Distribution System Requirements for Fire Protection

MANUAL OF WATER SUPPLY PRACTICES

M31

Fourth Edition

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Distribution System Requirements for Fire Protection

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Contents

List of Figures, v

List of Tables, vii

Preface, ix

Acknowledgments, xi

Chapter 1 Fire Flow Requirements 1

Impact on Distribution System Design, 1
Community Governance, 2
Fire Flow Requirements, 2
Calculating Fire Flow Requirements, 2
Practical Limits on Fire Flow, 13
Nonpotable Water Sources for Fire Fighting, 15
References, 16

Chapter 2 System Demand and Design–Flow Criteria 17

Methods of Distribution, 17
Rates of Water Use, 18
Distribution System Appurtenances, 19
System Evaluation and Design, 21
Determining Design Flow, 21
Flow Metering, 22
Standby Charges for Fire Protection Systems, 22
Water Distribution Analysis Techniques, 22
References, 23

Chapter 3 Distribution System Storage. 25

Functions of Distribution Storage, 25
Elevated and Ground Storage, 27
Pumping for Distribution Storage, 28
Location of Storage, 28
Storage Reservoir Overflow Level, 28
References, 30

Chapter 4 Adequacy and Reliability of Distribution Systems 31

Determining Level of Reliability, 31
Application of Reliability Considerations, 33
Reliability of Major System Components, 34
Operations, 36
References, 37

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Document Sharing Hub

Full document details: AWWA Manual M31 2008

Chapter 5 Automatic Fire Sprinkler Systems 39

Advantages of Sprinkler Systems, 39
Water Supply Requirements for Sprinklered Properties, 40
Types of Sprinklers for Commercial Buildings, 42
Standpipes, 43
Backflow Prevention for Fire Sprinkler Systems, 43
References, 45

Appendix A Agencies Involved in Fire Protection 47

Insurance Services Office Inc., 47
Insurance Organizations With Fire Protection Interests, 48
National Fire Protection Association, 48
National Fire Service Associations, 48
Fire Research Laboratories, 48
National Fire Sprinkler Association, 48
American Fire Sprinkler Association, 49
International Code Council, 49
Insurance Bureau of Canada, 49
Insurers' Advisory Organization, 49
National Research Council, 49
Underwriters Laboratories of Canada, 49

Appendix B Water Supply and Fire Insurance Ratings 51

Insurance Ratings, 51
References, 54

Index 55

List of AWWA Manuals 59

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Figures

1-1 Typical occupancy classifications—nonmanufacturing, 6

1-2 Typical occupancy classifications—manufacturing, 7

1-3 Comparison of fire flow calculations, 12

1-4 Comparison of fire flow calculations, including three exposure buildings, 14

2-1 Typical small city distribution system, 19

3-1 System A—hydraulic gradient with no storage, 29

3-2 System B—hydraulic gradients with storage between pump station and load center, 29

3-3 System C—hydraulic gradients with storage beyond load center, 30

5-1 Sprinkler system design curves, 41

B-1 Water supply evaluation, 53

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Tables

1-1 Fire flow durations, 3

1-2 Values of coefficient (F) construction class, 4

1-3 Occupancy factors for selected combustibility classes, 5

1-4 Factor for exposure (X_i), 8

1-5 Factor for communications (P_i), 9

1-6 Needed fire flow for one- and two-family dwellings, 9

2-1 Values commonly used in distribution piping, 20

3-1 Water use and storage depletion for maximum day in a typical city, 26

5-1 Hazard classification schedule, 42

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Preface

Water distribution systems have been developed and operated for a variety of reasons. In the past, many communities recognized the need for safe, potable water that could be used for drinking and cooking. Governmental agencies or private enterprise promptly took on the responsibility of providing safe water to meet these basic human requirements.

The need for nonpotable water arose because of an increasingly sophisticated lifestyle. In many cases, the water systems established to provide potable water were augmented and enlarged to provide water for irrigation, car washing, industrial processes, and other purposes. It also became necessary to provide an adequate supply of water for fire protection and suppression. Systems that provide for fire protection needs have frequently been incorporated into the systems that provide potable water service as well as nonpotable service. As technology advances, many alternatives to this basic water supply configuration can be found. A notable alternative is the use of dual distribution systems.

The American Water Works Association has published standards for materials used in the field of fire protection for many decades. However, it was not until the early 1980s that AWWA's Committee on Fire Protection developed the first edition of this manual, which addresses the planning, design, and maintenance of distribution systems that supply water for fire protection and suppression.

This manual provides specific guidance on the design, operation, and maintenance of water distribution systems as they relate to fire protection and fire suppression activities. When the governing body of a community makes a conscious decision to use the available water supply system for fire suppression purposes, this manual should be consulted, judiciously applied, and tempered as local conditions require.

This edition of the manual updates the information, clarifies some topics, and deletes material that is no longer essential. The manual still closely parallels the first edition prepared by the Fire Protection Committee.

As was the case with the first edition, this fourth edition does not intend to describe how firefighters should use water to control fires, but rather how water utilities should design and operate their systems to maximize fire protection benefits while delivering safe, potable water to customers. The emphasis is on public water systems and not on water systems exclusively designed for fire protection. Similarly, this manual does not intend to reproduce material available elsewhere in AWWA publications such as Manual M17, *Installation, Field Testing, and Maintenance of Fire Hydrants*, or Standards C502, Dry-Barrel Fire Hydrants, and C503, Wet-Barrel Fire Hydrants.

The adequacy of a water distribution system for fire protection depends on the fire flows required. Chapter 1 describes several methods for determining required fire flows. Once fire flow requirements are determined, these are added to the other water system demand requirements. Chapter 2 discusses the impact of fire protection on distribution system design. Chapter 3 focuses on distribution storage in terms of both sizing and location. Chapter 4 discusses reliability issues arising because systems must remain in operation even when individual components are out of service. Chapter 5 describes fire suppression sprinkler systems and their effect on water requirements, particularly because they affect how water is used for fire fighting.

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Appendix A lists organizations involved in fire protection and describes the organizations and their roles. Appendix B describes the relationship between the water supply system and fire insurance ratings, because one benefit of supplying needed fire flow is an improved fire insurance rating for a community.

The water utility has important partners in fire protection. The water utility must work together with local fire officials, building code officials, and others to effectively and efficiently promote fire protection. Good communication between all involved parties is essential to protect property and life.

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Chapter 1

Fire Flow Requirements

> For centuries, water has been used to extinguish fires. The inexpensiveness and availability of water are the primary factors leading to its widespread use. But, not only must water be available for fire protection, it must be available in adequate supply. As a result, the question must be asked, how much water is necessary to be considered an adequate supply for fire protection? (Milke 1980)

Most municipalities are willing to incur the higher cost for distribution system sizing because of the reduction in loss that is possible by using the water system for fire protection. Water in sufficient quantity can cool the fire; the steam can deprive the fire of oxygen, and in the case of miscible or dense fluids, water can disperse the fuel. The key question for water utilities is how large must distribution system components be to provide sufficient water for fire protection. The remainder of this manual presents methods for estimating these requirements.

IMPACT ON DISTRIBUTION SYSTEM DESIGN

The decision to provide water for fire protection means that a utility must explicitly consider fire flow requirements in sizing pipes, pumps, and storage tanks. In larger systems, fire protection has a marginal effect on sizing decisions, but in smaller systems these requirements can correspond to a significant increase in the size of many components. In general, the impact of providing water for fire protection ranges from being minimal in large components of major urban systems to being very significant in smaller distribution system pipes and small distribution systems.

The most significant impacts are installing and maintaining fire hydrants, providing adequate storage capacity, and meeting requirements for minimum pipe sizes (e.g., 6-in. [150-mm] pipes in loops and 8-in. [200-mm] dead ends) in neighborhood distribution mains when much smaller pipes would suffice for delivery of potable water only. These requirements make designing distribution systems easier for the engineer but more costly for the water utility. Other impacts include providing extra treatment capacity at plants and extra pumping capacity at pump stations.

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COMMUNITY GOVERNANCE

The decision of whether or not to size distribution system components, including water lines, appurtenances, and storage facilities, for fire protection must be made by the governing body of the community. This decision is made in conjunction with the water utility if the utility is privately owned. However, there is no legal requirement that a governing body must size its water distribution system to provide fire protection. In some instances, this undertaking may be prohibitively expensive. For privately owned utilities, the distribution system would not be sized for fire protection unless such an undertaking could be shown to be commercially profitable.

The governing bodies of most communities do provide water for fire protection for a variety of reasons, including protection of the tax base from destruction by fire, preservation of jobs that would be lost in the event of a large fire, preservation of human life, and reduction of human suffering.

When a community's governing body provides fire protection, it must do so in accordance with a well-thought-out plan that will provide adequate supplies for the intended purpose. An inadequate fire protection system provides a false sense of security and is potentially more dangerous than no system at all.

FIRE FLOW REQUIREMENTS

When establishing a fire protection plan, the governing body must first select a well-documented procedure for determining the fire flow requirement. Central to providing "enough" water is a determination of how much water should be made available for any given situation. The following definition of *required fire flow* will be used in this manual: the rate of water flow, at a residual pressure of 20 psi (138 kPa) and for a specified duration, that is necessary to control a major fire in a specific structure. A complete definition of required fire flow requires a determination of both the rate of flow required and the total amount of water that must be applied to control the fire. The rate of flow and the duration of flow required may be specified by the simple equation:

$$\text{quantity} = \text{rate} \times \text{duration} \qquad \text{(Eq. 1-1)}$$

Understanding Water Use

The importance of flow rate and total quantity must be realized when attempting to understand the ways in which water is used to suppress fire. Water applied to a fire accomplishes two things. First, it removes the heat produced by the fire, thereby preventing that heat from raising the temperature of unignited material to the ignition point. Water absorbs the heat of the fire when it changes from a liquid to a gaseous state as the heat is released as steam. Second, water not converted to steam by the heat of the fire is available to cool material not yet ignited. Water also blankets unignited material, excluding the oxygen required to initiate and sustain combustion.

CALCULATING FIRE FLOW REQUIREMENTS

All fires are basically different because of random variations in the structure and contents of the burning building, exposures (configuration of adjacent structures not involved in a fire but that are to be protected to prevent the fire from spreading), weather, temperature, and length of time the fire has been burning. Consequently, numerous methods have been proposed for determining how much water is enough to suppress a fire. The following sections describe four methods for calculating fire flow requirements. These methods have been developed by the Insurance Services Office

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Table 1-1 Fire flow durations

Required Fire Flow		Duration
gpm	(*L/sec*)	*hr*
2,500 or less	(158 or less)	2
3,000 to 3,500	(189 to 221)	3

Inc. (ISO),* Iowa State University (ISU),† the National Fire Academy,‡ and the Illinois Institute of Technology Research Institute (IITRI).§

Responsibility for determining needed fire flows for individual structures usually rests with the local fire officials based on information provided by the owner. Rating services such as ISO may determine this flow during an evaluation for insurance purposes. For planning purposes, water departments may determine representative fire flow requirements in portions of towns for system planning, hydraulic analysis, and design.

Flow Durations

Recommended fire flow durations¶ to be used in the four methods are given in Table 1-1. The maximum required fire flow for a single fire event is 12,000 gpm (757 L/sec).

Insurance Services Office Method

The ISO's technique for calculating required fire flow is documented in its publication *Fire Suppression Rating Schedule*. The term used in that document to describe the fire flow requirement is *needed fire flow* (NFF).

Needed fire flow (NFF). The NFF is the rate of flow considered necessary to control a major fire in a specific building for a certain duration. It is intended to assess the adequacy of a water system as one element of an insurance rating schedule. It is not intended to be a design criterion. However, it has been demonstrated that the NFF reasonably coincides with the actual flow required to suppress a fire in a real-life situation.

A water supply should be capable of providing the maximum NFF within its distribution system area. In designing a new water distribution system or improvements within an existing distribution system, it is customary to provide for the NFF within the design area. However, it is very unusual for an existing water distribution system to be capable of providing every NFF within its service area.

The ISO classification of a community's water system is based on the available rates of flow at representative locations, with an NFF of 3,500 gpm (221 L/sec), or less, as determined by the application of its Fire Suppression Rating Schedule. Private and public protection at properties with larger NFFs is individually evaluated and may vary from the community's classification.

* Insurance Services Office Inc., 545 Washington Blvd., Jersey City, NJ 07310-1686.
† Iowa State University, Fire Extension Service, Ames, IA 50011.
‡ US Fire Administration, 16825 S. Seton Ave., Emmitsburg, MD 21727.
§ Illinois Institute of Technology Research Institute, 10 W. 35th St., Chicago, IL 60616.
¶ Fire flow durations are based on the 19th edition of the National Fire Protection Association's *Fire Protection Handbook,* table 10.4.6.

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Table 1-2 Values of coefficient (F) construction class

Class		Coefficient
Class 1	Frame	1.5
Class 2	Joisted Masonry	1.0
Class 3	Noncombustible	0.8
Class 4	Construction (masonry, noncombustible)	0.8
Class 5	Modified fire resistive	0.6
Class 6	Fire resistive	0.6

Calculation. The calculation of an NFF, in gallons per minute (gpm), for a subject building, considers the construction (C_i), occupancy (O_i), exposure (X_i), and communication (P_i) factors of that building, or fire division, as outlined here.

Construction factor (C_i). That portion of the NFF attributed to the type of construction and area in square feet of the subject building is determined by the following formula*:

$$C_i = 18F\,(A_i)^{0.5} \qquad \text{(Eq. 1-2)}$$

Where:

F = coefficient related to the class of construction (see Table 1-2)

A_i = effective area

Effective area (A_i). This is the total area in square-feet of the largest floor† in the building plus the following percentage of the other floors:

- for buildings of construction class 1–4, 50 percent of all other floors;
- for buildings of construction classes 5 or 6, if all vertical openings in the building have 1.0 hr or more protection, 25 percent of the area not exceeding the two largest floors‡. The doors shall be automatic or self-closing and labeled as class B fire doors (1.0 hr or more protection). In other buildings, 50 percent of the area not exceeding eight floors.§

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† If division walls are rated at one hour or more with labeled class B fire doors on openings, they subdivide a floor. The maximum area on any one floor used shall be the largest undivided area plus 50 percent of the second largest undivided area on that floor. NOTE: Do not include basement and subbasement areas that are vacant, that are used for building maintenance, or that are occupied by C-1 or C-2 occupancies (see Table 1-3).

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Table 1-3 Occupancy factors for selected combustibility classes

Combustibility Class		Occupancy Factor (O_i)
C-1	Noncombustible	0.75
C-2	Limited combustible	0.85
C-3	Combustible	1.00
C-4	Free burning	1.15
C-5	Rapid burning	1.25

The maximum value of C_i is limited by the following: 8,000 gpm (505 L/sec) for construction classes 1 and 2; 6,000 gpm (378 L/sec) for construction classes 3, 4, 5, and 6; and 6,000 gpm (378 L/sec) for a one-story building of any class of construction. The minimum value of C_i is 500 gpm (32 L/sec). The calculated value of C_i should be rounded to the nearest 250 gpm (16 L/sec).

Occupancy factor (O_i). The occupancy factors, given in Table 1-3, reflect the influence of the occupancy in the subject building on the NFF. Representative lists of occupancies by combustibility class are given in Figures 1-1 and 1-2.

Exposures (X_i) and communication (P_i) factors. The exposures and communication factors reflect the influence of exposed and communicating buildings on the NFF. A value for ($X_i + P_i$) shall be developed for each side of the subject building as shown in Eq 1-3:

$$(X + P)_i = 1.0 + \sum_{i=1}^{n} (X_i + P_i) \qquad \text{maximum } 1.60 \qquad \text{(Eq. 1-3)}$$

Where:

n = number of sides of subject building

The factor for X_i (exposure) depends on the construction and length–height value (length of wall in feet times height in stories) of the exposed building and the distance between facing walls of the subject building and the exposed building. This factor shall be selected from Table 1-4. When more than one exposure side exists for the subject building, apply only the largest factor X_i for that side. When there is no exposure on a side, $X_i = 0$.

The factor for P_i (communications) depends on the protection for communicating party wall openings and the length and construction of communications between fire divisions. This factor shall be selected from Table 1-5. When more than one communication type exists in any one side wall, apply only the largest factor P_i for that side. When there is no communication on a side, $P_i = 0$.

Needed fire flow. The calculation for NFF is

$$\text{NFF} = (C_i)(O_i)[1.0 + (X + P)_i] \qquad \text{(Eq. 1-4)}$$

When a wood shingle roof covering on a building or on exposed buildings can contribute to spreading fires, add 500 gpm (32 L/sec) to the NFF. The NFF shall not exceed 12,000 gpm (757 L/sec) or be less than 500 gpm (32 L/sec). The NFF shall be rounded to the nearest 250 gpm (16 L/sec), if less than 2,500 gpm (158 L/sec), and to the nearest 500 gpm, if greater than 2,500 gpm.

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Classification 1

Steel or concrete products storage, unpackaged

Classification 2

Apartments	Hotels
Churches	Motels
Courthouses	Offices
Dormitories	Parking garages
Hospitals	Schools

Classification 3

Amusement park buildings, including arcades and game rooms
Automobile sales and service
Discount stores
Food and beverage—sales, service, or storage
General merchandise—sales or storage
Hardware, including electrical fixtures and supplies
Motion picture theaters
Pharmaceutical retail sales and storage
Repair or service shops
Supermarkets
Unoccupied buildings

Classification 4

Aircraft hangars, with or without servicing/repair
Auditoriums
Building material sales and storage
Freight depots, terminals
Furniture—new or secondhand
Paper and paper product sales and storage
Printing shops and allied industries
Theaters, other than motion picture
Warehouses
Wood product sales and storage

Classification 5

Chemical sales and storage
Cleaning and dyeing material sales and storage
Paint sales and storage
Plastic or plastic product sales and storage
Rag sales and storage
Upholstering shops
Waste and reclaimed material sales and storage

Figure 1-1 Typical occupancy classifications—nonmanufacturing

For one- and two-family dwellings not exceeding two stories in height, the NFF listed in Table 1-6 shall be used. For other habitable buildings not listed in Table 1-6, the NFF should be 3,500 gpm (221 L/sec) maximum. For a building protected by automatic sprinklers, the NFF is that needed for the sprinkler system, plus hose streams converted to 20 psi (138 kPa) residual pressure, with a minimum of 500 gpm. See the National Fire Protection Association Standard No. 13 (13D or 13R) for the water requirements at the base of riser for sprinklers.

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Classification 2

Ceramics manufacturing
Concrete or cinder products manufacturing
Fabrication of metal products
Primary metals industries

Classification 3

Banking and confectionary
Dairy processing
Leather processing
Soft drink bottling
Tobacco processing

Classification 4

Apparel manufacturing
Breweries
Cotton gins
Food processing
Metal coating or finishing
Paper products manufacturing
Rubber products manufacturing
Woodworking industries

Classification 5

Cereal or flour mills
Chemical manufacturing
Distilleries
Fabrication of textile products, except wearing apparel
Meat or poultry processing
Plastic products manufacturing
Textile manufacturing

Figure 1-2 Typical occupancy classifications—manufacturing

Iowa State University Method

Research conducted at the Fire Extension Service at ISU resulted in the development of a rate of flow formula. This formula addresses, in some detail, both the quantity of water required to extinguish a fire and the effects of various application rates and techniques. The formula is referenced in ISU Bulletin 18. The ISU method of determining required fire flows is the oldest method discussed in this manual. It was first published in 1967.

> The ISU technique referenced several Danish studies for its theoretical and statistical bases. In addition, several experiments were performed, including actual fires in small rooms. The resulting equation for computation of [needed] fire flow, G, according to this technique is:
>
> $$G^{*} = \text{volume of space (in cubic feet)} \div 100$$

* Fire flow G in this excerpt is synonymous with needed fire flow (NFF) referenced throughout this manual.

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Table 1-4 Factor for exposure (X_i)

			Construction of Facing Wall of Exposed Building			
			Construction Classes			
			1, 3	2, 4, 5, 6	2, 4, 5, 6	2, 4, 5, 6
Construction of Facing Wall of Subject Building	Distance to the Exposed Building	Length–Height* of Facing Wall of Exposed Building		Unprotected Openings	Semiprotected Openings (wire glass or outside open sprinklers)	Blank Wall
	ft		Exposure Factor X_i			
Frame, metal, or masonry with openings	0–10	1–100	0.22	0.21	0.16	0
		101–200	0.23	0.22	0.17	0
		201–300	0.24	0.23	0.18	0
		301–400	0.25	0.24	0.19	0
		Over 400	0.25	0.25	0.20	0
	11–30	1–100	0.17	0.15	0.11	0
		101–200	0.18	0.16	0.12	0
		201–300	0.19	0.18	0.14	0
		301–400	0.20	0.19	0.15	0
		Over 400	0.20	0.19	0.15	0
	31–60	1–100	0.12	0.10	0.07	0
		101–200	0.13	0.11	0.08	0
		201–300	0.14	0.13	0.10	0
		301–400	0.15	0.14	0.11	0
		Over 400	0.15	0.15	0.12	0
	61–100	1–100	0.08	0.06	0.04	0
		101–200	0.08	0.07	0.05	0
		201–300	0.09	0.08	0.06	0
		301–400	0.10	0.09	0.07	0
		Over 400	0.10	0.10	0.08	0
Blank masonry wall	When the facing wall of the exposed building is higher than subject building, use the above information, except use only the length–height of facing wall of the exposed building above the height of the facing wall of the subject building. Buildings five stories or more in height, consider as five stories. When the height of the facing wall of the exposed building is the same or lower than the height of the facing wall of the subject building, $X_i = 0$.					

Source: Insurance Services Office Inc., 2003.

NOTE: Refer to the *Fire Suppression Rating Schedule,* published by Insurance Services Office Inc., for complete information regarding factors of exposure.

* The length–height factor is the length of the wall of the exposed building, in feet, times its height in stories.

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Table 1-5 Factor for communications (P_i)*

Protection of Passageway Openings	Fire-Resistive, Noncombustible, or Slow-Burning Communications				Communications With Combustible Construction					
	Open	Enclosed			Open			Enclosed		
	Any length	10 ft or less	11 to 20 ft	21 to 50 ft†	10 ft or less	11 to 20 ft	21 to 50 ft	10 ft or less	11 to 20 ft	21 to 50 ft
Unprotected	0	‡	0.30	0.20	0.30	0.20	0.10	‡	‡	0.30
Single class A fire door at one end of passageway	0	0.20	0.10	0	0.20	0.15	0	0.30	0.20	0.10
Single class B fire door at one end of passageway	0	0.30	0.20	0.10	0.25	0.20	0.10	0.35	0.25	0.15
Single class A fire door at each end or double class A fire doors at one end of passageway	0	0	0	0	0	0	0	0	0	0
Single class B fire door at each end or double class B fire doors at one end of passageway	0	0.10	0.05	0	0	0	0	0.15	0.10	0

Source: Insurance Services Office Inc., 2003.

NOTES:
1. Refer to the *Fire Suppression Rating Schedule,* published by Insurance Offices Inc., for complete information regarding factors for communication.
2. When a party wall has communicating openings protected by a single automatic or self-closing class B fire door, it qualifies as a division wall for reduction of area.
3. Where communications are protected by a recognized water curtain, the value of P_i is 0.

* The factor for P_i depends on the protection for communicating party wall openings and the length and construction of communications between fire divisions. P_i shall be selected from this table. When more than one communication type exists in any one side wall, apply only the largest factor P_i for that side. When there is no communication on a side, $P_i = 0$. (Party wall means a division wall rated one hour or more with labeled class B fire doors on openings.)

† For more than 50 ft (15.3 m), $P_i = 0$.

‡ For unprotected passageways of this length, consider the two buildings as a single fire division.

Table 1-6 Needed fire flow for one- and two-family dwellings§

Distance Between Buildings		Needed Fire Flow	
ft	(*m*)	*gpm*	(*L/sec*)
More than 100	(more than 30.5)	500	(31.5)
31–100	(9.5–30.5)	750	(47.3)
11–30	(3.4–9.2)	1,000	(63.1)
Less than 11	(Less than 3.4)	1,400	(94.6)

§Dwellings not to exceed two stories in height.

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