous occupancies the same general spacing is recommended, with provision of additional units for special hazards.

Where standpipe with hose or other fixed or large-size portable extinguishing equipment appropriate for the hazard concerned is present, concentration of hand fire extinguishers greater than that required for light-hazard occupancies, would not in general be necessary. Where a unit consists of several duplicate pieces, all should preferably be grouped in the designated location for the unit.

(e) LOCATION AND SUPPORTS

Portable fire extinguishers should be located at points readily accessible and not likely to be blocked. Where standpipes with hose for use of occupants are present, hose rack and extinguisher might be placed within the same cabinet which can be recessed into the wall and fitted with glass doors. Metal doors with locks should be used only where proven to be a necessity, such as at some points in penal institutions and psychopathic hospitals. Where the occupancy of the building and general location of hazards are known when it is designed, the type, size, and location of portable fire extinguishers should be determined and proper supports and enclosures provided during construction.

XII. FIRE CAUSES AND THEIR ELIMINATION

1. THE FIRE WASTE

The fire loss on buildings and contents in continental United States now approximates a little less than $500,000,000 per year, as indicated in table 9, which is based on the reports of the Actuarial Bureau of the National Board of Fire Underwriters. Of this total loss, it has been estimated that about one-half occurs in cities and towns of over 2,500 population. An upward trend of losses is noted up to 1926 following which the losses have decreased, the latter in face of the large increase in insured values occurring up to 1930. This is significant since it indicates that the more general use of fire-resistive building construction for major buildings, introduction of fire-prevention measures, and improvements in public and private means for prevention and extinguishing fire, have been effective in reducing the loss. Even so, it constitutes a serious drain on the Nation's resources, considering particularly that the cost of public and private fire protection, and loss in wages and production chargeable to fire, increase the actual loss to a figure estimated to be in excess of 1 billion dollars per year. There is in addition a loss of about 7,000 lives per year from fire and burns, according to the mortality statistics published by the United States Census Bureau. It has been estimated that the loss would be increased to 10,000 lives if it included deaths due directly or indirectly to fire but reported under other classifications, such as those from exposure, nervous shock, and collisions and other accidents involving fire or incurred in connection with fire extinguishment. In addition to the deaths reported there are as many or more serious injuries.

TABLE 9.—*Fire losses in continental United States*

[Compiled from figures published by the National Board of Fire Underwriters]

Year	From known causes	From unknown causes	Total from known and unknown causes	Total, including 25 percent for unreported losses
	Dollars	*Dollars*	*Dollars*	*Dollars*
1920	214, 115, 000	144, 208, 000	358, 323, 000	447, 904, 000
1921	220, 741, 000	175, 584, 000	396, 325, 000	495, 406, 000
1922	219, 974, 000	185, 259, 000	405, 233, 000	506, 541, 000
1923	247, 925, 000	180, 373, 000	428, 298, 000	535, 373, 000
1924	249, 530, 000	189, 720, 000	439, 250, 000	549, 062, 000
1925	248, 364, 000	199, 179, 000	447, 543, 000	559, 429, 000
1926	247, 215, 000	202, 370, 000	449, 585, 000	561, 981, 000
1927	207, 309, 000	171, 038, 000	378, 347, 000	472, 934, 000
1928	201, 355, 000	170, 330, 000	371, 685, 000	464, 606, 000
1929	193, 991, 000	173, 566, 000	367, 557, 000	459, 446, 000
1930	209, 496, 000	192, 088, 000	401, 584, 000	501, 980, 000
1931	187, 412, 000	173, 904, 000	361, 316, 000	451, 645, 000
1932	168, 249, 000	152, 438, 000	320, 687, 000	400, 859, 000
Average	216, 590, 000	177, 697, 000	394, 287, 000	492, 859, 000

2. CAUSES OF FIRES

The tabulation of causes of fire loss given in table 10 is of interest as indicating relatively the loss attributable to the different types of causes, from which an indication of the extent to which the fire loss is preventable can be obtained. While the loss from known causes is only a little more than one-half of the total loss reported (not including the 25 percent added for unreported losses), it is probable that most of the causes enter into the loss from unknown causes and unreported losses in approximately the proportions given in the table. Exceptions might be causes easily identified, such as " exposure ", " lightning ", and " explosions ", the losses from which would be expected to appear largely under those from known causes. The volume of experience on which the figures are based was sufficiently large to give nearly the same percentage of loss attributable to individual causes for each of the 6 years. The percentage loss from " exposure including conflagrations " declined, however, from 21.8 percent in 1927 to 15.6 percent in 1932, and that from " incendiarism " increased from an average of 1.2 percent for the 3 years 1927 to 1929, to 3.7 percent in 1930, 8.9 percent in 1931, and 10.5 percent in 1932.

TABLE 10.—*Fire losses from known causes*

[Based on figures for continental United States for the 6-year period 1927–32, published by the National Board of Fire Underwriters]

Cause	Average annual loss	Loss from known causes
	Dollars	*Percent*
Exposure (including conflagrations)	35, 967, 000	18. 5
Matches (smoking)	28, 216, 000	14. 5
Defective chimneys and flues	20, 050, 000	10. 3
Stoves, furnaces, boilers, and their pipes	17, 681, 000	9. 1
Electricity	13, 735, 000	7. 0
Spontaneous combustion	12, 130, 000	6. 2
Sparks on roofs	11, 645, 000	6. 0
Petroleum and its products	11, 501, 000	5. 9
Incendiarism	8, 172, 000	4. 2
Lightning	7, 583, 000	3. 9
Hot ashes and coals, open fires	4, 761, 000	2. 4
Sparks from machinery	4, 592, 000	2. 4
Open lights	3, 328, 000	1. 7
Miscellaneous known causes	3, 149, 000	1. 6
Sparks from combustion	3, 028, 000	1. 6
Gas, natural and artificial	2, 543, 000	1. 3
Explosions	2, 297, 000	1. 2
Ignition of hot grease, tar, wax, etc	1, 884, 000	1. 0
Rubbish and litter	1, 500, 000	. 8
Fireworks, firecrackers, etc	652, 000	. 3
Steam and hot-water systems	222, 000	. 1
Total	194, 636, 000	100. 0

Examination of the fire loss from the standpoint of the nature of the losses indicates that about two-thirds of the loss is caused by defective construction and installation and lack of knowledge and care with respect to acts and conditions that originate or cause spread of fire. Losses from defective chimneys, flues, heating and electrical equipment, and roofing, open lights, petroleum, gas, sparks, explosions, ashes, rubbish, spontaneous ignition, and matches (smoking), are thus largely preventable, and loss of life from fires of such origins could be avoided. A considerable allowance must be made, however, for inability to control the acts of individuals and it has been found that in general for a large and permanent reduction in the fire loss, improvements must be made in construction, protection equipment, and other items not directly dependent on the human element.

A general grouping of predominating causes of fire, applying particularly to those occurring in major fire-resistive buildings, might include, 1, accumulations; 2, hazardous materials, and 3, unattended equipment. Accumulations of ordinary combustibles in undue amounts and for unnecessarily long periods, are responsible for many fires, since they can be ignited by discarded matches, cigarettes, sparks, spontaneous heating, or similar causes. Hazardous materials in solid, liquid, or gaseous form, such as flammable liquids and gases, celluloid, and other hazardous solids, are readily ignited and fires in them are more difficult to control than those in ordinary combustible materials such as wood and paper. Equipment such as burners, ovens, dryers, and gas or electrically heated flat irons, unless well protected or equipped with reliable automatic temperature regulation, are likely to cause fires if left unattended for unduly long periods.

3. POSSIBILITIES IN FIRE CONTROL

The above discussion of fire causes has indicated that a large percentage of the loss is preventable with the elimination of defective construction and installation and prevention of acts by individuals that directly or indirectly cause fires to originate and spread. While it is practical to achieve a considerable reduction in the fire loss by such means, it has been the general experience that for a large assured permanent betterment, prevention and protection measures must be provided that are not directly dependent on acts and habits. Fire-insurance experience is informative in this respect. The annual loss experienced by stock fire-insurance companies insuring property having value of over $200,000,000,000 has been near 20¢ per $100 of property value. The types of property and protection provided cover the full range from low- to high-hazard occupancies, combustible to fully fire-resistive construction, and protection ranging from none to supervised automatic-sprinkler installations backed by highly efficient public protection. The experience of dwelling and farm mutual-insurance companies indicates a similar loss in that on a value of over \$50,000,000,000 annual losses corresponding to about 20¢ per \$100 of property value have been incurred. The property involved would have little or no private protection and on the average only a moderate degree of public protection. The construction would in general be wood frame or masonry wall with wood interior framing, and the occupancy hazard light or moderate. No large values would be subject to a single fire that is confined to the building in which it originates.

Another class of risk includes mainly commercial and industrial establishments having fire-alarm and regular watchman service. Construction would be expected to be above the average from the standpoint of fire resistance. Private protection would consist of hand fire extinguishers and standpipe and hose as a general minimum, with automatic-sprinkler protection for a portion approximating one-third of the total. The occupancy hazard would vary from very light for office buildings to high hazard for some industrial occupancies. For these conditions the reported average annual loss for the period 1925 to 1932 was near 5¢ per \$100 of value, the total value involved being about \$16,000,000,000.

The experience of fire-insurance companies in writing improved risks gives a further indication of effect of protection measures on the fire loss. The properties covered would involve mainly construction of heavy interior timber framing with exterior masonry walls, or incombustible fire-resistive construction throughout, with occupancy hazards ranging from moderate to high. All but a relatively small portion would be covered by automatic-sprinkler protection backed by fire hose for which connections are provided inside and outside of buildings. The properties would generally have watchman service, suitable means for transmitting fire alarms, and protection against exterior exposure. Inspections of properties by experienced inspectors are made at regular intervals and every inducement is given property owners to prevent loss by fire. For a value at risk of near

$10,000,000,000, the average loss for the past 8 years has been a little less than 2¢ per $100 of value.

The loss rates given above are based on full value as distinguished from insured value. The saving in fire loss for the lower rates of loss is offset at least in part by the cost of the protection provided. Methods for estimating justifiable costs of protection, considering the different elements of the risk involved, are given in sections II 2 and XI 3(a).

4. GENERAL FIRE-PREVENTION MEASURES

While fire-resistive construction and fire-protection equipment should be provided to the extent justified by pertaining conditions, many operating practices and details of equipment can be introduced that result in material improvement without involving any considerable expense over what would otherwise be incurred. The present section deals with such items connected with the construction and equipment of buildings and general management of property.

(a) REVIEW OF PLANS FOR NEW CONSTRUCTION AND EQUIPMENT

Changes in plans cost less than changes in the building and in many cases desirable changes easily effected in the design stage are not possible from a practical standpoint after completion of the building. Submission of plans of major buildings for review by the groups that will carry the fire insurance is general practice for private construction, and many improvements are thus made to the advantage of the owner, since lower insurance rates are thereby obtainable. While Federal buildings are not insured, decided advantage would accrue from a similar review of building plans. The many structural and equipment items requiring attention are outlined in the previous sections of this manual. Mention might be made of requirements for fire resistance of the construction sufficient for the occupancy to be housed, including also the roof construction (sec. III 2, 3), subdivision into fire areas (sec. V 2) and protection of vertical and horizontal communications to restrict the spread of fire (sec. V 3), protection against exterior fire exposure (sec. V 4), and provision of ample means for exit of occupants in case of fire (sec. VI). Other items relate to materials for partitions, floor finish, interior trim, and fixed and movable equipment (sec. IV), structural and equipment provisions for safeguarding common and special hazards (secs. VII and VIII), and means for discovery and extinguishment of fire proportioned with respect to the fire hazard presented by the building and its occupancy. If fire-extinguishing equipment such as automatic sprinklers is to be provided for hazardous areas, the building construction should be designed so it will give the most effective protection, and provisions made for reducing water damage by means of tight floors sloping toward scuppers and drains, curbs around floor openings, and storage of goods on skids, trucks, or shelves (sec. XI 3(d)).

(b) TEMPORARY CONSTRUCTION AND INSTALLATIONS

It is possible to offset to a considerable extent the advantages of initial fire-resistive construction by additions, partitions, enclosures, and finishes of combustible materials. These generally remain for longer periods than intended. The same applies for temporary electric wiring and gas piping. Such constructions and installations should conform to recognized standards applied in the construction and equipment of buildings.

(c) PLAN OF FIRE-PROTECTION FACILITIES

An accurate plan of the property, locating and designating the fire-protection systems and equipment provided, should be made and kept up to date. This plan should be drawn to scale and give among others the following details:

Arrow indicating points of compass; size of buildings and number of stories; type of construction including thickness and materials of exterior walls, partitions, fire walls, floors, roofs; type of sash and kind of glass; age of each building; buildings with or without sprinklers; exposing structures and for these, type of construction, size, height, proximity, occupancy, sprinklered or unsprinklered, exterior wall openings and protection, if any; public water mains

68770—34——8

including size; private water supply and private fire protection including size of mains, hydrants, control valves, location and capacity of fire pumps, location, capacity and elevation of gravity tanks. The plan should be dated. A table of symbols has been developed to show the details mentioned above without crowding the plan and is given in appendix B.

In addition to the general plan outlined above, a schematic diagram should be made of risers for standpipes and hose; gravity tanks, including elevation and capacity; pressure tanks, including capacity; connections to pumps; connections to street (siamese) inlets and control valves. Where sprinklers are installed the distribution system should likewise be shown, together with the accessory equipment.

Where watchman's supervisory and manual or automatic fire-alarm systems are installed, plans should be made showing the wiring, distribution of the stations, thermostats, manual boxes, annunciators, bells, etc., and also a riser diagram showing this distribution in cross section.

Diagrams showing location of exits, posted at suitable locations in large buildings, would increase the effectiveness of the means provided for emergency egress.

The foregoing will afford a starting point for the proper maintenance of fire-fighting equipment and also a basis for studies relative to the protection of a project as a whole or in its details.

(d) HEATING, LIGHTING, AND POWER EQUIPMENT

Detached chimneys are to be preferred for other than small installations. Where metal stacks pass through combustible construction, they should be separated by a ventilated space of sufficient width maintained clear of dust and accumulations. The space above, to the side, and beneath furnaces, boilers, stoves, etc., should be sufficient to prevent any heat effects such as browning or scorching from occurring on exposed combustible construction or equipment. Where the space is not sufficient, protections of suitable materials must be applied or floor, wall, or roof construction of incombustible materials provided (26). Careful attention should be given to details of chimney construction (29). The fuel supply, whether solid, liquid, or gas, should be properly safeguarded and frequent inspections made for heating in coal storages and defects in oil or gas lines and tanks.

All loose or broken wiring or fixtures should be promptly repaired. Capacity of fuses or other circuit-protective devices should be checked to determine suitability for the size of wire and type of service, and bridging material removed. Extra fuses should be provided at accessible locations. Defective motors and other electrical equipment should not be allowed to remain in service and accumulations of oil from the equipment prevented.

(e) SERVICE EQUIPMENT AND FURNITURE

A considerable increase in fire safety at little added cost is attainable, particularly in fire-resistive buildings, with service equipment, lockers, desks, filing cabinets, shelving, and receptacles for waste, constructed as far as practical of incombustible materials (40). Information on construction, equipment, and general protection measures for records is given in sections IX and XIII. For receiving oily waste and other materials that may heat and ignite, self-closing waste cans are preferable.

(f) FLAMMABLE LIQUIDS AND OTHER HAZARDOUS MATERIALS

This subject presents so many aspects that a full consideration of each situation with the help of available information will be required. The following notes and references may be helpful in indicating the degree of hazard and need for protection measures. In general the amount of hazardous materials at individual points within buildings should be kept at a minimum unless special protection measures are applied. Flammable liquids should in general be limited to 1 or 2 gal contained in safety cans. Suitable cabinets, vented vaults, or separate buildings should be provided for the storage of larger quantities in cans or barrels. Portions of buildings used for such storage should be segregated by means of fire-resistive floors, walls, and protection for openings, and underground tanks provided for large storages in bulk (64, 65). Location of tanks above ground is preferred for liquified gases stored under pressure, so that inspection for defects can be made (66). The use of flammable liquids within buildings as in dry cleaning and paint spraying must be carefully safeguarded (67, 68, 69). Nonflammable liquids or those of relatively low hazard should be preferred for purposes such as dry cleaning of clothing and washing of machine parts. Where volatile flammable liquids are stored, handled, or used, it is essential that ventilation be provided in occupied spaces to prevent the formation of flammable or explosive mixtures of the vapors with air, and that all sources of ignition of the mixture be avoided. For extra-hazardous processes or storage in spaces that are not occupied or into which entry need be made only at infrequent intervals, inclosure may be provided and an inert atmosphere maintained by the use of carbon dioxide, flue gas, or engine exhaust gas. Spaces so flooded must be well ventilated before being entered to reduce the content of inert and toxic gases to safe limits. For other locations provision may be made for manual or automatic release of carbon dioxide in case of fire (sec. XI 4).

Nitrocellulose film, celluloid, or other pyroxylin products in quantities exceeding 25 lb should be stored in vented vaults or cabinets (34, 35, 70). Scraps and waste of such materials must be kept separate from ordinary waste and burned where the poisonous gases given off will not be objectionable. Acetate cellulose film is preferable to the nitrocellulose type as it presents no greater hazard than wood or paper. Similarly, other articles of cellulose, acetate cellulose, casein base plastics, or phenol-formaldehyde plastics are less hazardous than celluloid.

Where chemicals or explosives in appreciable quantity are handled, used, or stored, their fire and explosion hazard should be ascertained and proper precautions taken (71, 72). Where the quantity or hazard presented warrants it, storage should be in detached buildings, or, for less hazardous materials, in vaults provided with suitable vents. (See sec. VIII.) The preferable location for such vaults is in the upper story or on the roof.

(g) GENERAL MAINTENANCE

Orderliness and good maintenance conditions are known to be effective in preventing origin and spread of fire. Avoiding unnecessary accumulations of combustible materials within or outside of buildings, prompt collection, safe storage and disposition of waste paper and other refuse, and maintenance of orderliness in locations such as receiving and shipping rooms will prevent many fires. Incinerators, whether within or outside of buildings, should be designed and located so that the hazard to the building and surroundings is reduced to a minimum. Prohibition of smoking in hazardous areas with full compliance therewith as with other fire prevention regulations is another important management detail. Throwing smoking materials out of windows causes awning fires that have involved whole buildings. Provision of ash trays will decrease this hazard.

Prompt repair of roofs, floors, windows, shutters, doors, door hardware, and other building details will assist in preventing origin of fires from flying brands, locomotive sparks, exterior exposure, and those caused by trespassers.

Those in charge of property should be impressed with their responsibility for preventing loss by fire and that conditions or practices recognized as hazardous may result in fires that will be charged to negligence on their part.

(h) REPORTS ON FIRES

Requiring reports on all fires, large or small, will assist in locating hazardous conditions and practices and in correcting defects in construction and protection equipment. The investigation and report on a fire checked in its initial stage with little or no loss may result in changes in structrual or occupancy conditions or in provision of fire-protection equipment that will prevent a much larger subsequent loss. Reports of fires show many instances where substantially the same cause was responsible for successive fires in the same establishment. As an evidence of their recognition as effective fire-prevention measures, the large outlay of insurance organizations in investigating and reporting on fires can be cited. The necessity for reporting fires engenders a wholesome encouragement for fire-prevention activities.

For Federal property a fire report form has been prepared by the Federal Fire Council that is given in appendix C. Items are included that will give not only information on the fire, but also indicate any needed corrective measures. Copies sent to the Federal Fire Council supply the basis for determining the total fire loss on Government property and predominating causes, the ratio of loss to value subject to loss by fire, comparison of the loss ratio with that on private property, and the trend of the loss and loss ratio.

(i) ORGANIZATION FOR FIRE-LOSS PREVENTION

For all properties, large or small, there should be effected some degree of organization and inspection to eliminate fire hazards and a procedure to be followed in case a fire occurs. Suggestions for such organization are given in subsequent sections of this manual.

XIII. PROTECTION OF RECORDS AND VALUABLES

1. VALUE OF RECORDS

That records have value is demonstrated not only by the difficulties entailed in case of loss but also by the very considerable expense that is being incurred for their protection. The value of some records can be definitely appraised in terms of labor and material cost of their replacement in whole or the portion still useful. Such replacement may necessitate much labor in collation from original sources and even field surveys or other investigations or inquiry.

Other records have what has been termed consequential value which is appraised in terms of the loss that would be sustained in their absence. Records covering accounts receivable would come in this class. Other records have a contingent value and are difficult to appraise in terms of dollars and cents. A large class of public records would come under this head. The records to which this type of value pertains may under some circumstances never be called on as evidence of any important contract or other relation and again they may form the basis of very important contingencies in this respect.

In placing a value on records, those based on contingent or speculative bases should be avoided if possible, particularly where a cost of reproduction can be arrived at. Due consideration should also be given to the presence elsewhere of the information contained on the record. Thus, after publication, manuscripts and the data they are based on, retain generally only a small fraction of the original value.

An evaluation of records on bases such as those outlined above may disclose unexpectedly high values exceeding those of other more readily appraised forms of property. An informal appraisal of the value of the properties of the bureaus in the U.S. Department of Commerce conducted in 1931 to serve as information in connection with fire-hazard surveys, gave the following results:

Value of buildings	\$25,387,000
Inventory value of contents	10,875,000
Records and other uninventoried values	189,948,000

It is thus seen that the uninventoried values, which pertain almost wholly to records, constitute over 80 percent of the total appraised value. While they are based on the cost of production of useful records that carry information not present in full elsewhere, it is possible that in case of destruction it would not be necessary to duplicate them fully, which consideration might reduce considerably their present apparent value.

2. CLASSIFICATION

To serve as a basis for the planning of protection measures, classification from the standpoint of value is necessary since it is generally not possible to provide protection for all of the records of an establishment. The following classification is suggested:[2]

[2] The classification is the same as that adopted by the Committee on Protection of Records of the National Fire Protection Association (20).

(a) VITAL RECORDS

This class includes the basic instruments underlying the organization of a business, establishment, or Government unit, and those giving direct evidence of legal status, ownership, accounts receivable and incurred obligations. Among such records can be named charters, franchises, deeds, abstracts, easements, options, records of stock and bond issues and transfers, important contracts and accounting records, property plans, appraisals, current inventories, besides a range of town, county, municipal, State, and Federal records.

(b) IMPORTANT RECORDS

This class comprises records that can be reproduced from original sources although at considerable expense. In this class would be records giving derived data in tabulated, summarized, or charted form, and also records of other character not of sufficient importance to be placed in class (a) but quite apparently of value above that pertaining to class (c).

(c) USEFUL RECORDS

Under this class would come records the loss of which would cause temporary inconvenience but otherwise entail no serious permanent disadvantage. General correspondence for various periods after it originates, and records easily replaced, will constitute the bulk of material in this class.

(d) NONESSENTIAL RECORDS

This class includes records of all kinds that have no present or prospective value and should be destroyed. This class includes among other types, records of closed accounts after periods such as those defined by the statutes of limitation, and general correspondence beyond an age that can best be determined by the establishment concerned for the different kinds involved.

It is apparent that the age of a record is an element entering into the classification. While some important records increase in value with age, most classes decrease in usefulness with lapse of time which serves to place them successively in lower value classifications.

3. PERIOD OF RETENTION

The length of time records should be retained is a matter that requires study for each establishment. Such study over a period of years should enable a consistent schedule of retention of useful records and destruction of those no longer useful to be established. Generally those in the higher value classifications would be retained permanently or for longer periods than the others. However, this would not hold without many exceptions. For some establishments legal limitations such as statutes of limitations and the requirements of State or Federal regulatory bodies such as the Interstate Commerce Commission, will govern the period of retention. A large volume of records is, however, eligible for destruction soon after they originate. As an example, one large organization found that approximately 30 percent of all its correspondence is destructible at once or within 1 month after the date of origin. Further suggestions on retention periods for different types of records are contained in schedules such as those published by the National Fire Protection Association (20), the Edison Electric Institute (73), and for some types of public-utility companies, by the Interstate Commerce Commission.

4. PROTECTION REQUIREMENTS

(a) GENERAL PROTECTION MEASURES

The hazard of loss by fire can be decreased in varying degree by applying measures designed to prevent the occurrence of fire or effect fire extinguishment in its early stages, protecting records of value from destruction in case fire occurs, and by storing duplicates in a place where they would not be subject to loss by a fire that would affect the original record.

Very much can be done to decrease the fire hazard to record storage by observing well-recognized general principles of fire prevention and protection. This may attain a degree where further protection would not be required except possibly for the most vital records. If the records are housed in a fire-resistive building with a minimum amount of interior and exterior combustible trim, with openings well protected against exposure fires and with interior vertical and horizontal openings protected so that fire will not be communicated, a high degree of protection can be attained by the use of suitable equipment for housing the records (40). Such equipment should be of incombustible material with compartments as small as is consistent with the type of record and office routine. Six-sided inclosure such as in filing cabinets and closed shelves is preferable from the standpoint of protection from fire. (See sec. IX 5.) If these are placed on an incombustible floor finish and care is taken to avoid accumulations of unshelved or unfiled combustibles within the room, the possibility of a fire involving more than at the most a few containers or compartments is quite remote (74).

In nonfire-resistive buildings such protection cannot be premised since a general building collapse may occur from a fire anywhere within the building. General fire-protection equipment such as automatic sprinklers effects a decided improvement under the latter conditions since fires are then checked in their initial stage. The possible water damage to records is sometimes over-estimated considering that their main value is concerned with legibility rather than physical condition. General protection measures such as those outlined above are the only ones feasible where a large volume of records is involved. Special buildings erected and equipped for the purpose are preferable although good protection can be obtained in segregated portions of ordinary fire-resistive buildings conforming with the structural and finish requirements above outlined. (See sec. IX 4.)

(b) VAULTS AND PORTABLE RECORD CONTAINERS

Where structural or other conditions are unfavorable, and possibly under all conditions for very important records, further protection should be obtained by recourse to such means as record vaults and portable record containers such as insulated safes. (See sec. IX 2.) By avoiding storage of valuable records in basement vaults of high nonfire-resistive buildings, it is generally possible to obtain an assured degree of protection by means of vault storage. The basement location is unfavorable because of possibility of contact of hot debris with the walls and doors for a long period after the peak of the fire and also possibility of water damage (21).

While the volume of records that can be profitably stored in insulated portable containers such as safes, is limited, and under some conditions the protection cannot be definitely predicted, this type of device is an important factor in record protection. It will often be found that a large proportion of the value of an accumulation of records will be represented by only a small part of the total volume, which can be given this form of protection. The advantages consist in being able to place the container where the contents will be the most readily available. Protection can also be obtained by this means in buildings where vaults were not originally installed and in which their subsequent installation would be impracticable. (See sec. IX 5(b).) In fire-resistive buildings they can be selected to have a fire resistance that will enable them to preserve their contents in a fire that would consume the combustible contents of the portion of the building in which they are located. Consideration of weight and portability, however, place a practical limit on the protection that can be afforded, which at present is equivalent to that required to resist the first 4 hr of the furnace test (1). In a fire-resistive building this will correspond to the severity of a fire consuming the contents of a room having ordinary combustibles distributed over the floor area totalling between 30 and 40 lb/ft^2. (See sec. III 3(a).) For location with higher combustible contents the safes would afford temporary protection and the contents would be preserved in case the severity of the fire is decreased by fire extinguishment or other means to a limit not exceeding the fire resistance of the safe. In nonfire-resistive buildings the protection afforded by safes is limited by possibility of heavy impacts and prolonged exposure in hot debris of a severity that no such container could be expected to withstand. Safes buried in hot debris should be removed as soon as conditions permit or the adjacent ruins quenched as soon as they can be approached. It is this subsequent exposure rather than the initial high temperature incidental to the destruction of nonfire-resistive buildings that constitutes the main element of hazard for well-insulated portable containers (21).

A note of precaution might be given relative to damage to photographic negatives and prints, blueprints, and similar records, due to condensation of water within safes, and to lesser extent within vaults, when exposed to fire. The insulation of safes and insulated vault doors contains combined or both free and combined water that is vaporized by the fire exposure and condenses in part within the safe or vault. Storage within tight metal containers would decrease the possibility of damage from this cause.

Nitrocellulose film will begin to decompose at temperatures not greatly in excess of 100° C, 212° F, and hence should be given a higher degree of protection than ordinary paper records that can be exposed to temperatures of 150 to 175° C, 302 to 347° F, without appreciable damage.

5. DECIPHERING OF CHARRED RECORDS

One suggestion relative to the handling of charred or partly-charred records may be pertinent. The filing cabinets or other containers should be left as far as possible in their original location and the contents of each drawer or compartment extinguished with a minimum amount of water. If this precaution is observed it may be possible to reconstruct a partly charred file of records where it would be totally lost if taken out of its place or container. Charred records can frequently be read by eye due to the different color of the char under the writing. Photographic means can also be employed for deciphering records that are completely charred (75).

6. DESTRUCTION OF USELESS RECORDS

The unnecessary retention of records that have served their useful purpose involves expense for equipment and storage space and also makes the really useful records less available. Frequently such records will be stored in locations and containers that will introduce a decided fire hazard to the building and its more valuable contents. A schedule for the retention of records should be supplemented with a coordinated program of destruction of those that have reached the limit of their useful period. This can best be accomplished by classifying records when they originate and providing means for destroying those that are deemed useless after a certain period. Where records of a given class originate in large volume, they may be placed in separate files and marked for permanent retention, retention over a period of years, or destruction within comparatively short periods. By this means the contents of the containers can be destroyed at given intervals without requiring sorting of the contents.

Executive establishments of the Federal Government are by statute made responsible for the destruction of their useless records and the method of procedure is prescribed. (See appendix D.)

7. COORDINATION OF PROTECTION MEASURES

By means of coordinated programs of classification, retention, protection of the valuable portion, and destruction of those no longer useful, combined with proper general fire-prevention and protection measures for the building as a whole, a high degree of security should be obtainable for the records housed within it without disproportionate attention to the routine handling of the records or undue expense for their protection.

To obtain the full benefit of the protection provided, a routine should be established to insure that the facilities are effectively used. Records in use should be placed in their protective containers at night and the organization for emergency should provide for the removal or protection of important records in case of threatened fire. Periodical inspection is needed to maintain a high standard of housekeeping and maintenance of fire-protection equipment.

8. PROTECTION OF VALUABLES

The same general methods outlined above for the protection of records can be applied to the protection of valuables. Precautions must be observed to prevent damage from heat, or heat and moisture combined, at temperatures considerably lower than those causing written or printed records to become illegible, in the case of articles such as watches, optical goods, gems, paintings, stamps with adhesive facings, and articles made of celluloid. Storage within vaults having a considerable margin of fire resistance above that required for the location is preferable. When insulated safes are exposed to fire, temperatures up to 100° C with condensation of water obtain within them after fire exposures of comparatively short duration. Airtight incombustible containers are desirable for articles susceptible to damage by moisture.

A higher degree of theft or burglar protection is generally required for valuables than for records. Insulated safes and record vaults designed for protection against fire have incorporated details such as locks and bolts that give a moderate degree of theft protection. They cannot, however, resist burglar attacks with cutting torch or explosives, nor with mechanical tools if sufficient time is allowed. Where the values warrant it, further protection should be provided in the form of burglar-resistive chests, safes, or vault construction, including electric-alarm features. Where the volume to be protected is not large, burglar-resistive chests can be placed inside of insulated safes, or burglar-resistive safes within vaults. They should be well anchored into the safe or vault construction to prevent easy removal. For larger amounts combined fire-resistive and burglar-resistive vault construction must be used.

Burglar-resistive chests, safes, and vault linings are comparatively tight and would afford good protection against the moisture condensed within insulated safes and vaults when exposed to fire. Being uninsulated they can give very little protection against fire.

XIV. MAINTENANCE OF FIRE-PROTECTION EQUIPMENT

1. GENERAL MAINTENANCE REQUIREMENTS

Fire-protection equipment requires attention for maintenance in common with all plant equipment. Correction of apparent defects, such as leaks and corroded or defective piping and equipment, can be made as a part of the maintenance routine. Many defects are, however, not apparent until the equipment is called upon to function in case of fire, when, in general, repairs or corrections cannot be made in time to enable effective operation. Accordingly, the maintenance of such equipments must be based on inspections and tests designed to determine their operative condition, since no constant demands of service disclose conditions that need correction.

Valves controlling water supplies to standpipes, sprinkler systems, or hydrants, should be inspected, preferably daily, for open position. It is customary to seal such valves in open position with a leather strap or light wire that can be broken when valve must be closed. This detail is very important since the closed supply valve is the most frequent cause of failure of automatic sprinklers and other fire-extinguishing equipment. (See Annual Sprinkler Tables in NFPA Quarterly.) For important systems electrical supervision may be advisable (53, 54, 76). Control valves should be marked by means of a suitable sign to show the portion of the system served by each.

Valves which have not been operated for long periods may stick and in connection with inspections, all important valves should be turned. The operative condition of closed valves can generally be determined without turning them by an amount that would let water into the system.

2. CARE OF STANDPIPE AND HOSE SYSTEMS

New standpipe systems should be tested when installed for a period of 2 hr for tightness, at a hydrostatic pressure of 25 percent in excess of the highest normal pressure to be used. Flowing pressure tests should be made at the top hose outlet of each standpipe riser, and repeated annually. For test purposes a separate length of hose with nozzle and pressure gage for connection to the highest outlet is recommended. The discharge can be determined from hose stream tables for the given size of nozzle and flowing pressure at its base.

Control valves and hose outlets should be accessible. At each outlet small hose, usually 1½ in. unlined linen, should be coupled to the outlet and a rack provided so that the hose may be rolled or folded. Hose is sometimes found detached from the standpipe outlet. The linen hose should not be used for general utility purposes as the light covering is not designed to withstand hard usage. Protection from acid and avoidance of damp locations are necessary as acid will attack the covering and dampness may cause mildew. The hose should be unfolded and refolded at intervals to avoid permanent creases. Renewal of gaskets in couplings at hose valves and nozzles should receive attention.

Hose valves should be kept tight to prevent leakage which will wet the hose near the coupling, a common cause of injury to linen hose. Drip cocks may be placed in the hose valve body for draining any leakage that may occur.

Unlined linen hose usually recommended for inside use should be wet only at time of fire, or when there is doubt as to its condition. After use it should be thoroughly dried to prevent deterioration.

3. MAINTENANCE OF SPRINKLER SYSTEMS

The causes of failure of sprinkler systems are shown in table 11. The 2,102 unsatisfactory performances were from about 63,000 sprinkler fires reported, or about 3⅓ percent of the total number.

TABLE 11.—*Summary of unsatisfactory sprinkler performances*

[For period 1897 to 1933, as published in NFPA Quarterly, vol. 26, no. 4, p. 373, April 1933]

Cause of failure	Failures	
	Number	*Percent*
Water shut off	672	31.9
Generally defective equipment	386	18.4
Unsprinklered portions		
Defective water supply or supplies	186	8.8
Sprinkler system crippled due to freezing	54	2.6
Slow operation of dry system or defective valve	65	3.1
Slow or defective operation of high-test heads	25	1.2
Faulty building construction, concealed spaces, vertical openings, etc	108	5.1
Obstruction to distribution	126	6.0
Hazard of occupancy too severe for average sprinkler equipment	124	5.9
Explosion crippled sprinkler system	100	4.8
Exposure or conflagration	84	4.0
Plugged heads and piping (included with "miscellaneous" prior to 1921)	37	1.8
Miscellaneous	135	6.4
Total	2,102	100.0

It will be seen that among the most frequent causes of failure are closed valves, defective equipment, insufficient water supply, obstructions to distribution, and faulty building construction.

For new installations, tests required before acceptance are detailed in the sprinkler rules (45). Occasional tests of water flow by opening the drain at the top or base of the system and observing the drop in pressure, are recommended. Such tests are of value in indicating whether water is available and also any obstructions in the pipes. A drop in pressure during drain tests of amount greater than normal calls for investigation of the cause.

Inspection should be made for loose pipe hangers, corroded piping, and corroded or painted heads. Sprinkler pipes should not be used for clothes lines or similar purposes and a clear distance of not less than 12 in. should be maintained below deflectors to permit proper distribution of the discharge. Inspection for such conditions should be made at regular intervals, preferably not less than once each month.

Location of high-wattage lamps near sprinkler heads should be avoided and areas where high temperatures may obtain should be watched and if necessary higher-degree heads substituted. Locations under skylights and near steam pipes should be considered in this connection. Extra sprinkler heads to the extent of 10 percent of the number in one fire area should be kept in reserve, and in no case less than 25 except for small installations.

Extra precautions are urged during periods of repairs to sprinkler systems or to water-supply systems to make certain that the valves are opened when the work is completed. During repairs to large installations it is recommended that a man be stationed at the valve while it is closed.

Note of the air and water pressures at dry-pipe valves should be made daily, and in cold weather also the temperature of the inclosure. Monthly inspection should include observation of the valve accessories, including testing of alarm valves, although in cold weather water-motor alarms should be tested by means of a test switch. At intervals of 1 or 2 years dry-pipe valves should be tripped, the interior of the valve inspected for corrosion and incrustation, and cleaned before resetting. This may be done without admitting water to the system by nearly closing the water-supply valve, and when the dry-pipe valve trips, closing it completely before water flows into the system. After resetting the dry-pipe valve the supply valve should be reopened and sealed.

4. MAINTENANCE OF HYDRANTS AND RUBBER-LINED HOSE

Hydrant stems and caps should be lubricated occasionally with graphite mixed with cylinder oil. Hydrants should be tested annually for static and flowing pressures. In freezing weather they should not be opened; a slight turn of the stem will show whether or not hydrant is frozen. An alternative is to lower a weight into the hydrant and determine the presence of ice by the sound, and water by the wetting of the weight.

In hose houses, the cotton rubber-lined hose used in outside service, should be folded so that it may be pulled out without twisting or kinking. Rearrange the folds occasionally. At least 100 ft of hose should be kept attached to the hydrants. Water should be run through rubber-lined hose occasionally, preferably twice a year, to retard deterioration of the lining. Once a year test the hose, capped, to the highest static pressure available. After use drain all hose and dry the jacket thoroughly before replacing the hose in the hose house. The roof and doors of hose houses should be maintained weather tight and the houses kept free of rubbish. The hose houses should be constructed and maintained to keep out rats, mice, and other vermin that may attack the hose.

5. CARE OF FIRE PUMPS AND TANKS

For electrically driven centrifugal fire pumps, controlling equipment should be tested at intervals and electrical equipment protected against leakage from the pump. Pumps should be kept lubricated. Two independent sources of current supply are recommended (44). The pump room should be kept clean, heated, and well lighted. Steam pumps should be operated once each week for a period of several minutes. The discharge may pass through the relief valve. At least two employees should be qualified to operate the fire pumps and be fully familiar with all of their details.

Elevated steel and wood tanks and their supports should be kept painted and sediment within them removed at regular intervals. Heating equipment needs frequent inspections and floats or other device for indicating water level must be maintained in operative condition.

Pressure tanks should be tested for water level, accuracy of gages, reliability and capacity of air and water pumps, and strength of the tank. The latter can be determined by filling with water and increasing the pressure with a test pump to 50 percent in excess of that normally carried. Sediment must be blown out before it becomes objectionable, this maintenance item being particularly important where the tanks are a part of the domestic water-supply system.

6. SUPERVISION OF FIXED CARBON-DIOXIDE AND FOAM SYSTEMS

The carbon-dioxide cylinders should be weighed at 6- or 12-month intervals and if the loss in weight of any cylinder exceeds 10 percent it should be recharged. All inclosures for confining the gas are to be kept in good repair and automatic devices for releasing the gas and closing doors or shutters, maintained in operative condition (46).

For wet foam systems the condition of the solutions should be checked at intervals. The bicarbonate solution can be revived by passing carbon dioxide through it (65). An extra supply of dry foam-producing material should be kept on hand or readily available.

7. MAINTENANCE OF PORTABLE FIRE EXTINGUISHERS

The extinguishers should be examined frequently to make certain that they have not been tampered with or removed from their designated places, and to detect any injuries. Recharges or extra extinguishers should be kept on hand to replace any used in extinguishing fire (48).

Water pails, sand pails, and water-pump extinguishers should be kept full at all times and refilled immediately after use. Pumps should be operated occasionally. Antifreezing solutions can be tested for specific gravity with a hydrometer. Containers should preferably be kept covered.

Soda-acid and foam extinguishers should be protected against temperatures lower than 40° F. Cabinets heated by electric lamps may be used for the purpose. Inspections to determine whether nozzle is closed, hose cracked, or body dented, should be made. Annual recharging is required, extinguisher to be marked with a tag showing date of recharge and initials of employee. Loaded stream extinguishers require similar maintenance except that they do not need protection against freezing.

Carbon tetrachloride extinguishers should be kept filled at all times with the special fluid required for the purpose. At least once each year a portion of the contents should be discharged to determine operative condition, extinguisher examined for corrosion of parts, and tagged. The discharge can be made into a container and the fluid reused.

Carbon-dioxide extinguishers should be weighed at least once each year and recharged if they have lost more than

10 percent of the charge. They should be recharged immediately after discharge, even if only partly discharged. The carbon-dioxide cartridge in water-type (self-propelled) extinguishers should be weighed once each year and the weight compared with that stamped on the shell of the cartridge.

8. FIRE-ALARM AND SUPERVISORY EQUIPMENT

Where batteries are used for current supply, a routine must be established to effect proper recharging and maintenance. Trouble and alarm circuits, lamps, and bells need occasional tests to determine operative condition, with determination of resistance between ground and sides of circuits. Pneumatic tube or bulb systems need adjustment for operating pressure and vent, particularly for the period immediately following the installation.

XV. ORGANIZATION FOR COMBATING FIRES

All departments and establishments should require that definite and practical plans, appropriate for any given establishment, bureau or subdivision thereof, be outlined for combating fires in such establishments. This is especially advisable in the case of non-fire-resistive buildings, those housing large numbers of persons or stores, or processes requiring the presence of considerable quantities of highly combustible materials, and also where buildings are exposed to fire from adjacent non-fire-resistive structures or hazardous occupancies. The Federal Fire Council will, on request, give advisory service so far as practicable concerning such plans. Where advisory service from a public fire department is available locally, full advantage should be taken of such assistance. The organization and equipment needed will depend upon the extent, value, and fire hazard of the property, type of building construction and occupancy, and availability of outside assistance, such as from a public fire brigade.

1. LOW OR MODERATE-HAZARD OCCUPANCIES IN FIRE-RESISTIVE BUILDINGS, WITH PUBLIC PROTECTION AVAILABLE

For administrative or clerical groups occupying fire-resistive buildings in cities, the organization as far as the general personnel is concerned, might be limited to instruction in the use of hand fire extinguishers and hose and on the method of sending fire alarms. This might be in the form of a brief instruction sheet sent to all employees and posted on the bulletin boards, supplemented with occasional oral instructions and demonstrations. The method of sending alarms of fire should be given on the front page of the personnel or telephone directory. With proper subdivision of the building and an adequate number of protected exit ways (see sec. VI) no fire exit drills would be needed, although exits should be clearly marked and for large buildings diagrams should be posted showing location of all exits. The guards and other personnel connected with the operation and maintenance of the building should be given more detailed instructions on the procedure and training in the use of the equipment provided. Suggestions covering the above condition are given in appendix E.

Whether or not an organization of employees, such as that herein outlined, is to be set up would depend on the size of the establishment and the degree of hazard presented. As indicated in section XVI, inspections to eliminate fire hazards can also be effected through such an organization. The position of chief fire marshal can generally best be assumed by the superintendent of buildings and other physical plant. The assistant fire marshals should be chosen with respect to fitness and the space to be covered. The requirement that all personnel be instructed in the procedure and in the use of equipment is important since the probabilities are that someone other than the assistant fire marshal will have to handle the emergency, at least in its initial stage. Meetings of the fire-marshal group for instruction and demonstration will assist in maintaining interest. Other personnel that would be required to act in emergency could be invited to such meetings. The discharging of hand fire extinguishers preliminary to refilling might be made the occasion for demonstration of their use on fires.

2. HAZARDOUS AND INSTITUTIONAL OCCUPANCIES

For hazardous occupancies and for institutions such as schools, hospitals, asylums, and prisons, it may be necessary to effect an organization that will respond at all fires, even where a public fire brigade can be called. To prevent undue spread, it may be essential to have means for controlling fire in the shortest time possible, also, as in the case of penal institutions, it may not be desirable to admit men and equipment from the outside. Evacuation of whole buildings may also be necessary, particularly where high hazards or inferior construction are present.

Fire brigades (77) can be formed among the personnel responsible for the building or institution or partly composed of occupants or inmates. The degree of organization and equipment to be provided can be determined only from consideration of pertaining conditions. The same applies as concerns the need of fire exit drills (78).

3. ISOLATED LOCATIONS

Where no assistance from a public fire brigade can be had, or where, due to location, the response would be unduly delayed, organization and equipment for combating fires should be provided up to the limits set by considerations of justifiable cost of protection and safety to life. The type and extent of the organization and equipment to be provided depends so greatly on the local conditions that general suggestions are of little value. For establishments of any considerable extent, the situation should be studied by an experienced fire-protection engineer and a degree of protection provided proportioned to the values and hazards presented, on the basis outlined in section II. The organization required may range up to that approximating a city fire brigade (77, 79). The organization and training of such a brigade must in general be done by one experienced in the technique of fire extinguishment and fire-department organization. General information from available sources may be helpful at the different stages (80, 81, 82).

4. IMPORTANCE OF TRAINING

In addition to outlining plans for combating fires, selected personnel should be given actual training from time to time, in 1, using extinguishers of the type or types provided; 2, handling hose attached to standpipes in the building; and 3, the procedure to be followed in turning in a fire alarm properly when a city department is to be called. It is *especially important that this training be carried beyond the point of merely distributing printed or typewritten orders and directions with the hope that they will function in an emergency.* Actual drill at suitable intervals and practice in doing the proper thing at the right time as a matter of habit will give the greatest assurance that an emergency will be handled with maximum effectiveness when it actually develops. In many States training courses are held for the instruction of firemen, at which valuable information on fire prevention is also given. It would be of considerable benefit to men assigned to fire protection activities to attend such schools in their vicinity.

XVI. INSPECTION OF PROPERTIES

Millions of dollars are spent annually by insurance associations, industries, and municipalities for fire surveys, plans, and reports, which apparently are bringing returns in reduced fire losses. That such work is effective is further shown by the fact that fire losses increase directly with the interval between inspections. Thus one large insurance group has demonstrated by actual trial the advisability of not more than 6-month intervals, and other underwriting organizations have had similar experience.

Inspections can be classified into two groups, self-inspections and technical inspections. The former, while not covering all conditions and details, can be made at more frequent intervals and have been found very effective in reducing the fire loss. Technical inspections require more time and experience on the part of the inspecting group and supply information on needed major and minor improvements and a basis on which self-inspection procedure most suitable for the property can be planned.

1. SELF-INSPECTIONS

Almost all properties require some form of supervision and inspection as an assistance in eliminating fire hazards and maintaining any fire-protection equipment in proper condition. Where an emergency organization has been effected, this may to advantage be utilized for the purpose. In case this is in the form of a fire brigade, its members can be detailed for such duty (83). For less elaborate organizations self-inspections might be based on forms such as those given in appendix F. The longer self-inspection form is intended to cover all principal hazards and equipment items. The shorter form is intended for services occupying buildings that are controlled by another agency that is responsible for the building, its major services, and fire-protection equipment. There are, however, many occupancy conditions having a bearing on the fire hazard that can be controlled only by the service occupying the building.

In cases where it is not desirable to use the full self-inspection form for all reports, a brief form referenced to the full form can be used (appendix F). It would, however, be desirable to report on the full form once every 6 months or year, to the head of the group responsible for the technical inspection, or other official. The information from the reports covering the different portions of the property would then be assembled on one form covering the whole property.

Many corrections and needed improvements can be obtained by informal contact with those in immediate charge of properties and occupancies. The form reports can then be reserved for reporting conditions that cannot or have not been corrected by such means, and for obtaining a periodic record of what has been accomplished, the reports thus applied to be transmitted to those having general administrative authority over the property. This would justify increasing the regular intervals between reports with a consequent reduction in the volume of paper records.

Whatever plan is used, it is important that those charged with the inspection maintain contact with conditions having a bearing on the fire hazard.

2. TECHNICAL INSPECTIONS

The inspecting group should preferably include some one experienced in fire prevention and protection, although very acceptable surveys can be made by those experienced in management of property aided by information such as is contained in the present manual and references. While it will in general be made up of men from within the organization controlling the property concerned, occasional inspections, by a group from another establishment, or by an outside specialist, may be advantageous.

(a) INSPECTION PROCEDURE

The inspecting group should report first to the official having general or immediate charge of the premises. Someone intimately familiar with the occupancy and hazards should accompany it and bring to its attention all pertinent facts and conditions. Copies of plans of the property and buildings and previous inspection reports and plans should be procured if available and changes since construction or last inspection noted. Full notes should be taken of all information and for each property or class of property an outline or form for a report should be developed. Note should be made of the number and accessibility of hydrants, size of water mains in the vicinity of the property, distance to nearest public fire-alarm box and fire-department station, exposures in the immediate vicinity, and the conflagration hazard.

Inspection within the property should start at the roof from which point notation can be made of accessibility to fire apparatus and immediate exposure from buildings and properties, and any changes in these respects since the last inspection. At it proceeds, the inspection should cover the entire area of each floor of every building and structure. Notation should be made particularly of spaces not accessible for fire extinguishment, closets, storage rooms, inclosures under stairways, and openings in fire walls and floors, due attention being given to changes made or proposed in construction, occupancy, hazards, and protection. Tests should be made of the operative condition of fire doors, shutters, and fire alarm, supervisory, and fire-extinguishing equipment. The inspection should be made in a manner best fitted to create an interest on the part of the occupants in prevention of fire.

Exact and detailed information should be obtained on all fires, however small, that have occurred since the last inspection and on impairments and improvements in protection measures. The inspectors should develop keenness in discerning hazards and in distinguishing between major and minor causes of fire.

(b) FORM AND CONTENTS OF REPORT

The report should detail in logical order exposure, construction and occupancy hazards, the protection equipment provided and its maintenance, and recommendation for improvements. The form will vary with type of property, the object to be attained being the greatest clearness and brevity consistent with the necessary degree of inclusiveness (84). In outlining a form for inspection and report, it may be desirable to note the headings and subject material of the present manual, although their sequence need not necessarily be followed and titles not pertaining to the given property should be omitted. The important groups of subjects will be briefly indicated mainly by reference to sections in this manual. It is particularly important to locate by building, room, or portions thereof, the different hazards and conditions that need correction. For this purpose a consecutive account for each building or similar group may be necessary. Services and hazards common to all buildings may be treated for the group as a whole. The following items should be considered for inclusion in the inspection and report:

1. *Value of property and number of occupants.*—Section II. The most reliable method of computing present value of buildings will generally involve computation of cost of reproduction new with deduction for depreciation.
2. *Types of building construction.*—Section IV.

3. *Fire resistance of building members and fixed equipment.*—Section III 2.

4. *Adequacy of members and equipment to withstand the fire exposure from the occupancy.*—Section III 3.

5. *Structural control of fire spread.*—Section V.

6. *Means for egress of occupants.*—Section VI.

7. *Safeguarding common hazards.*—Sections VII, X, XI, and XII.

8. *Safeguarding special hazards.*—Sections VIII, X, XI, and XII.

9. *Protection of records.*—Sections IX and XIII, and appendix D.

10. *Fire-alarm and supervisory equipment.*—Sections X and XIV.

11. *Fire-extinguishing equipment.*—Sections XI and XIV.

12. *General fire prevention and maintenance conditions.*—Sections XII, XIV, and XVI, and appendix F.

13. *Organization for fire fighting.*—Section XV and appendix E.

14. *Maps, diagrams, sketches, and photographs.*—Sections XII and XVI, and appendix B.

The amount of details of this type should be kept at a minimum, as they entail considerable time and expense. However, information can be given in concise and clear form by means of such plans. When the report is made to those fully familiar with the property, only sufficient description for reference purposes need be included.

15. *Justifiable cost of protection.*—Data from report and sections II, X, XI, and XV.

16. *Recommendations.*—The recommendations should be given after the description of the condition needing correction and should be summarized in brief form at the end of the report; *further attention should be called to important recommendations* in the letter of transmittal. Their relative urgency should be indicated, which might be done by placing them under headings such as the following (84):

Emergency (urgent) recommendations; necessary (essential) recommendations; desirable (conditional) recommendations.

APPENDIX A. REFERENCES

The following abbreviations are used in the references:

AFM — Associated Factory Mutual Fire Insurance Companies, 184 High Street, Boston, Mass.
ASA — American Standards Association, 29 West 39th Street, New York, N.Y.
ASTM — American Society for Testing Materials, 260 South Broad Street, Philadelphia, Pa.
BFPC — British Fire Prevention Committee, in care of the National Fire Brigades Association, 8 Waterloo Place, Pall Mall, London, SW 1, England.
BS — Bureau of Standards, U.S. Department of Commerce, Washington, D.C.
CU — Columbia University, New York, N.Y.
DA — U.S. Department of Agriculture, Washington, D.C.
NBFU — National Board of Fire Underwriters, 85 John Street, New York, N.Y.
NFPA — National Fire Protection Association, 60 Batterymarch Street, Boston, Mass.
SD — Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.
UL — Underwriters' Laboratories, 207 East Ohio Street, Chicago, Ill.

The Government publications listed can be obtained from the Superintendent of Documents at the prices indicated, or consulted in the Department or Bureau libraries. Copies of papers, specifications, and Letter Circulars marked BS and for which no price is given can be obtained free from the National Bureau of Standards, unless indicated as out of print thus (*). Single copies of the publications of the National Board of Fire Underwriters and the standards and committee reports of the National Fire Protection Association can be obtained free unless a price is indicated. Complete information relative to the availability of the other references listed cannot be given.

1. Specifications for Fire Tests of Building Construction and Materials, ASA Standard; ASTM, NFPA, BS, sponsors.
2. Fire Tests of Building Columns, AFM, NBFU, BS Technologic Paper 184; 75 cents; SD.
3. Fire Resistance of Concrete Columns, BS Technologic Paper 272; 25 cents; SD.
4. Fire Tests of Columns Protected with Gypsum, BS Research Paper 563; 5 cents; SD.
5. Fire Resistance of Brick Walls, BS Letter Circulars 228 and 229.

6. Fire Resistance of Hollow Load-Bearing Wall Tile, BS Research Paper RP37; 75 cents; SD.
7. Reports on individual fire tests of partitions, floors, opening protectives, and roofing materials by UL.
8. Reports on individual fire tests of partitions, floors, and opening protectives by CU.
9. Tests of the Fire Resistance and Stability of Walls of Concrete Masonry Units, Proc. ASTM, vol. 31, part II, p. 607.
10. Reports on individual fire tests of partitions, floors, and opening protectives by BFPC.
11. *Fire Resistance of Gypsum Partitions, BS, Proc. ASTM, vol. 25, part 2, p. 299.
12. Recommended Minimum Requirements for Fire Resistance in Buildings, BS, BH14; 10 cents; SD.
13. Proposed Building Code for New York City, Merchants Association of New York, N.Y.
14. *Fire Tests of New Post Cap for Mill Construction, Engineering News-Record, vol. 87, No. 24, p. 972, Dec. 15, 1921.
15. *Technical News Bulletin 151, Nov., 1927, BS.
16. Mathematical Theory of Heat Conduction, by Ingersoll and Zobel, p. 78, 113, Ginn and Co., Boston, Mass.
17. Fire Tests of Floors in the United States, Proc. International Society for Testing Materials, paper 27, second section, ASTM.
18. Regulations for the Protection of Openings in Walls and Partitions, NFPA.
19. Recommended Building Code, NBFU.
20. Consolidated Report of the Committee on Protection of Records, NFPA; 50 cents.
21. Report of Committee on Protection of Records, Proc. NFPA, vol. 36, 1932, p. 316; vol. 37, 1933.
22. * Severity of Building Fires, BS; Proc. 14th annual meeting Building Officials Conference, p. 87, 1928; Quarterly NFPA, vol. 22, no. 1, p. 43, July 1928; Safety Engineering, Aug.–Sept. 1928; Architectural Forum, vol. 50, no. 5, p. 775, May 1929.
23. A New Test for Measuring the Fire Resistance of Wood, Proc. ASTM, vol. 29, part 2, p. 973, 1929.
24. The Fire Resistance of Wood Treated with Zinc Chloride and Diammonium Phosphate, Proc. American Wood Preservers Association, p. 130, 1930.
25. Report of Committee on Building Construction, NFPA, Proc., vol. 32, p. 226, 1928.
26. Recommended Minimum Requirements for Small Dwelling Construction, BS, BH18; 10 cents; SD.
27. Report of Committee on Protection of Openings in Walls and Partitions, Proc. NFPA, vol. 34, p. 417, 1930.
28. Building Exits Code, 1929, ASA Standard, NFPA; $1.
29. A Standard Ordinance for Chimney Construction, NBFU.
30. Regulations for Electric Wiring and Apparatus, NFPA.
31. National Electrical Safety Code, BS; $1; SD.

32. Requirements for House Piping and Appliance Installation, American Gas Association, 420 Lexington Avenue, New York, N.Y.
33. Recommended Good Practice Requirements for the Installation, Maintenance, and Use of Piping and Fittings for City Gas, NFPA.
34. Regulations for Nitrocellulose Motion Picture Film, NFPA.
35. Regulations for the Storage and Handling of Photographic and X-Ray Nitrocellulose Film, NFPA.
36. Report of Committee on Construction Operations, Proc. NFPA, vol. 34, p. 362, 1930.
37. Code for Protection Against Lightning, BS, HB 17; 15 cents; SD.
38. Safety Codes for the Prevention of Dust Explosions, NFPA, DA, sponsors. Bulletin 562, Bureau of Labor Statistics; 15 cents; SD.
39. American Table of Distances Between Storage Magazines for Explosives and Inhabited Buildings, Public Railways, and Public Highways, American Institute of Makers of Explosives, New York, N.Y.
40. Construction, Equipment, and Maintenance of Buildings in their Relation to Protection of Records, Proc. NFPA, vol. 35, p. 227, 1931.
41. Inert Gas for Fire and Explosion Prevention, Proc. NFPA, vol. 35, p. 121, 1931.
    Methods for Calculating the Volumetric Composition of Fluid Mixtures, Physics, vol. 5, no. 3, p. 64, March 1934.
42. Regulations for the Installation of Standpipe and Hose Systems, NFPA.
43. Specifications for Gravity Water Tanks and Steel Towers, AFM. Regulations for the Construction and Installation of Tanks, Gravity, Pressure, towers, etc., NFPA.
44. Rules for the Installation of Centrifugal Fire Pumps, NFPA. Notes and Suggestions on Fire Pumps, AFM. Specifications, Selection, and Installation of Centrifugal Fire Pumps, AFM.
45. Regulations for the Installation of Sprinkler Equipments, Wet Systems and Dry Systems, AFM. Regulations for the Installation of Sprinkler Equipment, NFPA.
46. Regulations for Carbon Dioxide Fire Extinguishing Systems, NFPA.
47. Regulations for Foam Fire Extinguishing Systems, NFPA.
48. Regulations for the Installation, Maintenance, and Use of First Aid Fire Appliances, NFPA. First Aid Fire Extinguishers, AFM.
49. Regulations for Outside Protection, NFPA. Rules for Laying Cast-Iron Water Pipes in Factory Yards, AFM.
50. Federal Specification AA–S–81 for Safes; insulated; 5 cents; SD.
51. Federal Specification W–F–391 for Fire-Alarm Systems; Electric, Hand-Operated; 5 cents; SD.
52. Federal Specification W–F–396 for Fire-Alarm Systems; Electric Hand-Operated, Shunt-Type; 5 cents; SD.

53. Regulations for the Installation, Maintenance, and Use of Central Station Protective Signaling Systems for Watchman, Fire Alarm, and Supervisory Service, NFPA.
54. Regulations for the Installation, Maintenance, and Use of Proprietary, Auxiliary, and Local Systems for Watchman, Fire Alarm, and Supervisory Service, NFPA.
55. Specifications for the Installation, Maintenance, and Use of Fire-Detecting Systems on Vessels, Bureau of Navigation and Steamboat Inspection, U.S. Department of Commerce.
56. Federal Specification W–W–101 for Watchmen's-Report-Apparatus; 5 cents; SD.
57. Federal Specification HH–I–531 for Insulation; Rubber Compound, Performance Type, for Wire and Cable for General Purposes; 5 cents; SD.
58. Federal Specification J–C–101 for Cable and Wire; Rubber-Covered, for Ordinary Purposes; BS.
59. Federal Specification O–F–355 for Fire Extinguishers; Chemical, Hand, Soda and Acid Type; 5 cents; SD.
60. Federal Specification O–F–351 for Fire Extinguishers; Chemical, Hand, Carbon-Tetrachloride Type; 5 cents; SD.
61. Federal Specification O–F–380 for Fire-Extinguishing Liquid; Carbon-tetrachloride Base; 5 cents; SD.
62. Federal Specification ZZ–H–451, for Hose; Fire, Cotton, Rubber-Lined; 5 cents; SD.
63. Federal Specification JJ–H–571, for Hose; Fire, Linen, Unlined; 5 cents; SD.
64. Suggested Municipal Ordinance to Regulate the Use, Handling, Storage, and Sale of Flammable Liquids and the Products Thereof, NFPA.
65. Fire Protection in Refineries, American Petroleum Institute, New York, N.Y.
66. Regulations for the Storage and Handling of Liquified Petroleum Gases, NFPA.
67. Safeguarding of Dry-Cleaning Plants, NFPA.
68. Regulations for Paint Spraying and Spray Booths, NFPA.
69. Spray Applications of Flammable Finishing Materials, NFPA; 25 cents.
70. Regulations for the Storage and Sale of Pyroxylin Plastic, NFPA.
71. A Table of Common Hazardous Chemicals, NFPA; 15 cents.
72. Fire and Explosion Risks, by Von Schwartz (English translation by Salter), Chas. Griffin & Co., London.
73. Preservation and Destruction of Records, Edison Electric Institute, New York, N.Y.; 40 cents.
74. Record Protection and Office Equipment, Quarterly, NFPA, vol. 24, no. 4, p. 410, April 1931.
75. Action of Charred Records on the Photographic Plate and a Method of Deciphering Charred Records. Scientific Paper 454, BS; 5 cents; SD.
76. Supervision and Care of Valves Controlling Water Supplies for Fire Protection, NFPA.

(77 and following references.—See p. 137.)

Appendix B. Table of Symbols for Fire Survey Plans

Colors

- Yellow—wooden walls—joist, T-4
- Red—brick walls—joist or mill, T-2. Note if tile
- Brown with yellow rectangle—fire resist with wooden roof, T-1-2
- Brown—fire resistive, T-1
- Brown with gray outline, T-1-2—fire resist with unprot steel in part
- Blue—stone, concrete, hollow concrete block, or adobe—joist, mill, T-2
- Gray—incombustible walls such as skeleton steel, metal lath & plaster, T-3
- Yellow with gray outline, T-4—wood, metal clad
- Gray with yellow rectangle, T-3-4—non-combustible except wood roof
- Yellow with red outline, T-4—wood, brick veneered—joist or mill
- Yellow with blue outline—joist or mill wood, stucco or stone veneered, T-4
- Blue—water courses—arrow indicates direction of flow

Exposure—color in outline

Miscellaneous

4,B,A	Four stories, bas't. & attic
40	Height of bldg in feet
	Composition roof, note type
	Metal, tile, or slate roof
	Wood shingle roof
	Driveway on first floor
LW2	Light well—2 stories. If open court so mark
SL	Sky lights—W.G=wired glass, M.F=metal frame, W.N=wire net
	Parapet walls—one line for each 6 inches in height
	Interior walls not complete to roof. Number of floors pierced to be noted
	Unprotected interior wall openings indicate floor
	Fire door—single, standard
	Fire door—single, non-standard. If double doors indicate by symbol each side of wall
	Sides of open sheds, also sides of platforms bridges & tunnels so marked
	Windows with non-standard shutter, 1st story
	Windows with standard shutters 1st & 2nd stories
	Non-standard wired glass windows 1st, 2nd, & 3rd stories
	Standard wired glass windows
	Windows—protected second & fourth; no protection, third, two openings; no opening, first.
	Dot represents opening, counting left to right looking towards building.
	Gasoline or fuel oil tank underground, label capacity
Pump	Gasoline pump
	Property line or fence
	Fire walls—better than fair cut off
	Retaining wall

	Open joists
	Line of eaves
	Sheathed floor & walls
	Plank and timber mill construction
	Fire resistive floor
	Brick arch floor
	Ground line
	Parapet wall
H 1-3	Open hoist or dumb waiter 1st to 3rd floor
H.T.	Trapped hoistway
E	Open elevator if trapped so indicate
F.E.	Enclosed elevator—frame
E	Elevator in masonry shaft.
	Open stairway—if trapped so indicate, S.T.
	Enclosed stairway
	Stairway in masonry shaft—use appropriate symbols to indicate presence of fire doors to stair or elevator shaft
	Boiler—not brick enclosed
	Boiler—brick enclosed
	Vertical boiler
6D'	Iron chimney
	Brick chimney
FA	Fire alarm box

Protection

	Water pipe—exposed
	Water pipe—buried
	Suction pipe
	Foot valve & strainer
	Frost-proof hydrant two-way private
	Public chuck or flush hydrant
	Public hydrant two outlets with suction connection
	Private hydrant—four-way with independent valves and hose house
	Monitor nozzle
SP.	Standpipe—label size
H.C.	Hose connection on pipe—label size
H.P.	High pressure hydrant
	Deluge valve
6"	Automatic sprinkler riser label size
	Open sprinkler riser label size & "to O S"
	Open sprinklers
	Underground valve requiring key to open it
	Ordinary gate valve
	Globe valve
	Indicator valve
	Post indicator valve
	Check valve—arrow indicates direction of flow
	Check valve with alarm attachment
	Alarm valve
	Dry pipe valve
	Fire dep't. connection
	Alarm gong with hood
	Steam fire pump with hose connection—sample label: 1000 gal Knowles under-writer pump, 18"x10"x12" lift 4' to 8'
	Centrifugal fire pump—sample label: 1000 gal. Knowles centrifugal pump, 2' to 8' head
	Rotary fire pump—sample label: 1000 gal national standard type B, Rodney Hunt rotary pump, 10' to 15' head
	Sprinkler pressure tank—sample label: 6000 gal pressure tank diameter 8', length 18', bottom 10' above top line of sprinklers
	Sprinkler gravity tank—on section—sample label: 50,000 gal gravity tank on 100' steel trestle, diameter 21', height 20', bottom 30' above top line of sprinklers, protected from freezing by tank heater, filled by city water through 2 inch by-pass
	Sprinkler gravity tank—on plan—label as noted above on section
	Reservoir or cistern—if for fire pump, indicate capacity and depth, also use to show mill use tanks
	Meter—give size and name, show by-pass & valves
	Valve in pit
A.S.	Automatic sprinklers on plan
A.S.	Automatic sprinklers on sections
C.R.L.	Cotton rubber-lined hose mark size
L.U.L.	Linen unlined hose mark size
F.E.	Fire escape

77. Private Fire Brigades, NFPA. Private Fire Brigades, AFM.
78. Fire Exit Drills and Alarm Systems, NFPA; 10 cents.
79. Functions and Organization of the District of Columbia Fire Department, by E. R. Pierce. Minutes of Jan. 1932 meeting of Federal Fire Council.
80. Rural Fire Departments, Equipment and Organization, NFPA; 10 cents.
81. Fire Fighting, An Analysis of the Fireman's Job with Suggestions as to the Organization and Operation of Training, Federal Board for Vocational Education; 30 cents; SD.
82. Municipal Fire Alarm System of the District of Columbia, by W. E. Kern. Minutes of the Oct. 1931 meeting of Federal Fire Council.
83. Organization and Operation of a Municipal Bureau of Fire Prevention, by H. A. Stone and G. E. Stecher, Syracuse University, Syracuse, NY.
84. Report on Form for Reports. Minutes of Oct. 1931 meeting of Federal Fire Council.

GENERAL REFERENCES

(a) Industrial Fire Hazards, by Gorham Dana and W. D. Milne, Lakeview Press, Framingham, Mass.
(b) Fire Prevention and Protection, Bureau of Yards and Docks, Navy Department.
(c) Field Practice Inspection Manual, NFPA; $1.50.
(d) Handbook of Fire Protection, by Crosby-Fiske-Forster, D. Van Nostrand Co., New York, N.Y.
(e) Fire Prevention and Protection, The Spectator Co., New York, N.Y., and Chicago, Ill.
(f) Fire Prevention and Protection as Applied to Building Construction, by J. K. Frietag, John Wiley & Sons, New York, N.Y.
(g) Automatic Sprinkler Protection, by Gorham Dana, John Wiley & Sons, Inc.
(h) Fire Protective Construction on the Farm, DA Farmers' Bulletin 1590; 5 cents; SD.
(i) Fire Safeguards for the Farm, DA Farmers' Bulletin 1643, 5 cents; SD.
(j) Value of Inert Gas as a Preventive of Dust Explosions in Grinding Equipment, DA Technical Bulletin 74; 5 cents; SD.
(k) Dust Control in Grain Elevators, DA Department Bulletin 1373; 15 cents; SD.
(l) Dust Explosions, Theory and Nature of Phenomena, Causes and Methods of Prevention, by David J. Price and Harold H. Brown, NFPA; $3.00.
(m) Report of the Joint Committee on Standard Specifications for Concrete and Reinforced Concrete, ASTM.
(n) The Fire Chief's Handbook, by Fredrick Shepperd Case, Sheppard-Mann Publishing Co., New York, N.Y.

68770—34——10

APPENDIX C. FEDERAL FIRE COUNCIL BLANK FORM FOR REPORT OF FIRE ON GOVERNMENT PROPERTY

For explanation of information desired under the different headings, see p. 139. Report in full or in part depending on extent of information available, should be made of all fires large or small, an estimate of the property damage to be included in all cases.

Reports should be transmitted promptly to the officer in general administrative charge of the property. The Federal Fire Council, National Bureau of Standards, Washington, D.C., will appreciate receiving copies of all fire reports. They will be used to determine the general ratio of fire losses to value of Government property and its trend. The individual or departmental loss figures will not be made public.

1. Location____________________
2. Time (date and hour)____________________
3. Department, Bureau or Independent Establishment____________________
   ____
4. Point of Origin____________________
5. Size of Building (length and width)__________ Height (stories)__________
6. Type of Construction:
   - (a) Framing__________
   - (b) Exterior walls__________
   - (c) Floor construction__________
   - (d) Floor surface__________
   - (e) Roof construction__________
   - (f) Roof covering__________
   - (g) Partitions__________
   - (h) Interior finish__________
7. Occupancy____________________
8. Extent of Damage____________________
   - (a) Amount of property damage in dollars:
     1. Building__________ $__________
     2. Inventoried contents__________ $__________
     3. Records and other uninventoried contents__________ $__________
   - (b) Highly valuable documents, works of art, or other irreplaceable contents__________
     ____
   - (c) Loss of life____________________
   - (d) Injury to persons____________________
9. Cause of Fire____________________
10. How was Fire Extinguished?____________________
11. What Fire-Alarm and/or Fire-Extinguishing Equipment is Provided in the Building?
    ____
12. Was there any Defect or Inadequacy in Fire Apparatus or any Other Deficiency? (Explain fully if any)____________________
    ____
13. Suggestions as to Preventing Similar Fires in Future____________________
14. Story of the Fire____________________

Report by____________________

Title____________________

Date of report____________________

Explanatory Notes on Information Desired Under the Different Headings of the Report of Fire. (Numbers refer to questionnaire items of appendix C.)

1. Identify building by name, street number, city, and State.
3. Designate Department, Bureau, or independent establishment having jurisdiction over the building and/or contents.
4. Indicate the room, floor, or part of building in which fire started and where applicable, the equipment in which fire originated.
6. The following materials are suggestive of common types used in building construction. For small fires controlled in their early stages details of building construction and finish need be given only if they contributed to the origin and assisted or retarded the spread of the fire.
   (a) Framing: Reinforced concrete; structural steel protected; structural steel unprotected; heavy timber; wood frame; etc.
   (b) Exterior walls: Brick; solid concrete; stone with brick or hollow-tile backing; brick veneer on wood frame and sheathing; corrugated iron or sheet metal on steel or wood framing; stucco on wood or metal lath on wood sheathing; wood shingles or boards on wood framing; etc.
   (c) Floor construction: Solid reinforced concrete of beam and girder type or flat slab; concrete joist with metal pans or hollow tile; steel joist; heavy timber; wood joist; etc.
   (d) Floor surface: Granolithic; terrazo; ceramic tile; cork tile; rubber tile; mastic; linoleum; wood block; wood; etc.
   (e) Roof construction: Reinforced concrete of beam and girder type or flat slab; same on protected steel beams and girders; same on unprotected beams and girders; wood on timber trusses; wood on unprotected steel trusses; wood sheathing on wood joist; etc.
   (f) Roof covering: Tar and gravel; slate; tile; cement-asbestos; asphalt roll roofing or shingles; wood shingles; etc.
   (g) Partitions: Hollow tile; gypsum block; wood stud; metal stud; steel and glass; wood and glass; etc.
   (h) Interior finish: Plaster on masonry; on wood lath, on metal lath, plasterboard, wood, wood-pulp board; etc.
7. Give general nature of occupancy of building such as office, laboratory, storage, mess hall, machine shop, etc., and specific occupancy where fire probably started.
8. Under (a) for 1 and 2 give estimated cost of damage to building and inventoried contents as the cost of reproduction less depreciation, the latter being taken as the ratio of age to total useful life, multiplied by the cost of reproduction.
   (a) 3 applies to correspondence, accounts, tracings, etc. Describe briefly and give best estimate possible.
   (b) Itemize those damaged or destroyed and give estimate of value if possible.
   For (c) and (d) state number of persons and whether men, women, or children, and whether disabled.
9. Where cause is definite, it can be stated; where problematical, give best information available and an opinion as to the cause. Common causes of fires are exposure from other buildings, forests, etc.; matches-smoking; defective chimneys and flues; stoves, furnaces, boilers, and their pipes; electricity; sparks on roofs; petroleum and its products; spontaneous ignition; lightning; sparks from machinery; and hot ashes and coals, and open fires. Contributory causes include spilled oil, and accumulations of rubbish and packing materials.
10. State whether fire was extinguished by sprinklers; hand extinguishers; hand hose; or public fire department; if by hand extinguishers, state whether soda and acid, carbon-tetrachloride, carbon dioxide, foam, water pails, or other hand device.
13. This report of your experience may be helpful in preventing similar fires on U.S. Government properties.
14. Give a concise story covering cause, discovery, sprinkler action if any, how alarm and extinguishing devices operated, how construction details withstood the fire, lessons of the fire, and other general information. Plans, sketches, or photographs, if obtainable, will be helpful in making a study of the fire.

APPENDIX D. FEDERAL STATUTE ON DISPOSITION OF USELESS GOVERNMENT PAPERS

An Act to Authorize and Provide for the Disposition of Useless Papers in the Executive Establishments

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That whenever there shall be in any one of the Executive Departments of the Government an accumulation of files and papers which are not needed or useful in the transaction of the current business of such Department and have no permanent value of historical interest, it shall be the duty of the head of such Department to submit to Congress a report of that fact accompanied by a concise statement of the condition and character of such papers. And upon the submission of such report, it shall be the duty of the presiding officer of the Senate to appoint two Senators, and of the Speaker of the House of Representatives to appoint two Representatives, and the Senators and Representatives so appointed shall constitute a joint committee to which shall be referred such report with the accompanying statement of the condition and character of such papers and such joint committee shall meet and examine such report and statement and the papers therein described and submit to the Senate and House, respectively, a report of such examination and their recommendation. And if they report that such files of papers, or any part thereof, are not needed or useful in the transaction of the current business of such Department and have no permanent value or historical interest then it shall be the duty of such head of the Department to sell as waste paper or otherwise dispose of such files of papers upon the best obtainable terms after due publication of notice inviting proposals therefor, and receive and pay the proceeds thereof into the Treasury of the United States, and make report thereof to Congress.

Approved, February 16, 1889.

Act of March 2, 1895

That the Act entitled "An Act to authorize and provide for the disposition of useless papers in the Executive Departments," approved February sixteenth, eighteen hundred and eighty-nine, be, and the same is hereby, amended so as to include in its provisions any accumulation of files of papers of a like character herein described now or hereafter in the various public buildings under the control of the several Executive Departments of the Government.

Executive Order No. 1499

It is hereby ordered that before reporting to Congress useless files of papers to be disposed of under the provisions of the Act of February 16, 1889, as extended and amended by section 1, chapter 189 of the act of March 2, 1895, lists of such papers shall be submitted to the Librarian of Congress in order that the several Executive Departments may have the benefit of his views as to the wisdom of preserving such of the papers as he may deem to be of historical interest.

Wm. H. Taft.

The White House,
March 16, 1912.

APPENDIX E. SUGGESTED PROCEDURE TO BE OBSERVED FOR COMBATING FIRES

Where No Private Fire Brigade is Organized and Public Protection is Readily Available

(Copies to be Supplied to all Employees)

Chief fire marshal

The chief fire marshal when present at fires will assume general supervision of operations until the arrival of the city fire department, at which time he or the assistant fire marshal in charge will give such information as to the exact location and nature of the fire, precautions to be taken, valuable equipment or material subject to damage, etc., as he may possess and stand by to render whatever assistance may be necessary.

Assistant fire marshals

The assistant fire marshals shall assist the chief fire marshal in combating fires in the areas to which they are assigned and assume full charge in the absence of the chief, until relieved by the city fire department. It shall also be the duty of these men to familiarize themselves with all activities on the floors, building, or area to which they are assigned, learn the location of shut-off valves in the various pipe lines, electric switches, stowage space for highly combustible or explosive materials, which knowledge would be of great value in combating fires. They shall also learn the location of valuable material, records, equipment, etc., in case they have an opportunity to salvage such material. They shall also familiarize themselves and other occupants with the most effective method of using fire extinguishers and handling hose. They shall inspect the fire equipment at frequent intervals and report any condition that may need attention to the superintendent's office. They shall inspect the various laboratories and offices in their jurisdiction at frequent intervals and report any hazardous conditions or practices to the chief of the division concerned and to the chief fire marshal.

Chief electrician and chief plumber

The chief electrician and chief plumber with their available mechanics, shall report at all fires prepared to render such assistance in their lines as may be necessary.

Laborer force

The laborer force shall report at all fires for such duty as those in charge may assign them.

First aid

Members of the first-aid team not otherwise engaged, shall report at fires with equipment to render first-aid treatment under direction of the staff physician, if needed.

Telephone operator

The telephone operator shall, upon receipt of a fire alarm, instruct the guard to turn in an alarm at the nearest alarm box and give him the location of the fire. She shall then telephone in an alarm to the city fire department. She shall then receive the report back from the guard and record the time, location, and name of the person calling and then notify the superintendent of the building or building group and the general administrative official in charge, giving the location of the fire.

Guard on duty

The guard on duty shall, upon being notified of a fire by the telephone operator, immediately turn in an alarm on the nearest city fire-alarm box and then report back to the operator that the alarm has been turned in. If the fire is located in any of the buildings not reached through the usual entrance, he shall proceed as quickly as possible to the main entrance to the grounds and direct the fire department's apparatus to the building concerned. Apparatus not so directed would proceed to the group of buildings served by the main entrance or nearest the box pulled.

All watchmen shall familiarize themselves with the location of telephones connected to the city exchange after working hours and shall use these telephones in turning in alarms to the city fire department whenever such telephones are more accessible than the alarm box and the use of the latter would result in delay in transmitting the alarm.

All fires occurring after regular working hours shall be reported immediately to the chief fire marshal or his designated substitute, by the guard on duty.

Engineman on duty

In case of a fire of such magnitude that it requires the use of outside fire hydrants supplied by a metered connection, the engineman on duty shall, after safeguarding the power plant, immediately open the by-pass around the water meter to permit an unobstructed flow of water.

Other employees

Employees not in the immediate vicinity of the fire and having no interest therein or not needed to assist in combating it, shall remain at their usual place of employment.

Employees in the building or part of building affected and not needed to assist in combating the fire, shall leave the building. Assistant fire marshals shall assist in enforcing this requirement in the interest of safety.

Report on fire

The fire marshal or assistant fire marshal shall prepare a report in duplicate on each fire on the form provided, one copy to be sent to the administrative officer in charge and the other to the Federal Fire Council.

Publicity

Employees shall refrain from discussing with newspaper representatives, the probable cause of fires and the damage caused thereby. Information of this character shall be released only through the administrative office.

Procedure in case of fire

Immediately upon the discovery of a fire, the discoverer shall summon such assistance as may be near at hand and proceed to extinguish the fire if in his opinion this can be accomplished with the apparatus and help available. However, if there is any doubt as to their ability to extinguish the fire immediately, the telephone operator shall be notified from the nearest telephone, giving the location of the fire and the name of the person calling. Meanwhile, all available employees shall attack the fire with all available means to the end that the fire may be confined as much as possible until further assistance or the city fire department arrives. Men not required to handle fire hose or extinguishers, should be directed by the occupant of the room to close windows and doors not needed, shut off apparatus using electricty or gas, and salvage valuable material, apparatus, and records. The discoverer of the fire or occupant of the room shall direct operations until relieved by the assistant fire marshal, bureau fire marshal, or the city fire department.

(Signed) ______________________
(Chief of Office, Bureau, or Establishment)

APPENDIX F. SELF-INSPECTION FORMS

REPORT OF ASSISTANT FIRE MARSHAL

Department ------------------------ Bureau ----------------------- Location ------------

To------------------------Chief of Bureau, and--------------------------Chief Fire Marshal
(Office) (Establishment)

The following matters referenced to items on the self-inspection form of the Federal Fire Council, where applicable, are noted and conditions now needing correction are called to your attention:

Form item number	Hazard, deficiency, etc.	Location, building, room	Recommendation, date	Condition corrected, date

Date----------------

Assistant Fire Marshal.

NOTE.—This report must be sent to the officer in general administrative charge of the property or occupancy and the chief fire marshal not later than 3 days after the close of the prescribed period (month, quarter, half year) to be covered by the report. Conditions that need immediate attention and for which correction cannot otherwise be obtained, should be made the subject of ad interim reports.

The assistant fire marshal should make frequent inspections and maintain contact with conditions having a bearing on the fire hazard with a view to obtaining elimination of fire causes, maintenance of fire-protection equipment, and proper functioning of the organization for combating fires, by obtaining the cooperation of those immediately concerned.

FEDERAL FIRE COUNCIL SELF-INSPECTION REPORT FORM FOR GOVERNMENT ESTABLISHMENTS

Inspections with this form as a basis should be made at intervals preferably not exceeding 1 month and for some properties it may be desirable to make them more frequently. Efforts should be made to obtain prompt correction of any hazardous conditions found, by contacting those in immediate charge of the property.

As a record of the condition of the property and to obtain improvements not otherwise possible, this form should be executed and sent to the officer in general administrative charge of the property not later than 3 days after the close of the prescribed interval (month, quarter, half year) between reports. Conditions requiring immediate attention should be made the subject of ad interim reports.

Hazards or deficiencies should be indicated by building or portion thereof under each item. Additional sheets supplementing given items should be used if necessary. Items may be omitted or added to fit particular needs.

Establishment and Building or Building Group. (Under this heading should be given the Bureau or other division having jurisdiction; the specific building or building group to which the inspection applies; and the location by street and number, city, and State. Generally it is desirable to cover in one report the buildings subject to one supervising agency.)______________

____

____

A. COMMON FIRE HAZARDS

A–1. *Are Combustible Materials in Unnecessary Amounts Creating Fire Hazard within Buildings?* The hazard from books, newspapers, etc., may be reduced by storage in enclosed metal cabinets or shelves. Paints, oils, lumber, and other combustible stocks should be segregated in fire-resistive inclosures or separate buildings and accumulations of waste prevented.)_____________

A–2. *Are Packing and Shipping Operations Properly Safeguarded?* (Excelsior and similar packing materials should be kept in covered metal bins and the rooms swept and put in order at the end of each day's operations.)

____

A–3. *Are Combustibles Unnecessarily Stored in the Yard or Court?* Rubbish should be removed promptly to avoid accumulations that would be difficult to have removed.)____

A–4. *Is Oily Waste, etc., Outside of Covered Metal Waste Cans?* (Oily waste is readily ignited and under some conditions is subject to spontaneous heating.)____

A–5. *Are Waste Cans Emptied at Sufficiently Frequent Intervals?* (Otherwise cans will be overfilled and materials placed outside of them.)_______________

A–6. *Are Open-flame Lights Near Combustible Materials?*_________________

A–7. *Is Woodwork or Other Combustible Material too Near Steam Pipes, Boilers, Flues, or Furnaces?* (In general, scorching or charring indicates a dangerous condition.)____

A–8. *Are Hot Ashes Properly Disposed of?* (Hot ashes should not be placed in contact with wood or other combustible material nor kept in combustible containers.)____

A–9. *Are Any Roof Covers Defective?* (Flying brands from chimneys, locomotives, and other sources will lodge and start fires more readily in weathered wood shingles and old torn or cracked roll roofings than in roofings in good condition. Fires may start in roof boards or inside of buildings by brands entering through holes in corroded metal or other roof coverings.)________

A–10. *Are Any Stoves, Furnaces, Pipes, Chimneys, or Flues Defective?* (Stovepipes are corroded by furnace fumes and joints of horizontal runs may separate. Chimneys become defective at the roof line from rain washing out mortar joints.)____

A–11. *Are Rules on Smoking Violated?*____

A–12. *Is There Evidence of Careless Disposition of Smoking Materials?* (One of the most frequent causes of fire within buildings. Thrown out of windows fire may be set to awnings and automobiles.)______________________

A–13. *Are Records Properly Protected?* (Records should be classified as to value, useless records destroyed, and the others given protection by duplication or in protective containers. Records of high value should be kept in vaults or insulated safes having fire resistance adequate for the location and if taken out during the day should be replaced at the close of working hours.)____

A–14. *Is Clothing Kept in Wooden Lockers?* (Metal lockers are preferable.)____

A–15. *Are the Storage, Handling, and Use of Gasoline, Kerosene, Fuel Oil, Alcohol, and Other Hazardous Liquids and Chemicals Properly Safeguarded?* (Preferably not more than 2 gal of flammable liquids should be kept at individual points in buildings and be contained in safety cans. Storage of relatively small quantities of flammable oils or other hazardous substances should be in protective cabinets and larger quantities in separate buildings. Large supplies of flammable liquids should be stored in underground tanks. Fuel-oil storage in closed steel tanks in buildings should not exceed 275 gal in individual tanks or 550 gal total, unless enclosures highly resistive to fire and pressure are provided for the tanks. Spillage should be avoided and all pipe connections kept tight. Where chemicals are used their nature should be ascertained and precautions taken against fire or explosion. Nitrocellulose film, celluloid, or other pyroxylin products should be kept in metal containers away from radiators or other sources of heat, and in excess of 25 lb stored in vented vaults or cabinets. Lights should not be in contact with or too near the storage.)____

B. ELECTRICAL HAZARDS

B–1. *Are Any Electric Fixtures or Wires Loose or Broken?*__________________

B–2. *Are Electric Cords Looped Over Nails or in Contact With Any Other Metallic Objects or Surfaces?*____

B–3. *Is Wiring Installed in Accordance With Accepted Practice?* (Reference may be made to the building code for the city or State in which the building is located, the National Electrical Code, or the National Electrical Safety Code.)____

B–4. *Are Any Electric Fuses Replaced by Wire or Other Improper Current-Carrying Materials or Devices?*_____________________________________

B–5. *Are Fuse or Switch Cabinet Doors Open or Covers of Other Boxes Open or Missing?* (If open, fire from short circuits may ignite adjacent combustible construction or materials.)___________________________________

B–6. *Are There Extra Fuses on Hand?* (Extra fuses of proper size will eliminate the temptation to insert fuses of improper size, wire, pennies, etc.)
____

B–7. *Are Circuits Properly Fused?* (When fuses are blown there is temptation to fuse circuits higher than their safe capacity. For no. 14 wire, fuses should not be larger than 15 amp.)____________________________________

C. FIRE SPREAD

C–1. *Are Fire Doors or Shutters Installed Where Needed and Are They in Condition to Operate Freely?* (Fire doors should not be obstructed. Self-closing fire doors should not be wedged open. If required to be open for certain periods they should be kept closed at other times.)_____________________

C–2. *Are There Any Broken Windows, Plastering, Partitions, Flooring, or Similar Deficiencies?*____

C–3. *Are Window Openings Protected from Exposure Fires?* (Openings in exterior walls of buildings exposed by nonfire-resistive buildings, lumber piles, etc., at distances of 30 ft or less should have windows with metal sash and wired glass, or shutters, or for severe exposure, both.)____________________

C–4. *Are Combustible Stocks or Hazardous Operations Isolated by Fire Walls?* (In general areas subject to one fire should not exceed 10,000 ft^2 in buildings of fire-resistive construction, or 3,000 to 5,000 ft^2 in buildings of nonfire-resistive construction. For hazardous materials and occupancies the areas should be smaller. Where buildings are sprinklered the areas may be increased.)____

C–5. *Are There Any Unnecessary Concealed Spaces?* (The flue effect produced by concealed spaces in walls and partitions can be reduced by fire stopping at floor and roof lines.)____

C–6. *Are Elevator and Stair Shafts Enclosed?* (It is desirable to have elevators and stairways completely enclosed with self-closing metal doors for the openings to prevent spread of fire from floor to floor.)__________________

C–7. *Do Temporary Partitions, Enclosures, and Containers of Combustible Construction Increase the Fire Hazard?* (Fire-resistive buildings can be made hazardous by such additions.)____

D. INSIDE FIRE PROTECTION

D–1. *Are Fire Pails, Hose, Nozzles, Chemical Extinguishers in Place, in Good Condition, and Unobstructed?* (First-aid extinguishers should be full and water pails subject to freezing filled with non-freezing solutions. Soda-acid extinguishers should be discharged and recharged annually with date of recharging marked on tag on extinguisher, and should not be placed in locations subject to freezing. Defective fire hose and discharge hose on hand extinguishing equipment should be replaced.)_________________________

D–2. *Are all Valves in Lines Supplying Water to Sprinkler Systems Open?* (If it is necessary to close the valves special precautions should be taken while they are closed and also to see that they are opened as soon as possible.)
____

D–3. *Are Sprinkler Heads Coated or Corroded?* ______________________________

D–4. *Are Sprinklers Obstructed by Partitions, Piles of Materials, etc.?* (They should be at least 12 in. below the sprinkler heads.) ________________

D–5. *Are Any Portions of Wet-Pipe Sprinkler Systems Exposed to Freezing?* ____

D–6. *How Many Sprinkler Heads are Kept in Reserve?* (A supply of 10 percent of the number in one area is reasonable, but in no case less than 25, except for very small installations.) ______________________________

D–7. *Are Any Sprinklers Disconnected?* ______________________________

D–8. *For Dry Valve Give Room Temperature.* (This should be kept above freezing, since valve contains water.) ______________________________

D–9. *What is Air Pressure for Dry Valve?* (This can be read from the gage provided in the installation.) ______________________________

D–10. *What is Water Pressure for Dry Valve?* (This can be read from the gage provided. The usual ratio of water to air pressure is about 6:1 for differential dry valves. It is customary, however, to carry an air pressure of 30 to 40 lb to provide a factor of safety.) ______________________________

E. OUTSIDE PRIVATE FIRE PROTECTION

E–1. *Are Hydrants Free from Obstruction and Are They Tested?* (They should be tested annually for static and flowing pressures but not by opening in freezing weather. A slight turn of the stem will show if hydrant is frozen or a weight lowered into the hydrant will determine presence of ice by sound, and water by wetting of the weight.) ______________________________

E–2. *Are Hose Houses Accessible and Free from Rubbish?* ______________

E–3. *Is Cotton Rubber-Lined Hose Tested Regularly?* (It should be tested once each year capped, or with shut nozzle at the highest static pressure available at its connection to the water system. Drain and dry thoroughly afterward.) ______________________________

E–4. *Are Post Indicator Valves Strapped Open?* (To prevent tampering strap them open in a manner that will permit breaking the strap when shutting the valve to stop water flow.) ______________________________

E–5. *Is Lettering on Post Indicator Valve Legible?* ______________________

F. GENERAL

F–1. *Are Watchman's Rounds Checked Regularly? By What Method and By Whom?* (Records from portable or stationary recorders should be checked daily. If reporting by telephone or signal to central station, failure to report should receive immediate attention.) ______________________________

F–2. *How Are Fire Alarms Transmitted? Are Fire Alarm Boxes or Telephones Accessible at All Times? Is Personnel Instructed in the Procedure to be Observed in Case of Fire?* (Fire alarm boxes or telephones should be accessible at all times. Rooms in which they are located should be unlocked. Private alarm systems should be tested at intervals.) ______________________

F–3. *Are Adequate Exits and Fire Escapes Provided, Carefully Indicated and Free from Obstructions?* (Two independent means of exit should be provided with not more than 150 ft of exit travel to reach a stairway which distance should be shorter where hazardous occupancies or conditions are involved.) ______________________________

F–4. *Are Vents Provided for Explosive or Obnoxious Gases?* (Explosion hazards cover a wide field and if there are indications that the hazard is not adequately cared for, further investigation should be made and proper preventive measures applied.)________________________________

F–5. *Is There a Fire Brigade or Other Group Organized to Respond in Case of Fire?*________________________________

F–6. *Give Date of Last Fire Drill, Number of Men Responding, and Time Taken to Man Equipment*________________________________

F–7. *Does Drill Include Placing Records into Their Protective Containers?*________________________________

F–8. *Note Existing Fire Hazards or Deficiencies in Fire Protection not Specifically Indicated in Previous Questions.*________________________________

F–9. *Summarize Corrections and Improvements Effected Since Last Report* ________________________________

Date________________ Report by________________________

Title________________________

FEDERAL FIRE COUNCIL SHORT FORM FOR SELF-INSPECTION REPORT

This form is intended for the use of services occupying buildings controlled by another agency responsible for the building and its major service and fire-protection equipment. Inspections should be made frequently and needed corrections obtained as far as possible by contact with those immediately concerned. This form should be executed and sent to the officer in general administrative charge of the occupancy not later than three days after the close of the prescribed interval (month, quarter, half year) between reports. Use additional sheets if necessary for items not on form or for supplementing given items.

Bureau or Service, and Location. (It is generally desirable to cover in one report all occupancies within a building or building group connected with one Bureau or service.)________________________________

1. *Are Combustible Materials in Unnecessary Amounts Creating Fire Hazards Within or Outside of Buildings?* (The hazard can be reduced by storage in metal containers. Large combustible stocks should be segregated and accumulations of waste prevented.)________________________________

2. *Are Packing and Shipping Operations Properly Safeguarded?* (Excelsior and similar packing material should be kept in covered metal bins and the rooms swept and put in order at the end of each day's operation.)
____

3. *Is Oily Waste, Etc., Allowed to Remain Outside of Covered Metal Waste Cans?* (Such waste is readily ignited and animal and vegetable oils may cause ignition from spontaneous heating.)________________________________

4. *Are Waste Cans Emptied at Sufficiently Frequent Intervals?* (Otherwise materials will be placed outside of the filled cans.)________________________

5. *Are Gas or Electric Plates, Lights, Heaters, Furnaces, Stoves and their Pipes, too Near Walls, Ceilings, Curtains, or Other Combustible Contents, or Without Proper Protection Beneath?* (Any scorching or charring indicates a dangerous condition.)____

6. *Are Burners, Hot Plates, Ovens, Dryers, Etc., Creating Hazard by Being Left Unattended for Unduly Long Periods?*________________________________

7. *Are Rules on Smoking Violated?*____

8. *Is there evidence of careless disposition of lighted matches or smoking materials?* (One of the most frequent causes of fire within buildings. Thrown out of windows fire may be set to awnings and automobiles.)_______

9. *Are records properly protected?* (Records should be classified as to value, useless records destroyed and others given protection by duplication or in protective containers. Records of high value should be kept in vaults or insulated safes having fire resistance adequate for the location, and if taken out during the day, replaced at the close of working hours or in case of fire.)____

10. *Is clothing kept in wooden lockers?* (Lockers or closets of incombustible materials are preferable.)____

11. *Do combustible partitions, enclosures, or containers increase the fire hazard?* (Fire-resistive buildings can be made hazardous by such additions.)____

12. *Are the storage, handling, and use of gasoline, kerosene, fuel oil, alcohol, celluloid, and other hazardous substances in gas, liquid, or solid form, properly safeguarded?* (Preferably not more than 2 gal of flammable liquids should be kept at individual points within buildings and be contained in safety cans. Storage of minor amounts of miscellaneous oils or other hazardous substances should be in protective cabinets and for large quantities in separate buildings or containers placed outside of buildings. Nitrocellulose film, celluloid, or other pyroxylin products should be kept in metal containers away from radiators or other sources of heat, and in excess of 25 lb, stored in vented vaults or cabinets.)______________________________

13. *Are electric fixtures or wires loose or broken?*___________________________

14. *Are electric cords or wiring supported on nails or otherwise not properly insulated?*____

15. *Is personnel organized and instructed in the procedure to be observed in case of fire, use of extinguishers, etc?*_______________________________________

16. *Note any other hazards or deficiencies not otherwise covered.*___________

17. *Note improvements since last report.*___________________________________

Date__________________ Report by_________________________

INDEX

Page

68770—34——11

O