Distribution System Requirements for Fire Protection

AWWA MANUAL M31

Fourth Edition

American Water Works Association

Contents

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.

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

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.

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*:

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

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.§

* Reprinted with permission—Insurance Services Office Inc., 2006. Copyright ISO Properties Inc., 2001, 2006.

† 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).

‡ Reprinted with permission—Insurance Services Office Inc., 2006. Copyright ISO Properties Inc., 2001, 2006.

§ Reprinted with permission—Insurance Services Office Inc., 2006. Copyright ISO Properties Inc., 2001, 2006.

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:

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

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.

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.

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.

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.

Table 1-5 Factor for communications (P_i)*

	Fire-Resistive, Noncombustible, or Slow-Burning Communications				Communications With Combustible Construction					
	Open	Enclosed			Open			Enclosed		
Protection of Passageway Openings	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.

> The equation was based on the combustion of fuel being dependent on the available oxygen supply in the closed compartment and the vaporization of applied water into steam. The expansion ratio of water to steam was considered to assess the capability of vaporizing water to displace oxygen. Time-temperature curves for the fires were analyzed to determine optimal rates of water application for which steam generation was a maximum. The equation noted above has been revised by dividing by 200, 300, or 400 instead of 100 to relate the hazard imposed by the contents.
>
> This equation is the easiest of the [four] to be discussed in this article. If the ceiling height in a room is approximately 10 feet, the equation reduces to:
>
> $$G = \text{area of room (in square feet)} \div 10$$
>
> A limitation of this equation is a result of the assumption that the entire space must be involved in fire. Thus, for a large, open warehouse or other noncompartmented building, use of this equation yields fire flows which will be quite large. (Milke 1980)

National Fire Academy Method*

The United States Fire Administration (USFA, www.usfa.dhs.gov) is a part of the Department of Homeland Security's Federal Emergency Management Agency. The USFA's mission is to reduce life and economic losses due to fire and related emergencies through leadership, advocacy, coordination, and support. The National Fire Academy (NFA, www.nfaonline.dhs.gov) promotes, for USFA, the professional development of the fire and emergency response community by delivering educational and training courses having a national focus.

One NFA training program, Command and Control Decision Making at Multiple Alarm Incidents (Q297), describes how to use a method for determining fire flow requirements. This method is a modification of the Iowa State University method. The NFA method uses a "quick calculation" formula as a tactical tool for use at the scene of an incident or for preplanning fire flow requirements for major structures. The basic quick calculation formula for a one-story building that is 100 percent involved is:

$$\text{Needed Fire Flow (NFF)} = \frac{\text{length} \times \text{width}}{3}$$

Length and width are in feet rounded to the nearest 10.
The calculated NFF is in gpm.

The basic formula is modified if the building is less than 100 percent involved as follows:

$$\text{Needed Fire Flow (NFF)} = \frac{\text{length} \times \text{width}}{3} \times \%\ \text{involvement}$$

If more than one floor of a multistory building is involved, the fire flow calculated for each floor using the basic formula (modified by the percent involvement if less than 100 percent) is added to determine the total NFF for the building.

Interior and exterior exposures (exposure charge) also add to the needed fire flow. For interior exposure, add 25 percent of the 100 percent involvement figure determined by the basic formula for each floor above the fire floor for up to a maximum of five floors. For exterior exposure, add 25 percent of the 100 percent involvement figure determined by the basic formula for each side of the fire building that has an exposed building (within 30 feet) facing it.

* US Fire Administration, 16825 S. Seton Ave., Emmitsburg, MD 21727.

Illinois Institute of Technology Research Institute Method

The IITRI technique was developed from a survey. Data was collected from 134 fires in several occupancy types in the Chicago area to determine the water application rate needed for control as a function of fire area. Reported fires were of differing levels of magnitude, so not to concentrate solely on large-loss fires. Water application rates for the studied fires were calculated through a knowledge of length and diameter of hose used and calculated nozzle pressure.

Calculations.

The [needed] fire flow G, in gallons per minute, is calculated by one of the following equations:

$$\text{Residential Occupancies: } G = 9 \times 10^{-5} A^2 + 50 \times 10^{-2} A$$

$$\text{Nonresidential Occupancies: } G = -1.3 \times 10^{-5} A^2 + 42 \times 10^{-2} A$$

where A is the area of the fire in square feet.

These equations were obtained through a curve-fitting analysis of available data points on a graph. The investigation noted that tactical procedures can influence the application rate of water use greatly, e.g., interior versus exterior attack, leading off with large-diameter rather than small-diameter hose and similar concerns. As a supplement, 21 laboratory experiments on the use of manual streams to extinguish compartment fires also were reported for comparison purposes. Analysis of this experiment indicated that fire fighter training and comfort were key parameters in determining the amount and rate of water used, and the application rates of the 134 actual fires observed by IITRI were approximately double the rate used in the laboratory. (Milke 1980)

Comparison of Calculation Methods

Comparisons between the various techniques for computing fire flows are not easily made, because each situation to which the fire flow calculation is applied varies greatly. Comparisons are made here (Figures 1-3 and 1-4) to show the relative results obtained by the four different methods discussed for certain fairly typical situations.

The comparison here consists of two parts. First, a single incidence involving a building being evaluated for fire flow requirements is analyzed using the four methods. Next, a building of a fixed type of construction and configuration, but varying size, is analyzed using the four methods. This is done to illustrate how each method deals with the problem of relating the required fire flow to the size of the structure.

Part one—Three alternative construction scenarios. In this example, the subject building is 15,000 ft^2 (1,394 m^2) in size, one story, 12 ft high, and of ordinary construction. The building, occupied as a supermarket, is being analyzed to determine the fire flow required to control and contain fire within this structure. Because the ISO method involves evaluating the fire flow requirement for an adjacent structure, known as the *exposure building*, this situation is analyzed for three different exposure buildings. The exposure-building variations used in these calculations are described in Figures 1-3 and 1-4. These two figures describe the situations being analyzed, provide a pictorial representation of the situations, and provide the fire flow calculations determined by the four methods discussed here.

Insurance Services Office Method (ISO)

NFF = needed fire flow; O_i = occupancy factor; P_i = communications factor
C_i = construction factor; X_i = exposure factor

$$C_i = 18F(A_i)^{0.5}$$
$$= (18)(1)(15{,}000)^{0.5}$$
$$= 2{,}204\text{, round to } 2{,}250$$

$$\text{NFF} = (C_i)(O_i)[1.0 + (X + P)_i]$$

Where:
C_i = $18F(A_i)^{0.5}$
F = construction class coefficient from Table 1-2
A_i = effective area
O_i = occupancy factor from Table 1-3

$$(X + P)_i = 1.0 + \sum_{i=1}^{n} (X_i + P_i) \quad \text{maximum 1.60}$$

X_i = factor for exposure from Table 1-4
P_i = factor for communication from Table 1-5

Example 1: NFF= $(C_i)(O_i)$ [1.0 + $(X_i + P_i)$] = 2,250 [1.0 + (0.19 + 0.10)] = 2,250 × (1.0 + 0.29) = 2,902 gpm, or 3,000 gpm*

Example 2: NFF = $(C_i)(O_i)$ [1.0 + $(X_i + P_i)$] = 2,250 [1.0 + (0.21 + 0.30)] = 2,250 × (1.0 + 0.51) = 3,398 gpm, or 3,500 gpm*

Example 3: NFF= $(C_i)(O_i)$ [1.0 + $(X_i + P_i)$] = 2,250 × 1.0 + (0 + 0) = 2,250 gpm*

*The needed fire flow shall be rounded off to the nearest 250 gpm if less than 2,500 gpm and to the nearest 500 gpm if greater than 2,500 gpm.

Iowa State University Method (ISU)

NFF = needed fire flow
A = area
= 15,000 ft^2
H = height of building
= 12 ft
V = volume of space
NFF = $V/100$
V = AH
So NFF = $AH/100$

$$F = \frac{AH}{100} = \frac{15{,}000 \times 12}{100} = \frac{180{,}000}{100} = 1{,}800 \text{ gpm}$$

National Fire Academy Method (NFA)

$$\text{NFF} = \frac{A}{3} \times \%\ \text{involvement}$$
$$A = (\text{length} \times \text{width})$$
$$= \frac{A}{3} \times \%\ \text{involvement}$$
$$= \frac{15{,}000}{3} \times 100$$
$$\text{NFF} = 5{,}000 \text{ gpm}$$

Illinois Institute of Technology Research Institute Method (IITRI)

Nonresidential NFF = $-1.3^{10^{-5}} \times A^2 + 42 \times 10^{-2}A$
F = flow
A = area
= 15,000 ft^2
NFF = $-1.3^{10^{-5}} \times A^2 + 0.42A$
= $-0.000013 \times 225{,}000 + 6{,}300$
= $-2{,}925 + 6{,}300$
NFF = 3,375 gpm

Figure 1-3 Comparison of fire flow calculations

NFF calculation example for four methods.

Nonresidential structure, ordinary construction
One story
Area = 15,000 ft^2 (1,394 m^2)
Height = 12 ft
Adjacent structures (exposure building shown in Figure 1-4)

	X_i from Table 1-4	P_i from Table 1-5
Example 1	0.19	0.10
Example 2	0.21	0.30
Example 3	0.0	0.0

Part two—Various structure sizes. In the second part of the comparison, a one-story building of ordinary construction and nonresidential occupancy, but varying in size from 0 to 15,000 ft^2 (1,394 m^2), is analyzed for each method to determine fire flow required for the various sizes of buildings.

Comparison. While there are no firm rules to follow when comparing the calculations derived from the four methods, there are some reasonable conclusions that can be made by comparing the two situations previously discussed.

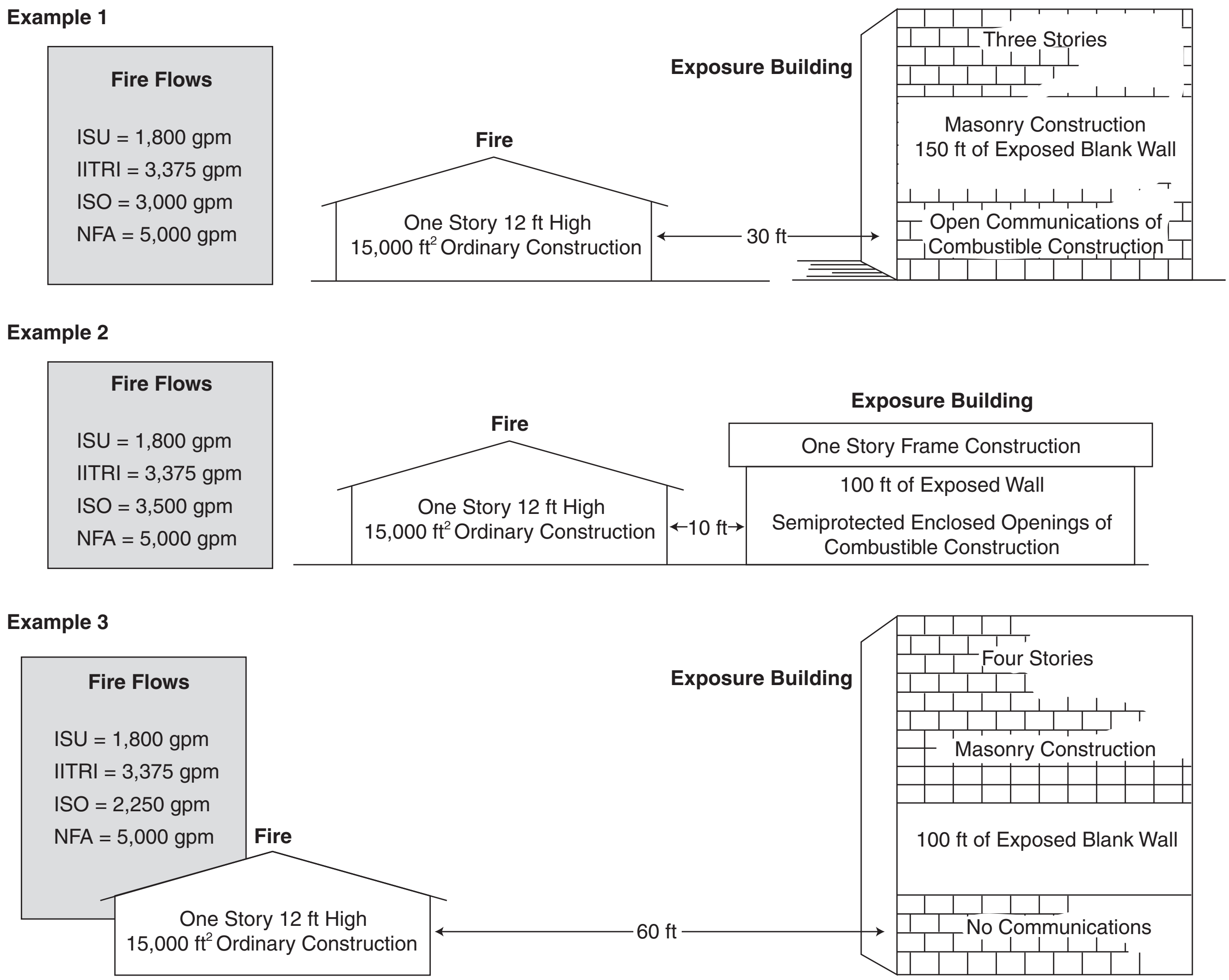
The IITRI method generally yields the highest fire flow requirement. Generally, the ISO and ISU methods parallel one another, with the ISO method being somewhat, but not significantly, higher. This arises from a number of probable causes. First, the ISO method deals not only with the building presumed to be involved but it also considers the need to protect the exposure buildings. In addition, ISO factors the status of the fire department equipment and personnel experience and other variables into its calculations. The ISU method is a somewhat stylized approach. This method envisions that the water being supplied to fight a fire is applied in a theoretically ideal manner so as to obtain maximum effectiveness. Clearly this is not always an achievable situation. The NFA formula result depends on the percent involvement.

PRACTICAL LIMITS ON FIRE FLOW

Using an engine or hose company from a local fire department, which draws large amounts of water from the public water supply system, is not the preferred method of fire suppression. In many cases, an automatic fire suppression system, such as a sprinkler or a chemical system in combination with an alarm system, is more effective. In fact, a building developer who properly designs and installs a fire suppression system can do far more to protect life and property than a fire company can do with any amount of water delivered through the standard hose system. Fire sprinklers are intended to control a fire, not to completely extinguish it. Hose streams are almost always necessary. However, water from the public distribution system remains an important part of any fire suppression system.

Fire Flow Limits—Nonsprinklered Buildings

If the public water supply is to be used for fire suppression and a sprinkler system is not available, the supply available at a given point in the system is usually required to be no less than 500 gpm (32 L/sec) at a residual pressure of 20 psi (138 kPa). This represents the amount of water required for two standard hose streams on a given fire. Many professionals state that this is the minimum amount of water that can safely and effectively control any fire. Above that minimum, it is recommended that at any given point in the water distribution system, the system be able to provide the required



NOTE: Fire flows are from Iowa State University (ISU), Illinois Institute of Technology Research Institute (IITRI), Insurance Services Office (ISO), and National Fire Academy (NFA).

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

design flow as discussed earlier, or by using techniques adopted by responsible authorities. The ISO method is most likely to yield realistic requirements.

The NFF is a number used to evaluate the water system for fire insurance purposes. Actual flow used in fire fighting depends on the nature of the fire and how the fire department approaches the fire. There is no evidence that indicates a marginal shortfall in meeting the NFF can be related to an increase in loss. Inability of the distribution system to fully deliver NFF should not be considered a failure of the system.

In areas of a community with nonsprinklered buildings, the minimum fire flow provided to those areas is usually set at 500 gpm (32 L/sec) unless there are buildings that need higher fire flows. This is a community decision to be made by the community's governing body. If the water distribution system is serviced by a privately owned utility, some arrangement should be made by the governing body with that supplier to provide the required degree of protection.

Fire Flow Limits—Sprinklered Buildings

Installing fire sprinklers in a building can significantly reduce the NFF from the amount calculated by the methods presented earlier in this chapter. In such cases, the NFF is the sum of the sprinkler flow required at the base of riser plus a hose stream allowance. This is discussed further in chapter 5.

Exceptions to Fire Flow Limits

There are some exceptions to the required fire flow. For example, if a community has a large concentration of housing units with required fire flows not in excess of 1,500 gpm (95 L/sec) and a small number of properties require an increased level of flow (3,500 gpm [221 L/sec]), it would not make good economic sense to provide 3,500 gpm to those isolated properties. The community's governing body would be advised to simply develop ordinances and regulations that require those isolated properties to provide for their own private fire protection, to reduce the fire flow requirement by using a higher level of sprinkling, or to provide on-site storage and pumping capabilities to meet their own fire suppression needs.

There could be circumstances in which a community might arrange to deliver the upper limits of a required fire flow to an isolated building. For example, a single, large, high-hazard mercantile establishment, which provides most of the jobs in the community and produces most of the community's tax revenue, may receive the required fire flow from the community. By working with the building owner, adequate fire suppression could be provided. This might be achieved through sprinklers or some other means.

NONPOTABLE WATER SOURCES FOR FIRE FIGHTING

Numerous nonpotable water sources may be used as the primary or backup supply for fire protection. These sources may be divided into two major groups. One group comprises the nonpotable portion of a dual distribution system, which provides potable and nonpotable water to all or selected areas of a community.

Dual distribution systems for community water supplies are increasingly common. Diminishing supplies of high-quality resources and rapidly escalating costs of treating both potable water and wastewater are the two main causes.

As dual distribution systems become available, they will increasingly be used as water sources for fire suppression. When the systems are used for fire suppression, the design requirements are generally identical to those specified for potable systems in this manual, with the exception of special markings and fittings for public safety purposes. Detailed local regulations are still being developed. See AWWA Manual M24 *Dual Water Systems* for more information.

The other nonpotable water source consists largely of suction supplies, most frequently (but not exclusively) used as a source for private fire protection systems in accordance with NFPA Standard 1142, Water Supplies for Suburban and Rural Fire Fighting.

REFERENCES

City of Dallas Fire Flow Study. Spring 1983. *Sprinkler Quarterly*. Dallas, Texas.

Côté, A.E., and J.L. Linville, eds. 2003. *Fire Protection Handbook*. 19th ed. Quincy, Mass.: National Fire Protection Association.

Dual Water Systems. AWWA Manual M24. Denver, Colo.: American Water Works Association.

Fire Suppression Rating Schedule. 2003. Jersey City, N.J.: Insurance Services Office Inc.

Installation of Private Fire Service Mains. NFPA Standard 24-07. Quincy, Mass: National Fire Protection Association.

Installation of Sprinkler Systems. NFPA Standard 13-07. Quincy, Mass.: National Fire Protection Association.

Milke, J.A. 1980. How Much Water Is Enough? *The International Fire Chief* (March), pp. 21–24.

Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes. NFPA Standard 13D-07. Quincy, Mass.: National Fire Protection Association.

Sprinkler Systems in Residential Occupancies Up To and Including Four Stories in Height. NFPA Standard 13R-07. Quincy, Mass.: National Fire Protection Association.

Water for Fire Fighting—Rate of Flow Formula. Bulletin 18. Ames, Iowa: Iowa State University Fire Extension Service.

Water Supplies for Suburban and Rural Fire Fighting. NFPA Standard 1142. Quincy, Mass.: National Fire Protection Association.