

**VIRGINIA DEPARTMENT OF HOUSING AND COMMUNITY DEVELOPMENT**

**2015 Code Change Cycle  
Attachments from cdpVA for Consensus Proposals to go with Book 2**

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## C-103.3(2) cdpVA-15

**Proponent :** College Laboratory Sub-workgroup (of DHCD's Workgroup Two)

DHCD Staff Contact: Vernon.Hodge@dhcd.virginia.gov

### 2012 Virginia Construction Code

**103.3 Change of occupancy.** No change of occupancy shall be made in any structure when the current USBC requires a greater degree of accessibility, structural strength, fire protection, means of egress, ventilation or sanitation. When such a greater degree is required, the owner or the owner's agent shall comply with the following:

1. When involving Group I-2 or I-3, written application shall be made to the local building department for a new certificate of occupancy and the new certificate of occupancy shall be obtained prior to the new use of the structure. When impractical to achieve compliance with this code for the new occupancy classification, the building official shall consider modifications upon application and as provided for in Section 106.3. In addition, the applicable accessibility provisions of Section 1012.8 of Part II of the *Virginia Uniform Statewide Building Code*, also known as the "*Virginia Rehabilitation Code*," or the "VRC" shall be met.

**Exception:** This section shall not be construed to permit noncompliance with any applicable flood load or flood-resistant construction requirements of this code.

2. In other than Group I-2 or I-3, the provisions of the VRC for change of occupancy shall be met.

**103.3.1 Group B teaching and research laboratories.** Where the use of new or different hazardous materials or a change in the amount of hazardous materials in existing Group B teaching and research laboratories in educational occupancies above the 12th grade would constitute a change of occupancy, Section 302.6 of the VRC shall be permitted to be used as an acceptable alternative to compliance with change of occupancy requirements to permit the increased amounts of hazardous materials stipulated without the laboratories being classified as Group H.

## SECTION 202 DEFINITIONS

**CHEMICAL FUME HOOD.** A ventilated enclosure designed to contain and exhaust fumes, gases, vapors, mists and particulate matter generated within the hood.

**LABORATORY SUITE.** A fire-rated enclosed laboratory area that will provide one or more laboratory spaces, within a Group B educational occupancy, that are permitted to include ancillary uses such as offices, bathrooms, and corridors that are contiguous with the laboratory area, and are constructed in accordance with section 427.3.

**TEACHING AND RESEARCH LABORATORY.** A building or portion of a building where hazardous materials are stored, used and handled for the purpose of testing, analysis, teaching, research or developmental activities on a nonproduction basis rather than in a manufacturing process.



## 2015 International Building Code

(As Part of the 2015 Virginia Construction Code)

[F] **414.2 Control areas.** *Control areas* shall comply with Sections 414.2.1 through 414.2.5 and the *International Fire Code*.

**Exception:** Higher education teaching and research laboratories shall be permitted to comply with Section 427.

### SECTION 427 HIGHER EDUCATION LABORATORIES

**427.1 Scope.** ~~Group B~~ Teaching and research laboratories in ~~Group B~~educational occupancies ~~used for educational purposes~~ above the 12th grade complying with the requirements of this section shall be permitted to comply with Tables 427.3, 427.4(1), or 427.4(2) without requiring classification as a Group H occupancy. Except as specified in this section, such laboratories shall comply with all applicable provisions of this code. In addition, as set out in Section 5001.7 of the SFP C, approval under this section is contingent upon operational requirements in the SFPC being complied with and maintained.

**427.2 Application.** The provisions of this section shall be applied as exceptions or additions to applicable requirements of this code.

**427.3 Laboratory suite construction.** Where laboratory suites are provided, they shall be constructed in accordance with this section. The number of laboratory suites and percentage of maximum allowable quantities of hazardous materials in laboratory suites shall be in accordance with Table 427.3.

**427.3.1 Separation from ~~other adjacent non-laboratory~~ areas.** Laboratory suites shall be separated from other portions of the building in accordance with the most restrictive of either Table 427.3 with fire barriers constructed in accordance with Section 707 and horizontal assemblies constructed in accordance with Section 711 or Section 508.4. Where individual laboratories within a laboratory suite are separated one from the other, the separation shall consist of one-hour fire barriers.

**Exception:** Where an individual laboratory suite occupies more than one story, the fire resistance rating of intermediate floors contained within the laboratory suite shall comply with the

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requirements of this code.

**427.3.2 Separation from other laboratory suites.** Laboratory suites shall be separated from other laboratory suites in accordance with Table 427.3.

**427.3.427.3.3 Floor assembly fire resistance.** The floor assembly supporting the laboratory suite and the construction supporting the floor of the laboratory suite shall have a fire resistance rating of not less than 2 hours.

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**Exception:** The floor assembly of the laboratory suite and the construction supporting the floor of the laboratory suite are allowed to be 1-hour fire resistance rated in buildings of Types IIA, IIIA and VA construction, provided that the building is 3 or fewer stories.

**427.3.427.3.4 Maximum number.** The maximum number of laboratory suites per floor shall be in accordance with Table 427.3. Where a building contains both laboratory suites complying with Section 427.3 and control areas complying with Section 414.2, the total number of laboratory suites and control areas shall not exceed the maximum number of laboratory suites in accordance with Table 427.3.

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**427.3.3 Means of egress.** Means of egress shall be in accordance with Chapter 10.

**Comment [ZA1]:** Removed because redundant with an existing requirement.

**427.3.427.3.5 Standby or emergency power.** Standby or emergency power shall be provided in accordance with Section 414.5.2 where laboratory suites are located above the sixth story above grade plane or located in a story below grade plane.

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**427.3.5427.3.6 Ventilation.** Ventilation shall be in accordance with Chapter 7 of NFPA 45, and the International Mechanical Code. The design and installation of ducts from chemical fume hoods shall be in accordance with NFPA 91.

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**427.3.6427.3.7 Liquid tight floor.** Portions of the laboratory suite where hazardous materials are present shall be provided with a liquid tight floor.

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**427.3.7427.3.8 Automatic fire sprinkler systems.** Buildings shall be equipped throughout with an approved automatic sprinkler system in accordance with Section 903.3.1.1.

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**427.3.8427.3.9 Automatic fire alarm and detection system.** Laboratory suites shall be equipped throughout with an automatic fire detection system in accordance with Section 907.2. The building shall be equipped throughout with an automatic fire alarm system in accordance

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with Section 907.2.

**427.3.9427.3.10 Percentage of maximum allowable quantity in each laboratory suite.** The percentage of maximum allowable quantities in each laboratory suite shall be in accordance with Table 427.3.

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**TABLE 427.3**  
**DESIGN AND NUMBER OF LABORATORY SUITES PER FLOOR**

| Floor Level          |       | Percentage of the<br>Maximum<br>Allowable—<br>Quantity per Lab | Number of Lab<br>Suites per Floor | Fire-Resistance-<br>Rating for Fire<br>Barriers in Hours <sup>b</sup> |
|----------------------|-------|----------------------------------------------------------------|-----------------------------------|-----------------------------------------------------------------------|
| Above Grade<br>Plane | 21+   | 5                                                              | 1                                 | 2                                                                     |
|                      | 16-20 | 25                                                             | 1                                 | 2                                                                     |
|                      | 11-15 | 50                                                             | 1                                 | 2                                                                     |
|                      | 7-10  | 50                                                             | 2                                 | 2                                                                     |
|                      | 4-6   | 75                                                             | 4                                 | 1                                                                     |
| Below Grade<br>Plane |       |                                                                |                                   |                                                                       |
|                      |       | 1-75                                                           | 4                                 | 1                                                                     |
|                      |       | 2-50                                                           | 2                                 | 1                                                                     |

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**Comment [ZA2]:** Brings floors above the 20th in line with chapter 50 requirements.

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a. Percentage shall be of the maximum allowable quantity per control area shown in Tables 307.1(1) and 307.1(2), with all increases allowed in the notes to those tables. b. Fire barriers shall include walls, floors and ceilings necessary to provide separation from other portions of the building.

c. Vertical fire barriers separating laboratory suites from other spaces on the same floor

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~~may be one hour rated.~~

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**427.4 Teaching and research laboratories utilizing control areas.** Group B teaching and research laboratories in educational occupancies above the 12th grade utilizing control areas are permitted to increase amounts of hazardous materials stipulated in 414.2 without the laboratories being classified as Group H. The percentage of maximum allowable quantities of hazardous materials per control area and the number of control areas permitted at each floor level within a building shall be permitted to comply with Table 427.4(1) in buildings equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1 or shall be permitted to comply with Table 427.4(2) in buildings not equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1. In addition, as set out in Section 5001.7 of the SFPC, approval under this section is contingent upon operational requirements in the SFPC being complied with and maintained.

**TABLE 427.4(1)**

**DESIGN AND NUMBER OF CONTROL AREAS IN BUILDINGS EQUIPPED THROUGHOUT WITH AN AUTOMATIC SPRINKLER SYSTEM IN ACCORDANCE WITH SECTION 903.3.1.1 WITH GROUP B TEACHING AND RESEARCH LABORATORIES IN EDUCATIONAL OCCUPANCIES ABOVE THE 12TH GRADE**

| Floor Level          |                   | Percentage of<br>the Maximum<br>Allowable<br>Quantity<br>per Control | Number<br>of Control Areas per<br>Floor | Fire- Resistance<br>Rating for Fire<br>Barriers and<br>Horizontal<br>Assemblies in |
|----------------------|-------------------|----------------------------------------------------------------------|-----------------------------------------|------------------------------------------------------------------------------------|
| Above Grade<br>Plane | Higher than<br>20 | 5                                                                    | 1                                       | 2                                                                                  |
|                      | 11-20             | 10                                                                   | 1                                       | 2                                                                                  |
|                      | 7-10              | 25                                                                   | 2                                       | 2                                                                                  |
|                      | 4-6               | 50                                                                   | 2                                       | 2                                                                                  |
| Below Grade<br>Plane | 1-3               | 75                                                                   | 3                                       | 1                                                                                  |
|                      | 2                 | 50                                                                   | 2                                       | 1                                                                                  |

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a. Percentage shall be of the maximum allowable quantity per control area shown in Tables 307.1(1) and 307.1(2), with all increases allowed in the notes to those tables.

b. Separation shall include ~~shall~~ fire barriers and horizontal assemblies as necessary to provide

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separation from other portions of the building.

~~e. Fire barriers separating control areas from other spaces on the same floor may be one hour rated.~~

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TABLE 427.4(2)

DESIGN AND NUMBER OF CONTROL AREAS IN BUILDINGS NOT EQUIPPED THROUGHOUT WITH AN AUTOMATIC SPRINKLER SYSTEM IN ACCORDANCE WITH SECTION 903.3.1.1 WITH GROUP B TEACHING AND RESEARCH LABORATORIES IN EDUCATIONAL OCCUPANCIES ABOVE THE 12TH GRADE

| Floor Level          |               | Percentage of<br>the Maximum<br>Allowable<br>Quantity<br>per Control | Number<br>of Control Areas per<br>Floor | Fire- Resistance<br>Rating for Fire<br>Barriers and<br>Horizontal<br>Assemblies in |
|----------------------|---------------|----------------------------------------------------------------------|-----------------------------------------|------------------------------------------------------------------------------------|
| Above-Grade<br>Plane | Higher than 9 | $\frac{5}{10}$                                                       | $\frac{1}{2}$                           | 2                                                                                  |
|                      | 7-9           | $\frac{5}{10}$                                                       | $\frac{1}{2}$                           | 2                                                                                  |
|                      | 4-6           | $\frac{25}{75}$                                                      | $\frac{2}{2}$                           | 2                                                                                  |
|                      | 3             | $\frac{25}{75}$                                                      | $\frac{2}{2}$                           | 1                                                                                  |
| Below Grade<br>Plane | 1             | $\frac{75}{50}$                                                      | $\frac{3}{2}$                           | 1                                                                                  |
|                      | 2             | $\frac{50}{50}$                                                      | $\frac{2}{2}$                           | $\frac{1}{1}$                                                                      |

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a. Percentage shall be of the maximum allowable quantity per control area shown in Tables 307.1(1) and 307.1(2), excluding with all increases allowed in the notes to those tables.

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b. Separation shall include shall fire barriers and horizontal assemblies as necessary to provide separation from other portions of the building.

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c. Fire barriers separating control areas from other spaces on the same floor may be one hour rated.

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**427.4.1 Separation requirements.** Control areas shall be separated from each other and from other non-control areas by fire barriers constructed in accordance with Section 707 or horizontal assemblies constructed in accordance with Section 711, or both.

**427.4.2 Fire-resistance-rating requirements.** The required fire-resistance rating for fire barriers shall be in accordance with Table 427.4(1) in buildings equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1 or in accordance with Table 427.4(2) in buildings not equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1. The floor assembly of the control area and the construction supporting the floor of the control area shall have a fire-resistance rating in accordance with Table 427.4(1) in buildings equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1 or in accordance with Table 427.4(2) in buildings not equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1.

**Exception:** The floor assembly of the control area and the construction supporting the floor of the control area are allowed to be 1-hour fire resistance rated in buildings of Types IIA, IIIA and

VA construction, provided that the building is 3 or fewer stories.

427.4.3 **Standby or emergency power.** Standby or emergency power shall be provided where control areas are located above the sixth floor level above grade plane or located in a floor level below grade plane.

427.4.4 **Restricted materials in storage and use.** Where approved by the building official, the storage and use of the following hazardous materials prohibited by Table 307.1.1 in buildings not equipped throughout with an automatic sprinkler system in

accordance with Section 903.3.1.1, shall be allowed within a control area at 25% of Table 307.1.1 limits for a building equipped throughout with an automatic sprinkler system:

~~1. Organic Peroxides—UD~~ 2.

Pyrophorics

3. Class 4 Oxidizers

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No additional quantity increases shall be allowed. All such materials shall be stored and used in accordance with Section 5001.7 of the SFPC.

**427.4.5 Automatic fire alarm and detection system.** Control areas where hazardous material are used or stored shall be equipped throughout with an automatic fire detection system in accordance with Section 907.2. The building shall be equipped throughout with an automatic fire alarm system in accordance with Section 907.2.

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~~427.4.5 Automatic fire alarm and detection.~~ An automatic fire alarm and detection system shall be provided in accordance with Section 907.

427.4.6 **Ventilation.** Ventilation shall be in accordance with the International Mechanical Code.

**[F] 907.2.2 Group B.** An automatic fire alarm and detection system shall be provided in Group B occupancies where an increase in hazardous materials is allowed in accordance with Section 427. A manual fire alarm system shall be installed in Group B occupancies where one of the following conditions exists:

1. The combined Group B *occupant load* of all floors is 500 or more.
2. The Group B *occupant load* is more than 100 persons above or below the lowest *level of exit discharge*.
3. The *fire area* contains an ambulatory care facility.

**Exception:** Manual fire alarm boxes are not required where the building is equipped throughout with an *automatic sprinkler system* installed in accordance with Section 903.3.1.1 and the occupant notification appliances will activate throughout the notification zones upon sprinkler water flow.

## CHAPTER 35 REFERENCED STANDARDS

NFPA 45-15 Standard on Fire Protection for Laboratories Using Chemicals



## 2015 International Existing Building Code

(As Part of the 2015 Virginia Rehabilitation Code)

### **302.6 Change of occupancy in existing Group B teaching and research laboratories.**

Where the use of new or different hazardous materials or a change in the amount of hazardous materials in existing Group B testing and research laboratories in educational occupancies above the 12th grade would constitute a change of occupancy, this section shall be permitted to be used as an acceptable alternative to compliance with change of occupancy requirements to permit the increased amounts of hazardous materials stipulated without the laboratories being

classified as Group H. In addition, as set out in Section 5001.7 of the SFPC, approval under this section is contingent upon operational requirements in the SFPC being complied with and maintained.

**302.6.1 Hazardous materials in existing Group B teaching and research laboratories.** The percentage of maximum allowable quantities of hazardous materials per control area and the number of control areas permitted at each floor level within an existing building shall be permitted to comply with Table 302.6.1(1) in buildings equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1 of the VCC or shall be permitted to comply with Table 302.6.1(2) in buildings not equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1 of the VCC.

**TABLE 302.6.1(1)**  
**DESIGN AND NUMBER OF CONTROL AREAS IN EXISTING BUILDINGS EQUIPPED**  
**THROUGHOUT WITH AN AUTOMATIC SPRINKLER SYSTEM IN ACCORDANCE WITH**  
**SECTION 903.3.1.1 OF THE VCC WITH GROUP B TEACHING AND RESEARCH**  
**LABORATORIES IN EDUCATIONAL OCCUPANCIES ABOVE THE 12TH GRADE**

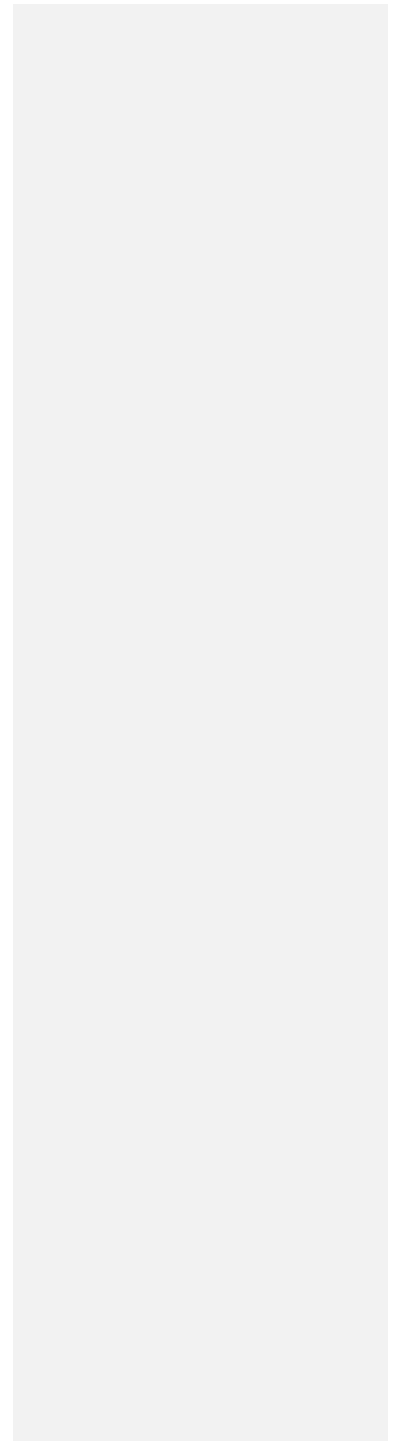
| Floor Level          |                    | Percentage of<br>the Maximum<br>Allowable<br>Quantity<br>per Control | Number<br>of Control Areas per<br>Floor | Fire- Resistance<br>Rating for Fire<br>Barriers and<br>Horizontal<br>Assemblies in |
|----------------------|--------------------|----------------------------------------------------------------------|-----------------------------------------|------------------------------------------------------------------------------------|
| Above Grade<br>Plane | Higher than<br>20' | 5                                                                    | 1                                       | 2 <sup>h</sup>                                                                     |
|                      | 11-20'             | 10                                                                   | 1                                       | 2 <sup>h</sup>                                                                     |
|                      | 7-10'              | 25                                                                   | 2                                       | 2 <sup>h</sup>                                                                     |
|                      | 4-6'               | 50                                                                   | 2                                       | 2 <sup>h</sup>                                                                     |
|                      | 3'                 | 75                                                                   | 3 <sup>2</sup>                          | 1 <sup>h</sup>                                                                     |
| Below Grade<br>Plane |                    | 75                                                                   | 3                                       | 1 <sup>h</sup>                                                                     |
|                      |                    | 50                                                                   | 2                                       | 1 <sup>h</sup>                                                                     |

- Percentage shall be of the maximum allowable quantity per control area shown in Tables 307.1(1) and 307.1(2) of the VCC, with all increases allowed in the notes to those tables.
- Separation shall **shall include** fire barriers and horizontal assemblies as necessary to provide separation from other portions of the building.
- Fire barriers separating control areas from other spaces on the same floor may be one hour rated.**

**TABLE 302.6.1(2)**  
**DESIGN AND NUMBER OF CONTROL AREAS IN EXISTING BUILDINGS NOT EQUIPPED**

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- Comment [ZA3]: Aligns the number of control areas by floor with existing requirements
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THROUGHOUT WITH AN AUTOMATIC SPRINKLER SYSTEM IN



**ACCORDANCE WITH SECTION 903.3.1.1 OF THE VCC WITH GROUP B TEACHING AND RESEARCH LABORATORIES IN EDUCATIONAL OCCUPANCIES ABOVE THE 12TH GRADE**

| Floor Level       |               | Percentage of the Maximum Allowable Quantity per Control | Number of Control Areas per Floor | Fire- Resistance Rating for Fire Barriers and Horizontal Assemblies in |
|-------------------|---------------|----------------------------------------------------------|-----------------------------------|------------------------------------------------------------------------|
| Above Grade Plane | Higher than 9 | 5                                                        | 1                                 | 2 <sup>e</sup>                                                         |
|                   | 7-9           | 10                                                       | 2                                 | 2 <sup>e</sup>                                                         |
|                   | 4-6           | 25                                                       | 2                                 | 2 <sup>e</sup>                                                         |
|                   | 3             | 75                                                       | 2                                 | 1                                                                      |
|                   | 1-2           | 100                                                      | 3                                 | 1                                                                      |
| Below Grade Plane |               | 75                                                       | 3                                 | 1                                                                      |
|                   |               | 50                                                       | 2                                 | 1                                                                      |

a. Percentage shall be of the maximum allowable quantity per control area shown in Tables 307.1(1) and 307.1(2) of the VCC, ~~excluding~~ including all increases allowed in the notes to those tables.

b. Separation shall ~~include~~ shall fire barriers and horizontal assemblies as necessary to provide separation from other portions of the building.

c. ~~Fire barriers separating control areas from other spaces on the same floor may be one hour rated.~~

~~302.6.1.1 — Separation requirements. Control areas shall be separated from each other and from other non-control areas by fire barriers constructed in accordance with Section 707 of the VCC or horizontal assemblies constructed in accordance with Section 711 of the VCC, or both.~~

~~302.6.1.2 — Fire resistance rating requirements. The required fire resistance rating for fire barriers shall be in accordance with Table 302.6.1(1) in existing buildings equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1 of the VCC or in accordance with Table 302.6.1(2) in existing buildings not equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1 of the VCC. The floor assembly of the control area and the construction supporting the floor of the control area shall have a fire resistance rating in accordance with Table 302.6.1(1) in existing buildings equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1 of the VCC or in accordance with Table 302.6.1(2) in existing buildings not equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1 of the VCC.~~

**Exceptions:**

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Comment [ZA4]: Aligns number of control areas by floor with existing requirements

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1. The floor assembly of the control area and the construction supporting the floor of

~~the control area are allowed to be 1-hour fire-resistance-rated in buildings of Types **IIA**, **IIIB** and **VB** construction, provided that the building is 3 or fewer stories.~~

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~~2. In existing buildings that were constructed prior to the initial edition of the USBC and that comply with the semi-fireproof or fireproof construction classification under the state fire and public building regulations in effect prior to March 31, 1986, the existing floor assemblies and supporting construction for control areas shall be deemed to meet the requirements of this section.~~

~~302.6.1.3~~ **302.6.1.1 Restricted Materials Automatic fire alarm and detection systems.** ~~Where Pyrophorics or Class IV Oxidizers are used in buildings not equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1, a~~ **An** automatic fire detection system shall be provided in the control area ~~where such materials are used~~ in accordance with Section 907 of the VCC. An automatic fire alarm system shall be provided throughout the building in accordance with Section 907 of the VCC.

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~~302.6.1.4~~ **302.6.1.2 System supervision and monitoring.** Automatic fire detection systems shall be electronically supervised and monitored by an approved supervising station or, where approved, shall initiate an audible and visual signal at a constantly attended on-site location.

~~**302.6.1.5 Separation from adjacent areas.** New laboratories in existing buildings that increase maximum allowable quantities of hazardous materials based upon the requirements in this chapter shall be separated from adjacent areas by one-hour vertical fire barriers or two-hour barriers where required by Table 302.6.1(1) or Table 302.6.1(2).~~

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## CHAPTER 16 REFERENCED STANDARDS

NFPA 45-15 Standard on Fire Protection for Laboratories Using Chemicals

## 2015 International Fire Code

(As Part of the 2015 Virginia Statewide Fire Prevention Code)

**CHEMICAL FUME HOOD.** A ventilated enclosure designed to contain and exhaust fumes, gases, vapors, mists and particulate matter generated within the hood.

**LABORATORY SUITE.** A fire-rated enclosed laboratory area that will provide one or more laboratory spaces, within a Group B educational occupancy, that are permitted to include ancillary uses such as offices, bathrooms, and corridors that are contiguous with the laboratory

area, and are constructed in accordance with Section 427.3 of the VCC.

**SPECIAL EXPERT.** An individual who has demonstrated qualifications in a specific area, outside the practice of architecture or engineering, through education, training and experience.

**TEACHING AND RESEARCH LABORATORY.** A building or portion of a building where hazardous materials are stored, used and handled for the purpose of testing, analysis, teaching, research or developmental activities on a nonproduction basis rather than in a manufacturing process.

#### 5001.7 Operational requirements for Group B teaching and research

**laboratories.** ~~Group B Teaching and research laboratories in Group B educational occupancies above the 12th grade utilizing the alternative compliance requirements of~~ Section 427 of the VCC or Section 302.6 of the VRC shall comply with this section and other applicable requirements of this code. In the case of conflicts between the requirements of Section 427 of the VCC or Section 302.6 of the VRC and provisions of this code other than those set out in this section, Section 427 of the VCC or Section 302.6 of the VRC, as applicable, shall govern.

**Comment [ZAS]:** Simplifying the language used.

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**5001.7.1 Chemical safety reviews.** Operating and emergency procedures planning and documentation shall be as set out in Sections 5001.3.3.11 through 5001.3.3.17. Such documentation shall be prepared by laboratory safety personnel or special experts, and shall be made available in the workplace for reference and review by employees. Copies of such documentation shall be furnished to the fire code official for review upon request.

**5001.7.2 Hazardous materials handling.** Receiving, transporting on site, unpacking and dispensing of hazardous materials shall be carried out by persons trained in proper handling of such materials and shall be performed in accordance with Chapters 50 through 67, as applicable.

**5001.7.3 Hazard identification signage.** Warning signs for other than building components shall be provided in accordance with Section 5003.5.

**5001.7.4 Maintenance of equipment, machinery and processes.** Maintenance of equipment, machinery and processes used with hazardous materials shall comply with Section 5003.2.6.

**5001.7.5 Time sensitive materials.** Containers of materials that have the potential to become hazardous during prolonged storage shall be dated when first opened, and shall be managed in accordance with NFPA 45 Section 8.2.4.4.1.

5001.7.6 Maintenance of storage, dispensing, use and handling requirements. Storage, dispensing, use and handling requirements in the VCC or VRC shall be maintained. Operational requirements not affecting the manner of construction shall comply with this chapter and Chapters 51 through 67, as applicable.

5001.7.7 Hazardous wastes. Storage, dispensing, use and handling of hazardous waste shall comply with this chapter and Chapters 51 through 67, as applicable.

5001.7.8 Container Size. The maximum container size for all hazardous materials shall be 5.3 gallons for liquids, 50 pounds for solids, 100 cf. for health hazard gases per table 5003.1.1(2) and 500 cf. for all other gases in accordance with Table 5003.1.1(1).

Exception: Hazardous waste collection containers, for other than Class I and Class II flammable liquids, are permitted to exceed 5.3 (20L) gallons where approved.

5001.7.9 Density. Quantities of Class I, II & IIIA combustible or flammable liquids in storage and use within control areas or laboratory suites shall not exceed 8 gallons (30 liters) per 100 square feet of floor area, with not more than 4 gallons (15 liters) per 100 square foot being in use. Quantities of Class I flammable liquids in storage and use shall not exceed 4 gallons per 100 sf of floor area with not more than 2 gallons (7.5 liters) being in use. The maximum in use in open systems is limited to 10% of these quantities. Densities shall be reduced by 25 percent on the 4th through 6th floor levels above grade plane of the building and 50% above the 6th floor level. The density is to be reduced to



50% of these values for buildings that are not protected throughout with an approved automatic fire sprinkler system. Regardless of the density, the maximum allowable quantity per control area or laboratory suite shall not be exceeded.

**Exception:** Density limits may be exceeded in designated hazardous waste collection areas or rooms within a control area or laboratory suite ~~are not limited~~, but stored quantities shall not exceed the maximum allowable quantity per laboratory suite or control area.

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**5001.7.109 Restricted materials in storage.** Storage of ~~hazardous materials~~ **Pyrophorics and Class 4 Oxidizers** prohibited by Table 5003.1.1(1) in existing buildings not equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1 of the VCC shall be allowed within a control area at 25 percent of the limits in Table 5003.1.1(1) for a building equipped throughout with an automatic sprinkler system, with no additional increases allowed, provided that such materials are stored in accordance with all of the following:

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1. Containers shall be completely sealed and stored according to the manufacturer's recommendations .

2. Storage shall be within approved hazardous materials storage cabinets in accordance with Section 5003.8.7, or shall be located in an inert atmosphere glove box in accordance with NFPA 45 Section 7.11.

3. The storage cabinet or glove box shall not contain any storage of incompatible materials .

**5001.7.10-11 Restricted materials in use.** Use of ~~hazardous materials~~ **Pyrophorics and Class 4 Oxidizers** prohibited by Table 5003.1.1(1) in existing buildings not equipped throughout with an automatic

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sprinkler system in accordance with Section 903.3.1.1 of the VCC shall be allowed within a control area at 25 percent of the limits in Table 5003.1.1(1) for buildings equipped throughout with an automatic sprinkler system, with no additional increases allowed, provided that such materials are used in accordance with all of the following:

1. Use shall be within an approved chemical fume hood listed in accordance with UL 1805, or in an inert atmosphere glove box in accordance with NFPA 45 Section 7.11, or other approved equipment designed for the specific hazard of the material.

2. Combustible materials shall be kept at least two feet (0.610 m) away from the work area.

except for those items directly related to the research.

3. A portable fire extinguisher appropriate for the specific material shall be provided within 20 feet of the use in accordance with Section 906.

#### **CHAPTER 80 REFERENCED STANDARDS**

NFPA 45-15 Standard on Fire Protection for Laboratories Using Chemicals UL 1805-2002 Standard for Laboratory Hoods and Cabinets

**Reason:** This proposed code change attempts to address the limiting factors of MAQs within facilities (via the use of control areas) by answering the following questions:

1. How do we increase MAQs beyond those already allowed while still incorporating an acceptable level of safety, protection, and/or fire resistance ratings?

2. How do we apply these requirements to existing buildings?

3. How do we accomplish the first two without a large re-write of the code (i.e., Group L) or relying on a standard that may not be completely written in enforceable terms (i.e., NFPA 45)?

The answer to question #1 above is to allow for an increased number of control areas – which would in effect, allow for increased MAQs per floor level. Providing an acceptable level of safety is addressed by limiting this change to apply only to Group B labs and by considering the following:

- in Group B laboratories, the use of hazardous chemicals is generally limited to small quantities used on a short-term basis and in operations where the chemicals and procedures change frequently. 29 CFR 1910.1450, which is referred to as the 'Laboratory Standard' requires the development and implementation of a formal, written, and employee-accessible program, referred to as a Chemical Hygiene Plan (CHP), where this plan must be capable of protecting employees (and users) from health hazards associated with hazardous chemicals used in the laboratory, and
- where research funding is obtained from Agencies such as the National Institute of Health (NIH), development of a Chemical Hygiene Plan for Laboratory operations is already a requirement, and
- in such Group B labs, the students and faculty tend to be more careful in their handling of hazardous materials, and
- the students tend to be better educated and more closely supervised, and such
- facilities tend to undergo more inspections, and
- many Group B facilities (i.e., higher education) have dedicated departments whose mission is to ensure proper procedures and safety precautions are adhered to and implemented.

The level of protection and fire resistance ratings are addressed by requiring a minimum 2-hour enclosure from the 3rd floor level and higher (4th floor level or higher is allowed now). Also, since control areas are required to be compartmentalized and completely enclosed (all sides, top, and bottom), any additional control areas allowed under this code change proposal would be required to be completely separated from the remainder of the facility and from other control areas.

It has been said that approximately 90% of the current higher education laboratory facilities are 4 stories or less – including new and existing buildings, so the number of facilities this code change would affect would potentially be a smaller percentage (since the major benefit is for buildings 4 stories and higher).

Per the VDFP fire data "Tally" charts ([http://vdfp.virginia.gov/fire\\_data\\_statistics/index.htm](http://vdfp.virginia.gov/fire_data_statistics/index.htm)), within the last ten years, when it comes to laboratories there have been:

- 0.03% frequency percentage of calls, zero
- deaths (civilian or fire fighters), two
- injuries (to fire fighters), and
- minimal property damage (approximately \$230,000 over the 10-year period with \$200,000 of that in one year alone - 2005).

Empirical data suggests that laboratories (including Group B higher education) appear to be relatively safe occupancies. The imposition of additional performance-based safety requirements in the SFPC where increased quantities will be allowed to be used further enhance the safety of operations using hazardous materials.

The answer to question #2 above is to allow existing facilities to benefit from the Virginia amendments and thus, existing Group B laboratories could utilize the proposed amendments included in this code change proposal, rather than be evaluated under the building code in which it was constructed.

If you accept the answers to #1 and #2, then the answer to question #3 above could be accomplished by adding a new subsection to 414.2 in the VCC and a new subsection 302.6 in the VRC.

The new definitions are provided to better describe what a "testing and research lab" is and also mimic the language use in 2015 IMC 510.1.

NATIONAL IFC WORKGROUP SUPPORTING STATEMENT: [copied verbatim without any edits and therefore, refers to information that is not a part of this code change proposal, but still conveys the conceptual approach]

There is quite possibly no industry more important to lives across the world than higher education academic institutions. The advance of technologies, science, medicine and our knowledge of the world often relies on having vibrant and successful academic institutions.

These academic institutions often have chemistry, biology, medical, engineering and other laboratories where hazardous materials are used. The IFC does not specifically address teaching and research laboratories, so users must try to apply general hazardous materials provisions, which oftentimes are not appropriate for specialized academic laboratory settings. The following is a list of several conditions typically present in academic laboratories

that make them unique:

1. Lower chemical density in individual research laboratories. In a teaching and research environment, there are often many small laboratories within a building that are using small quantities of hazardous materials in each location. Individually, they do not store or use a large quantity of hazardous materials, but together, they may often exceed the maximum allowable quantities for the control area. This lower chemical density often mitigates the overall risk, but the IFC currently has no provisions to recognize this condition.
2. Ongoing staff oversight from "Special Experts" in laboratory safety. Many higher education institutions have a full cadre of faculty and staff with chemical expertise. These "Special Experts" often include, but are not limited to: Fire Marshals, Industrial Hygienists, Radiation Safety Officers, Biological Safety Officers, Chemical Hygiene Officers and Environmental Health and Safety Officers. These individuals are an integral part of the preparation/review of laboratory safety documentations, as well as regularly scheduled safety audits. Fire and life safety expertise and oversight on our campuses is continually increasing with the addition of these highly capable professionals.
3. Limited, or "directed", funding streams. Also unique to academic institutions are the funding sources for research. In a "non-profit" teaching and research environment, the majority of research is funded through grants and endowments. Unfortunately, many grants only support the costs of research personnel and equipment, not structural upgrades to accommodate newer research processes.
4. Mixed-use occupancies. A typical university science building will house laboratories, office space, storerooms, classrooms and lecture halls. The current limits on hazardous materials are so restrictive on upper floors that many universities are forced to locate classrooms and lecture halls on the upper floors so that they can take full advantage of the hazardous materials quantities allowed on the lower floors. This results in moving large numbers of students through hallways, past laboratories to get to the upper floors. They will also have to exit back down the

same routes in the event of an emergency.

This proposal introduces a post-secondary academic laboratory chapter to address these unique circumstances. University fire and life safety professionals from across the United States have collaborated on writing this chapter. Conscientious effort has been made to balance the proposed IFC modifications with enhanced administrative, emergency planning and structural provisions.

This chapter also introduces some important provisions from NFPA 45, Fire Protection for Laboratories. Although the IFC references many national standards on specific topics, there are no such references currently for laboratories. This standard contains many laboratory specific requirements and design professionals rely heavily upon this national standard for current laboratory designs.

Specifically, the chapter addresses three primary needs: 1) increasing general laboratory safety requirements, 2) increasing MAQ's in large or multi-story laboratories, or laboratories located in multi-story buildings and, 3) allowing very small quantities of currently prohibited hazardous materials in non-sprinklered laboratory buildings. A brief description of each is as follows:

1. Increased general laboratory safety requirements: This proposal introduces a post-secondary academic laboratory chapter in to the IFC. Currently, there is no teaching/research laboratory

specific chapter in the IFC, and there are no references to NFPA 45 (Fire Protection for Laboratories). This new chapter fills a much needed gap in the IFC, and provides for enhanced safety requirements in these academic laboratories.

2. Control Area Limitations: As post-secondary campuses across the world grow to meet increasing populations, they often are landlocked, and require that new buildings are built taller and/or larger. This is particularly true in large metropolitan areas. The current "Control Area" restrictions in the ICC codes severely restrict functioning laboratories on upper floor levels or in larger buildings.

In response to this critical issue, numerous jurisdictions have adopted state or local amendments to allow for greater numbers of control areas and larger percentages of MAQs in academic and/or non-production laboratories. Such jurisdictions include California, Arizona, Minnesota, Seattle and New York City. One of the primary purposes of this proposal is to provide standardized model code language to address this topic.

This chapter provides an alternate design approach for such scenarios where traditional control area limitations are not feasible, and where building Group H-Occupancies is not possible. The "Laboratory Suite" concept gives users an option to allow more flexibility in hazardous materials use, in exchange for additional administrative and structural safeguards, while still remaining a "B" occupancy.

3. Non-Sprinklered Limitations: There are thousands of existing post-secondary academic institutions, with some dating back to 1800's, where retrofitting automatic sprinklers is not practical. This proposal addresses a critically important issue to selected laboratories in existing, non-sprinklered buildings, who need very small quantities of materials that have blanket restrictions in non-sprinklered buildings. This proposal provides a limited exception to allow very small quantities of such materials when specific mitigation controls are provided.

#### PART 1 REASON:

Section 3801. Provides general scoping information. It clarifies that the chapter applies to both existing laboratories in existing buildings and new laboratories as referenced in the sections.

The definition used for laboratories mirrors the definition found in the International Mechanical Code, with the addition of language to clarify that the chapter is limited to "Laboratories in higher education institutions beyond the 12th grade".

Section 3802. Provides definitions for new terms introduced in this chapter. The term "Special Expert" is in the International Performance Code in the appendix. It was utilized in this chapter to reflect the high level of faculty and staff safety professionals available at many academic institutions.

Section 3803. Requires additional safety pre-planning for all laboratories or laboratory suites utilizing this chapter, also consistent with laboratory safeguards found in NFPA 45. Enhanced safety requirements found in this section include:

1. New hazard analysis documentation shall include: Process Hazard Analysis, Pre-startup Safety Review, Operating and Emergency Procedures, Management of Change, Accident Procedures, Consequence Analysis

and Safety Audits. Requires that such documentation shall be submitted to the fire code official. (IFC Section 5001).

2. Time-sensitive materials shall be dated and pro-actively managed. (NFPA 45).

3. Maximum container size of Class I flammable liquids is 5.3 gallons. (NFPA 45).

4. Density of Class I flammable liquids in storage and use shall be no greater than 8 gallons per 100 square feet of floor area. (NFPA45).

Section 3804. Provides the "Laboratory Suite" design option in addition to traditional control area options.

Enhanced safety requirements in this section include:

1. All of those listed above in Section 3803.

2. Rated fire barriers for compartmentation of laboratory suites within buildings.

3. In laboratories above the 6th story, or in a story below grade plane, requirements for standby or emergency power for safety-related equipment and enhanced automatic sprinkler protection.



4. Automatic sprinkler design and density exceeding that which would be required by NFPA 45.

If the vertical fire barrier between lab suites is required to be two-hour rated, a fire rated duct enclosure, UL listed duct wrap, or multiple building shafts is required. Footnote c in the table allows the vertical fire barriers between laboratory suites on a floor to be one-hour rated because of the reduced quantities of hazardous materials in each laboratory suite on the floors above the 6th story, and additional safety provisions in Chapter 38 which apply to all laboratories utilizing this chapter. In addition, chemical exhaust ducts routed through the one-hour rated barriers would be permitted to be installed without fire dampers, where the duct needs to be routed to the nearest chemical exhaust shaft. Fire dampers are not installed in laboratory exhaust ducts to maintain exhaust ventilation in laboratories in the event of a fire. In the IBC, Section 714.1.1 and Section 717.5.2, Exception 3; and IMC 607.5.5 allow exhaust system ducts to penetrate fire rated barriers and fire rated shafts without a fire damper. These provisions carry significant importance and allow multiple laboratory suites per floor of a building. The footnote has no effect on other provisions of the code and does not change the structural fire resistance requirements of IBC Chapter 6, or the continuity requirements of IBC Chapter 7.

Historical fire data over the last 25 years has shown that the vast majority of laboratory fires do not typically extend beyond the area, or even the room of origin. This is primarily due to the limited quantities of hazardous materials in use, and the following safety features that are incorporated into laboratory designs:

1. Ventilation systems provide large volumes of airflow through laboratories to continuously remove hazardous vapors, fumes and gases.
2. Fume hoods provide local ventilation control for containment and removal of hazardous vapors, fumes and gases during the use of hazardous materials.
3. Automatic fire sprinkler systems can confine the fires to the room of origin
4. Fire alarm systems provide prompt notification to building occupants and/or emergency responders.

All of these structural safety features are required in some combination in laboratories utilizing this chapter, as well as the additional NFPA 45 requirements for monitoring of time-sensitive materials, limitations on container sizes and limiting the density of flammable liquids over the floor area of laboratory space.

Section 3805. Provides and clarifies general hazardous materials requirements for non-sprinklered laboratories. Provides an option to allow for very small quantities of prohibited materials in non-sprinklered laboratories. Enhanced safety requirements in this section include:

1. All of those listed above in Section 3803.
2. Enhanced storage requirements in accordance with NFPA 45.
3. Prohibition of storage of any incompatible materials.
4. Use of hazardous materials use must be in a chemical fume hood, glove box or other approved

laboratory equipment designed for the specific hazard.

5. The work area must be free of all unnecessary combustible materials.

6. There must be an appropriate extinguishing media located within 20 feet.

Section 3806. Provides requirements for existing laboratories in existing sprinklered buildings. Enhanced safety requirements in this section include all of those in Section 3803, including complete hazard analysis and safety audits, and limits on container sizes for all hazardous materials and density limits on flammable liquids.

PART 2 REASON:

Modifies IBC 414.2 to identify that "Laboratory Suites" are an exception to traditional control area provisions.

PART 3 REASON:

Modifies IFC 604.2 to identify that "Laboratory Suites" require emergency or standby power. PART 4

REASON:

Adds NFPA 45 as recognized standard.

This chapter was written and reviewed by a national taskforce made up of fire and life safety professionals from colleges, universities, municipal fire organizations and private industry across the United States. Taskforce members are individuals representing their own institutions, as well as members who were assigned participants by national college and university safety associations.

National endorsements:

Campus Safety, Health, and Environmental Management Association (CSHEMA)

This proposal [their proposal is similar (e.g., uses the new IBC but existing NFPA 45 concept of laboratory suites), but not identical to this code change proposal (e.g., which uses the existing IBC concept of control areas)] is submitted by the ICC Fire Code Action Committee (FCAC). The FCAC was established by the ICC Board of Directors to pursue opportunities to improve and enhance assigned International Codes with regard to fire safety and hazardous materials in new and existing buildings and facilities and the protection of life and property in wildland urban interface areas. In 2014 and 2015 the Fire-CAC has held 5 open meetings. In addition, there were numerous conference calls, Regional Work Group and Task Group meetings for the current code development cycle, which included members of the committees as well as any interested parties, to discuss and debate the proposed changes. Related documentation and reports are posted on the FCAC website

**Cost Impact:** Although the cost of construction may increase (because you would be constructing more control areas that are separated by fire barriers and horizontal assemblies), such Group B laboratories may be in a much better position to apply for research grants and funding, and could possibly attract the top students and faculty that might otherwise go to other universities or businesses.

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## Workgroup Recommendation

**Workgroup 2 Recommendation:** None

**Workgroup 2 Reason:** None

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## Board Decision

None

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# EVALUATION OF INDIRECT LIGHTNING- CURRENT WITHSTAND OF COUNTERSTRIKE CSST

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PREPARED BY

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22 DECEMBER 2014

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## EVALUATION OF INDIRECT LIGHTNING-CURRENT WITHSTAND OF COUNTERSTRIKE CSST

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### EXECUTIVE SUMMARY

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In response to concerns with the adequacy of electrical bonding of CSST gas piping systems, the National Fire Protection Association (NFPA) in 2009 instigated an investigation into the efficacy of direct bonding of such systems as a means of preventing lightning damage. This investigation led to the formation of a task group to assist the NFP 54 Fuel Gas Code Technical Committee. A report of the findings of this task group was provided to the NFPA 54 Technical Committee in May of 2013 followed by a presentation in June of 2013. The recommendations of the task force that direct bonding of CSST was effective at preventing damage from indirect lightning strikes was adopted by the NFPA Committee in 2013. The present study is an extension of that work and is intended to assess the equivalence of the use of arc-resistant CSST to indirect lightning strikes when indirectly bonded through appliances grounded to the electrical supply system and in the absence of a direct bonding conductor.

CounterStrike is the proprietary name of a flexible arc-resistant corrugated stainless steel tubing manufactured by Omega Flex, Inc. for fuel gas distribution. The product utilizes the same stainless steel tubing as traditional CSST, but encases the tubing in conductive plastic covering in place of the insulated plastic covering of the original product. The purpose of the conductive jacket is to provide protection of the steel tubing against electrical arcs, particularly those resulting from lightning discharges. The present report is an evaluation of the electrical withstand of CounterStrike to indirect lightning currents. This evaluation is based on laboratory measurements of the resistance of the jacket to arc damage from simulated lightning currents, measurements of the electrical parameters of the tubing and computer models to simulate the expected lightning currents for the defined scenarios used for the original NFPA study.

In recent high-current high-voltage laboratory tests, the variation of the susceptibility of CounterStrike to damage by electrical arcs of different durations has been found to confirm earlier preliminary data. The data are plotted as a curve of expected damage threshold versus total arc duration. This curve shows a minimum value of about 8 coulombs for arc durations of 15,000 microseconds (0.015 seconds), increasing to about 15 coulombs for the shorter arc durations of 3000  $\mu$ s (0.003 seconds) and greater than 20 C for arc durations of 1000  $\mu$ s (typical of the standard double-exponential 10x350  $\mu$ s test waveform). This arc resistance of CounterStrike may be compared to conventional (yellow-jacket) CSST, from which it is concluded that CounterStrike has fifty times the arc resistance of conventional CSST.

The electrical parameters of self-inductance and resistance of a 30-foot sample of 3/4 inch diameter CounterStrike were measured in the laboratory, from which it was concluded that CounterStrike would behave similarly to other metallic conductors in conducting high-frequency lightning currents.

Computer simulations were run to predict the current magnitudes and waveshapes that would flow in an arc to the jacket of CounterStrike for scenarios in which indirect lightning currents were injected into a residence either on the incoming metallic gas line or electrical service. These scenarios were similar to those used for the earlier evaluation of the effectiveness of bonding in protecting conventional (yellow-jacket) CSST from indirect lightning events [1]. The present simulations eliminated the bonding conductor and assumed the CounterStrike was grounded only at an appliance. The simulations on CounterStrike were run with currents having a waveshape of 10x350  $\mu$ s with a magnitude of 10 kA, as used in the original study.

It was concluded that, for the scenarios studied, the arc charge and duration would be insufficient to damage CounterStrike and that this result would be expected for simulated 10x350  $\mu$ s lightning currents up to 50 kA, a magnitude that significantly exceeds all indirect lightning and includes a fraction of direct strikes.

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## INTRODUCTION

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### BACKGROUND

In response to concerns with the adequacy of electrical bonding of CSST gas piping systems, the National Fire Protection Association (NFPA) in 2009 instigated an investigation into the efficacy of direct bonding of such systems as a means of preventing lightning damage. This investigation led to the formation of a task group to assist the NFP 54 Fuel Gas Code Technical Committee.

In July 2010 an engineering firm in the lightning area, SEFTIM, was selected by the technical panel. SEFTIM's first task was to complete a literature review and develop a gap analysis to inform a future research project designed to validate installation methods for CSST gas piping to mitigate damage due to lightning events. This initial engineering review and gap analysis work is referred to as 'Phase I' of the project.

The SEFTIM report *Validation of Installation Methods for CSST Gas Piping to Mitigate Lightning Related Damage* (Phase I) was completed in April 2011. The executive summary of the report concludes with reference to the beneficial role of bonding metallic systems, but that there is a lack of sufficient information to validate installation methods of CSST gas piping to mitigate damage due to lightning events. The summary concludes with the need to perform a targeted testing program to gain greater information as a proposed Phase II of the project.

The project technical panel accepted SEFTIM's recommendation, and also selected SEFTIM to produce the Phase II Test Plan. SEFTIM produced the test plan, *Validation of Installation Methods for CSST Gas Piping to Mitigate Lightning Related Damage, Phase II, Proposal V2* (November 2011), and this test plan was also accepted by the project technical panel. In April 2012, the sponsors of the project, selected Gas Technology Institute (GTI), to manage the testing phase of the project as laid out in the SEFTIM Test Plan Phase II V2 (November 2011).

In October 2012, GTI presented a project update and initial findings to the NFPA 54 Technical Committee. GTI conducted further testing through December of 2012, and simulations in 2012 and early 2013. A report of the findings was provided to the NFPA 54 Technical Committee in May of 2013 followed by a presentation in June of 2013. The recommendations from this study were presented to the NFPA Technical committee in 2013 and were recommended for adoption in 2013.

### PRESENT STUDY

CounterStrike is the proprietary name of a flexible arc-resistant corrugated stainless steel tubing manufactured by Omega Flex, Inc. for fuel gas distribution. The product utilizes the same stainless steel tubing as the traditional (yellow-jacket) TracPipe, but encases the tubing in conductive plastic covering in place of the insulated plastic covering of the earlier standard product. The purpose of the conductive jacket is to provide protection of the steel tubing against electrical arcs, particularly those resulting from lightning discharges. This type of product is referred to generically as "Arc-Resistant CSST".

The present report covers an evaluation of the electrical withstand of CounterStrike to indirect lightning currents, based on measurements of the physical properties of the tubing and computer models to simulate the expected lightning currents for several defined scenarios. The objective of this report is to replicate the results of the previous study done with conventional CSST (when electrically bonded in accordance with the recommendations of the earlier GTI report), but with unbonded CounterStrike. This study evaluates CounterStrike's efficacy in resisting arc-damage from indirect lightning strikes when connected to a grounded appliance.

Details of lightning current waveforms used in the laboratory tests and for computer simulations are described in Appendix D.

## EXPERIMENTAL DATA

### ARC RESISTANCE OF CONVENTIONAL CSST

Arc damage has been observed to occur to conventional (insulated jacket) CSST tubing products, damage that is frequently ascribed to lightning discharges. When an electrical arc terminates on a metal surface, metal will be removed or displaced by a number of processes. The amount of metal removed or displaced depends on the energy dissipated in the arc/metal interface and its duration. The voltage of the arc is approximately constant, therefore, for a given waveshape, the energy is roughly proportional to the time integral of current, that is, the total electrical charge transfer. Many studies have confirmed that the size of hole created by electrical arcs in thin metals is closely proportional to the charge transfer for a given waveshape or duration of current.

The necessary charge to create a hole of a given size occurs for a current duration that has a minimum typically between about 0.01 and 0.1 seconds. This duration is of the same order of magnitude as the long-duration currents that occur in some lightning strikes as well as that of power frequency fault currents. In order to assess the likely damage from an electrical arc, the dependent variables that must be assessed are the magnitude of the current and its duration.

Duration represents the total time that the arc is present and was derived from work that used direct currents [3]. The duration of a double-exponential wave (typically used for lightning simulations) may be taken as approximately three times the time to half-value. This represents the time at which approximately 90% of the energy has been delivered by the wave. For example, the 10 kA 10x350  $\mu$ s current wave used for these studies is shown in Fig. 1. The current waveform is the red curve with left vertical axis in kA and the cumulative charge waveform is the blue curve with right vertical axis in coulombs. This wave may be considered to have a total duration of 3x350  $\mu$ s, which is 1,050  $\mu$ s or 1.05 milliseconds. Test data shown on Fig. 2 use this criterion for the duration of double-exponential test waves.

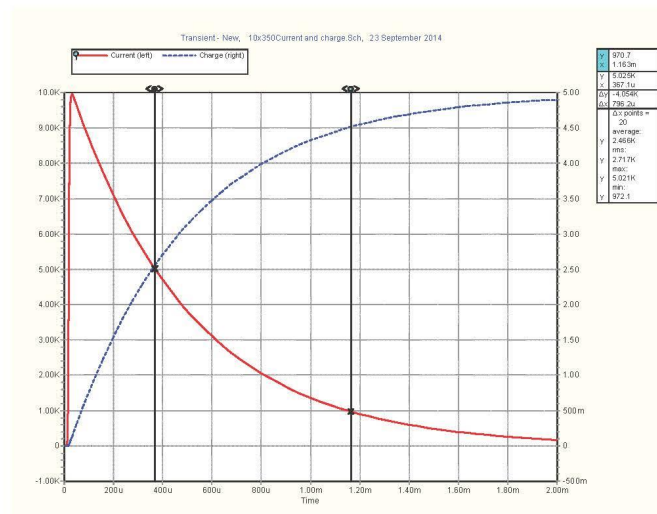


Fig. 1: Current and charge waveforms for the 10 kA 10x350  $\mu$ s waveform



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To assist with the evaluation of the likelihood of arc damage, the author has developed a set of susceptibility curves to describe the necessary charge to cause perforation in conventional CSST as a function of arc duration. These curves are based on an extrapolation of published curves from earlier testing work [2, 3, 4, and 5] together with more recent laboratory tests on CSST [6, 7, 8, 9, 10, and 11]. The latest susceptibility curves derived by the author for conventional (yellow jacket) CSST are shown in Fig 2.

Actual test data points for conventional CSST are shown for currents of  $8 \times 20 \mu\text{s}$ ,  $10 \times 50 \mu\text{s}$ ,  $10 \times 350 \mu\text{s}$ , and  $19 \times 543 \mu\text{s}$  waveshapes. Where a perforation was observed in testing, the data point is colored red, where no perforation occurred, the data point is colored green.

It can be seen that the data support the general shape of the curves, although there are too few data points for these curves to be determined more exactly, especially for very short-duration and very long-duration arcs. It can also be seen that experimental tests with the same charge and duration result in cases of both perforation and no perforation. This appears to be a result of the quite wide variance of test data, which has been widely reported by other investigators. This variance led to the two curves shown in Fig. 2. The upper (red) curve shows the limits above which arc damage is likely, the lower (green) curve shows the limits below which arc damage is unlikely. The region between the curves describes a zone where arc damage is possible.

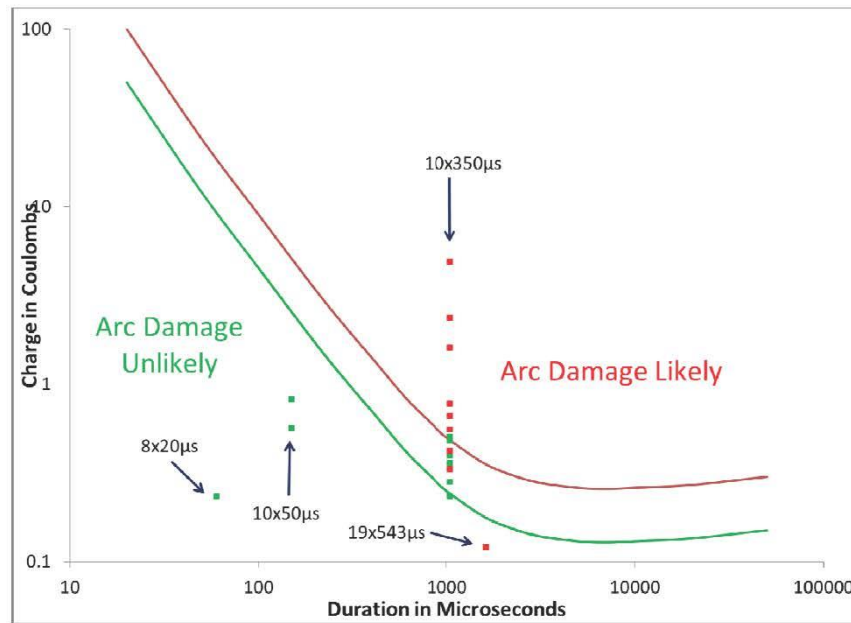


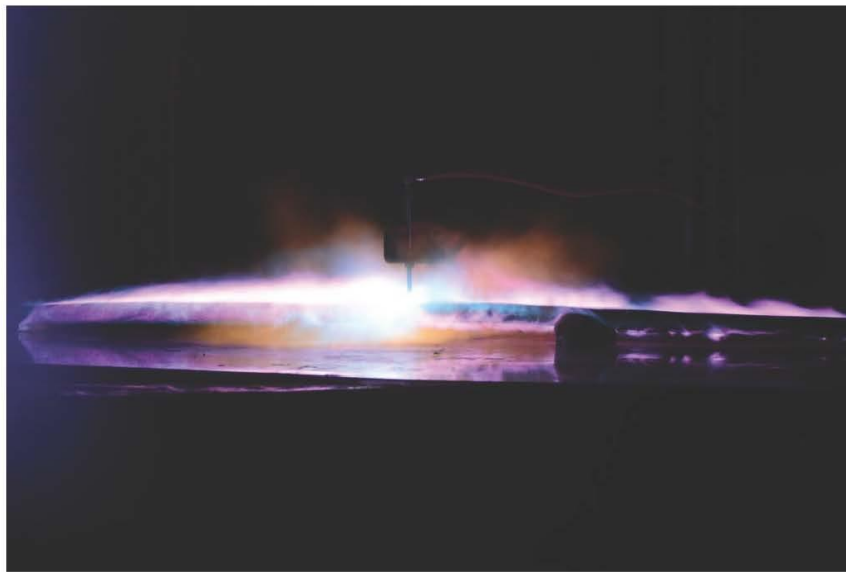
Fig. 2: Arc charge versus duration required to damage conventional CSST

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## ARC RESISTANCE OF COUNTERSTRIKE

CounterStrike provides its arc-resistance property by dissipating the electrical energy of an arc over a larger surface area of the metal surface through the conductive jacket, significantly reducing metal displacement at the arc location. This process has been verified by laboratory testing with simulated lightning currents of various magnitudes and durations. In these laboratory tests, the dissipation of the electrical current over significant portions of the jacket is clearly evident (Fig. 3). In some cases, the conductive jacket is punctured or ruptured by the arc (Fig. 4) but nevertheless protects the metal tubing from arc damage.

Although this process may be significantly different from that occurring on a purely metal surface, the general physical processes that result in more energy being required to perforate the tubing for very short-duration arcs and very long-duration arcs are somewhat similar. Consequently, for the initial assessment of the arc-resistance of CounterStrike, it will be assumed that its behavior is similar to that of a metal of greater thickness than standard CSST, with a minimum required charge occurring with arc durations of between 0.01 and 0.1 seconds. Based on recent test data [8], the minimum charge to perforate CounterStrike using 12x3000  $\mu$ s waves was found to be between 5 and 6 coulombs. This would suggest that the arc-resistance of CounterStrike is not too different from that of metal of thickness around 80 mils (seven to eight times thicker than regular CSST). Based on prior arc-puncture testing on metals of this thickness [2], approximate preliminary charge/time curves can be calculated and are shown in Fig. 5.



*Fig. 3: Laboratory testing of CounterStrike with simulated lightning currents*



*Fig. 4: High-current arc damage to jacket with undamaged tubing*

Also shown on Fig. 5 are calculated points that represent the transferred charge and duration for the standard  $10 \times 350 \mu\text{s}$  waveform that is used to represent lightning at levels of 10 kA, 25 kA and 50 kA. The 10 kA  $8 \times 20 \mu\text{s}$  wave used for some indirect lightning currents has a charge that lies below the minimum level of the chart and is not shown.

The 10 kA  $10 \times 350 \mu\text{s}$  wave was used in the earlier simulation scenarios [1] to represent indirect lightning by the partial transfer of direct lightning currents into a building on the incoming services. This is a fairly long-duration waveform and the 10 kA magnitude for indirect events is considered conservative. The 50 kA  $10 \times 350 \mu\text{s}$  waveform may be considered representative of a fairly severe direct stroke lightning current.

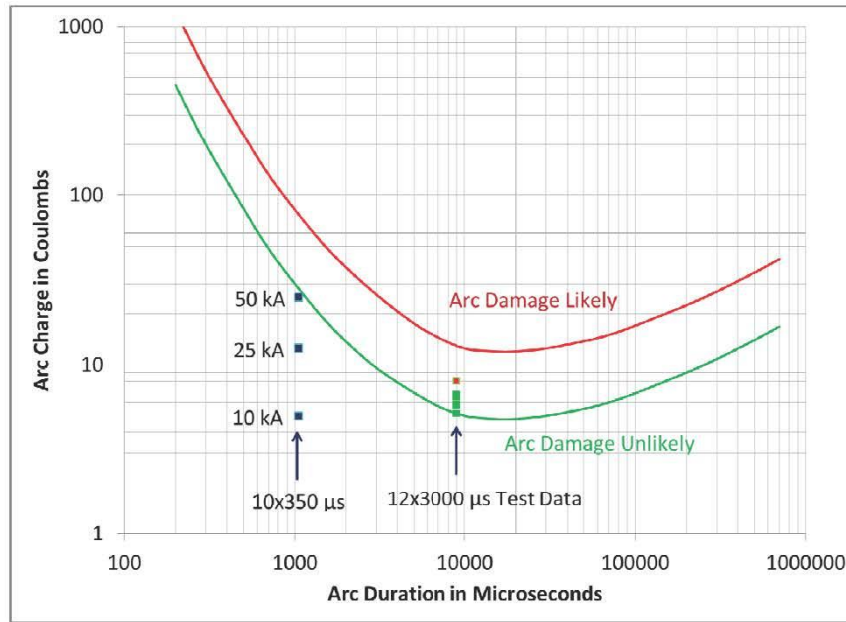


Fig. 5: Arc charge versus duration required to damage CounterStrike (preliminary)

It should be noted from the susceptibility curves shown in Fig. 5 that the arc withstand capabilities of CounterStrike greatly exceeds all the indirect lightning scenarios (10 kA, 10x350 μs), having been directly laboratory tested with this waveshape at up to 22 kA (12 C). This increased arc resistance enables CounterStrike to withstand many direct strike scenarios (possibly exceeding 50 kA 10x350 μs).

More recent laboratory test data extended the arc susceptibility measurements of CounterStrike with lightning test waveforms of 10x350 μs, 10x1000 μs, 10x2840 μs and 10x4000 μs. The results of these tests for ½-inch CounterStrike are shown in Fig. 6 and for 1-inch CounterStrike in Fig. 7, together with the estimated damage threshold curves.

It can be seen that the new data confirm that the arc resistance of CounterStrike is not only substantially higher than TracPipe, but also follows a similar trend in requiring higher magnitudes of charge to cause damage when arc duration is shorter.

Damage to CounterStrike using 10x350 μs waves was never achieved during laboratory tests since the required levels exceed the capabilities of the surge generator, but a minimum level of 25 coulombs for this wave appears consistent with the test data.

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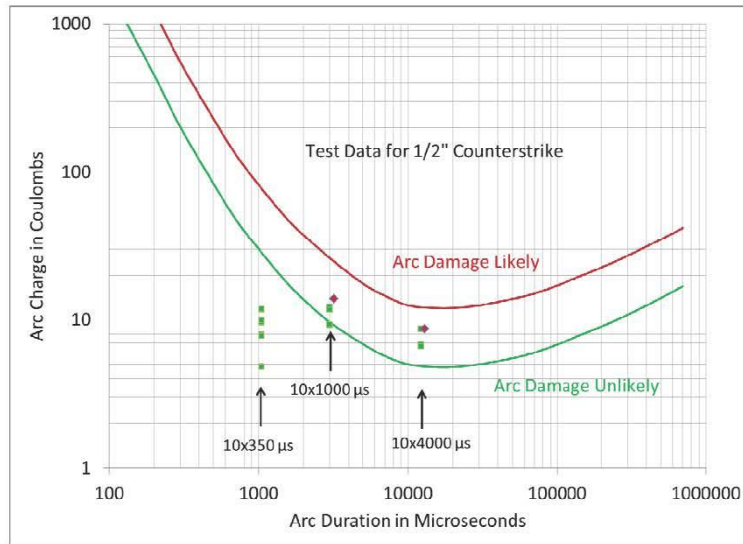


Fig. 6: Arc charge versus duration required to damage 1/2" CounterStrike

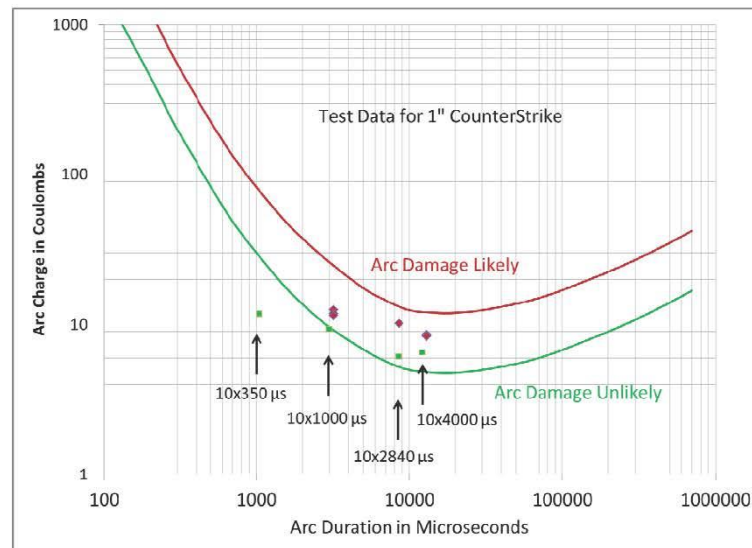


Fig. 7: Arc charge versus duration required to damage 1" CounterStrike

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## ELECTRICAL PARAMETERS OF COUNTERSTRIKE

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### SELF-INDUCTANCE

In order to calculate the distribution of current and voltage on an installation involving CounterStrike, it is necessary to have a reasonably accurate estimate of its electrical self-inductance and resistance of any length involved. These characteristics of conventional CSST have been recently measured by the author [1]. The result of these measurements was that the self-inductance can be calculated using standard formulae using the radius of the conductor as one half of its maximum diameter and that the high-frequency resistance is equivalent to that measured at low frequencies.

The self-inductance of conventional CSST was measured on a two-turn circular loop of the material using a commercial precision LCR meter (Agilent) and the resistance assessed by measuring the voltage drop created by a 1-amp direct current around the loop.

This procedure was repeated for a sample of CounterStrike having a nominal internal diameter of  $\frac{3}{4}$  inch. Using a 30-foot length of the tubing, the two-turn loop was measured to have a diameter of 4 feet 10 inches (1.48 meters). The CounterStrike tubing outside diameter was measured at 1.5 inches (38 mm). The self-inductance of the two-turn loop was measured using the Agilent LCR meter at a frequency of 10 kHz and was found to be 13.95  $\mu$ H. The standard formula (Appendix B) predicts that the self-inductance of a two-turn loop with a loop radius of 2 feet 5 inches (0.74 m) and tubing radius of 0.75 inches (19 mm) is 13.92  $\mu$ H. The difference between the measured and theoretical values is insignificant and again confirm that the standard formulae may be used, taking the radius as half the outside diameter.

### RESISTANCE

The resistance of the nominally 30-foot loop of CounterStrike was assessed by measuring the voltage drop created by an applied 1-amp direct current and found to be 0.50 ohms. A 3-feet 5 inch (1.04 meter) long section of the conductive jacket was removed from the sample of CounterStrike and its resistance measured using the Agilent LCR meter at 1 kHz and found to be 7.4 ohms, or 2.2 ohms per foot (7.1 ohms per meter). The expected resistance of a 30-foot length of the metal tubing from prior measurements on standard CSST is 0.53 ohms. The resistance of a 30-foot length of jacket is approximately 66 ohms, leading to an estimated overall resistance of the jacketed product of 0.52 ohms, close to the measured value of 0.50 ohms.

From these resistance measurements, it may be concluded that the behavior of the material in conducting electricity along the length of the tubing is affected very little by the presence of the conductive jacket, which has a much higher resistance than the metal tubing itself.

### PARAMETERS FOR SIMULATIONS

The above measurements confirm the earlier ones that show that the self-inductance of CSST may be computed using standard (Rosa) formulae using the maximum diameter of the tubing. For CounterStrike, this maximum diameter may be taken as that of the external conductive jacket.

The electrical resistance of CounterStrike is slightly lower than that of comparable CSST provided with an insulating jacket.



## COMPUTER SIMULATIONS

### INDIRECT STRIKE SCENARIOS SIMULATED

Three scenarios were initially developed as part of the original SEFTIM/NFPA study on the benefits of bonding CSST to mitigate arc damage from indirect lightning surges [1] (Appendix C). These scenarios described simplified installations of fuel gas piping and electrical wiring in a residence. Of these, only Scenario 2 was considered fully applicable to a CounterStrike installation. Scenario 2 was also expanded to include the alternative injection of lightning current at the electrical service entrance to give a modified Scenario 3. These are now referred to as Indirect Strike Scenario 1 (Fig. 8) and Indirect Scenario 2 A (Fig. 9) respectively. Replacement of the incoming metallic gas pipe with a plastic non-conducting pipe (considered more representative of present installation practice) was simulated in Scenario 2B (Fig. 10).

The point of simulated arc-attachment is at the mid-point of a 100-foot (30 m) length of CounterStrike. The CSST is connected to a manifold from which a second 16-foot (5m) length of CounterStrike feeds an appliance, which it is electrically grounded to the electrical service. This connection provides the minimum safety bonding of gas piping systems required in residences by the National Electrical Code (Section 250.104 B).

The current magnitude and waveforms in the arc to the CounterStrike jacket, the ground connected to the CSST at the appliance were measured for indirect lightning currents of 10 kA with the standard 10x350  $\mu$ s waveform. In the original simulations, a 30 kV flashover voltage was assumed between the grounded object and the CSST. For the CounterStrike simulations, this voltage is assumed to be zero (direct contact). This assumption results in slightly higher charge transfer to the CounterStrike and may be regarded as a conservative assumption.

### Indirect Strike Scenario 1

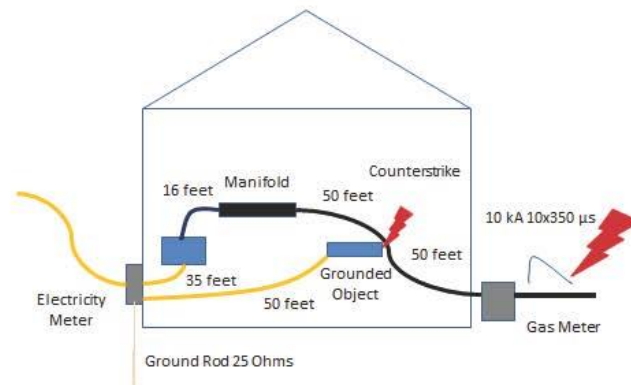


Fig 8: Indirect Strike Scenario 1

## Indirect Strike Scenario 2 A

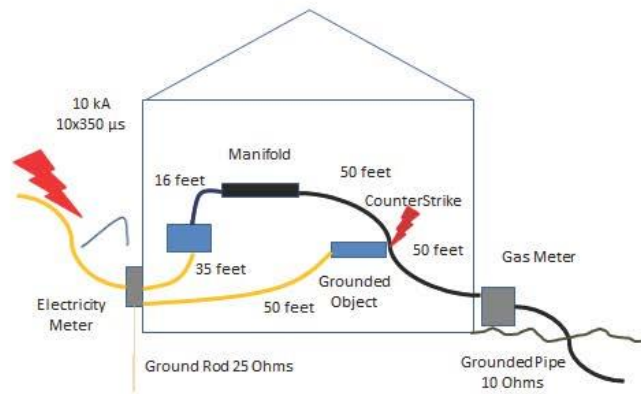


Fig. 9: Indirect Strike Scenario 2 A

## Indirect Strike Scenario 2 B

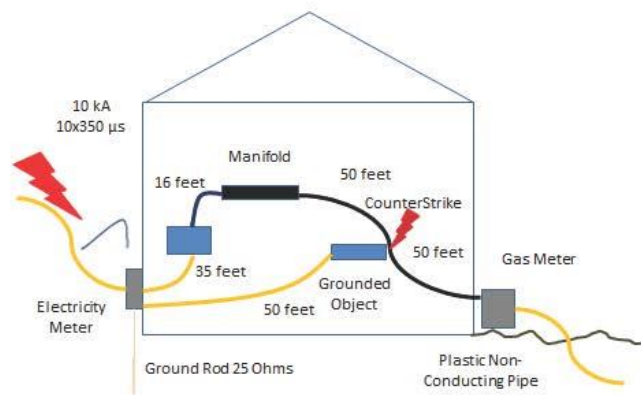


Fig. 10: Indirect Strike Scenario 2 B

Three further scenarios (Figs 11, 12 and 13) were also studied based on the second simulations done as part of the original CSST bonding validation study.



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These scenarios are somewhat similar to the first three except that the gas system is connected to an attic-mounted HVAC system and contact with the jacket occurs 10-feet from this equipment. The grounding conductor of the power supply to this unit provides the required bonding for the CounterStrike.

### Indirect Strike Scenario 3

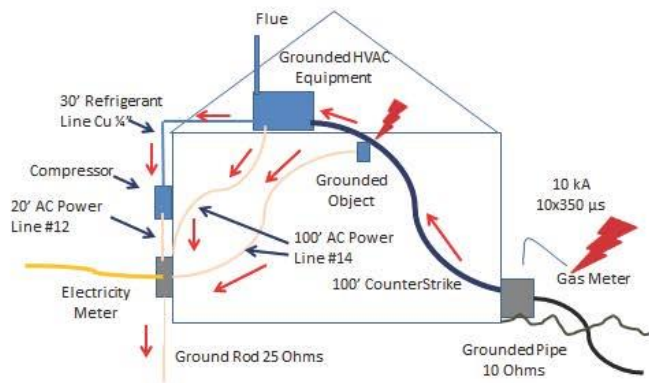


Fig. 11: Indirect Strike Scenario 3

### Indirect Strike Scenario 4 A

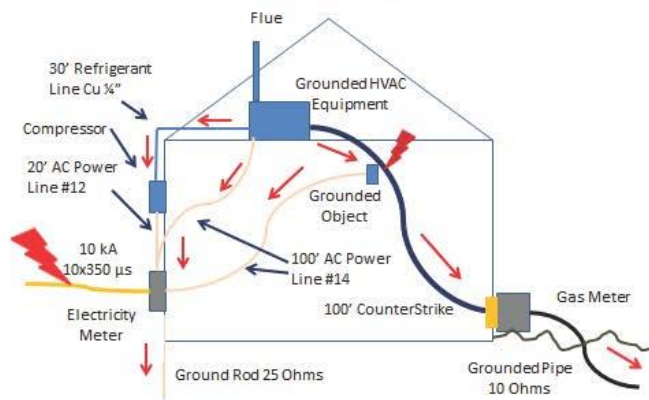


Fig. 12: Indirect Strike Scenario 4 A

### Indirect Strike Scenario 4 B

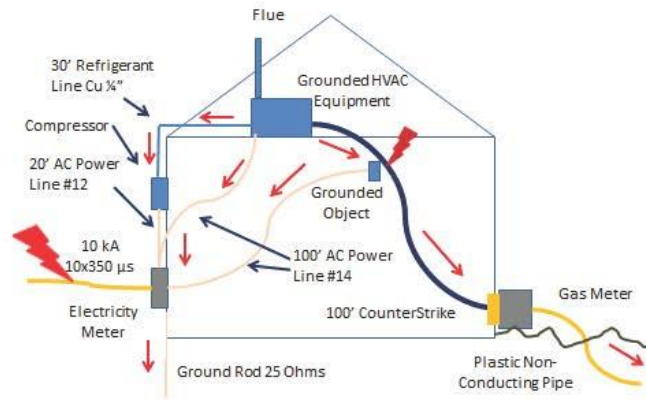


Fig. 13: Indirect Strike Scenario 4 B

## SIMULATION RESULTS

### INDIRECT STRIKE SCENARIO 1

The computed waveshapes for Scenario 1 are shown in Fig. 14 for a current of 10 kA, 10x350  $\mu$ s injected on the incoming gas service at the meter.

In this scenario, the only path for the lightning current into the building is along the gas pipe. The lightning current divides at the point of contact between the CounterStrike and grounded object, but in this scenario this is the lowest impedance path and the majority of the lightning current flows through the arc to the jacket. The charge computed through the arc is nearly 4.5 C and 90% of this is delivered in about 1.1 milliseconds.

From the data shown in Figs. 6 and 7, the arc withstand of CounterStrike for these conditions is likely above 25 C, so no damage is expected.

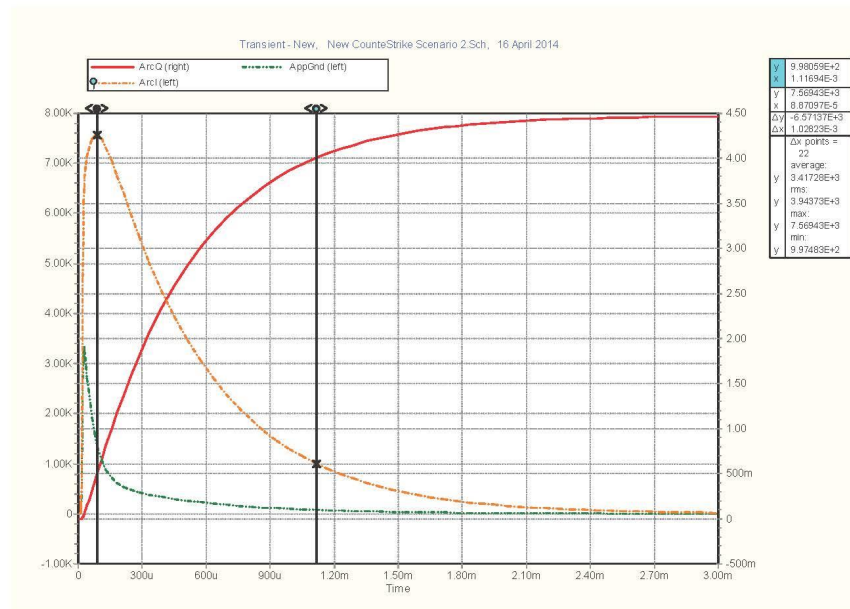


Fig. 14: Scenario 1 calculated waveshapes for 10kA 10x350 $\mu$ s

The continuous red line shows the calculated charge transfer in the arc to the CounterStrike

The dotted red line shows the calculated current in the arc to the CounterStrike

The dotted green line shows the calculated current in the ground

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## INDIRECT STRIKE SCENARIO 2 A

The computed waveshapes for Scenario 2 A for a 10kA 10x350 $\mu$ s wave injected at the electrical service entrance with a buried metallic gas service pipe are shown in Fig. 15.

In this scenario, a substantial portion of the lightning current flows to the electrical service ground, with the other fraction flowing along the gas line. This fraction further divides at the arc contact point, with some current flowing to earth through the buried gas line and another portion flowing through the arc to the grounded object. The charge computed in the arc for this scenario is just over 3 C and again 90% of this charge is delivered in about 1.1 milliseconds.

From the data shown in Figs. 6 and 7, the arc withstand of CounterStrike for these conditions is likely above 25 C, so no damage is expected.

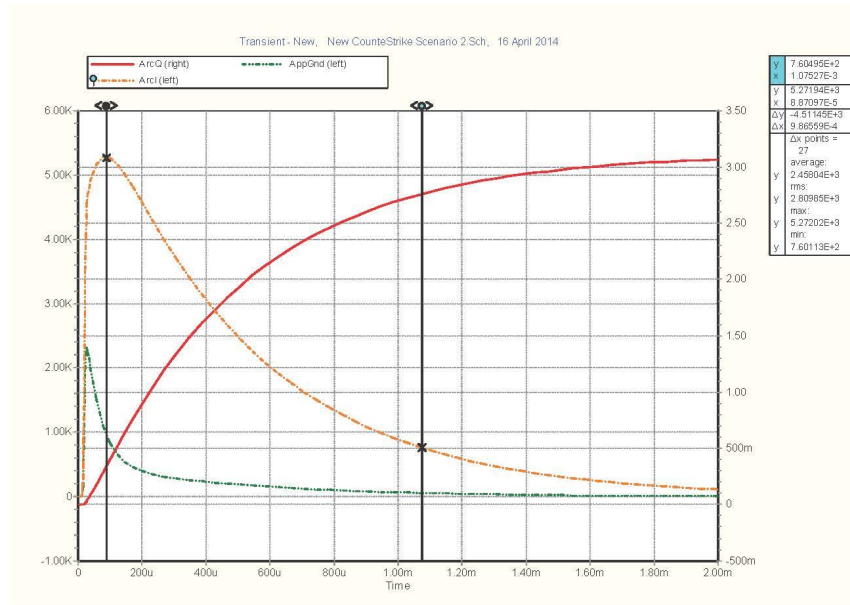


Fig. 15: Scenario 2 A calculated waveshapes 10kA 10x350 $\mu$ s, metallic gas service

The continuous red line shows the calculated charge transfer in the arc to the CounterStrike

The dotted red line shows the calculated current in the arc to the CounterStrike

The dotted green line shows the calculated current in the ground

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## INDIRECT STRIKE SCENARIO 2 B

The computed waveshapes for Scenario 2 B for a 10kA 10x350 $\mu$ s wave injected at the electrical service entrance with a plastic non-conducting gas service pipe are shown in Fig. 16. In this scenario, there is no significant current flow through the CounterStrike jacket.

From the data shown in Figs. 6 and 7, the arc withstand of CounterStrike for these conditions is likely above 25 C, so no damage is expected.

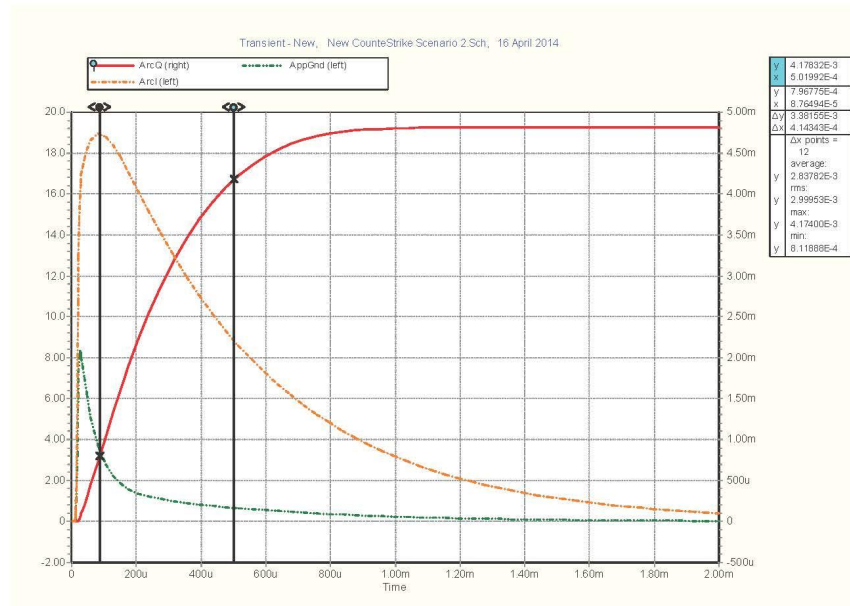


Fig. 16: Scenario 2 B calculated waveshapes 10kA 10x350 $\mu$ s, plastic gas service

The continuous red line shows the calculated charge transfer in the arc to the CounterStrike

The dotted red line shows the calculated current in the arc to the CounterStrike

The dotted green line shows the calculated current in the ground

### INDIRECT STRIKE SCENARIO 3

The computed waveshapes for Scenario 3 for a 10 kA, 10x350  $\mu$ s wave injected on the incoming gas service are shown in Fig. 17. The arc current reaches a peak of just under 1 kA and deposits a total charge of about 0.4 C, with the time to 90% being about 900  $\mu$ s.

From the data shown in Figs. 6 and 7, the arc withstand of CounterStrike for these conditions is likely above 25 C, so no damage is expected.

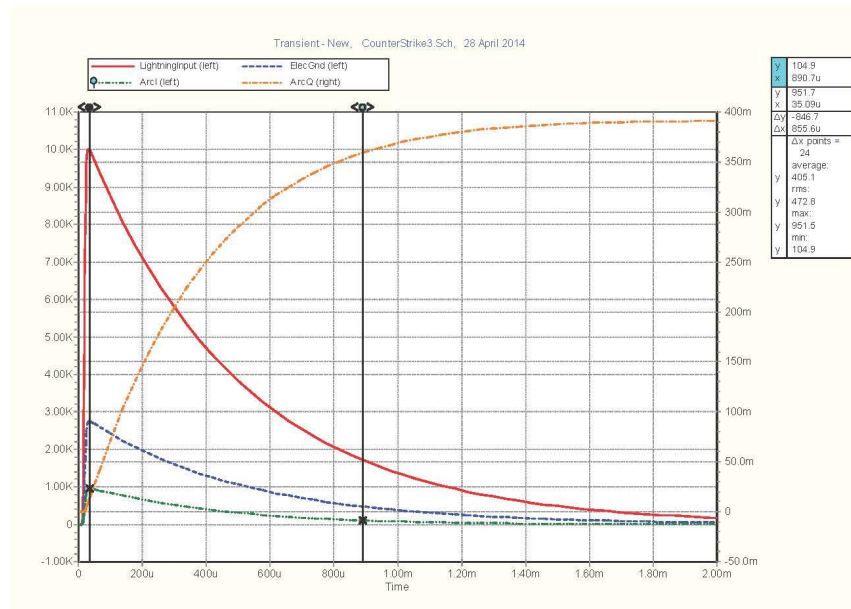


Fig. 17: Scenario 4 A calculated waveshapes 10kA 10x350 $\mu$ s, metallic gas service

The continuous red line shows the lightning input waveform

The dotted red line shows the calculated charge transfer in the arc to the CounterStrike

The dotted green line shows the calculated current in the arc to the CounterStrike

The dotted blue line shows the calculated current in the electrical service ground

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## INDIRECT SCENARIO 4 A

The computed waveshapes for Scenario 4 A for a 10 kA, 10x350  $\mu$ s wave injected on the incoming electricity service are shown in Fig.18. The arc current reaches a peak of about 2.4 kA and deposits a total charge of about 1.0 C, with the time to 90% being about 800  $\mu$ s.

From the data shown in Figs. 6 and 7, the arc withstand of CounterStrike for these conditions is likely above 25 C, so no damage is expected.

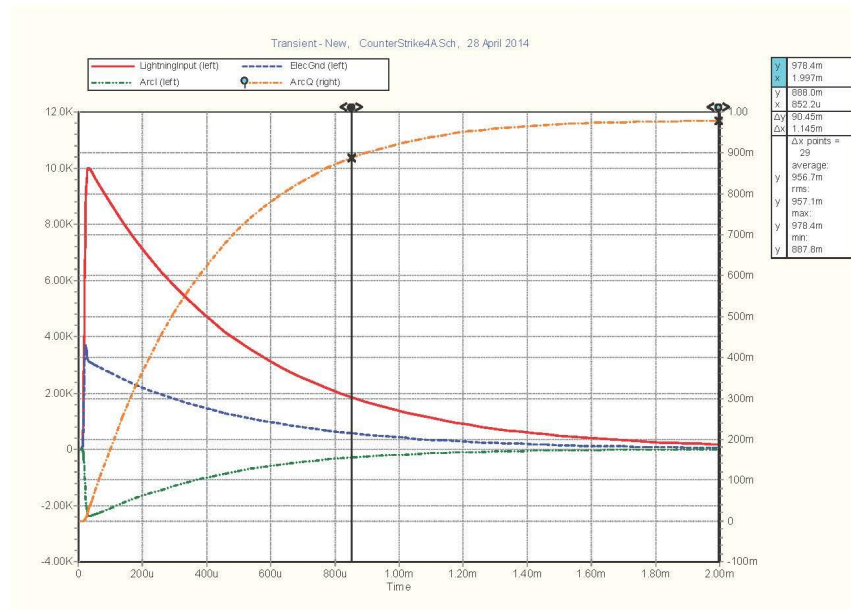


Fig. 18: Scenario 4 A calculated waveshapes 10kA 10x350 $\mu$ s, metallic gas service

The continuous red line shows the lightning input waveform

The dotted red line shows the calculated charge transfer in the arc to the CounterStrike

The dotted green line shows the calculated current in the arc to the CounterStrike

The dotted blue line shows the calculated current in the electrical service ground



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## INDIRECT SCENARIO 4 B

The computed waveshapes for Scenario 4 A for a 10 kA, 10x350  $\mu$ s wave injected on the incoming electricity service are shown in Fig. 19. The arc current reaches a peak of just 9 A, with insignificant charge transfer to the CounterStrike jacket.

From the data shown in Figs. 6 and 7, the arc withstand of CounterStrike for these conditions is likely above 25 C, so no damage is expected.

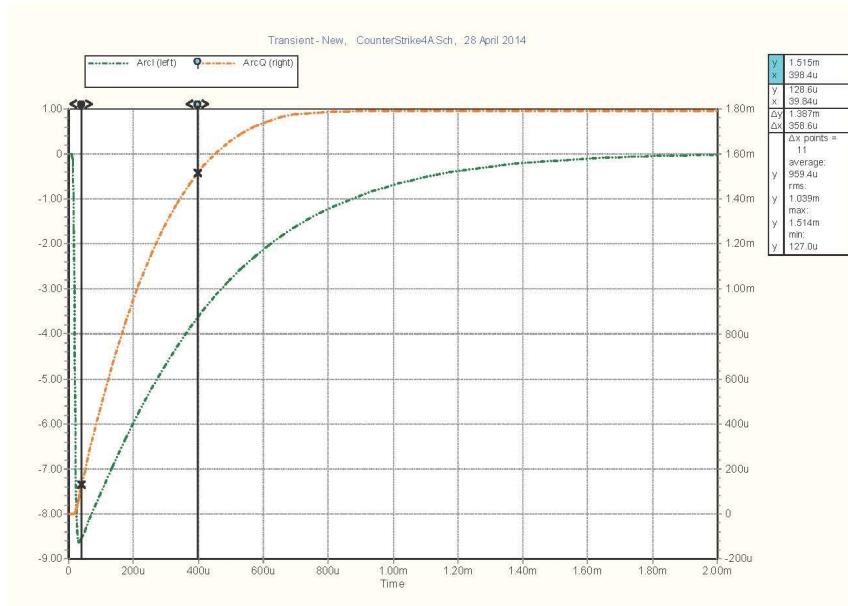


Fig. 19: Scenario 4 B calculated waveshapes 10kA 10x350 $\mu$ s, plastic gas service

The dotted red line shows the calculated charge transfer in the arc to the CounterStrike

The dotted green line shows the calculated current in the arc to the CounterStrike



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## SUMMARY OF SIMULATION RESULTS

| Indirect Strike Scenario  | Arc Current | Arc Duration | Arc Charge | CounterStrike Damage Threshold |
|---------------------------|-------------|--------------|------------|--------------------------------|
| 1 (Metal Gas Service)     | 7.6 kA      | 1.1 ms       | 4.5 C      | ~25 C                          |
| 2 A (Metal Gas Service)   | 5.3 kA      | 1.1 ms       | 3.1 C      | ~25 C                          |
| 2 B (Plastic Gas Service) | 19 A        | 0.5 ms       | ~ 0.1 C    | ~25 C                          |
| 3 (Metal Gas Service)     | 950 A       | 0.9 ms       | 0.4 C      | ~ 25 C                         |
| 4 A (Metal Gas Service)   | 2.4 kA      | 0.8 ms       | 1.0 C      | ~ 25 C                         |
| 4 B (Plastic Gas Service) | 9 A         | 0.4 ms       | 0.0 C      | ~ 25 C                         |

Table 1: Summary of simulation results

## DISCUSSION OF COUNTERSTRIKE SIMULATIONS

As already noted, the input lightning current selected for the original CSST bonding study [1] was 10 kA with a double-exponential waveshape of 10x350  $\mu$ s, which is generally regarded as rather severe for exposure of building services to indirect or partial direct lightning currents. This wave delivers a total electric charge of about 5 coulombs in a time of just over 1 millisecond and appears incapable of rupturing CounterStrike, even if the total charge were to be discharged through a single arc to the jacket. Indeed, it appears from Fig. 5 that CounterStrike may be able to withstand arc discharges having a waveshape of 10x350  $\mu$ s at currents of up to 50kA (charge of 25 coulombs) without damage. This magnitude likely covers not only all indirect scenarios but also a significant portion of direct strikes also.

Simulation results of scenario 1 show a large part of the incident lightning current deposited through the arc to the CounterStrike jacket, with a total charge transfer computed at 4.5 coulombs. Simulation results of scenario 2 A show rather less current and charge through the arc, but a still significant 3.1 coulombs. The simulation result of scenario 2 B shows an insignificant current flow through the arc to the CounterStrike jacket. The simulation results of scenario 3 show a modest charge transfer of 0.4 coulombs. The results of simulation 4A show about one fifth of the lightning charge through the arc, or 1.0 coulombs. Similarly to the results of the simulation of scenario 2 B, replacement of a buried metal gas service with an insulating plastic pipe in scenario 4 B dramatically lowered the current and charge flow to the CounterStrike.

These simulations show that the presence of a grounded metallic gas service that is not electrically bonded to the electrical service ground significantly increases current flow from indirect lightning currents entering on the electric utility and exacerbates damage in such cases where an arc occurs to gas tubing. However, it should be noted that plastic pipes are now being used for buildings of new construction and such services will become predominant.

These data points from Table 1 are shown with the arc susceptibility curves developed for CounterStrike in Fig. 20. All three simulation calculated arc charge/duration points lie below the lower (green) susceptibility curve, suggesting that no arc damage would occur. The data point for Scenario 2B is not shown as it was far below the plotted ranges.

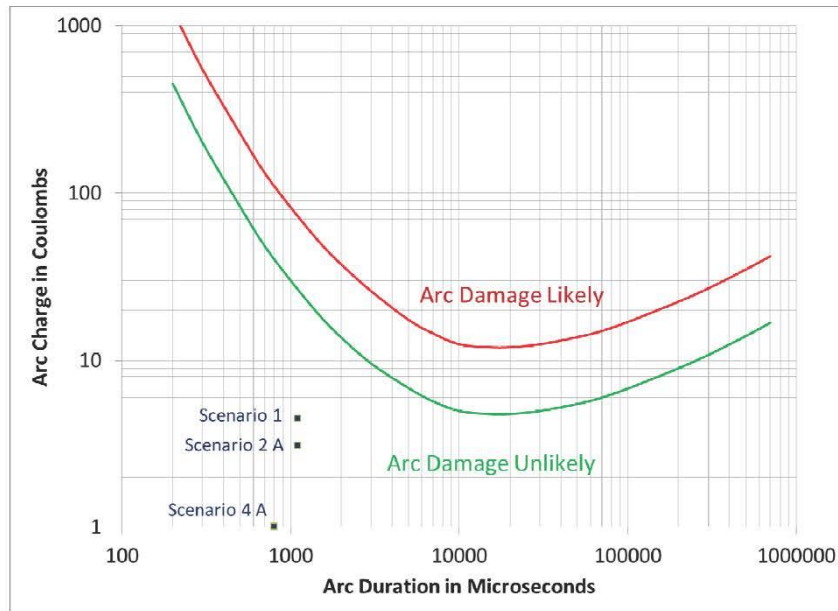


Fig. 20: Arc susceptibility curves for CounterStrike with simulation data

#### COMPARISON WITH BONDED TRACPIPE SIMULATIONS

The comparative performance of TracPipe (insulated yellow jacket) CSST with CounterStrike (conducting jacket) is of interest, particularly for installations in which CounterStrike is grounded only through connected equipment and not with a direct bonding conductor as used for TracPipe installations.

To compare these, the original simulations 1 and 2 for TracPipe equipped with a 75 foot #6 bonding conductor were compared with a similar installation in which CounterStrike was grounded only indirectly through electrical equipment. The configuration of these simulations is similar to those shown in Figs. 9 and 10.

As expected, without the bond, significantly larger currents and charge flowed through the simulated arc to the CSST, approaching the full 5 coulombs of the incident lightning current. With a 75 foot bonding conductor, arc currents were computed to be both significantly smaller in magnitude and shorter in duration. In both cases, the expected charge transferred through the arc to the CSST was well below the threshold of damage for the particular CSST product. These data points are illustrated in Fig. 21.

These data may also be interpreted by the ratio between the incident arc charge and the expected threshold of susceptibility of the CSST, which gives a measure of the safety factor. These are shown for the two scenarios for Bonded TracPipe and Unbonded CounterStrike in Table 2.

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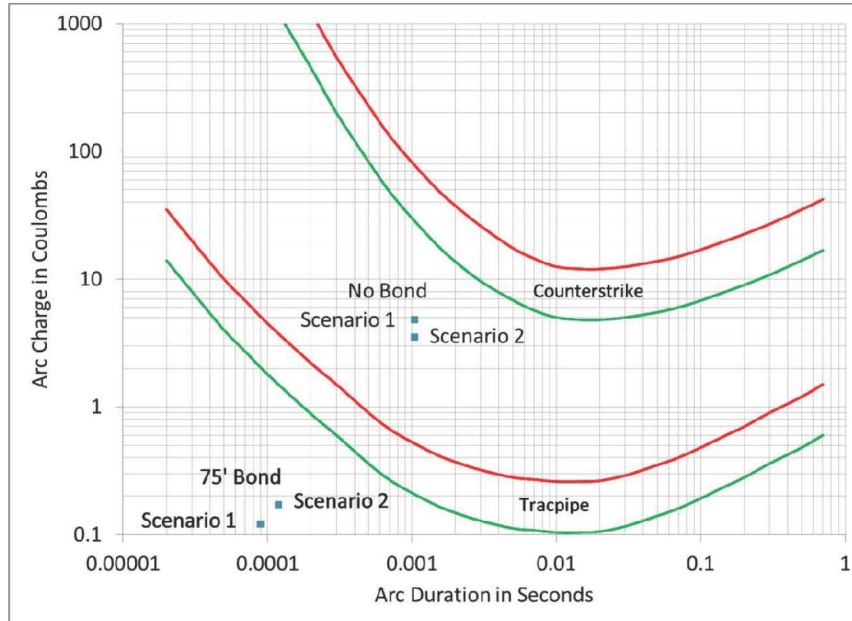


Fig. 21: Comparison between Indirect Strike Performances of Bonded TracPipe with Unbonded CounterStrike

| Scenario                  | Arc Charge | Duration | CSST Withstand | Safety Factor |
|---------------------------|------------|----------|----------------|---------------|
| # 1 Bonded TracPipe       | 0.12       | .00009   | 2.0            | 16.7          |
| #2 Bonded TracPipe        | 0.17       | .00012   | 1.5            | 8.8           |
| #1 Unbonded CounterStrike | 4.8        | .0011    | 30             | 6.3           |
| #2 Unbonded CounterStrike | 3.5        | .0011    | 30             | 8.6           |

Table 2: Comparison of Safety Factor between Bonded TracPipe and Unbonded CounterStrike

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## CONCLUSIONS

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The laboratory measurements of electrical self-inductance and resistance of CounterStrike CSST show it to have similar characteristics to other metallic conductors when subjected to impulsive lightning currents.

Experimental measurements of the arc resistance of CounterStrike when subjected to simulated lightning currents show that it has more than fifty times the arc-resistance of conventional CSST.

Simulations of the expected distribution of lightning current for installation scenarios developed initially for the evaluation of the effectiveness of bonding for protecting conventional CSST against indirect lightning strikes [1] were adapted to evaluate CounterStrike. These simulations show that CounterStrike will be immune from the effects of indirect lightning at the 10 kA levels with the 10x350  $\mu$ s waveform used for this evaluation and likely will survive impressed currents of up to 50 kA and arc charges of up to 25 coulombs. These are severe levels more consistent with the effects of direct lightning strikes than the lower energy indirect events.

For these indirect strike scenarios, it may be concluded that CounterStrike will be immune from lightning damage, even if it is bonded only indirectly through the grounding conductor of the electrical equipment to which it is connected.

Comparison between the performance of TracPipe equipped with a bonding conductor and CounterStrike grounded only indirectly through electrical equipment shows large and comparable safety margins. The performance of both is expected to be similar.

It should finally be noted that the scope of this report is limited to the effects of lightning on gas tubing and is not intended to be a comprehensive study of the effects of lightning on the gas and electrical services in buildings or the safety of gas systems in general. Furthermore, this study pertains to the individual tubing components of a gas supply system and not to the whole system. Lightning damage to the other components of a gas supply system, including appliance connectors, control valves, pressure regulators and similar devices is possible. A full analysis of the safety of gas piping systems, whether rigid steel pipe or flexible tubing, would require further comprehensive study.



Michael F. Stringfellow

22 December 2014

Chief Scientist

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## APPENDIX A

### COMPUTER SIMULATION MODELS

#### SCENARIO 1

The computer model used for Scenario1 is shown in the schematic below. The 10 kA, 10x350  $\mu$ s indirect lightning current is applied at the gas meter.

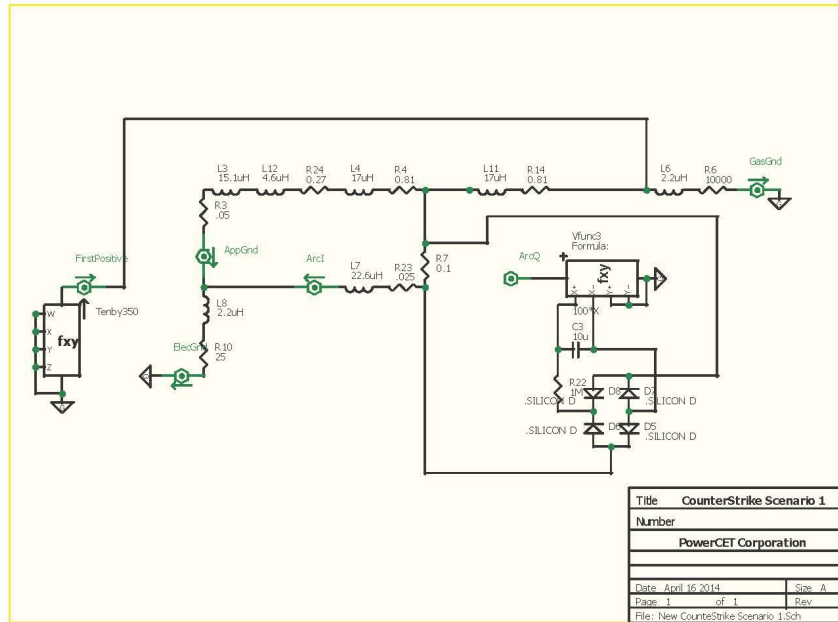


Fig. A1: Scenario 1 simulation model

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## SCENARIO 2

The computer model used to simulate Scenario 2 is shown in the schematic below. The 10 kA, 10x350  $\mu$ s indirect lightning current is applied at the electric service entrance. The incoming gas service is simulated as plastic by increasing the grounding resistance R6 from 10 ohms to 10,000 ohms.

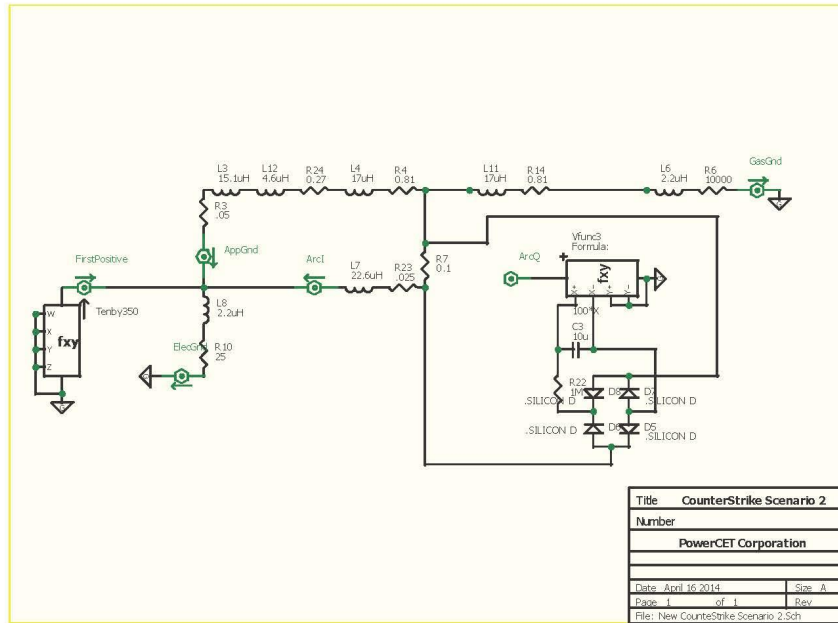


Fig. A2: Scenario 2 simulation model

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## SCENARIO 3

The computer model used for Scenario 3 is shown in the schematic below. The 10 kA, 10x350  $\mu$ s indirect lightning current is applied at the gas meter.

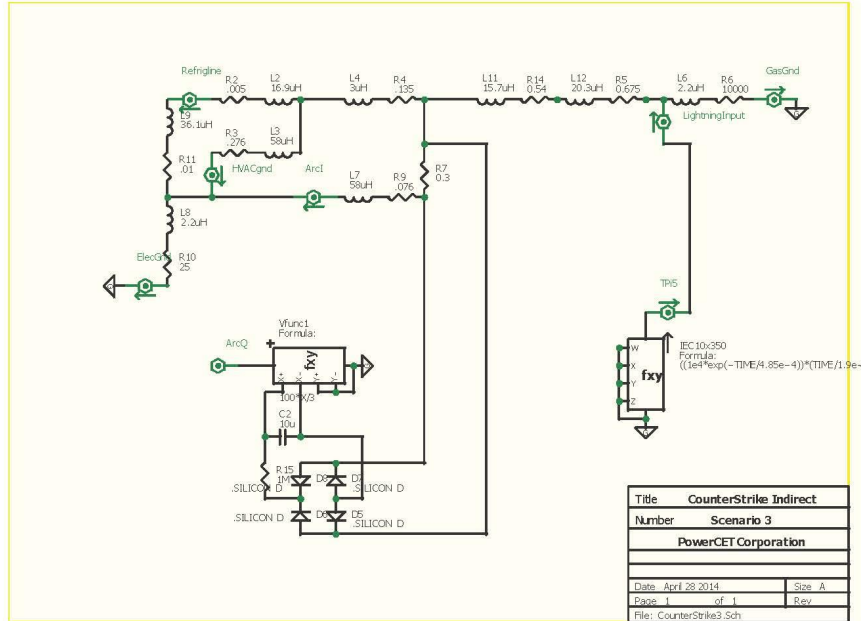


Fig. A 3: Scenario 3 simulation model



## SCENARIO 4

The computer model used to simulate Scenario 4 is shown in the schematic below. The 10 kA, 10x350  $\mu$ s indirect lightning current is applied at the electric service entrance. The incoming gas service is simulated as plastic by increasing the grounding resistance R6 from 10 ohms to 10,000 ohms.

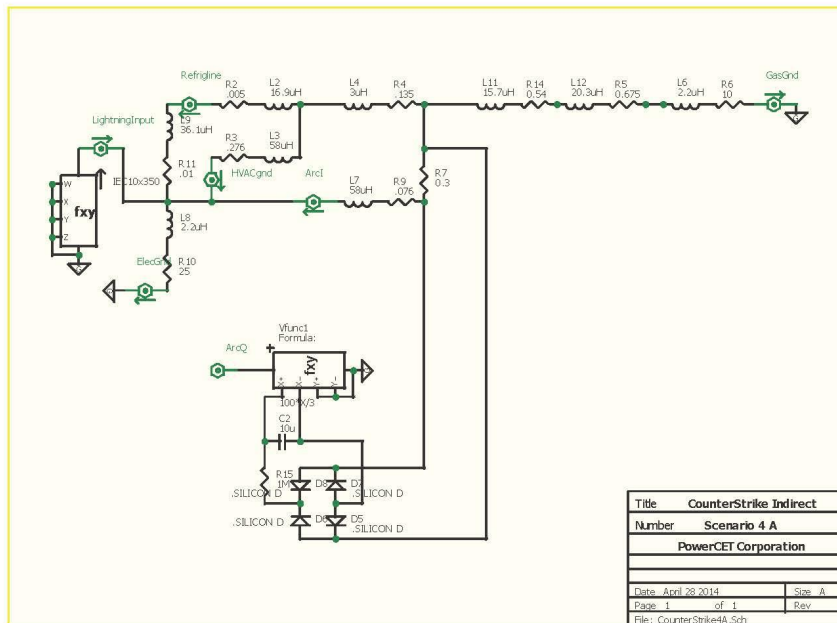


Fig. A 4: Scenario 4 simulation model

## APPENDIX B

## MEASURED &amp; CALCULATED SELF-INDUCTANCE OF CSST

## MEASURED &amp; CALCULATED INDUCTANCE OF CSST LOOPS

The measurement of the self-inductance of linear conductors is non-trivial, since any laboratory measurement requires the injection of a current into the conductor as well as its return to the source through a second conductor. The self-inductance of the return conductor as well as mutual inductance between circuit elements makes this approach subject to variation resulting from the geometry of the test set-up.

PowerCET's approach is to measure the self-inductance of loops of conductor, which ensures that any test current injected flows only on the CSST and not on any other required return circuits. The measured value of inductance measured in this way is then compared with the calculated value of inductance using the standard formula given below:

$$L = \mu_0 n^2 R (\ln(8R/r) - 2)$$

Where L is the self-inductance of the circular loop, R is the radius of the loop, n the number of turns and r the radius of the CSST. This formula ignores skin effects, considered a valid assumption for the frequencies involved.

Four samples were measured in this way, a 6.32 m length of ½" CSST formed into a two-turn circular loop of inside diameter 1.003m, a 4.445m length of ½" CSST formed into a two-turn loop of 0.346m inside diameter and a 4.445m length of 1" CSST formed into a two-turn loop of 0.338m inside diameter and a 9.3m length of ¾" CounterStrike. The self-inductance of each of these four samples was measured using an Agilent LCR meter. The calculated self-inductance was derived from the above formula, taking the effective radius of each CSST sample as half its maximum diameter (0.0095m for ½" CSST, 0.016m for 1" CSST and .019m for ¾" CounterStrike). The results of these measurements and calculations are shown in Table B1 below:

| Sample                                | Measured Self-Inductance<br>@ 10kHz | Calculated Self-Inductance |
|---------------------------------------|-------------------------------------|----------------------------|
| Two turns, 6.32m of ½" CSST           | 9.61µH                              | 10.15µH                    |
| Two turns, 4.445m of ½" CSST          | 6.35µH                              | 6.39µH                     |
| Two turns, 4.445m of 1" CSST          | 5.38µH                              | 5.32µH                     |
| Two turns, 9.30 m of ¾" CounterStrike | 13.95µH                             | 13.92µH                    |

Table B1: Measured and calculated self-inductance of CSST loops

---

## CALCULATED INDUCTANCE OF LINEAR CSST

---

The self-inductance of linear conductors may be calculated using the formula attributed to Rosa:

$$L = (\mu_0/2\pi)l(\ln(2l/r)-1)$$

Where L is the self-inductance of the linear conductor, l is its length and r is its radius. Like the earlier formula for circular loops, this also ignores skin effects.

---

## CONCLUSIONS

---

The measured data for self-inductance of CSST show that it may be calculated to an accuracy of better than 90% using standard formulae. The Rosa formula for linear conductors may be applied, taking the effective radius of the CSST as one half of its largest diameter. The estimated self-inductance of linear ½" and 1" TracPipe and ¾" CounterStrike tubing for various lengths is given below in Table B2.

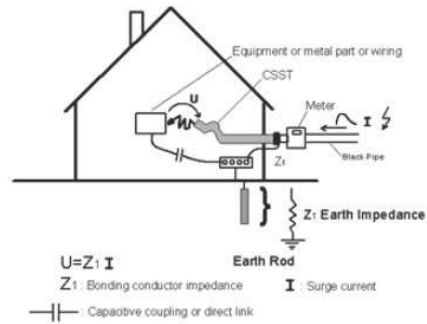
| Length in meters | Self-Inductance ½" CSST | Self-Inductance 1" CSST | Self-Inductance ¾" CounterStrike |
|------------------|-------------------------|-------------------------|----------------------------------|
| 1                | 0.87µH                  | 0.77µH                  | 0.73µH                           |
| 2                | 2.02µH                  | 1.81µH                  | 1.74µH                           |
| 5                | 5.96µH                  | 5.44µH                  | 5.27µH                           |
| 10               | 13.3µH                  | 12.3µH                  | 11.9µH                           |
| 30               | 46.5µH                  | 43.4µH                  | 42.4µH                           |

Table B2: Calculated self-inductance of TracPipe and CounterStrike

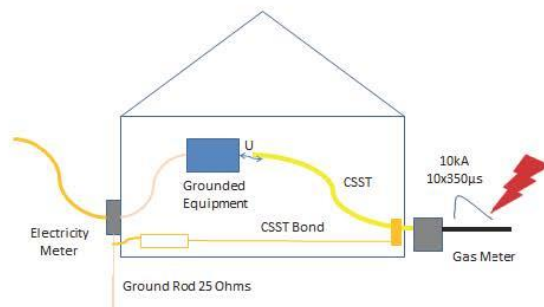
## APPENDIX C

SIMULATION SCENARIOS DEVELOPED FOR ORIGINAL STUDY

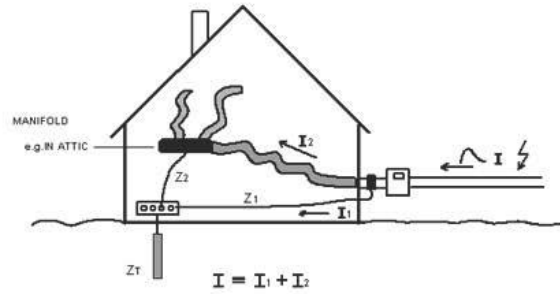
### SEFTIM Proposed Scenario 1



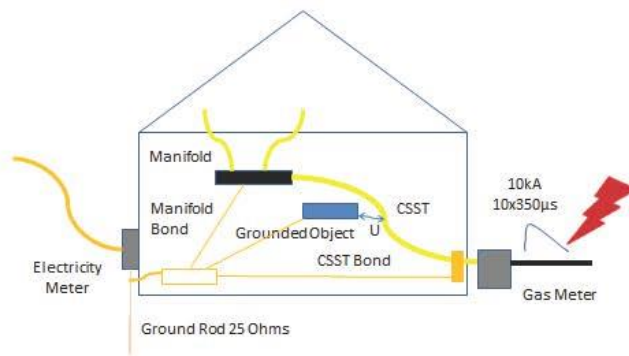
### MFS Proposed Scenario 1



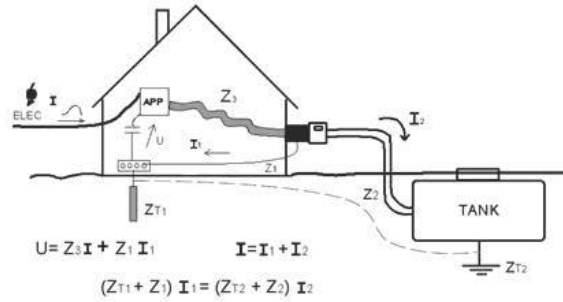
## SEFTIM Proposed Scenario 2



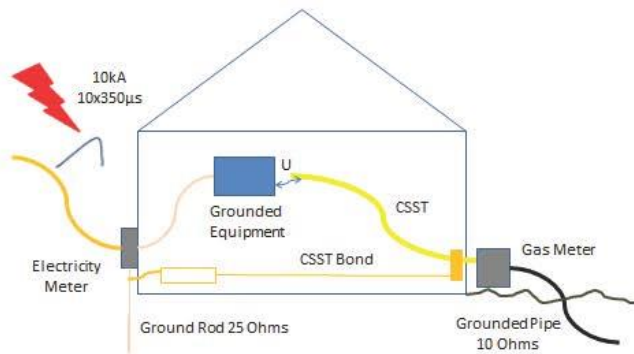
## MFS Proposed Scenario 2



### SEFTIM Proposed Scenario 3



### MFS Proposed Scenario 3



## APPENDIX D

### LIGHTNING AND TEST WAVEFORMS

Lightning ground flashes may be considered to be a current source that consists of one or more impulsive currents together with longer continuing currents that may carry either negative or positive current from cloud to ground.

Negative downward lightning flashes, which comprise about 85% of ground flashes in the USA, have electrical parameters that are well-defined. Several experimental studies have recorded the magnitude and waveshape of first and subsequent strokes as well as continuing currents in these events. The median peak current for first negative strokes is 30 kA, 95% are larger than 14 kA and 5% are larger than 80 kA. The charge delivered by first strokes has a distribution of 95% larger than 1.1 C, a median of 5.2 C and 95% exceed 24 C. The charge delivered by subsequent strokes has a median of 1.4 C, 95% exceed 0.2 C and 5% exceed 11 C. The charge delivered by the whole negative flash has a median value of 7.5 C, 95% exceed 1.3 C and 5% exceed 40 C.

The risetime of the first stroke has a median of 5.5  $\mu$ s and 5% are shorter than 1.8  $\mu$ s. The time to half value (tail time) has a median value of 75  $\mu$ s and 5% are longer than 200  $\mu$ s.

Positive downward flashes comprise about 15% of ground flashes in the USA and have electrical properties that are less well known. Most data on positive flashes that are used for lightning protection were derived from measurements of Berger on a mountain-top tower in Switzerland. It is widely acknowledged that Berger's data on positive flashes consisted mainly of upward discharges that are not representative of downward flashes. These upward flashes are believed to have longer durations and larger charge transfer than downward flashes. However, data from other sources does confirm that positive flashes have a greater incidence of large magnitude peak currents than negative flashes and also frequently contain continuing current that transfers more charge than negative flashes.

Berger's data gives a median positive flash current peak of 35 kA, 95% exceed 6 kA and 5% exceed 250 kA. The impulsive stroke charge has a median of 16 C, 95% exceed 90 C and 5% exceed 150 C. Total positive flash charge has a median of 80 C, 95% exceed 20 C and 5% exceed 350 C. These data give median risetimes for positive flashes of 22  $\mu$ s, with 5% shorter than 3.5  $\mu$ s. Stroke duration has a median value of 230  $\mu$ s with 5% longer than 2 milliseconds.

Over the years, many laboratory test waveforms have been used to simulate lightning voltages and currents. The earliest impulsive voltage test waveforms used were double-exponential waves of approximately 1x50  $\mu$ s and the earliest impulsive current waveform was 8x20  $\mu$ s. The latter was selected because of limitations of early surge generators rather than being considered representative of lightning and it was discovered that discharging an 8x20  $\mu$ s wave through a lightning arrester resulted in an approximately 1x50  $\mu$ s voltage wave. Lightning currents in communications circuits were found to be longer duration, so a standard waveform of 10x1000  $\mu$ s was developed for testing these. Continuing currents of lightning were simulated either by double-exponential waves of long duration or by rectangular waves (a switched dc source).

More recently, emphasis has been placed on the more energetic positive flashes and several waveforms have been developed for laboratory testing. The most common of these is the 10x350  $\mu$ s wave, developed originally as a German DIN standard and adopted by the International Electrotechnical Commission (IEC) in its Lightning Protection Standards.

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The tests in this report are based on both laboratory tests and computer simulations using the 10x350  $\mu$ s and 10x1000  $\mu$ s standard waveforms as well as two non-standard 10x2840  $\mu$ s and 10x4000  $\mu$ s waveforms. The latter resulted from limitations in the test generator.

---

## STANDARD REFERENCES

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1. ANSI/IEEE C 62.1-1984, Standard for Surge Arresters for AC Power Circuits.
2. ANSI C62.91-1982, Standard for Power Systems – Insulation Coordination
3. ANSI/IEEE C62.41-1991, Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits
4. Overvoltage Protection of Low Voltage Systems, Peter Hasse, IEE London, 2000
5. IEC 62305–2013, Protection Against Lightning Part 1, General Principles





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**PMG-1058**

Valid: 02/15 to 02/16

**DIVISION: 23 00 00—HEATING, VENTILATING, AND AIR-CONDITIONING**  
**SECTION: 23 11 00—FACILITY FUEL PIPING**

**REPORT HOLDER:**

**OMEGAFLEX® INC.**

**451 CREAMERY WAY  
EXTON, PA 19341-2509**

**EVALUATION SUBJECT:**

**TRACPIPE® COUNTERSTRIKE® CONDUCTIVE JACKETED  
CORRUGATED STAINLESS STEEL TUBING**



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CSI: DIVISION: 23 00 00—HEATING, VENTILATING, AND AIR-CONDITIONING  
Section: 23 11 00—Facility Fuel Piping

## Product certification system:

The ICC-ES product certification system includes testing samples taken from the market or supplier's stock, or a combination of both, to verify compliance with applicable codes and standards. The system also involves factory inspections, and assessment and surveillance of the supplier's quality system.

Product: TracPipe® CounterStrike® Conductive Jacketed Corrugated Stainless Steel Tubing

Listee: OmegaFlex® Inc.  
451 Creamery Way  
Exton, Pennsylvania 19341-2509  
[www.omegaflex.com](http://www.omegaflex.com)

## Compliance with the following codes:

2015, 2012, 2009 and 2006 *International Fuel Gas Code*® (IFGC)  
2015, 2012, 2009 and 2006 *International Mechanical Code*® (IMC)  
2015, 2012, 2009 and 2006 *International Residential Code*® (IRC)  
2012, 2009 and 2006 *Uniform Plumbing Code*® (UPC)\*  
2012, 2009 and 2006 *Uniform Mechanical Code*® (UMC)\*

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## Compliance with the following standards:

ANSI LC 1/CSA 6.26-2014, Fuel Gas Piping Systems Using Corrugated Stainless Steel Tubing (CSST)  
NFPA 54-2015, National Fuel Gas Code  
ICC-ES LC1024-2012, PMG Listing Criteria for Corrugated Stainless Steel Tubing Utilizing a Protective Jacket

## Identification:

Tubing: Each 2 feet (610 mm) of tube bears the trade names TracPipe® CounterStrike®, part number, rated pressure [5 psi (34 kPa)], equivalent hydraulic diameter (EHD), the words "Fuel Gas", and the ICC-ES PMG listing mark.

Components: Fittings, termination outlets and distribution manifolds are stamped with the OmegaFlex® logo, the part number and a date stamp.

Listings are not to be construed as representing aesthetics or any other attributes not specifically addressed, nor are they to be construed as an endorsement of the subject of the listing or a recommendation for its use. There is no warranty by ICC Evaluation Service, LLC, express or implied, as to any finding or other matter in this listing, or as to any product covered by the listing.

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Page 1 of 2

## Installation:

**General:** Installation must be in accordance with the TracPipe® Flexible Gas Piping Guide and Installation Instructions, IFGC Section 404, IRC Section 2415, UMC Section 1309 and UPC Section 1211, as applicable. The system installation consists of CSST distribution lines installed between the point of delivery and fuel gas appliances. The use and system installation must be in accordance with ICC-ES PMG-1046.

**Plenum Installation:** When tested in accordance with ASTM E 84, TracPipe® CounterStrike® satisfies the plenum installation requirement, with a flame spread index of less than 25 and a smoke developed index of less than 50.

**Electrical Bonding:** The TracPipe® CounterStrike® Conductive Jacketed Corrugated Stainless Steel Tubing (CSST) System is electrically continuous and is considered to be bonded where it is connected to appliances that are connected to the equipment grounding conductor of the circuit supplying that appliance. Additional bonding prescribed by IFGC Section 310.1.1 is not required for TracPipe® CounterStrike® Conductive Jacketed Corrugated Stainless Steel Tubing when it is installed in accordance with this listing.

**Models:** The TracPipe® CounterStrike® Conductive Jacketed CSST System consists of three parts: (1) a black conductive exterior jacket; (2) corrugated stainless steel tubing which is recognized in PMG-1046 as conforming to ANSI LC-1; and (3) mechanical fittings designed for use only with the OmegaFlex® Inc. CSSTs. Mechanical fittings utilize a metal-to-metal seal, and include mechanical fittings, distribution manifolds, shutoff valves, termination outlet devices, pressure regulators and protection devices.

## Conditions of Listing:

1. TracPipe® CounterStrike® has been tested (in accordance with LC1024) and shown to resist a transient arc of 1000 amps minimum peak delivering 4.5 coulombs within 20 milliseconds (0.020 seconds). Assumed energy associated with a transient arc from lightning inside a building is less than 2.0 coulombs, providing a factor of safety of 2.25 for CounterStrike. Evaluation of this product for an arc exceeding this level or a direct strike from lightning is outside the scope of this listing.
2. The CSST piping system must not be used as a grounding electrode for an electrical system.
3. Additional information and requirements are defined in ICC-ES PMG-1046.
4. The TracPipe® CounterStrike® is manufactured by OmegaFlex® Inc. in Exton, Pennsylvania, under a quality control program with semi-annual surveillance inspections by ICC-ES.

TABLE 1—PART NUMBERS FOR TRACPIPE COUNTERSTRIKE TUBING

| TUBING SIZE (inches) | PART NUMBER    |
|----------------------|----------------|
| $\frac{3}{8}$        | FGP-CS-375-XXX |
| $\frac{1}{2}$        | FGP-CS-500-XXX |
| $\frac{3}{4}$        | FGP-CS-750-XXX |
| 1                    | FGP-CS-100-XXX |
| $1\frac{1}{4}$       | FGP-CS-125-XXX |
| $1\frac{1}{2}$       | FGP-CS-150-XXX |
| 2                    | FGP-CS-200-XXX |

For SI: 1 inch = 25.4 mm.

XXX: Length of tubing in feet.

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*Marking and Application Guide*

# **DAMPERS**

**JANUARY 2015**

Dampers  
Marking and Application Guide

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## PREFACE

**Fire and smoke protection** - Building codes rely on fire and smoke protection features to safeguard the public from fire hazards and hazards associated with smoke and hot gases attributed to the built environment during a fire situation and to provide safety to fire fighters and emergency responders during emergency operations. One aspect of this protection is based on limiting the movement of fire, along with the associated smoke and toxic gases, through the building using a compartmentation approach. This includes requiring fire-resistance-rated assemblies, such as fire walls, fire barriers, fire partitions, smoke barriers, shaft enclosures and horizontal assemblies be provided to limit the spread of fire. Building codes also include requirements designed to limit the movement of smoke and toxic gases through the building using smoke barriers and partitions. This passive protection is an integral part of the overall safety scheme included in the codes.

An important aspect of limiting the spread of fire, smoke and toxic gases is protecting openings in fire and smoke rated assemblies that are provided to allow the building to be functional. Dampers are often used to protect openings for heating, ventilation and air conditioning (HVAC) ducts through these rated assemblies. This includes fire, smoke, combination fire-smoke, ceiling radiation and corridor dampers. UL certifies all five of these types of dampers in accordance with the requirements in building codes. These dampers and the applications for which they are certified are covered in detail in this guide. More information on those products is located on the UL Online Certifications Directory.

UL has developed this guide for use by code authorities, architects, contractors, installers and other interested parties. It is intended to aid in understanding the types of dampers which exist, in association with the applicable codes and standards to facilitate safe, code-compliant installations.

UL Marking and Application Guides are updated as necessary due to new product development, changes in the codes, or the need for clarification. To confirm the current status of any UL Marking and Application Guide, please consult the Code Authorities page of the UL Web site at [www.ul.com/codeauthorities](http://www.ul.com/codeauthorities).

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# 1. INTRODUCTION

## A. USE OF THIS GUIDE

This guide is intended to assist code authorities, architects, contractors, installers and other interested parties in determining the suitability of fire, smoke, combination fire-smoke, ceiling radiation and corridor dampers in a particular installation and use, and to address concerns related to fire and smoke related performance.

Products are Certified, Listed or Classified by UL under an appropriate product category. A four-letter code (shown in parenthesis) following every category title in this guide is the UL product category code designation. A list of damper related product categories, along with the applicable category code and standard(s), can be found in Appendix A.

Each UL product category code provides a direct link to the Guide Information for the product category. The Guide Information includes the scope of the products covered, information relating to limitations or special conditions applying to the product, the requirements used for the investigation of the products, general installation and use information, and information on product markings and the UL Mark to be used on the product. Guide information is available in the UL Online Certifications Directory at [www.ul.com/database](http://www.ul.com/database).

The product markings identified in this Guide do not include every possible marking that could be provided either on a product or in its installation or operation instructions. The purpose of this Guide is to provide you with an indication of the type of text and location of markings that address features that may be critical in determining if a product is certified and / or if it is installed correctly. Refer to the specific Guide Information for the product category for additional marking information.

The numbering for code sections used in this document may change as the code is updated. A list of model codes and standards applicable for products covered by this guide can be found in Appendix B.

## B. INFORMATION ON CERTIFICATION, LISTING AND CLASSIFICATION

Most codes and regulations require the certification of products to applicable safety-related standards. They also may require these products to be certified to performance standards as well. Products that are certified to safety-related standards have been evaluated with regard to all reasonably foreseeable safety-related hazards, including fire, electrical shock and mechanical hazards. Such products are termed “UL Listed.” Products that are certified to a limited range of hazards, or for use under specific conditions are termed “UL Classified”. Alternatively, any of these products can be “UL Certified” and bear the UL Certification Mark.

It is important to distinguish the difference between “UL Listed” and “UL Classified” and the relation these terms have with the term “listed,” as used in various codes. The term “listed” in the codes generally indicates that the product is required to be evaluated in accordance with the appropriate standard(s) by an independent third party certification organization such as UL. The term “listed” in the codes should not be confused with the term “UL Listed,” as explained above. It is important to recognize that not all certification agencies make this distinction in their certification services.

## C. UL MARK CONSIDERATIONS

There are several types of UL Marks that are utilized for building products. General information on the UL Marks is provided below. Each has its own specific meaning and significance. The only way to determine if a product has been certified by UL is to look for the UL Mark on the product itself.

The UL Mark on a product means that UL has tested and evaluated representative samples of that product and determined that they meet the requirements in the applicable standard(s). Under a variety of UL programs, certified products are periodically checked by UL at the manufacturing facility to determine that they continue to comply with the standard(s).

The UL Marks may only be used on, or in connection with products certified by UL, and under the terms of a written agreement between the manufacturer and UL. All listed dampers are identified with the UL Classification Mark.

### IDENTIFICATION OF UL CERTIFIED PRODUCTS

Launched in mid-2013, the enhanced UL Certified Mark can be used on both UL Listed and Classified products and is intended to make it easier and simpler for stakeholders to understand the scope of UL's certifications of a specific product. The enhanced UL Certified Mark makes it possible to bundle multiple UL certifications for multiple geographies into a single Mark design. Today, this mark is used for products certified to U.S., Canadian, European and Japanese requirements. This Mark utilizes a unique identifier to enable stakeholders to search UL's Online Certifications Directory at [www.ul.com/database](http://www.ul.com/database) to quickly to review detailed certification information.

All currently existing versions of UL's Listing and Classification Marks remain valid and should continue to be accepted as an indication of certification.

UL expects the transition to the Enhanced Mark to happen over time, so you may not see it in the immediate future. For more information on this important development, please go to [www.ul.com/markshub](http://www.ul.com/markshub) > Resources. Access to the Marks Hub is free and open to all regulators, but registration to use it is required.



### UL Listing Mark

This is one of the most common UL Marks. If a product carries this Mark, it means UL found that representative samples of this product met UL's *safety* requirements. These requirements are primarily based on UL's own published Standards for Safety, or other recognized third party standards. The UL Listed Mark includes the UL symbol, the word "Listed," the product or category name, and a control number assigned by UL.



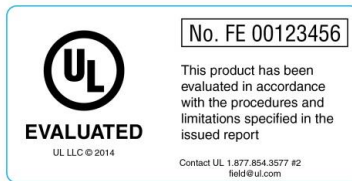
### UL Classification Mark

This Mark appears on representative samples of products that UL has evaluated but only with respect to specific properties, a limited range of hazards, or suitability for use under limited or special conditions. The UL Classification Mark includes the UL symbol, the word "Classified," a statement of the scope of evaluation, the product or category name, and a control number assigned by UL.



## D. FIELD ENGINEERING SERVICES

You may encounter situations in which you are unable to determine if a product has been listed by a third-party organization. Or in other situations you might encounter a product bearing a listing label that may have been modified in the field, and now you question whether or not the product still complies with the applicable standard. UL offers a field engineering services that provides data to assist you in making your decision whether to accept the product and/or approve the installation. Anyone directly involved with a product – including manufacturers, owners, contractors, and regulatory authorities – can request a field inspection or field evaluation. Detailed information for these programs can be found on UL's Web site at [www.ul.com/field](http://www.ul.com/field).



## 2. CODES AND STANDARDS

### A. MODEL CODES

Dampers have been investigated for installation in accordance with the following model codes, among others:

- The International Building Code
- The International Mechanical Code
- The NFPA 101 Life Safety Code
- The NFPA 5000 Building Construction and Safety Code

Among other things these codes specify the locations in which these products are to be installed, the ratings required for each installation, the standards with which the products must comply, the related installation standards, and other details.

### B. INSTALLATION STANDARDS

As compared to model codes, which generally describe where dampers are to be installed, installation standards provide more detailed information on how the products are intended to be installed and maintained. Model codes often require dampers to be installed in accordance with installation standards, such as NFPA 90A, NFPA 80 and NFPA 105. A brief summary of these standards is noted below.

**NFPA 90A** - NFPA 90A is the Standard for the Installation of Air-Conditioning and Ventilating Systems. It regulates the installation, control and acceptance testing of fire, smoke, combination fire-smoke and ceiling dampers used to protect ducts and air transfer openings in walls, floors, and ceilings against the spread of fire and smoke within, into, or out of buildings. The standard addresses products that have been subjected to standardized fire tests, including UL fire and smoke leakage tests.

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The installation requirements of NFPA 90A include topics such as where dampers are required, testing requirements, rating requirements, installation requirements and requirements for maintenance in accordance with NFPA 80, the Standard for Fire Doors and Other Opening Protectives, and NFPA 105, the Standard for Smoke Door Assemblies and Other Opening Protectives. The control requirements of NFPA 90A include provisions for manual and automatic control of smoke and combination fire-smoke dampers. Acceptance testing shall demonstrate the damper functions as intended prior to occupancy of the building.

**NFPA 80** - NFPA 80 is the Standard for Fire Doors and Other Opening Protectives. It regulates the installation, operational testing, periodic inspection and maintenance of fire, combination fire-smoke and ceiling radiation dampers used to protect ducts and air transfer openings in walls, floors, and ceilings against the spread of fire within, into, or out of buildings. The standard addresses products that have been subjected to standardized fire tests, including UL fire tests.

The installation requirements of NFPA 80 include topics such as damper location, listing and labeling requirements, preparation of openings, securement, access to fusible links and serviceability. Operational test shall demonstrate the damper is installed and functions as intended. Periodic inspection and testing requirements include the required inspection and testing, the required frequency and the required documentation. The maintenance requirements include topics such as the changes in the airflow and noise from the duct, lubrication and required documentation.

Combination fire-smoke dampers are also required to comply with NFPA 105, the Standard for Smoke Door Assemblies and Other Opening Protectives.

**NFPA 105** - NFPA 105 is the Standard for Smoke Door Assemblies and Other Opening Protectives. It includes requirements for smoke and combination fire-smoke dampers used to restrict the movement of smoke through duct assemblies in order to maintain a tenable environment. It does this by regulating the installation, operational testing, periodic inspection and maintenance of these dampers. It is also applicable to dampers intended to restrict the passage of smoke through ducts and for dampers used in smoke control systems.

The installation requirements of NFPA 105 include topics such as damper location, damper actuator and linkage, access to fusible links and serviceability. The operational test shall demonstrate the damper is installed and functions as intended. Periodic inspection and testing requirements include the required inspection and testing, the required frequency and the required documentation. The maintenance requirements include topics such as changes in the airflow and noise from the duct, lubrication and required documentation.

Combination fire-smoke dampers are also required to comply with NFPA 80, the Standard for Fire Doors and Other Opening Protectives.

## C. PRODUCT SAFETY STANDARDS

In many cases installation codes require products to comply with UL Standards for Safety, such as the Standard for Fire Dampers, [UL 555](#), Standard for Smoke Dampers, [UL 555S](#) or the Standard for Ceiling Dampers, [UL 555C](#). These are product safety standards that include a comprehensive set of construction and performance requirements that products must comply with in order to be certified by a product certification organization such as UL.

Manufacturers also use UL product safety standards to design their products so they comply with the applicable requirements. Product testing and certification organizations such as UL use these standards to evaluate the products and determine their compliance with the product standards.

When UL has determined that a product complies with all applicable product safety standards, the manufacturer is authorized to apply a UL Certification Mark (Listing or Classification) to production of the product. The standard(s) used to investigate UL Certified products are identified in the product category guide information found in the UL Online Certifications Directory at [www.ul.com/database](http://www.ul.com/database). The product safety standard may also be marked on the product or indicated in the manufacturer's installation instructions.

When an installation code or standard requires a product, system or assembly to comply with a UL standard, designers, contractors and code authorities are encouraged to look at the certification mark on the product and the corresponding guide information to identify the product safety standard used during the investigation. It is not generally necessary, or useful, for designers, contractors and code authorities to obtain a copy of the UL product safety standard.

### **3. TYPES OF FIRE-RESISTANCE-RATED ASSEMBLIES**

Model codes include requirements to restrict the spread of fire through a building using assemblies with specific requirements concerning their construction and placement.

#### **A. FIRE WALLS, FIRE BARRIERS, FIRE PARTITIONS AND SHAFT ENCLOSURES**

Fire walls and fire barriers are both fire-resistance-rated vertical assemblies which restrict the spread of fire from one side to the other. A fire wall extends continuously from the foundation to or through the roof, with sufficient structural stability under fire conditions to allow collapse of construction on either side without collapse of the wall. In comparison a fire barrier is only required to extend from the top of the foundation or floor/ceiling assembly below to the underside of the floor or roof sheathing, slab or deck above. Fire barriers are used to protect areas such as shafts, exit passageways, horizontal exits and atriums. Openings in fire walls and fire barriers may have maximum individual size and aggregate width requirements, as specified in the code.

Fire partitions are generally required to have a fire-resistance rating of not less than 1 hour and are used to provide protection between dwelling units, sleeping units, stores in malls, corridors and elevator lobbies. They must extend from the top of the foundation or floor-ceiling below to (1) the underside of the floor or roof sheathing, deck or slab above or to (2) the fire-resistance-rated floor-ceiling or roof-ceiling assembly above.

Shaft enclosures are generally used to protect openings and penetrations through floor-ceiling and roof-ceiling assemblies. Shaft enclosures are constructed of fire barriers and horizontal assemblies. When constructed of fire barriers, the shaft enclosure shall extend from the top of the foundation or floor/ceiling assembly below to the underside of the floor or roof sheathing, slab or deck above. When constructed of horizontal assemblies, the shaft enclosure shall be continuous without unprotected openings.

#### **B. HORIZONTAL ASSEMBLIES**

Horizontal assemblies are fire-resistance-rated floor-ceiling or roof-ceiling assemblies which restrict the vertical spread of fire from the underside to the top. A horizontal assembly shall be continuous without unprotected openings.

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## C. SMOKE BARRIERS AND SMOKE PARTITIONS

Model codes also include requirements to restrict the spread of smoke through a building. This is done by using the concept of smoke compartments, which are spaces within a building enclosed by smoke barriers on all sides, including the floor and ceiling of the room.

A smoke barrier is a continuous membrane designed and constructed to restrict the movement of smoke. Smoke barriers are generally required to have a minimum one hour fire-resistance rating. They must form an effective membrane continuous from outside wall to outside wall and from the top of the foundation or floor/ceiling assembly below to the underside of the floor or roof sheathing, deck or slab above, including continuity through concealed spaces, such as those found above suspended ceilings, and interstitial, structural and mechanical spaces.

In comparison smoke partitions are not usually required to have a fire-resistance rating. They must extend from the top of the foundation or floor below to (1) the underside of the floor or roof sheathing, deck or slab above or to (2) the underside of the ceiling above where the ceiling membrane is constructed to limit the transfer of smoke.

## D. CORRIDORS

Corridors are intended as a means of egress in the event of a fire emergency. A corridor is an enclosed exit access component that defines and provides a path of egress travel to an exit. The model codes define the use and location of corridors in building construction. The model codes should be consulted for construction specifications for corridor ceilings. One specific construction described is a tunnel corridor where the ceiling of the corridor is constructed as required for the walls.

## 4. DAMPER TYPES

In order to provide for an acceptable level of life safety and property protection, model codes require the use of fire-resistance-rated assemblies, and smoke barriers and partitions to form compartments to keep fire and smoke from readily moving throughout the building. However, in order for the building to serve the needs of its occupants, openings in these fire and smoke rated assemblies are required to serve the heating, ventilation and air conditioning needs of the building. Model codes require these openings to be protected with dampers. Dampers fall into five types, each with a specific function. Types of dampers include fire dampers, smoke dampers, combination fire-smoke dampers, ceiling radiation dampers and corridor dampers. Their functions vary depending on the damper type.

### A. FIRE DAMPERS

Fire dampers are used to restrict the spread of fire where ducts and air transfer openings penetrate fire walls, fire barriers, fire partitions, horizontal assemblies and shaft enclosures. They can also be employed in air transfer openings in walls and partitions. The building codes specify where fire dampers are required. Fire dampers are available in two types, static fire dampers and dynamic fire dampers. Both fire dampers for use in static systems and dynamic systems are certified by UL to carry an hourly fire-protection rating, usually 1-1/2 or 3 hours.

Fire dampers for use in static systems, as their name implies, are used in duct systems or penetrations where the HVAC system is automatically shut down in the event of a fire.

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Fire dampers for use in dynamic systems are required at locations in which fan pressure and airflow will be on during a fire incident, and as such, the dampers are expected to operate (close) against the air velocity and pressure produced by the system fan. In addition to an hour fire-protection rating, fire dampers for use in dynamic systems are also provided with an airflow rating which indicates the maximum velocity and static pressure that the damper is designed for. Refer to the section in this guide entitled Airflow Ratings for a more detailed explanation of the limitations of the ratings.

Fire dampers are tested as part of fire-resistance rated vertical or horizontal assemblies in accordance with the Standard for Fire Dampers, [UL 555](#), and are covered under the Dampers for Fire Barrier and Smoke Applications ([EMME](#)) category. Fire dampers are investigated for use in specific fire-resistive vertical or horizontal assemblies as specific in the installation instructions supplied with the product. Each listing is specific with respect to (1) construction details of the assembly in which the damper is installed, (2) the hourly fire-protection rating, (3) the damper mounting position (i.e. vertical or horizontal), (4) the maximum size of a single section, and (5) the maximum size of multiple damper sections. In addition, listings of fire dampers for use in dynamic systems also include the maximum air flow and maximum static pressure for which the damper is designed.

## B. SMOKE DAMPERS

Smoke dampers are used to restrict the movement of smoke where ducts and air transfer openings penetrate assemblies that are designed to restrict the movement of smoke. The devices are installed to operate automatically, controlled by a smoke detection system, and where required, capable of being positioned from a remote command station.

Smoke dampers may be required where ducts penetrate through smoke barriers or smoke partitions, or at other locations within an engineered smoke control system. Smoke dampers can be used in HVAC systems where the fans are shut down in the event of fire, and can also be used in smoke control systems designed to operate during a fire incident. Smoke dampers are designed to operate against air velocity and fan pressure.

Smoke dampers certified by UL carry a leakage class rating that indicates the level of air leakage measured through the damper under test conditions. Leakage ratings are identified as Class Designation I, II or III as shown in the following table. Leakage ratings of the dampers are established at a minimum differential pressure of 4 in. water gauge (WG), across the closed damper. Leakage rates may also be established at higher differential pressures, in increments of 2 in. water gauge.

| Maximum Leakage (CFM/ft <sup>2</sup> ) |          |          |          |           |           |
|----------------------------------------|----------|----------|----------|-----------|-----------|
| Class                                  | 4 In. WG | 6 In. WG | 8 In. WG | 10 In. WG | 12 In. WG |
| I                                      | 8.0      | 9.5      | 11.0     | 12.5      | 14.0      |
| II                                     | 20.0     | 24.0     | 28.0     | 31.5      | 35.0      |
| III                                    | 80.0     | 96.0     | 112.0    | 125.0     | 140.0     |



Smoke dampers are also provided with an airflow rating which indicates the maximum velocity and static pressure for which the damper is designed. Refer to the section in this guide entitled Airflow Ratings for a more detailed explanation of the limitations of the ratings.

Smoke dampers are tested as part of a vertical or horizontal assemblies in accordance with the Standard for Smoke Dampers, [UL 555S](#), and are covered under the Dampers for Fire Barrier and Smoke Applications ([EMME](#)) category. Smoke dampers are investigated for use in specific vertical or horizontal assemblies as specific in the installation instructions supplied with the product. Each listing is specific with respect to (1) construction details of the assembly in which the damper is installed, (2) the leakage rating, (3) the damper mounting position (i.e. vertical or horizontal), (4) the minimum and maximum sizes of a single section, and (5) the maximum size of multiple damper sections.

### C. COMBINATION FIRE-SMOKE DAMPERS

Combination fire-smoke dampers are used to restrict the spread of fire and movement of smoke where ducts and air transfer openings penetrate assemblies that are designed to restrict the passage of both fire and smoke. Dampers that are marked as combination dampers comply with both the Standard for Fire Dampers, [UL 555](#) and the Standard for Smoke Dampers, [UL 555S](#).

### D. CEILING RADIATION DAMPERS

Ceiling radiation dampers are used to limit the passage of heat in fire-resistance-rated floor-ceiling or roof-ceiling assemblies where ducts or air transfer openings are made only through a ceiling membrane which is providing the fire performance for the assembly. Fire resistive ceiling membranes are part of floor-ceiling or roof-ceiling assemblies that have been evaluated in accordance with the Standard for Fire Tests of Building Construction and Materials, [UL 263](#). The construction of floor-ceiling or roof-ceiling assemblies evaluated by UL are published in the [UL Online Certifications Directory](#).

Ceiling radiation dampers are intended to function only as heat barrier to limit heat transfer into the concealed space of a floor-ceiling or roof-ceiling assembly. As such, the building codes have not defined the use of these products in so far as their use as smoke barriers, nor do the UL certification include the use of these products to limit the migration of smoke. Ceiling radiation dampers are evaluated by UL in one of two ways as explained below.

**Ceiling Radiation Dampers For Use In Lieu Of Hinged Door Type Dampers** – Where floor-ceiling or roof-ceiling designs contain air ducts and specify the use of hinged door type dampers over each duct outlet, ceiling radiation dampers are investigated for use in lieu of the specified hinged door type dampers.

The basic Standard used to evaluate ceiling radiation dampers for use in lieu of hinged door type dampers is The Standard for Ceiling Dampers, [UL 555C](#). It is important to note that ceiling radiation dampers covered by this scheme are only intended for use in those UL fire resistance designs that indicate the use of a hinged door type damper in the design. This information is located in the [UL Online Certifications Directory](#) in the text and drawings of the specific designs. The UL Classification of ceiling radiation dampers does not cover the products for general installation in any floor-ceiling or roof-ceiling design. Examples of this scenario can be found in UL Fire Resistance Design Nos. [G214](#), [G526](#) and [L201](#).

Ceiling radiation dampers evaluated in this fashion are covered under the product categories Air Terminal Units ([BZGU](#)), Ceiling Air Diffusers ([BZZU](#)) and Ceiling Dampers ([CABS](#)). The Classification text for ceiling radiation dampers evaluated in this manner will specify the types of designs in which they may be used and the conditions under which they may be substituted for the hinged door type dampers.

**Ceiling Radiation Dampers For Use In Specific Fire Resistance Designs** – Alternatively, some floor-ceiling or roof-ceiling designs specify one or more specific ceiling radiation damper. Dampers covered by this method of evaluation are generally tested along with the specific design construction in accordance with the Standard for Fire Tests of Building Construction and Materials, [UL 263](#). Information describing the installation of ceiling radiation dampers covered under this scheme, including a reference to the specific ceiling radiation damper model, is included in the text and drawings for the specific designs in the UL [Online Certifications Directory](#). Examples of this scenario can be found in UL Fire Resistance Design Nos. [L501](#), [L521](#) and [L550](#).

Ceiling radiation dampers evaluated in this fashion are covered under the Ceiling Dampers ([CABS](#)) category. The Classification text for the ceiling radiation dampers will make reference to the specific floor-ceiling or roof-ceiling designs in which they are intended to be installed.

The application of ceiling radiation dampers versus horizontal fire dampers, smoke dampers, combination fire-smoke dampers and corridor dampers are distinctly different. Refer to the section in this guide entitled Horizontal Dampers under Installation Considerations for a detailed explanation of these differences.

## **E. CORRIDOR DAMPERS**

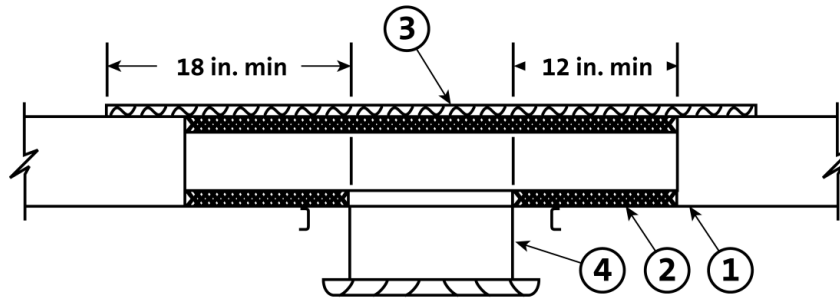
Corridor dampers are combination fire-smoke dampers that have been evaluated for mounting only in specific tunnel corridor ceiling constructions. In most cases, the ceiling construction of a tunnel corridor will be as required for the corridor walls.

Corridor dampers are tested horizontally as installed in specific tunnel corridor ceiling constructions and are covered under the Dampers for Fire Barrier and Smoke Applications ([EMME](#)) category. Corridor dampers are investigated for both a fire-resistance rating of 1 h, and a Class I or II leakage rating as defined under SMOKE DAMPERS. Leakage ratings of corridor dampers are determined at an elevated temperature 250°F or 350°F. Leakage ratings of corridor dampers are established based on test conditions using air. Corridor dampers have also demonstrated acceptable closure performance when subjected to 150 fpm velocity across the face of the damper during fire exposure. Corridor dampers are investigated for use in specific horizontal ceiling constructions as specific in the installation instructions supplied with the product. Each listing is specific with respect to (1) construction details of the ceiling in which the damper is installed, (2) the hourly fire-protection rating, (3) the damper leakage Class, (4) the damper mounting position (i.e. vertical or horizontal), and (5) the minimum and maximum size of a single damper section.

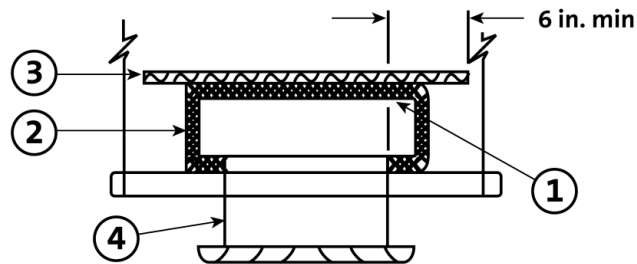
## **5. ALTERNATE TYPES OF PROTECTION**

Under certain specific conditions, openings through the ceiling membrane of a fire resistance-rated ceiling may be protected using Duct Protection Systems A or B, as described in the Guide Information for the Fire Resistance Ratings – ANSI/UL 263 ([BXUV](#)) category. Below is information on the use of Duct Outlet Protection Systems A and B.

## A. DUCT OUTLET PROTECTION SYSTEM A



**Longitudinal Cross-Section**

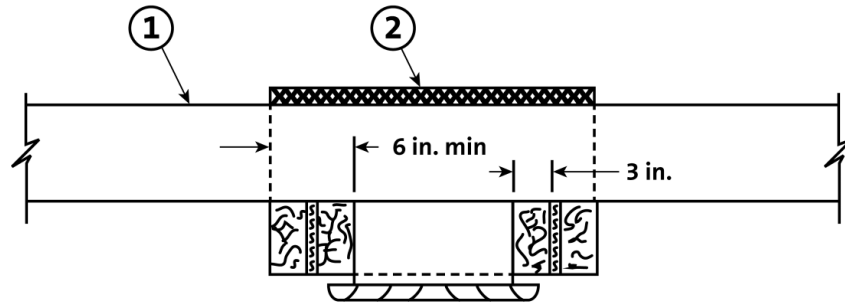


**Transverse Cross-Section**

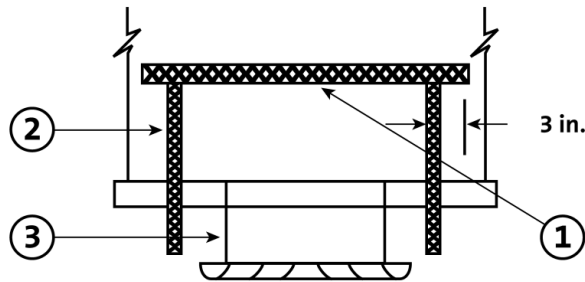
- Item 1 – Steel Duct
- Item 2 – Glass Fiber Duct Lining
- Item 3 – Acoustical Lay-in Panel
- Item 4 – Ceramic Paper

Duct Outlet Protection System A may only be used when specified in the individual design. This method of construction consists of a combination of protecting the inside of rectangular shaped steel ducts with a minimum 1 in. thick, 3.0 to 5.0 pcf glass fiber duct lining, applying an acoustical ceiling lay-in panel on top of the duct and protecting the duct outlet with ceramic paper where specified in the individual design. See the Guide Information for the Fire Resistance Ratings – ANSI/UL 263 ([BXUV](#)) category for further details on the use of this protection method.

## B. DUCT OUTLET PROTECTION SYSTEM B



**Longitudinal Cross-Section**



**Transverse Cross-Section**

- Item 1 – Steel Air Duct
- Item 2 – Mineral Wool Batts
- Item 3 – Ceramic Paper

Duct Outlet Protection System B may be used in any design which contains a steel duct with the duct outlet protected by a hinged door damper, for equal or smaller outlet size. This system has been investigated for effectiveness in retarding the transfer of heat into the concealed space above the ceiling. This method of construction consists of protecting the outside of rectangular shaped steel ducts with a minimum 1-1/4 in. thick, 3.5 to 8.0 pcf mineral wool batts and protecting the duct outlet with ceramic paper where specified in the individual design. See the Guide Information for the Fire Resistance Ratings – ANSI/UL 263 ([BXUV](#)) category for further details on the use of this protection method.

## 6. INSTALLATION CONSIDERATIONS

In order to function properly, a damper must be installed in accordance with the applicable code requirements and its listing. Below are some installation considerations which should be considered prior to installation of the damper.

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## A. DAMPERS IN HORIZONTAL ASSEMBLIES

Since there are multiple types of dampers for use in protecting openings in horizontal assemblies, it is important to carefully consider the proper damper for each application. The correct damper depends on the application.

The model codes provide guidance for ducts penetrating through fire-resistance-rated horizontal assemblies. As a general rule, vertical ducts rising through fire rated floors are to be protected within fire rated shaft enclosures. As the fire resistive shaft rises through the structure, it is not necessary to protect the opening at the floors the duct passes through because the duct is located in a fire rated shaft. The shaft should be penetrated horizontally so that vertical dampers can be used to protect the penetration through the shaft.

The model codes contain several exceptions to the shaft enclosure requirements. Where a vertical duct penetrates a horizontal assembly without a shaft enclosure, a horizontal fire damper is required. If the horizontal assembly is also a smoke barrier, a combination fire-smoke damper is required.

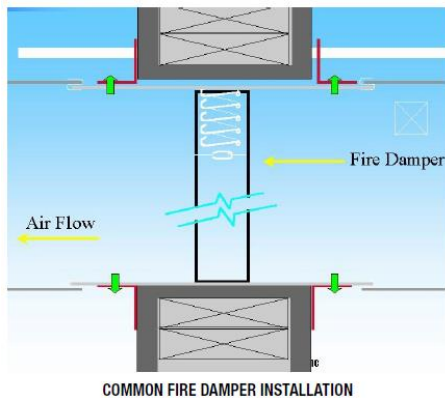
When the duct penetrates through the membrane ceiling of a fire-resistance-rated floor-ceiling or roof-ceiling assembly, but not through the floor or roof, then a ceiling radiation damper is used. The intent of the lower ceiling membrane is to retard the passage of heat into the concealed space. As such, the ceiling radiation damper must likewise retard the passage of heat. The certification of ceiling radiation dampers does not cover the product for general installation in any floor-ceiling or roof-ceiling design. Refer to the section in this guide entitled Ceiling Radiation Dampers under Damper Types for a detailed explanation of the limitations of the certifications applied to ceiling radiation dampers.

Openings entirely through the ceiling of a tunnel corridor, where the ceiling is constructed as required for the walls, are protected with corridor dampers. These dampers must restrict the spread of fire and the movement of smoke through the ceiling assembly.

In all cases, the damper manufacturer's installation instructions depict the appropriate installation parameters and limitations.

## B. INSTALLATION INSTRUCTIONS

Each damper shipment is supplied with a copy of the installation instructions appropriate for the specific damper model. These instructions are an integral part of the UL certification on the dampers. The instructions contain the information necessary to properly install the damper as well as limitations on the installation of the product such as the type of floor or wall construction that is required for the correct installation.



#### **Example of a common fire damper installation:**

The damper shall be secured in the opening using retaining angles. Ducts are attached to the damper sleeve using breakaway methods. A remote sensor device may activate the damper actuator.

Some manufacturers elect to provide basic instructions that cover only common installations, and then rely on supplemental instruction pages that cover unique installation scenarios. As with the basic installation instructions, the supplemental instructions are also an integral part of the UL certification program.

#### **C. MULLIONS**

The certifications covering fire dampers are limited to the single and/or multiple assembly sizes that are evaluated. The size limitations are specified in the published certification information for each damper model.

In certain circumstances, steel mullions can be used to divide a large wall or vertical partition opening into smaller individual openings, allowing fire dampers for use in static systems to be sized and installed within the limitations of the certification. These mullions are generally fabricated in the field. Damper manufacturers can provide installation details covering the fabrication, installation and use of mullions.

Because airflow ratings of fire dampers for use in dynamic systems and combination fire-smoke dampers are size dependent, the use of the mullions discussed herein are only intended for application with fire dampers for use in static systems. Further, the mullions are limited to use in vertical partitions.

#### **D. DAMPER ACTUATORS**

Smoke dampers and combination fire-smoke dampers are equipped with factory installed electric or pneumatic actuators which remotely control the dampers. The airflow and pressure ratings marked on the dampers are dependent upon the particular combination of damper type, actuator type and linkages between the damper blades and actuator. As such, field mounting or substitution of actuators is not covered within the scope of the UL certification of the product. However, this does not necessarily preclude replacement of actuators in the field. Like any appliance, field servicing of these products is not covered under the scope of the UL certification program. As with any part of the damper, it is expected that replacement of actuators in the field be done in accordance with the damper manufacturer's normal field servicing program.

Under certain circumstances, UL can conduct a field evaluation on products that have been modified in the field. For additional information on field evaluations, refer to the section in this guide entitled Field Engineering Services.

## **E. DETECTORS AND SMOKE DAMPERS**

Smoke dampers may be required by the model or installation codes to be closed when smoke detectors operate.

Duct type smoke detectors have a minimum and maximum airflow rating. The ratings must be compatible with the ratings of the smoke damper. Smoke dampers have a minimum airflow rating of 0 fpm and a maximum airflow rating as marked on the damper. Duct type smoke detectors typically have a minimum airflow rating of 300-500 fpm. However, there are duct type smoke detector models available that are rated for use at zero airflow. For HVAC systems that are shut down in the event of a fire, smoke dampers equipped with duct type smoke detectors with a greater than zero minimum airflow rating, may also need to be controlled with a device that will close the damper in the event that the damper is in the open position and the fans are shut down.

## **F. AIRFLOW RATINGS**

Dynamic fire dampers, smoke dampers and combination fire-smoke dampers are marked with airflow and closure pressure ratings. These ratings represent the maximum airflow and closure pressure ratings tested for that product. The closure pressure rating is not the pressure drop across an open damper.

Maximum airflow ratings are marked in 1000 fpm increments with a minimum rating of 2000 fpm. Maximum closure pressure ratings are marked in increments of 2 in. WG with a minimum closure pressure rating of 4 in. WG.

The end user needs to analyze the expected airflow across an open damper in the design of the HVAC system. There are many permutations of opened and closed dampers that may occur under different fire scenarios. The airflow rating for a particular application is not necessarily one that matches the normal design airflow within the ducts. Some dampers may become fully isolated against the fan pressure. Authorities having jurisdiction should field-test various combinations of opened and closed dampers to represent the worst expected condition across the damper.

Similarly, closed dampers may be isolated against the fan pressure and have a pressure higher than the rating. These dampers would be unable to be opened. This has significance for system designs that require dampers to be opened under fire and/or smoke conditions.

## **G. METHODS USED TO REDUCE OR LIMIT THE MOVEMENT OF SMOKE**

In order to determine the proper damper to use, some background information on the methods used to limit smoke movement is necessary. There are design guides published that provide specific information on the design of systems such as smoke control systems. This guide provides only an overview of the different designs with an emphasis on the role that a damper may have on the system.

There are different methods used to limit the movement of smoke through the HVAC system. The amount of smoke generated from a fire can be quite substantial. It is important to recognize that the goal of the system designer is to reduce the migration of smoke to other parts of a building to

prolong evacuation time. An improper damper use can be detrimental to the performance of the system. This guide is not intended to advocate one type of method over another.

There are three different basic approaches used to limit smoke migration. First, a passive or barrier system use solid barriers, with protected openings to limit the movement of smoke. When this approach is used, model and installation codes recommend that the fans should be shut down in the event of a fire. Second, a smoke control system utilizes fans to create pressure differentials across smoke boundaries. Third, a smoke management system uses a variety of methods to reduce or confine smoke movement in large spaces such as malls and atria.

For passive systems, consideration should be given for how smoke dampers are to close in the event of a fire and/or the presence of smoke in the HVAC duct. The user should be aware of the limitations of the different devices used to signal the damper to move to the closed position. See the section on Detectors and Smoke Dampers for a further explanation. The user should decide on the basic strategy to reduce smoke migration such as only closing the dampers adjacent to the fire or to close all of the dampers in the system. The building control strategy then should match the control strategy for the dampers.

For smoke control and smoke management systems, the dampers may be used to assist with the development of the pressure differentials in the different smoke zone boundaries. The user needs to determine the expected performance of the dampers in the system and match the control system accordingly. Consideration should be given for the mode of damper failure (open or closed) in the event that the fire scenario exceeds the limitations of the dampers or control system.

The smoke dampers are tested to the elevated temperature noted on the Classification Mark. The dampers will continue to operate under elevated temperatures and can be used by firefighters to adjust smoke control strategies but the dampers will not operate indefinitely. Extreme heat and fire conditions can damage control systems and render the dampers without power. There are significant fire related safety issues with respect to having dampers fail (loss of power, etc.) in the open position. Heat, fire and smoke could travel beyond the open damper.

An analysis of different fire scenarios can be conducted to estimate the airflow and pressure conditions across different dampers within the system. The airflow and pressure ratings of the dampers should exceed the worst case projections from the analysis. Controlling smoke movement during a fire is a complex engineering task. Model codes generally provide equivalency clauses that allow for other engineered methods to control the movement of smoke. Smoke dampers can also be used in these systems, provided that the designer of such a system is cognizant of the limitations of the individual components that make up the system.

## **H. MAINTENANCE**

Like any mechanical device, dampers require periodic maintenance to ensure continued proper operation. The level of maintenance required is dependent on several factors including the product manufacturer's and system designer's recommendations, code requirements, and the complexity of the system in which the damper is installed.

Periodic maintenance of dampers should include the following:

- Removal of debris buildup from the damper and surrounding area
- Manual cycling of dampers released by fusible links
- Cycling of damper and actuator assemblies

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Additional information on periodic testing can be found in the model codes and installation standards.

## I. DAMPER MARKINGS

The UL Classification Mark is the only method used by UL to identify products that have been produced under UL's Classification and Follow-Up Service Program. In addition to the UL Classification symbol, additional information is located on the label that has significance towards the installation and use of the damper. Examples of markings used on dampers are shown below:

### Fire Dampers for use in Static Systems

UL Classification Marking



FIRE DAMPER FOR USE IN STATIC SYSTEMS  
FIRE RESISTANCE RATING 1-1/2 HOUR  
No. \_\_\_\_\_

### Fire Dampers for use in Dynamic Systems

UL Classification Marking



FIRE DAMPER FOR USE IN DYNAMIC SYSTEMS  
FIRE RESISTANCE RATING 1-1/2 HOUR  
No. \_\_\_\_\_

Additional Marking

Airflow rating (2000 fpm minimum, and 1000 fpm increments); Closure pressure rating (4 in. WG minimum and 2 in. WG increments)

### Smoke Dampers

UL Classification Marking



SMOKE DAMPER  
LEAKAGE RESISTANCE CLASS I - 350°F  
No. \_\_\_\_\_

Additional Marking

Airflow rating (2000 fpm minimum, and 1000 fpm increments); Closure pressure rating (4 in. WG minimum and 2 in. WG increments)

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## Combination Fire and Smoke Dampers

UL Classification Marking



COMBINATION FIRE AND SMOKE DAMPER  
FIRE RESISTANCE RATING 1-1/2 HOUR  
LEAKAGE RESISTANCE CLASS I - 350°F  
No. \_\_\_\_\_

Additional Marking

Airflow rating (2000 fpm minimum, and 1000 fpm increments); Closure pressure rating (4 in. WG minimum and 2 in. WG increments)

## Corridor Dampers

UL Classification Marking



CORRIDOR DAMPER  
FIRE RESISTANCE RATING 1 HOUR  
LEAKAGE RESISTANCE CLASS I - 350°F  
No. \_\_\_\_\_

Additional Marking

Airflow rating (2000 fpm minimum, and 1000 fpm increments); Closure pressure rating (4 in. WG minimum and 2 in. WG increments)

## Ceiling Radiation Dampers

UL Classification Marking



AIR TERMINAL UNITS  
FIRE RESISTANCE CLASSIFICATION  
SEE UL FIRE RESISTANCE DIRECTORY  
No. \_\_\_\_\_

Or



AIR TERMINAL UNITS  
FIRE RESISTANCE CLASSIFICATION  
DESIGN NO(S). \_\_\_\_\_  
SEE UL FIRE RESISTANCE DIRECTORY  
No. \_\_\_\_\_

Or



CEILING AIR DIFFUSER  
FIRE RESISTANCE CLASSIFICATION  
SEE UL FIRE RESISTANCE DIRECTORY  
No. \_\_\_\_\_

Or



CEILING AIR DIFFUSER  
FIRE RESISTANCE CLASSIFICATION  
DESIGN NO(S). \_\_\_\_\_  
SEE UL FIRE RESISTANCE DIRECTORY  
No. \_\_\_\_\_

Or



CEILING DAMPER  
FIRE RESISTANCE CLASSIFICATION  
SEE UL FIRE RESISTANCE DIRECTORY  
No. \_\_\_\_\_

Or



CEILING DAMPER  
FIRE RESISTANCE CLASSIFICATION  
DESIGN NO(S). \_\_\_\_\_  
SEE UL FIRE RESISTANCE DIRECTORY  
No. \_\_\_\_\_

Because the hourly rating of ceiling radiation dampers is dependent on the specific fire resistance designs in which it can be installed, an hourly fire resistance rating is not marked on the product. Therefore, the marking of ceiling dampers consists of the UL Classification symbol, the product category Air Terminal Units ([BZGU](#)), Ceiling Air Diffusers ([BZZU](#)) or Ceiling Damper ([CABS](#)), and a reference to the product category description in UL's Fire Resistance Directory. For those ceiling radiation dampers intended only for use in one or more specific designs, the marking includes a reference to those designs.

## 7. DAMPER SELECTION AND INSTALLATION

In order to properly select a UL Classified damper one needs to know and understand the building design criteria and applicable model code requirements. The following steps provide a systematic approach that can be followed to provide a safe, code compliant installation. This process can also be used by code authorities during the building approval process.

**1. Determine the size and location of dampers** – A number of factors dictate the design of the building heating, ventilation and air conditioning system. These may be driven by code requirements or by the needs of the occupants and tenants. Prior to selecting the appropriate dampers, the size and location of the basic system needs to be identified, and size and routing of the supply and return ducts needs to be identified.

**2. Confirm if dampers are required to limit the passage of fire, smoke, or both** – The fire safety system embodied in building code requirements is based on the use of walls and partitions, and horizontal floor-ceiling and roof-ceiling assemblies designed to contain fires and the resulting smoke and products of combustion in certain areas within the building. This concept is often referred to as compartmentation (e.g. containing fires within various compartments). The codes require HVAC openings to be protected to restrict the passage of fire and smoke. One of the options within the codes to protect these openings in walls and horizontal assemblies is the use of dampers which are required to comply with specific UL standards, and to have certain ratings.

To determine the standards and ratings these dampers must meet, one first needs to determine if the walls and horizontal assemblies in which they installed are covered by code requirements.

### Fire Walls, Fire Barriers and Fire Partitions

These are all fire-resistance-rated vertical assemblies designed to restrict the spread of fire in which continuity is maintained. However the hourly rating, construction, extent of continuity and support for these assemblies varies.

Ducts and air transfer openings in these assemblies are required to be protected against the spread of fire in accordance with the requirements included in the code. As such, the code requires the use of fire dampers in these openings.

Fire dampers installed in assemblies having a fire-resistance rating of less than 3 hours shall have an hourly fire-protection rating of 1-1/2 hours. Fire dampers installed in assemblies having a fire-resistance rating of 3 hours or greater shall have an hourly fire-protection rating of 3 hours.

### Horizontal Assemblies

Horizontal assemblies are fire-resistance-rated floor-ceiling and roof-ceiling assemblies designed to restrict the spread of fire in which continuity is maintained. However, the hourly rating, construction and support for these assemblies varies.

Ducts which pass through these assemblies are required to be protected against the spread of fire in accordance with the requirements included in the code. As such, the code requires the use of fire dampers in these openings.

Fire dampers installed in horizontal assemblies having a fire-resistance rating of less than 3 hours shall have an hourly fire-protection rating of 1-1/2 hours. Fire dampers installed in assemblies having a fire-resistance rating of 3 hours or greater shall have an hourly fire-protection rating of 3 hours.

Ducts and air transfer openings which penetrate only the ceiling membrane of a floor-ceiling or roof-ceiling assembly where the ceiling is providing the fire protection are required to be protected so as to limit the passage of heat into the concealed space of the assembly. As such, the code requires the use of ceiling radiation dampers in these openings.

### **Shaft Enclosures**

Shaft enclosures are constructed using fire-resistance-rated fire barriers and horizontal assemblies designed to restrict the spread of fire and movement of smoke in which continuity is maintained.

Ducts and air transfer openings in shaft enclosures are required to be protected against the spread of fire and movement of smoke in accordance with the requirements included in the code. As such, the code requires the use of individual fire and smoke dampers, or a combination fire-smoke damper.

To determine the appropriate ratings for dampers in shaft enclosures, refer to the specific code requirements covering ducts and air transfer openings in shaft enclosures. This will include a leakage rating in conjunction with an hourly fire-protection ratings.

### **Smoke Barriers and Smoke Partitions**

Smoke barriers are continuous membranes, either vertical or horizontal, such as a wall, floor or ceiling assembly, that are designed to restrict the movement of smoke through a building. In addition to restricting the movement of smoke, smoke barriers have a fire-resistance rating as specified in the code. Smoke partitions are continuous vertical membranes, such as a wall, that are also designed to restrict the movement of smoke through a building, but are not required to have a fire-resistance rating.

Ducts and air transfer openings in smoke barriers are required to be protected against the spread of fire and movement of smoke in accordance with the requirements included in the code. As such, the code requires the use of individual fire and smoke dampers, or a combination fire-smoke damper in these assemblies.

Openings in smoke partitions are required to be protected to restrict the movement of smoke in accordance with the requirements included in the code. As such, the code requires the use of smoke dampers in these openings.

To determine the appropriate ratings for dampers in these assemblies, refer to the specific code requirements covering ducts and air transfer openings in these wall assemblies. This will include a leakage rating for dampers used in smoke barriers and partitions, in conjunction with hourly fire-protection ratings for dampers in smoke barriers.

### **Corridors**

Corridors are constructed using fire-resistance-rated fire partitions designed to restrict the spread of fire and movement of smoke in which continuity is maintained. However, the hourly rating, construction and support for these assemblies varies.

Ducts and air transfer openings in these assemblies are required to be protected to resist the spread of fire and movement of smoke in accordance with the requirements included in the code. As such, the code requires the use of combination fire-smoke dampers.

To determine the appropriate ratings for dampers in corridors, refer to the specific code requirements covering ducts and air transfer openings in these assemblies. This will include a leakage rating in conjunction with hourly fire-protection ratings.

Ducts and air transfer openings which penetrate only the ceiling of a corridor where the ceiling is constructed as required for the walls, shall be protected to resist the spread of fire and movement of smoke with a corridor damper.

**3. Determine if static or dynamic fire dampers are needed** – If fire dampers are determined to be required in the HVAC system, determine if the system is to be automatically shut down in the event of a fire. If it is, either static or dynamic fire dampers may be utilized. If the system is not shut down, dynamic fire dampers shall be specified. The specified dynamic fire damper must have a maximum airflow and static pressure consistent with the design of the HVAC system.

**4. Determine the type of actuator to be utilized** – Smoke dampers and combination fire-smoke dampers are equipped with factory installed electric or pneumatic actuators which remotely control the dampers. The airflow and pressure ratings are dependent on the particular combination of damper type, actuator type, and linkage between the damper blades and the actuator. The specified damper and actuator combination specified must have a maximum airflow and static pressure consistent with the design of the HVAC system.

**5. Identify the barrier construction** – Once the size, location, type, rating, actuator and airflow requirements for the dampers are established, the next step is identify the construction of the barriers into which they will be mounted. It is imperative that the barrier construction match the barrier construction which is specified in the damper installation instructions.

If ceiling radiation dampers are required, it is important to know the UL fire-resistance-rated Design No. which is being used for the floor-ceiling or roof-ceiling assembly. If a damper is not specified in the design being utilized, no HVAC penetrations of the ceiling membrane are permitted. If an HVAC penetration is permitted, there are two methods by which ceiling radiation dampers are specified in the designs. First, if a hinged door type damper is specified in the design, then either the hinged door type damper may be used, or a listed Air Terminal Units ([BZGU](#)), Ceiling Air Diffusers ([BZZU](#)) or Ceiling Dampers ([CABS](#)) may be substituted for the hinged door type damper in accordance with the provisions of the listings. It is imperative that the ceiling radiation damper selected be used as specified in its listing. Second, if one or more specific ceiling radiation damper(s) is specified by manufacturer and model number, then only the specified damper(s) may be used and it must be used in accordance with the provisions stated in the design and in its listing.

As an alternate to the use of a listed Air Terminal Units ([BZGU](#)), Ceiling Air Diffusers ([BZZU](#)) or Ceiling Dampers ([CABS](#)), Duct Outlet System B may be used in accordance with the provisions of the Guide Information for the Fire Resistance Ratings – ANSI/UL 263 ([BXUV](#)) category. Duct Outlet Protection System B may be used in any design which contains a steel duct with the duct outlet

protected by a hinged door damper, for equal or smaller outlet sizes. Duct Protection System A may only be used when specified in the individual design.

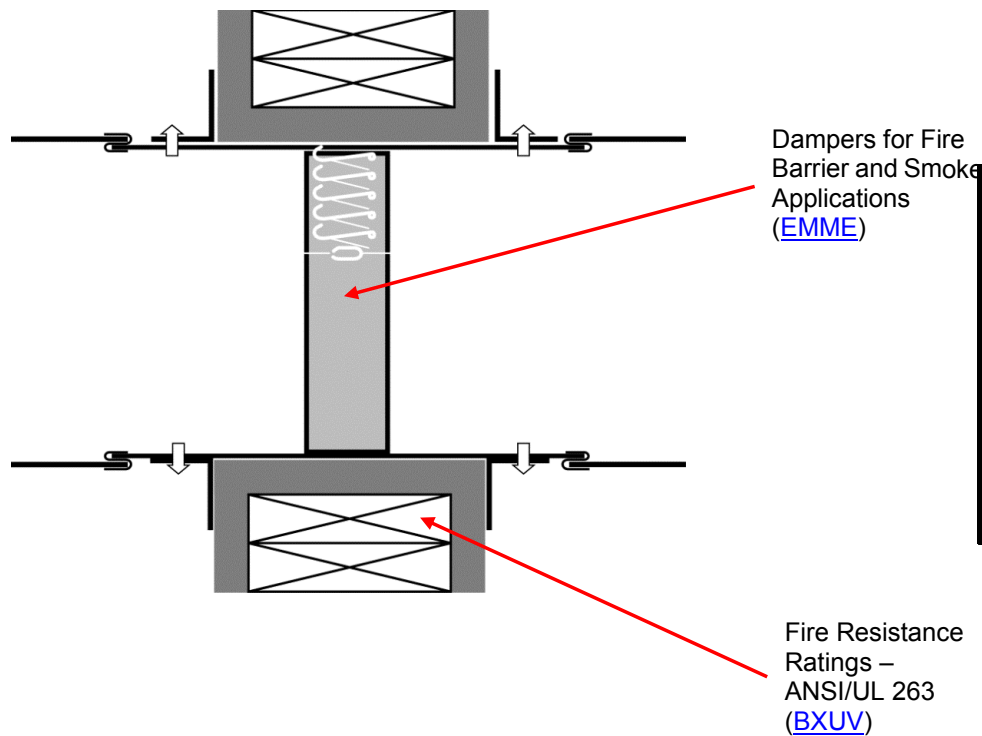
**6. Putting it all together** – In order to provide for a damper installation that complies with applicable code requirements it is important to identify the size, location, type, rating, actuator, airflow and pressure requirements, along with the specific type of construction the damper will be installed in. This information can then be used to identify the specific dampers required using the UL [Online Certifications Directory](#) in conjunction with the manufacturer's installation instructions.

Care should be taken to verify that the dampers are installed in accordance with the manufacturer's installation instructions, and in accordance with NFPA 90A, NFPA 80 and NFPA 105 requirements.

## 8. DIAGRAMS OF COMPLETE ASSEMBLIES

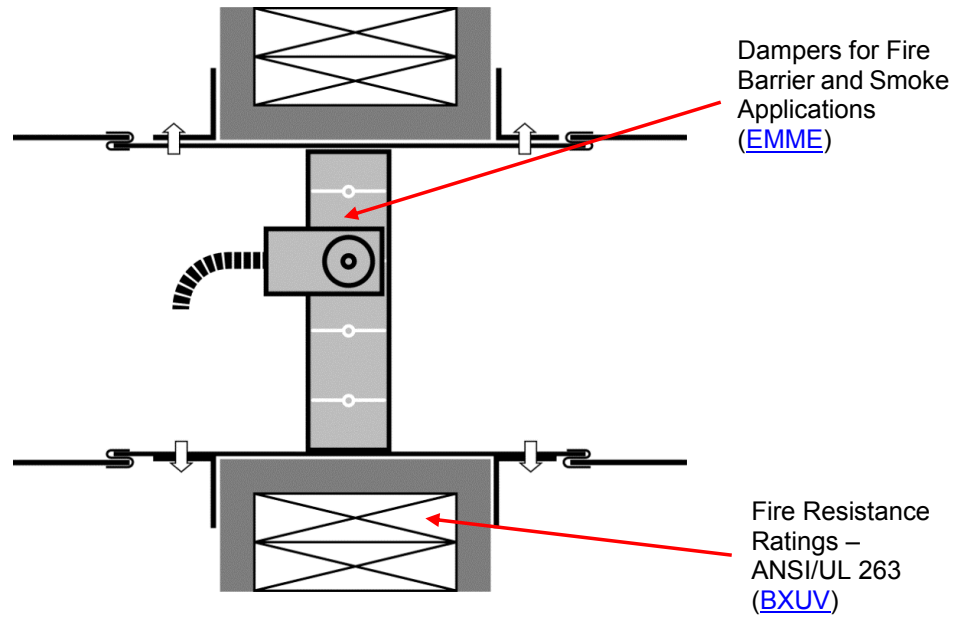
The following diagrams identify the components that make up complete assemblies, along with links to the guide information for the various product categories. Refer to Appendix for a complete list of related product categories.

### A. FIRE DAMPER ILLUSTRATION



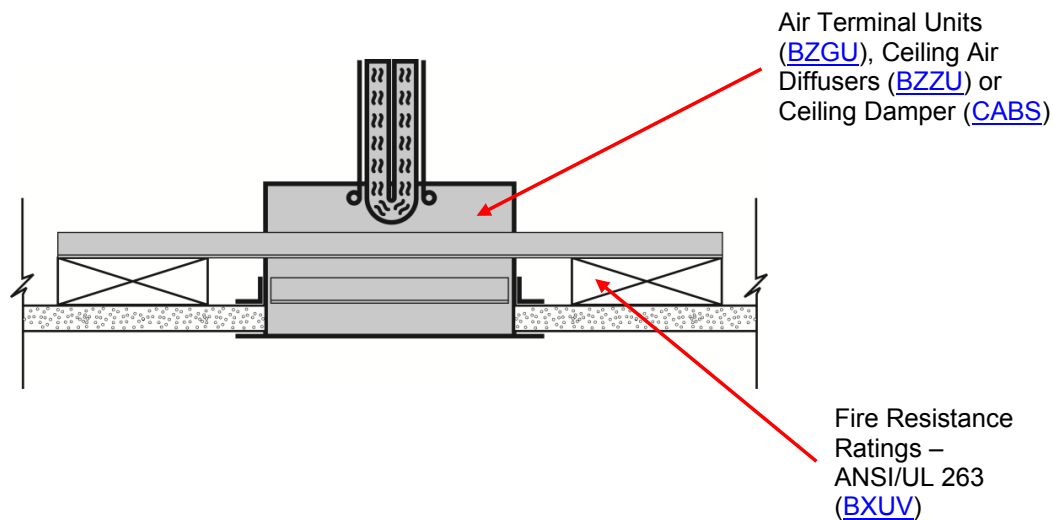
Dampers  
Marking and Application Guide

## B. SMOKE AND COMBINATION FIRE-SMOKE DAMPER ILLUSTRATION

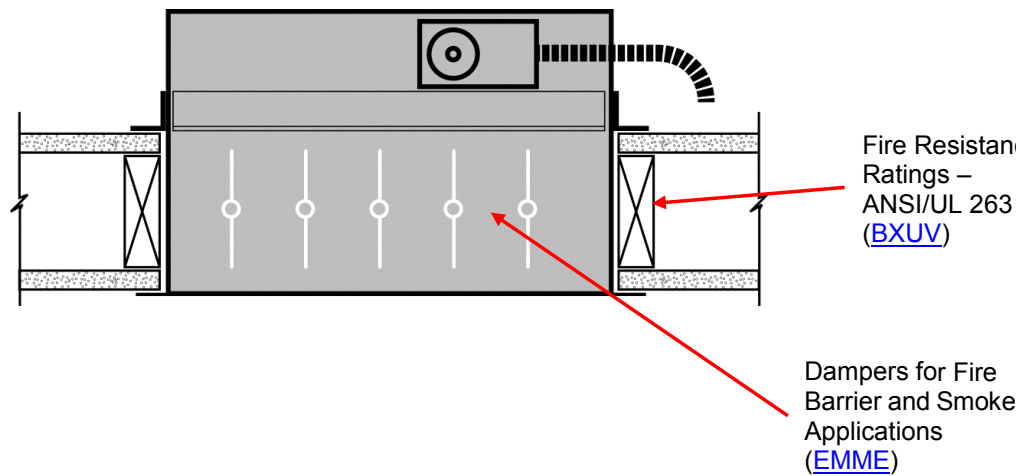




C. CEILING RADIATION DAMPER ILLUSTRATION



D. CORRIDOR DAMPER ILLUSTRATION



Dampers  
Marking and Application Guide

## APPENDIX A – DAMPER RELATED CATEGORIES

UL certifies dampers under the following product categories. Click on Category Code links to view UL Guide Information for the product category. The Guide Information also has links to manufacturers whose products are certified under the category. To view all UL certifications (e.g. Listings and Classifications) see the UL Online Certifications Directory at [www.ul.com/database](http://www.ul.com/database).

| Category Code        | Category Name                                   | Standard Used                                                                |
|----------------------|-------------------------------------------------|------------------------------------------------------------------------------|
|                      |                                                 |                                                                              |
| <a href="#">BZGU</a> | Air Terminal Units                              | <a href="#">UL 263</a> and <a href="#">UL 555C</a>                           |
| <a href="#">BZZU</a> | Ceiling Air Diffusers                           | <a href="#">UL 263</a> and <a href="#">UL 555C</a>                           |
| <a href="#">CABS</a> | Ceiling Dampers                                 | <a href="#">UL 263</a> and <a href="#">UL 555C</a>                           |
| <a href="#">EMME</a> | Dampers for Fire Barrier and Smoke Applications | <a href="#">UL 555</a> , <a href="#">UL 555S</a> and <a href="#">UL 555C</a> |

## APPENDIX B – DAMPER CODES AND STANDARDS

Dampers are intended to be installed in accordance with model codes and installation standards. The model codes require these products to be listed and labeled in accordance with applicable product standards.

UL standards are typically identified as Standards for Safety and contain the construction, performance and marking criteria used by UL to investigate a product. Limitations applicable to the products covered by the standard are delineated in the Scope section of the standard. UL standards are intended to:

- Identify requirements for evaluation of products and provide consistency in the application of these requirements.
- Provide guidance for development of products by manufacturers.
- Provide requirements compatible with nationally recognized installation codes.

|                         |                                                                             |
|-------------------------|-----------------------------------------------------------------------------|
| ASTM E 119              | Standard Test Methods for Fire Tests of Building Construction and Materials |
| IBC                     | International Building Code                                                 |
| NFPA 80                 | Standard for Fire Doors and Other Opening Protectives                       |
| NFPA 90A                | Standard for the Installation of Air-Conditioning and Ventilating Systems   |
| NFPA 101                | Life Safety Code                                                            |
| NFPA 105                | Standard for Smoke Door Assemblies and Other Opening Protectives            |
| NFPA 5000               | Building Construction and Safety Code                                       |
| <a href="#">UL 263</a>  | Fire Tests of Building Construction and Materials                           |
| <a href="#">UL 555</a>  | Fire Dampers                                                                |
| <a href="#">UL 555C</a> | Ceiling Dampers                                                             |
| <a href="#">UL 555S</a> | Smoke Dampers                                                               |

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## CABS.GuideInfo Ceiling Dampers

[View Listings](#)
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### Ceiling Dampers

[Guide Information for Fire-resistance Ratings](#)

#### USE AND INSTALLATION

This category covers ceiling dampers investigated for use in fire-resistance designs as detailed in Fire-resistance Ratings - ANSI/UL 263 (BXUV).

Ceiling dampers are designed to function as a heat barrier in air-handling openings penetrating the ceiling membrane of fire-resistive floor-ceiling designs and/or roof-ceiling designs for which they have been investigated.

The certifications for ceiling dampers are published in two different methods:

1. Some ceiling dampers are intended for use in lieu of hinged-door-type dampers in floor-ceiling and/or roof-ceiling designs that contain air ducts and specify the use of a hinged-door-type damper over each duct outlet. Under this method of certification, a certified ceiling damper may be substituted for the hinged-door-type damper specified in the design in accordance with the provisions of the certification of the ceiling damper. An air duct with a hinged-door-type damper must be a specified component of the floor-ceiling and/or roof-ceiling design for this certification method to apply. For ceiling dampers of this type, the individual certifications specify (1) the model number of the damper, (2) the type of assembly (floor-ceiling and/or roof-ceiling) in which the damper may be used, (3) the hourly rating of the assembly in which the damper may be used, and (4) the conditions under which the ceiling damper may be substituted for the hinged-door-type damper (e.g., one ceiling damper for each 113 sq in. or larger duct outlet protected with a hinged-door-type damper).
2. Some ceiling dampers are intended for use in specific floor-ceiling and/or roof-ceiling designs as specified in the designs and marked on the damper. Under this method of certification, the certified ceiling damper must be directly referenced in the floor-ceiling and/or roof-ceiling design, by manufacturer and model number, in order to be utilized in that design. Only the dampers specified in the design may be utilized. For ceiling dampers intended for use in specific designs, the individual certifications specify (1) the model number of the damper, (2) the size of the ceiling damper, and (3) the specific design(s) in which the damper may be utilized. Where the design indicates the damper is optional, the intent is the inclusion of the duct outlet is optional. If a duct outlet is provided, it must be protected with the specified ceiling damper.

Ceiling dampers are intended to be installed in accordance with the provided installation instructions. For ceiling dampers intended for installation in a duct outlet in lieu of hinged-door-type dampers, the location of the ceiling damper in the duct outlet relative to the ceiling level is specified in the installation instructions. This location must be followed during installation in order to obtain the hourly fire-rated performance of the design.

#### PRODUCT MARKINGS

A separate label located adjacent to the Certification Mark identifies whether the ceiling damper has been investigated for use in static or dynamic systems. The label for ceiling dampers for use in dynamic systems also includes the maximum air flow and closure pressure for which the damper has been investigated. A ceiling damper labeled for use in dynamic systems is also suitable for use in static systems.

#### PRODUCT IDENTITY

The following product identity appears on the product:

Ceiling Damper

#### RELATED PRODUCTS

For information on related products, see Fire-resistance Ratings - ANSI/UL 263 (BXUV).

#### ADDITIONAL INFORMATION

For additional information, see Fire-resistance Ratings (BXRH).

#### REQUIREMENTS

The basic standard used to investigate the physical performance of ceiling dampers in this category is [ANSI/UL 555C](#), "Ceiling Dampers."

The basic standard used to investigate the fire-resistance performance of ceiling dampers in this category for use in floor-ceiling and/or roof-ceiling designs in lieu of the hinged-door-type dampers shown in those designs is [ANSI/UL 555C](#).

The basic standard used to investigate the fire-resistance performance of ceiling dampers in this category for use in floor-ceiling and/or roof-ceiling designs that do not indicate the use of hinged-door-type dampers in the design is [ANSI/UL 263](#), "Fire Tests of Building Construction and Materials."

Fire performance measured by [ANSI/UL 263](#) is based upon the assumption that air movement will be effectively stopped at the start of a fire. Ceiling dampers intended for use in HVAC systems where the airflow is operational at the time of a fire, such as in a smoke-control system, or from other situations in which the fan system is operational at the time of a fire, are investigated for dynamic closure. Ceiling dampers intended for use where the air movement is effectively stopped at the start of a fire are not required to be investigated for dynamic closure.

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**UL MARK**

The Certification Mark of UL on the product is the only method provided by UL to identify products manufactured under its Certification and Follow-Up Service. The Certification Mark for these products includes the UL symbol, the words "CERTIFIED" and "SAFETY," the geographic identifier(s), and a file number.

**Additional Certification Markings**

Products covered under this category are additionally marked with the following information:

**AS TO FIRE RESISTANCE  
DESIGN NO(S). \_\_\_\_\_  
SEE UL ONLINE CERTIFICATIONS DIRECTORY**

or

**AS TO FIRE RESISTANCE  
SEE UL ONLINE CERTIFICATIONS DIRECTORY**

**Alternate UL Mark**

The Classification Mark of UL on the product is the only method provided by UL to identify products manufactured under its Classification and Follow-Up Service. The Classification Mark for these products includes the UL symbol, the word "CLASSIFIED" above the UL symbol (as illustrated in the Introduction of this Directory), and the following additional information:

**CEILING DAMPER  
FIRE RESISTANCE CLASSIFICATION  
DESIGN NO(S). \_\_\_\_\_  
SEE UL FIRE RESISTANCE DIRECTORY  
No.**

or

**CEILING DAMPER  
FIRE RESISTANCE CLASSIFICATION  
SEE UL FIRE RESISTANCE DIRECTORY  
No.**

\*\*\*\*\*

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### Buildings for the 21st Century

Buildings that are more energy efficient, comfortable, and affordable... that's the goal of DOE's Office of Building Technology, State and Community Programs (BTS). To accelerate the development and wide application of energy efficiency measures, BTS:

- Conducts R&D on technologies and concepts for energy efficiency, working closely with the building industry and with manufacturers of materials, equipment, and appliances
- Promotes energy/money saving opportunities to both builders and buyers of homes and commercial buildings
- Works with state and local regulatory groups to improve building codes, appliance standards, and guidelines for efficient energy use
- Provides support and grants to states and communities for deployment of energy-efficient technologies and practices



# CRAWLSPACE INSULATION

*Improve comfort and increase durability in the home*

## EFFECTIVE CRAWLSPACE INSULATION

A properly sealed, moisture-protected, and insulated crawlspace will increase comfort, save on energy costs, improve the durability of the home, and reduce entry of moisture, radon, and other potential irritants or pollutants into the home. Whichever design is followed, the keys to an effective crawlspace are:

**Moisture control**—using a water-managed foundation system to drain rainwater and groundwater away from foundations.

**Airtight construction**—sealing all air leaks between the conditioned space and the outside prior to insulation installation.

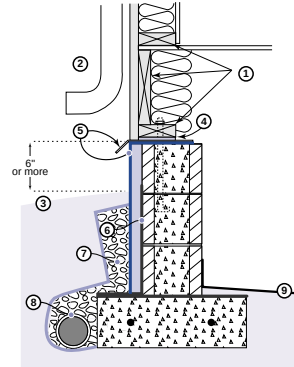
**Complete insulation coverage**—properly installing the correct insulation levels and making sure the insulation coverage is continuous and complete.

## WATER-MANAGED FOUNDATION SYSTEM

A crawlspace is susceptible to moisture and deterioration problems because of contact with the earth. The best approaches for preventing these problems will depend on the local climate and style of construction, but the following general rules apply to most crawlspace designs.

1. Keep all untreated wood materials away from the earth.
2. Provide rain drainage, such as gutters, to conduct rainwater away from the house.
3. Slope the earth away from the house for at least 5 feet at a minimum 5% grade (3 inches in 5 feet). Establish drainage swales to direct rainwater around the house.
4. Add a sill gasket to provide air sealing.

## WATER-MANAGED CRAWLSPACE FOUNDATION



5. Install a protective membrane, such as an EPDM-type membrane, to serve as a capillary break that reduces wicking of water from the masonry wall. This membrane, in addition to metal flashing, can serve as a termite shield.
6. Dampproof the below-grade portion of the foundation wall to prevent the wall from absorbing ground moisture by capillary action.
7. Install drainage plane material or gravel against the foundation wall to relieve hydrostatic pressure and channel water to the foundation drain.
8. Provide a foundation drainage system at the bottom of the footing, not on top, when the foundation floor (interior grade) is below the exterior grade. Surround a perforated 4-inch drain pipe with gravel and cover them with filter fabric.
9. Install 6-mil polyethylene across the crawlspace floor to prevent soil moisture from migrating into the crawlspace. Overlap and tape all seams by 12 inches, and seal the polyethylene 6 inches up the crawlspace walls.

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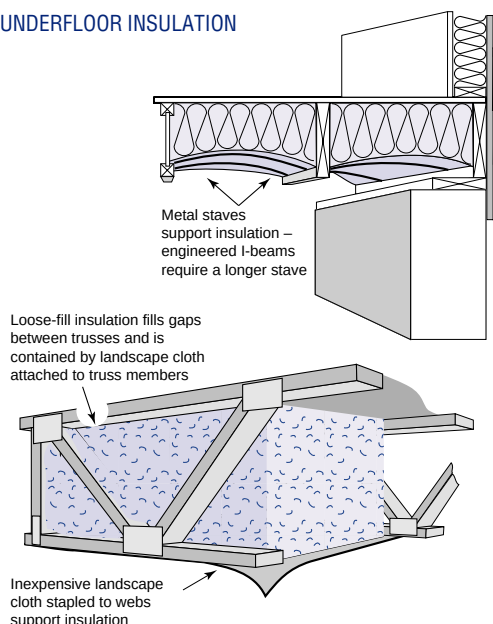
## CRAWLSPACE INSULATION

5. Locate the crawlspace access inside the home or install an access through the perimeter that will remain airtight after repeated use.
6. Select insulation levels in accordance with the International Energy Conservation Code or the DOE Insulation Fact Sheet. The Insulation Fact Sheet (DOE/CE-0180) can be ordered from the Energy Efficiency and Renewable Energy Clearinghouse or accessed from the Internet at [www.ornl.gov/roofs+walls](http://www.ornl.gov/roofs+walls).
7. Install rigid or batt insulation using one of three options (exterior foam, interior foam, or interior batt) to achieve complete insulation coverage. Insulate the band joist with batt insulation, and the crawlspace access if it is located in the wall. Install a continuous termite shield between the band joist and masonry foundation wall that covers the wall insulation and extends completely outside, or leave a 2- to 4-inch insulation gap at the top for termite inspection.
8. Install a supply outlet in the crawlspace, relying on the leakiness of the floor to provide the return air path.

### STEPS FOR INSTALLING UNDERFLOOR INSULATION

1. During the early phases of construction, meet with the mechanical subcontractors (plumbing, electrical, and heating/cooling) to inform them of the importance of keeping the space between floor joists as clear as possible. Run drain lines, electrical wiring, and ductwork below the bottom of the insulation so that a continuous layer of insulation can be installed. For protection against freezing, supply plumbing may be located within the insulation. The best approach is to run supply plumbing together in a few joist spaces. The insulation can be split and run around the piping.
2. Seal all air leaks between the conditioned area of the home and the crawlspace. High-priority leaks include holes around bathtub drains and other drain lines, plenums for ductwork, and penetrations for electrical wiring, plumbing, and ductwork (including duct boot connections at the floor).
3. Select insulation levels in accordance with the International Energy Conservation Code or the DOE Insulation Fact Sheet.
4. Insulation batts with an attached vapor barrier are usually used to insulate framed floors. Obtain insulation with the proper width for the joist spacing of the floor being insulated. Complete coverage is essential – leave no insulation voids. The batts should be installed flush against the subfloor to eliminate any gaps that may serve as passageways for cold air to flow between the insulation and the subfloor. The batts should be cut to the full length of the

### UNDERFLOOR INSULATION



#### • INSULATING TRUSS FLOOR SYSTEMS

Instead of batt insulation, a better approach is to install netting or rigid insulation to the underside of the floor trusses and filling the space created between the netting or insulation and subfloor with a loose-fill insulation.

joist being insulated and slit to fit around wiring and plumbing. Insulate the band joist area between air ducts and the floor as space permits. Use insulation hangers (wire staves) spaced every 12-18 inches to hold the floor insulation in place without compressing the insulation more than 1 inch.

5. The orientation of the vapor barrier depends on the home's location. In most of the country, the vapor barrier should face upward. However, in certain regions of the Gulf states and other areas with mild winters and hot summers, it should face downward.
6. Insulate all ductwork in the crawlspace.
7. Insulate all hot and cold water lines in the crawlspace unless they are located within the insulation.
8. Close crawlspace vents after making sure the crawlspace is dry and all construction materials have dried out.





















































































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# **U.S. EXPERIENCE WITH SPRINKLERS AND OTHER AUTOMATIC FIRE EXTINGUISHING EQUIPMENT**

**John R. Hall, Jr.**

**February 2010**



**National Fire Protection Association  
Fire Analysis and Research Division**

# **U.S. EXPERIENCE WITH SPRINKLERS AND OTHER AUTOMATIC FIRE EXTINGUISHING EQUIPMENT**

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## Abstract

Automatic sprinklers are highly effective elements of total system designs for fire protection in buildings. They save lives and property, producing large reductions in the number of deaths per thousand fires, in average direct property damage per fire, and especially in the likelihood of a fire with large loss of life or large property loss. When sprinklers are present in the fire area, they operate in 93% of all reported structure fires large enough to activate sprinklers, excluding buildings under construction. When they operate, they are effective 97% of the time, resulting in a combined performance of operating effectively in 91% of reported fires where sprinklers were present in the fire area and fire was large enough to activate sprinklers. In homes (including apartments), wet-pipe sprinklers operated effectively 96% of the time. When wet-pipe sprinklers are present in structures that are not under construction and excluding cases of failure or ineffectiveness because of a lack of sprinklers in the fire area, the fire death rate per 1,000 reported structure fires is lower by 83% for home fires, where most structure fire deaths occur, and the rate of property damage per reported structure fire is lower by 40-70% for most property uses. In homes (including apartments), wet-pipe sprinklers were associated with a 74% lower average loss per fire. Also, when sprinklers are present in structures that are not under construction and excluding cases of failure or ineffectiveness because of a lack of sprinklers in the fire area, 95% of reported structure fires have flame damage confined to the room of origin compared to 74% when no automatic extinguishing equipment is present. When sprinklers fail to operate, the reason most often given (53% of failures) is shutoff of the system before fire began. (All statistics are based on 2003-2007 fires reported to U.S. fire departments, excluding buildings under construction.)

Keywords: fire sprinklers; fire statistics; automatic extinguishing systems; automatic suppression systems

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## Executive Summary

Automatic sprinklers are highly effective and reliable elements of total system designs for fire protection in buildings. In 2003-2007, sprinklers operated in 93% of all reported structure fires large enough to activate sprinklers, excluding buildings under construction and buildings without sprinklers in the fire area. When sprinklers operate, they are effective 97% of the time, resulting in a combined performance of operating effectively in 91% of all reported fires where sprinklers were present in the fire area and fire was large enough to activate them. The combined performance for the more widely used wet pipe sprinklers is 92%, while for dry pipe sprinklers, the combined performance is only 79%. In homes (including apartments), wet-pipe sprinklers operated effectively 96% of the time. By comparison, combined performance is 60% for dry chemical systems, 79% for carbon dioxide systems, 81% for foam systems, and 88% for halogen systems. (Wet chemical systems may be included with dry chemical systems or with other special hazard systems.) These most current statistics are based on 2003-2007 fires reported to U.S. fire departments, excluding buildings under construction and cases of failure or ineffectiveness because of a lack of sprinklers in the fire area and after some recoding between failure and ineffectiveness based on reasons given.

When wet-pipe sprinklers are present in structures that are not under construction and excluding cases of failure or ineffectiveness because of a lack of sprinklers in the fire area, the fire death rate per 1,000 reported home structure fires is lower by 83% and the rate of property damage per reported structure fire is lower by 40-70% for most property uses. In homes (including apartments), wet-pipe sprinklers were associated with a 74% lower average loss per fire. Also, when sprinklers are present in structures that are not under construction and excluding cases of failure or ineffectiveness because of a lack of sprinklers in the fire area, 95% of reported structure fires have flame damage confined to the room of origin compared to 74% when no automatic extinguishing equipment is present.

Of reported 2003-2007 structure fires in health care properties, an estimated 57% showed sprinklers present, with higher percentages for hospitals (71%) and nursing homes (65%) and a much lower percentage for clinics and doctor's offices (28%). Sprinklers were also reported as present in half or more of all reported fires in laboratories (60%), manufacturing facilities (52%), theaters (50%), and prisons and jails (50%). In every other property use, more than half of all reported fires had no sprinklers.

The few surveys that have been done of sprinkler presence in general, not limited to fires, have found that in any property group, the percentage of buildings with sprinklers is much higher than the percentage of reported fires with sprinklers present. Sprinklers apparently are still rare in many of the places where people are most exposed to fire, including educational properties, offices, most stores, and especially homes, where most fire deaths occur. There is considerable potential for expanded use of sprinklers to reduce the loss of life and property to fire.

When sprinklers fail to operate, the reason most often given (53% of failures) was shutoff of the system before fire began, as may occur in the course of routine inspection maintenance. Other leading reasons were inappropriate system for the type of fire (20%), lack of maintenance (15%), and manual intervention that defeated the system (9%). Only 2% of sprinkler failures were attributed to component damage.

When sprinklers operate but are ineffective, the reason usually had to do with an insufficiency of water applied to the fire, either because water did not reach the fire (43% of cases of ineffective performance) or because not enough water was released (31%). Other leading reasons were inappropriate system for the type of fire (12%), manual intervention that defeated the system (5%), and lack of maintenance (4%). Only 4% of cases of sprinkler ineffectiveness were attributed to component damage.

When people are fatally injured in spite of the operation of wet-pipe sprinklers, the victims often had special vulnerabilities that are less often found with fatal victims of home fires in general. For example,

- 93% of fatal victims in home fires with wet-pipe sprinkler operation were located in the area of fire origin, where they could have suffered fatal injuries before sprinkler activation, compared to 53% of fatal home fire victims in general;
- 30% of fatal victims in home fires with wet-pipe sprinkler operation had their clothing on fire, compared to 7% of fatal home fire victims in general;
- 50% of fatal victims in home fires with wet-pipe sprinkler operation were age 65 or older, compared to 28% of fatal home fire victims in general; and
- 37% of fatal victims in home fires with wet-pipe sprinkler operation returned to the fire after escaping, compared to 19% of fatal home fire victims in general.



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## U.S. Experience with Sprinklers

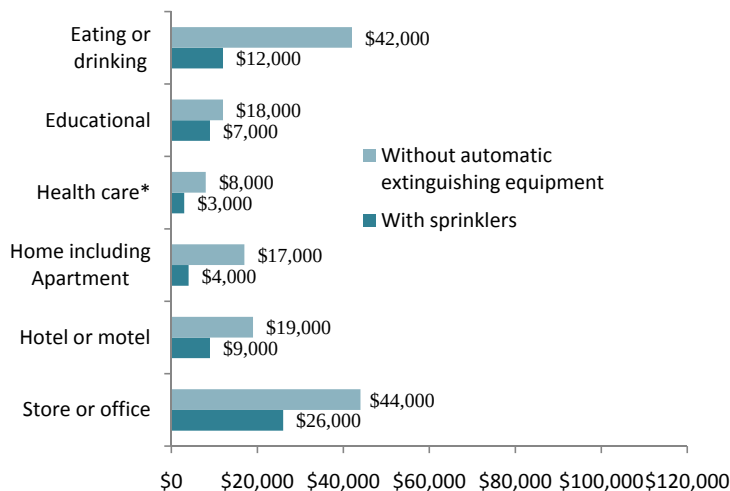
Sprinklers save lives and protect property from fires.

Compared to properties without automatic extinguishing equipment

- The death rate per fire in sprinklered homes is lower by 83%.
- For most property uses, damage per fire is lower by 40-70% in sprinklered properties.

Flame damage was confined to the room of origin in 95% of fires in sprinklered properties vs. 74% in fires with no automatic extinguishing equipment.

**Damage per Fire With and Without Sprinklers, 2003-2007**



\*Health care refers to hospitals, nursing homes, clinics, doctor's offices, and mental retardation facilities.

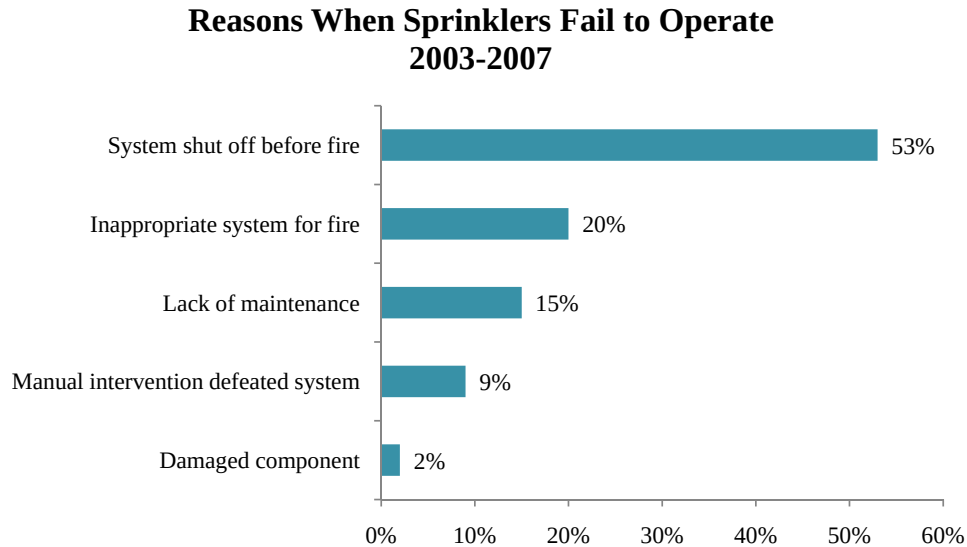
Sprinklers are reliable and effective.

- In reported structure fires large enough to activate them, sprinklers operated in 93% of fires in sprinklered properties.
- Wet pipe sprinklers operated in 95% of these fires vs. 83% for dry pipe sprinklers.
- In reported structure fires large enough to activate them, sprinklers operated and were effective in 91% of fires in sprinklered properties.
- Wet pipe sprinklers operated and were effective in 92% of fires vs. 79% for dry pipe sprinklers.

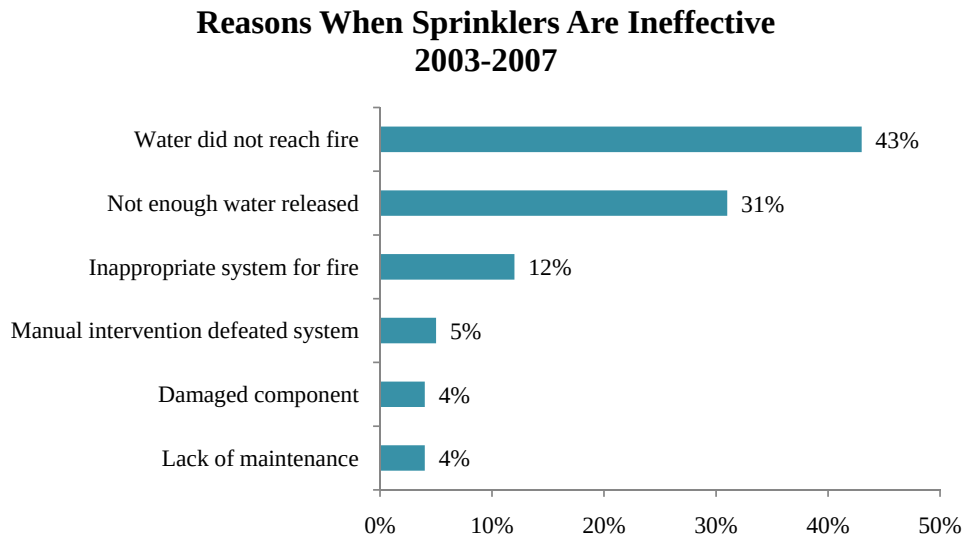
**NOTE:** NFPA's Fire Sprinkler Initiative: Bringing Safety Home is a nationwide effort to encourage the use of home fire sprinklers and the adoption of fire sprinkler requirements for new construction. See [www.firesprinklerinitiative.org](http://www.firesprinklerinitiative.org).

Statistics are based on 2003-2007 U.S. reported fires excluding buildings under construction. Sprinklered properties exclude properties with no sprinklers in fire area.

The graph below is based on the 7% of fires in sprinklered properties (roughly 1,000 fires per year) in which the sprinkler should have operated but did not.



In fires where sprinklers operated, they were effective in 97% of the cases. The graph below is based on the other 3% (roughly 400 fires per year), in which the sprinkler was ineffective.



Usually only 1 or 2 sprinklers are required to control the fire.

- When wet pipe sprinklers operated, 89% of reported fires involved only 1 or 2 sprinklers.
- For dry pipe sprinklers, 74% involved only 1 or 2 sprinklers.

Statistics are based on 2003-2007 U.S. reported fires excluding buildings under construction. Sprinklered properties exclude properties with no sprinklers in fire area.

## **Before You Read the Report: Some Introductory Notes on Incident Coding and Analysis**

See Appendix A for general information on the statistical methodology and see Appendix B for a detailed overview of data elements related to automatic extinguishing equipment.

Here are some important points on incident coding and analysis that apply to this report:

### **Fires excluded from analysis**

- Fires in buildings with reported structure status of under construction are excluded. No fire protection systems or features can be expected to perform as designed in a building that is under construction.
- Statistics on reliability, effectiveness, and performance exclude partial systems as identified by reason for failure and ineffectiveness equal to equipment not in area of fire. Not all partial systems will be so identified, and the codes and standards for this equipment do not require coverage in all areas. For example, concealed spaces and exterior locations may not be required to have coverage.

### **Missing choices and misleading labels when coding presence or type of automatic extinguishing report**

- The established generic name of “automatic extinguishing equipment” is misleading, because many if not most such equipment is designed to control fires and not to fully extinguish them.
- There is no code for wet chemical system, which was mandated as the type of non-water-based system to be used in eating and drinking establishments shortly after the coding rules were set for NFIRS Version 5.0, the current version of the U.S. Administration’s National Fire Incident Reporting System.<sup>1</sup> Wet chemical systems may be coded as dry chemical systems, foam systems, or other special hazard systems and are probably more common than all of these other systems.
- Fire extinguishers are not automatic equipment and should not be coded but sometimes are reported under any of several types of automatic extinguishing equipment.
- There was no way to code automatic extinguishing equipment as unknown during 1999 to 2003, although there was the option of leaving the field blank. During that period, the U.S. Fire Administration advised that unknowns should be reported as no equipment present.<sup>2</sup> This arrangement had the potential to severely understate the presence of automatic extinguishing equipment. However, the estimates for 2002 and 2003 are not substantially lower than either the pre-1999 estimates or the three years of estimates from 2004 and later. Therefore, this potential problem seems to have had little effect in practice.

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<sup>1</sup> NFIRS compiles fire incident and casualty reports from participating U.S. local fire departments. NFPA’s national estimates are based on NFIRS data and estimated totals from the annual NFPA fire experience survey of U.S. fire departments.

<sup>2</sup> U.S. Fire Administration, *NFIRS Coding Questions*, revised January 2, 2002, p.13.

**Recoding of sprinkler performance based on reasons for failure or ineffectiveness.**

The coding of reasons for failure or ineffectiveness has been used in this analysis to recode system performance entries. Unknown reasons have been proportionally allocated to avoid the dubious alternative assumption that the coded performance is correct if no reason is given for the performance.

|                       |   |                          |                                           |
|-----------------------|---|--------------------------|-------------------------------------------|
| <u>If Performance</u> | = | <u>Not Effective</u>     | <u>Then Change to:</u>                    |
|                       |   | <u>And Reason =</u>      |                                           |
|                       |   | System shut off          | Performance = Failed to operate           |
|                       |   | Not in area of fire      | Presence = No; Performance not applicable |
| <u>If Performance</u> | = | <u>Failed to Operate</u> | <u>Then Change to:</u>                    |
|                       |   | <u>And Reason =</u>      |                                           |
|                       |   | Not enough agent         | Performance = Not effective               |
|                       |   | Agent didn't reach fire  | Performance = Not effective               |
|                       |   | Not in area of fire      | Presence = No; Performance not applicable |

Note that this recoding will not address partial sprinkler systems where there were sprinklers in part or all of the fire area unless the system is ineffective because of fire spread to or from uncovered areas.



## **Presence of Sprinklers and Other Automatic Extinguishing Equipment**

Of reported 2003-2007 structure fires in health care properties, an estimated 57% showed sprinklers present, with higher percentages for hospitals (71%) and nursing homes (65%) and a much lower percentage for clinics and doctor's offices (28%). Sprinklers were also reported as present in half or more of all reported fires in laboratories (60%), manufacturing facilities (52%), theaters (50%), and prisons and jails (50%). In every other property use, more than half of all reported fires had no sprinklers.

In 1994-1998, only 7% of reported structure fires had any type of automatic extinguishing equipment present. By 2003-2007, this percentage had risen by about half, to 10%. Before 1999, the type of automatic extinguishing equipment was not reported, and so it is not possible to show the trend in sprinkler presence. It is possible to show the trend in presence of automatic extinguishing equipment generally and to show how sprinkler presence compares to automatic extinguishing equipment presence in the most recent years. See Table 1 for percentage of reported structure fires, excluding buildings under construction, in which automatic extinguishing equipment was present for the year groups of 1994-1998 and 2003-2007.<sup>3</sup> Table 1 also shows percentage of fires with any type of sprinkler reported present for 2003 to 2007.

The following properties where large numbers of people routinely are present show less than one-third of reported fires in properties with sprinklers present in 2003-2007:

- Every type of public assembly property except theaters
- Educational properties
- Clinics and doctor's offices
- Homes including apartments
- Every type of store or office except department stores

Most fires in storage properties are not in warehouses but are in garages, barns, silos, and small outbuildings. It is these types of buildings that drive the very low percentage of reported fires with automatic extinguishing equipment in all storage properties combined.

In 2003-2007, sprinklers were reported in only 5% of fires in homes (including apartments). Clearly, there is great potential for expanded installation.

The 2007 American Housing Survey included a question about sprinkler presence in homes.<sup>4</sup> The survey indicated 3.9% of occupied year-round housing units had sprinklers. A much smaller percentage of single family homes had sprinklers as compared to multi-unit housing. Sprinklers were present in:

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<sup>3</sup> Some fires after 1999 are coded as confined fires, which are fires confined to cooking vessel, chimney or flue, furnace or boiler, incinerator, commercial compactor, or trash receptacle. Confined fires permit limited reporting with most data fields not required and usually left blank. Confined fires permit limited reporting with most data fields not required and usually left blank. Confined fires combine with very low sprinkler usage to make estimates for one- and two-family dwellings too volatile and uncertain to list separately, and so estimates are provided only for all homes combined

<sup>4</sup> *American Housing Survey 2007*, U.S. Department of Commerce and U.S. Department of Housing and Urban Development, September 2008, Table 1C-4, 2-4, and 2-25.

- 1.5% of single family detached homes,
- 1.9% of single family homes, whether detached or attached,
- 10.6% of all housing units in multi-unit buildings,
- 2.9% of housing units in buildings with 2-4 units,
- 5.8% of housing units in buildings with 5-9 units,
- 12.1% of housing units in buildings with 10-19 units,
- 16.3% of housing units in buildings with 20-49 units, and
- 27.3% of housing units in buildings with 50 or more units.

Sprinklers are installed in 13.0% of housing units in buildings that were constructed no more than four years ago. This is more than triple the percentage for all housing units. No statistics are provided on sprinkler installation specifically in recently constructed single family homes, but detached single-family homes are a larger share of recently built housing units than of total housing units (70% vs. 63%). This strongly suggests that single family homes are part of the recent jump in sprinkler installation.

Sprinkler presence percentages are higher in the West region than in other regions and lower in rural areas than in non-rural areas.

To underscore the principal finding, more than 1 million single family detached dwellings now have fire sprinklers.

The Home Fire Sprinkler Coalition, formed in 1996, developed a variety of educational materials about the benefits of home fire sprinklers. These materials address common questions and misconceptions. They may be accessed through their web site <http://www.homefiresprinkler.org>.

Because sprinkler systems are so demonstrably effective, they can make a major contribution to fire protection in any property. NFPA 101®, *Life Safety Code*; NFPA 1, *Fire Code*; and NFPA 5000®, *Building Construction and Safety Code*, have required sprinklers in all new one- and two-family dwellings, all nursing homes, and many nightclubs since the 2006 editions. The 2009 edition of the *International Residential Code*, also added requirements for sprinklers in one- and two-family dwellings, effective January 2011. This protection can be expected to increase in areas that adopt and follow these codes. NFPA is supporting adoption of these requirements through its Fire Sprinkler Initiative (see <http://www.firesprinkler.initiative.org>).

The few surveys that have been done of sprinkler presence in general, not limited to fires, have found that in any property group, the percentage of buildings with sprinklers is much higher than the percentage of reported fires with sprinklers present. Sprinklers apparently are still rare in many of the places where people are most exposed to fire, including educational properties, offices, most stores, and especially homes, where most fire deaths occur. There is considerable potential for expanded use of sprinklers to reduce the loss of life and property to fire.

As with detection/alarm systems and all other fire protection features, in property classes where sprinklers are not required, they will tend to go first into the properties that can afford them most, not the high-risk fire-prone properties that would benefit most from their presence.

**Table 1. Presence of Sprinklers and Other Automatic Extinguishing Equipment  
in Structure Fires, 1994-1998 vs. 2003-2007**

| Property Use                                             | Number of Structure Fires With Equipment Present and<br>Percentage of Total Structure Fires in Property Use |           |                      |           |           |       |
|----------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|-----------|----------------------|-----------|-----------|-------|
|                                                          | <u>Any Automatic Extinguishing Equipment</u>                                                                |           | <u>Any Sprinkler</u> |           |           |       |
|                                                          | 1994-1998                                                                                                   | 2003-2007 | 1994-1998            | 2003-2007 | 2003-2007 |       |
| All public assembly                                      | 4,380                                                                                                       | (26%)     | 7,650                | (49%)     | 3,040     | (19%) |
| Fixed-use amusement place                                | 150                                                                                                         | (18%)     | 170                  | (29%)     | 150       | (24%) |
| Variable-use amusement place                             | 140                                                                                                         | (16%)     | 270                  | (22%)     | 260       | (22%) |
| Religious property                                       | 90                                                                                                          | (5%)      | 280                  | (15%)     | 270       | (14%) |
| Library or museum                                        | 110                                                                                                         | (28%)     | 190                  | (28%)     | 180       | (28%) |
| Eating or drinking establishment                         | 3,240                                                                                                       | (29%)     | 4,730                | (58%)     | 1,380     | (17%) |
| Passenger terminal                                       | 60                                                                                                          | (35%)     | 180                  | (28%)     | 110       | (16%) |
| Theater                                                  | 110                                                                                                         | (35%)     | 140                  | (51%)     | 140       | (50%) |
| Educational property                                     | 1,820                                                                                                       | (24%)     | 2,250                | (34%)     | 2,010     | (31%) |
| Health care property                                     | 4,400                                                                                                       | (68%)     | 4,010                | (61%)     | 3,770     | (57%) |
| Nursing home                                             | 2,060                                                                                                       | (76%)     | 2,060                | (70%)     | 1,910     | (65%) |
| Hospital                                                 | 1,650                                                                                                       | (74%)     | 1,210                | (77%)     | 1,110     | (71%) |
| Clinic or doctor's office                                | 70                                                                                                          | (29%)     | 200                  | (28%)     | 200       | (28%) |
| Prison or jail                                           | 430                                                                                                         | (19%)     | 290                  | (51%)     | 290       | (50%) |
| All residential                                          | 11,110                                                                                                      | (3%)      | 26,980               | (8%)      | 25,820    | (7%)  |
| Home (including apartment)                               | 8,440                                                                                                       | (2%)      | 21,110               | (5%)      | 20,130    | (5%)  |
| Hotel or motel                                           | 1,690                                                                                                       | (35%)     | 1,900                | (48%)     | 1,790     | (45%) |
| Dormitory or barracks                                    | 620                                                                                                         | (29%)     | 1,670                | (46%)     | 1,550     | (42%) |
| Rooming or boarding home                                 | 230                                                                                                         | (17%)     | 970                  | (33%)     | 950       | (32%) |
| Board and care home                                      | NA                                                                                                          | (NA)      | 900                  | (43%)     | 790       | (38%) |
| Store or office                                          | 5,230                                                                                                       | (21%)     | 6,090                | (30%)     | 4,660     | (23%) |
| Grocery or convenience store                             | 1,190                                                                                                       | (27%)     | 2,030                | (44%)     | 1,010     | (22%) |
| Laundry or dry cleaning or<br>other professional service | 310                                                                                                         | (13%)     | 350                  | (19%)     | 340       | (18%) |
| Service station or motor<br>vehicle sales or service     | 230                                                                                                         | (6%)      | 230                  | (10%)     | 170       | (7%)  |
| Department store                                         | 1,100                                                                                                       | (52%)     | 610                  | (43%)     | 560       | (39%) |
| Office                                                   | 1,470                                                                                                       | (25%)     | 1,210                | (32%)     | 1,170     | (31%) |
| Laboratory                                               | 120                                                                                                         | (48%)     | 110                  | (65%)     | 100       | (60%) |
| Manufacturing facility                                   | 6,400                                                                                                       | (50%)     | 4,070                | (57%)     | 3,740     | (52%) |
| All storage                                              | 1,090                                                                                                       | (3%)      | 950                  | (4%)      | 920       | (4%)  |
| Warehouse excluding cold<br>storage**                    | 740                                                                                                         | (22%)     | 510                  | (38%)     | 510       | (38%) |
| All structures                                           | 37,100                                                                                                      | (7%)      | 53,940               | (10%)     | 44,310    | (9%)  |

NA – Category not defined in fire incident data prior to 1999.

\*Also includes development disability facilities. In 1994-98, this category also includes care of physically inconvenienced and excludes doctor's office and care of aged facilities without nursing staff.

\*\*In 1994-1998, includes general warehouse, textile storage, processed food storage except cold storage and storage of wood, paper, plastics chemicals, and metals.

Notes: These are structure fires reported to U.S. municipal fire departments and so exclude fire reported only to Federal or state agencies or industrial fire brigades. Post-1998 estimates are based only on fires reported in Version 5.0 of NFIRS and include fires reported as confined fires. Estimates are not shown for 1999-2002 because of lower participation in NFIRS Version 5.0 in those years. After 1998, buildings under construction are excluded.

Source: NFIRS and NFPA survey.





## Automatic Extinguishing Equipment Type

**In reported fires, most automatic extinguishing equipment is recorded as sprinklers, and most sprinklers are wet pipe sprinklers.**

Table 2 shows the percentage of non-confined and confined fires, excluding buildings under construction, by type of automatic extinguishing equipment for each of the major property groups and some subgroups.<sup>5</sup> Percentage calculations are based only on fires where automatic extinguishing equipment presence and type were known and reported. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started.

Some type of sprinklers were present in 82% of 2003-2007 fires where automatic extinguishing equipment was present. Wet pipe sprinklers accounted for 73% of all systems and so outnumbered dry pipe sprinklers by roughly 10-to-1.

The major property class with the largest share for dry pipe sprinklers was storage, where dry pipe sprinklers accounted for 20% of the systems cited. Cold storage was the only property class for which dry pipe sprinklers constituted a majority (in this case, 53%) of systems cited.

For public assembly properties, there was a 40% to 60% split between sprinklers and other types of automatic extinguishing equipment, respectively. Dry chemical systems accounted for 40% of the systems present. Eating or drinking establishments (the dominant part of public assembly) had a 29% to 71% split between sprinkler systems and other types of automatic extinguishing equipment, respectively. Dry chemical systems accounted for 47% of total systems in eating or drinking establishments, compared to a 29% share for all sprinklers combined. Note that wet chemical systems have no clearly identified equipment type category but have been the mandated type of system for eating and drinking establishments for roughly a decade. It seems likely that most of the dry chemical systems reported are either wet chemical systems or dry chemical extinguishers, which should not be reported as any type of automatic equipment.

Public assembly properties, especially eating and drinking establishments, have the highest percentages for both dry chemical systems (40% and 47%, respectively) and other special hazard systems (11% and 12%, respectively), both of which probably are dominated by wet chemical systems, for which there is no labeled category. Roughly ten years ago, the applicable standards for eating and drinking establishments required that dry chemical systems be replaced by wet chemical systems. It seems likely that some wet chemical systems will be coded as other special hazard systems and some will be coded as dry chemical systems, the latter being the well-defined equipment type closest to a wet chemical system.

It would be useful to have a better sense of what kind of equipment is coded as “other special hazard systems.” There are some types of automatic extinguishing equipment that do not fit exactly into any of the defined categories, such as equipment using wet chemicals. It is also

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<sup>5</sup> Some fires after 1999 are coded as confined fires, which are fires confined to cooking vessel, chimney or flue, furnace or boiler, incinerator, commercial compactor, or trash receptacle. Confined fires permit limited reporting with most data fields not required and usually left blank. Confined fires combine with very low sprinkler usage to make estimates for one- and two-family dwellings too volatile and uncertain to list separately, and so estimates are provided only for all homes combined

possible that some fires will be coded as other special hazard system when they really involved automatic extinguishing equipment of one of the defined types. The category also could be used for some devices that are not automatic and so should not be coded as automatic extinguishing equipment present, such as portable extinguishers.

Some insight into what is being coded under “other special hazard systems” comes from a check of uncoded narratives for the three restaurant fires in recent years in Minnesota where such equipment was reported. (The narratives on these fires were part of a data set provided for a special analysis described on p. 49.) One fire involved a wet chemical system, and another involved an undefined hood system, which could have involved wet or dry chemical agents. The third fire involved use of portable extinguisher and should not have been coded as automatic extinguishing equipment present.

**Table 2.**  
**Type of Automatic Extinguishing Equipment Reported as Percentage of All Fires**  
**Where Equipment Was Present and of Known Type, by Property Use**  
**2003-2007 Structure Fires Reported to U.S. Fire Departments**

| Property Use                                             | Fires per year<br>with any<br>automatic<br>extinguishing<br>equipment | All<br>sprinklers | Wet pipe<br>sprinklers | Dry pipe<br>sprinklers | Other<br>sprinklers* |
|----------------------------------------------------------|-----------------------------------------------------------------------|-------------------|------------------------|------------------------|----------------------|
| All public assembly                                      | 7,650                                                                 | 40%               | 34%                    | 2%                     | 4%                   |
| Fixed-use amusement place                                | 170                                                                   | 85%               | 82%                    | 3%                     | 1%                   |
| Variable-use amusement place                             | 270                                                                   | 97%               | 84%                    | 13%                    | 0%                   |
| Religious property                                       | 280                                                                   | 97%               | 86%                    | 4%                     | 7%                   |
| Library or museum                                        | 190                                                                   | 99%               | 92%                    | 5%                     | 2%                   |
| Eating or drinking establishment                         | 4,730                                                                 | 29%               | 23%                    | 2%                     | 4%                   |
| Passenger terminal                                       | 180                                                                   | 58%               | 35%                    | 22%                    | 1%                   |
| Theater                                                  | 140                                                                   | 99%               | 95%                    | 3%                     | 1%                   |
| Educational property                                     | 2,250                                                                 | 89%               | 80%                    | 6%                     | 3%                   |
| Health care property**                                   | 4,010                                                                 | 94%               | 81%                    | 12%                    | 1%                   |
| Nursing home                                             | 2,060                                                                 | 93%               | 78%                    | 15%                    | 1%                   |
| Hospital                                                 | 1,210                                                                 | 92%               | 85%                    | 6%                     | 1%                   |
| Clinic or doctor's office                                | 200                                                                   | 98%               | 95%                    | 3%                     | 1%                   |
| Prison or jail                                           | 290                                                                   | 98%               | 87%                    | 10%                    | 2%                   |
| All residential                                          | 26,980                                                                | 96%               | 87%                    | 7%                     | 2%                   |
| Home (including apartment)                               | 21,110                                                                | 95%               | 86%                    | 6%                     | 3%                   |
| Hotel or motel                                           | 1,900                                                                 | 94%               | 85%                    | 6%                     | 3%                   |
| Dormitory or barracks                                    | 1,670                                                                 | 93%               | 77%                    | 14%                    | 1%                   |
| Rooming or boarding house                                | 970                                                                   | 98%               | 88%                    | 11%                    | 0%                   |
| Board and care home                                      | 900                                                                   | 89%               | 82%                    | 7%                     | 0%                   |
| Store or office                                          | 6,090                                                                 | 77%               | 67%                    | 7%                     | 3%                   |
| Grocery or convenience store                             | 2,030                                                                 | 50%               | 44%                    | 3%                     | 3%                   |
| Laundry or dry cleaning or other<br>professional service | 350                                                                   | 95%               | 85%                    | 9%                     | 1%                   |
| Service station or motor vehicle<br>sales or service     | 230                                                                   | 76%               | 70%                    | 5%                     | 1%                   |
| Department store                                         | 610                                                                   | 91%               | 78%                    | 12%                    | 1%                   |
| Office                                                   | 1,210                                                                 | 97%               | 85%                    | 7%                     | 4%                   |
| Laboratory                                               | 110                                                                   | 92%               | 69%                    | 2%                     | 21%                  |
| Manufacturing facility                                   | 4,070                                                                 | 92%               | 79%                    | 10%                    | 3%                   |
| All storage                                              | 950                                                                   | 97%               | 75%                    | 20%                    | 2%                   |
| Warehouse excluding cold storage                         | 510                                                                   | 99%               | 82%                    | 15%                    | 1%                   |
| All structures***                                        | 53,940                                                                | 82%               | 73%                    | 7%                     | 3%                   |

\* Includes deluge and pre-action sprinkler systems and may include sprinklers of unknown or unreported type.

\*\* Nursing home, hospital, clinic, doctor's office, or development disability facility

\*\*\* Includes some property uses that are not shown separately.

Note: These are based on structure fires reported to U.S. municipal fire departments in NFIRS Version 5.0 and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Row totals are shown in the leftmost column of percentages, and sums may not equal totals because of rounding error. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

**Table 2. (Continued)**  
**Type of Automatic Extinguishing Equipment Reported as Percentage of All Fires**  
**Where Equipment Was Present and of Known Type, by Property Use**  
**2003-2007 Structure Fires Reported to U.S. Fire Departments**

| Property Use                                         | All systems<br>other than<br>sprinklers | Dry chemical<br>system* | Carbon<br>dioxide (CO2)<br>system | Halogen type<br>system* | Foam<br>system | Other<br>special<br>hazard<br>system* |
|------------------------------------------------------|-----------------------------------------|-------------------------|-----------------------------------|-------------------------|----------------|---------------------------------------|
| All public assembly                                  | 60%                                     | 40%                     | 3%                                | 3%                      | 4%             | 11%                                   |
| Fixed-use amusement place                            | 15%                                     | 14%                     | 0%                                | 0%                      | 0%             | 1%                                    |
| Variable-use amusement place                         | 3%                                      | 2%                      | 0%                                | 0%                      | 0%             | 1%                                    |
| Religious property                                   | 3%                                      | 2%                      | 0%                                | 0%                      | 0%             | 1%                                    |
| Library or museum                                    | 1%                                      | 1%                      | 0%                                | 0%                      | 0%             | 0%                                    |
| Eating or drinking establishment                     | 71%                                     | 47%                     | 3%                                | 3%                      | 5%             | 12%                                   |
| Passenger terminal                                   | 42%                                     | 41%                     | 0%                                | 0%                      | 0%             | 1%                                    |
| Theater                                              | 1%                                      | 1%                      | 0%                                | 0%                      | 0%             | 0%                                    |
| Educational property                                 | 11%                                     | 8%                      | 0%                                | 0%                      | 1%             | 2%                                    |
| Health care property**                               | 6%                                      | 4%                      | 1%                                | 0%                      | 0%             | 1%                                    |
| Nursing home                                         | 7%                                      | 5%                      | 1%                                | 0%                      | 0%             | 0%                                    |
| Hospital                                             | 8%                                      | 5%                      | 0%                                | 0%                      | 0%             | 3%                                    |
| Clinic or doctor's office                            | 2%                                      | 0%                      | 0%                                | 0%                      | 0%             | 1%                                    |
| Prison or jail                                       | 2%                                      | 1%                      | 0%                                | 0%                      | 0%             | 0%                                    |
| All residential                                      | 4%                                      | 2%                      | 0%                                | 0%                      | 0%             | 2%                                    |
| Home (including apartment)                           | 5%                                      | 2%                      | 0%                                | 0%                      | 0%             | 2%                                    |
| Hotel or motel                                       | 6%                                      | 2%                      | 0%                                | 0%                      | 0%             | 4%                                    |
| Dormitory or barracks                                | 7%                                      | 5%                      | 0%                                | 0%                      | 1%             | 1%                                    |
| Rooming or boarding home                             | 2%                                      | 1%                      | 0%                                | 0%                      | 0%             | 0%                                    |
| Board and care home                                  | 11%                                     | 4%                      | 0%                                | 0%                      | 4%             | 3%                                    |
| Store or office                                      | 23%                                     | 15%                     | 2%                                | 1%                      | 2%             | 4%                                    |
| Grocery or convenience store                         | 50%                                     | 31%                     | 4%                                | 1%                      | 6%             | 7%                                    |
| Laundry or dry cleaning                              | 5%                                      | 0%                      | 0%                                | 0%                      | 0%             | 4%                                    |
| Service station or motor<br>vehicle sales or service | 24%                                     | 20%                     | 0%                                | 1%                      | 0%             | 2%                                    |
| Department store                                     | 9%                                      | 8%                      | 0%                                | 0%                      | 0%             | 0%                                    |
| Office                                               | 3%                                      | 1%                      | 1%                                | 0%                      | 0%             | 0%                                    |
| Laboratory                                           | 8%                                      | 2%                      | 4%                                | 1%                      | 0%             | 1%                                    |
| Manufacturing facility                               | 8%                                      | 2%                      | 4%                                | 0%                      | 0%             | 1%                                    |
| All storage                                          | 3%                                      | 1%                      | 0%                                | 0%                      | 0%             | 2%                                    |
| Warehouse excluding cold storage                     | 1%                                      | 0%                      | 0%                                | 0%                      | 0%             | 0%                                    |
| Cold storage                                         | 0%                                      | 0%                      | 0%                                | 0%                      | 0%             | 0%                                    |
| All structures***                                    | 18%                                     | 11%                     | 1%                                | 1%                      | 1%             | 4%                                    |

\* "Dry chemical system" may include wet chemical systems, because there is no category designated for wet chemical systems. "Halogen type system" includes non-halogenated suppression systems that operate on the same principle. "Other special hazard system" may include automatic extinguishing systems that are known not to be sprinklers but otherwise are of unknown or unreported type.

\*\* Nursing home, hospital, clinic, doctor's office, or development disability facility.

\*\*\* Includes some property uses that are not shown separately.

Note: These are based on structure fires reported to U.S. municipal fire departments in NFIRS Version 5.0 and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Row totals are shown in the leftmost column of percentages, and sums may not equal totals because of rounding error. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Building under construction are excluded.

Source: NFIRS and NFPA survey.



## Automatic Extinguishing Equipment Reliability and Effectiveness

In order to estimate the reliability and effectiveness of any type of automatic extinguishing equipment, the database must first be edited to remove fires, buildings, and systems where operation cannot be expected, such as small fires, buildings under construction, and partial installations. Table 3 shows the percentage of non-confined and confined structure fires, excluding buildings under construction and incidents with partial systems not in area of fire, where fires were too small to activate operational automatic extinguishing equipment. Table 3 also shows, for fires large enough to activate equipment, the percentage of fires where equipment operated, the percentage of operating equipment cases where equipment was effective, and the percentage of fires where equipment operated effectively. This is shown for:

- All sprinklers
- Wet pipe sprinklers
- Dry pipe sprinklers
- Dry chemical systems (which probably includes and may be dominated by wet chemical systems and may include some miscoded portable extinguishers),
- Carbon dioxide systems (which may include some wet chemical systems and some miscoded portable extinguishers),
- Foam systems (which may include some wet chemical systems and some miscoded portable extinguishers), and
- Halogen systems (which may include some wet chemical systems and some miscoded portable extinguishers).

Property use classes are shown only if they accounted for at least 100 projected fires per year with the specific type of automatic extinguishing equipment present.

### **For most property use groups and most types of automatic extinguishing equipment, the majority of reported fires were too small to activate operational equipment.**

When automatic extinguishing equipment was present, the percentages of fires too small to activate operating equipment, based on overall reported structure fires, were as follows:

- 65% for all sprinklers,
- 65% for wet pipe sprinklers,
- 70% for dry pipe sprinklers,
- 61% for dry (or possibly wet) chemical systems,
- 43% for carbon dioxide systems,
- 66% for foam systems, and
- 59% for halogen systems.

### **Sprinklers in the area of fire failed to operate in only 7% of reported structure fires large enough to activate sprinklers.**

Failure rates are equal to 100% minus the percentage of systems that operated, which is the percentage shown in Table 3A. The other estimated failure rates corresponding to percentage operating rates shown in Table 3A are:

- 5% for wet pipe sprinklers,

- 17% for dry pipe sprinklers,
- 26% for dry (or possibly wet) chemical systems,
- 17% for carbon dioxide systems,
- 3% for foam systems, and
- 4% for halogen systems.

For major property classes and sprinklers, the estimated failure rates range from a low of 4% for residential properties, public assembly properties and stores and offices to a high of 32% for educational properties and 29% for storage properties. The estimated failure rates for wet pipe sprinklers specifically were 25% for educational properties and 16% for storage properties.

**For sprinklers that operated, their performance was deemed effective in 97% of the cases. For all confined or non-confined fires large enough to activate sprinklers, excluding buildings under construction, sprinklers operated effectively 91% of the time.**

The percentages of effective operation for all structures were as follows for other types of automatic extinguishing equipment:

- 92% for wet pipe sprinklers,
- 79% for dry pipe sprinklers,
- 60% for dry (or possibly wet) chemical systems,
- 79% for carbon dioxide systems,
- 81% for foam systems, and
- 88% for halogen systems.

Wet pipe sprinklers are both much more reliable than dry pipe sprinklers (95% vs. 83%) and slightly more effective when they operate (98% vs. 95%), resulting in a much higher percentage of effective operation (92% vs. 79%). Operating effectiveness is much lower for dry (or possibly wet) chemical systems than for any other type of automatic extinguishing equipment (60% vs. 79-92%) and is especially low (51%) for eating or drinking establishments, which account for most of the fires reported with this type of equipment. Eating or drinking establishments also account for most fires reported with carbon dioxide, foam, or halogen systems. These installations may all include a high proportion of misclassified wet chemical systems or portable extinguishers, because carbon dioxide, foam, and halogen systems are rarely appropriate for eating or drinking establishments.

A disadvantage of measuring automatic extinguishing equipment effectiveness by judgments made in incident reports is the ambiguity and subjectivity of the criterion of “effective,” which has never been precisely defined, let alone supported by an operational assessment protocol that could be executed consistently by different people. Also, confined fires usually have these details unreported, and so their few fires with details reported will be weighted far more heavily, after allocation of unknowns, than will non-confined fires.

**The majority of sprinkler failures occurred because the system was shut off.**

Table 4 provides the percentages of reasons for failure, after recoding, by type of automatic extinguishing system and property use. Other or unclassified reason for failure is treated as an unknown and allocated.

For all types of sprinklers combined:

- 53% of failures to operate were attributed to the equipment being shut off,
- 20% were because the equipment was inappropriate for the type of fire,
- 15% were because of lack of maintenance,
- 9% were because manual intervention defeated the equipment, and
- 2% were because a component was damaged.

If manual intervention occurs before fire begins, one would expect that to be coded as system shut off before fire. If manual intervention occurs after sprinklers operate, one would expect that to constitute ineffective performance, not failure to operate. What is left is manual intervention after fire begins but before sprinklers operate, but we do not know whether that is the only condition associated with this coding.

*Only 2% were because of a failing of the equipment rather than a failing of the people who designed, selected, maintained, and operated the equipment.* If these human failings could be eliminated, the overall sprinkler failure rate would drop from the estimated 7% of reported fires to less than 0.2%. That is the kind of sprinkler failure rate reported by Marryatt<sup>6</sup> for Australia and New Zealand, where high standards of maintenance are reportedly commonplace.

Training can sharply reduce the likelihood of three other causes of failure – system defeating due to manual intervention, lack of maintenance, and installation of the wrong system for the hazard.

**Most cases of sprinkler ineffectiveness were because water did not reach the fire (43%) or because not enough water was released (31%).**

Table 5 provides distributions of reasons for ineffectiveness, by property class and type of automatic extinguishing equipment. In Table 5, two of the reasons for ineffectiveness are (extinguishing) agent did not reach the fire and not enough (extinguishing) agent was released. For sprinklers, the agent is water. In addition to the two reasons cited, other reasons for sprinkler ineffectiveness for all structures were inappropriate equipment for the type of fire (12%), defeating due to manual intervention (5%), damage to a system component (4%), and lack of maintenance (4%).

There are a number of different ways in which water may not reach the fire. One is shielded fires such as rack storage in a property with ceiling sprinklers only. Another is fire spread above exposed sprinklers, through unsprinklered concealed spaces, or via exterior surfaces. Another reason would be a deep-seated fire in bulk storage. A different kind of problem would be droplet sizes that are too small to penetrate the buoyant fire plume and reach the seat of the fire.

Insufficient water can be released if there are problems with the system's water supply. This reason for ineffectiveness can also overlap with other reasons, such as inappropriate equipment (if, for example, the hazard has changed under the equipment and now requires a higher water flow density than is provided by the now inappropriate equipment) and defeating by manual intervention (if, for example, the sprinklers are turned off prematurely so that insufficient water reaches the fire). Insufficient water also could be one of the reasons that could be cited if a flash

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<sup>6</sup> H.W. Marryatt, *Fire: A Century of Automatic Sprinkler Protection in Australia and New Zealand, 1886-1986*, 2<sup>nd</sup> edition, Victoria, Australia: Australian Fire Protection Association, 1988.

fire or a fire with several points of origin overwhelms the system or if an explosion reduces the water flow but does not cause complete system failure.

Reasons for ineffectiveness are different for wet pipe sprinklers and dry pipe sprinklers, with dry pipe sprinklers having 60% of cases attributed to not enough water released compared to 25% for wet pipe sprinklers. Because the design of dry pipe sprinklers assures a delayed release of water, it is not surprising that when such systems are ineffective, an insufficiency of water is usually involved.

Even a well-maintained, complete, appropriate system requires the support of a well-considered integrated design for all the other elements of the building's fire protection. Unsatisfactory sprinkler performance can result from an inadequate water supply or faulty building construction. More broadly, unsatisfactory fire protection performance can occur if the building's design does not address all five elements of an integrated system – slowing the growth of fire, automatic detection, automatic suppression, confining the fire, and occupant evacuation.

**Effectiveness should be measured relative to the design objectives for a particular system.** For most rooms in most properties, sprinklers are designed to confine fire to the room of origin.

**Table A. Non-Confined Fires With Areas of Origin That Could Be Room Larger Than the Sprinkler Design Area for the Space, as Percent of Total Non-Confined and Confined Structure Fires for Buildings Not Under Construction and With Sprinklers in Fire Area Percentage of 2003-2007 Structure Fires Reported to U.S. Fire Departments**

| Property Use                                               | Large Assembly Area (At Least 100 People) | Sales, Showroom or Performance Area | Storage Room, Area, Tank or Bin | Shipping, Receiving or Loading Area | Unclassified Storage Area | All Areas Combined |
|------------------------------------------------------------|-------------------------------------------|-------------------------------------|---------------------------------|-------------------------------------|---------------------------|--------------------|
| Eating or drinking establishment                           | 1.0%                                      | 0.2%                                | 1.7%                            | 0.2%                                | 1.2%                      | 4.3%               |
| Public assembly excluding eating or drinking establishment | 2.4%                                      | 0.7%                                | 0.9%                            | 0.2%                                | 0.8%                      | 5.0%               |
| Educational                                                | 1.3%                                      | 0.3%                                | 0.6%                            | 0.0%                                | 0.7%                      | 2.9%               |
| Health care property*                                      | 0.1%                                      | 0.0%                                | 0.5%                            | 0.0%                                | 0.3%                      | 0.9%               |
| Home (including apartment)                                 | 0.0%                                      | 0.0%                                | 0.2%                            | 0.0%                                | 0.2%                      | 0.4%               |
| Hotel or motel                                             | 1.6%                                      | 0.0%                                | 0.3%                            | 0.0%                                | 0.5%                      | 1.4%               |
| Store or office                                            | 0.1%                                      | 5.7%                                | 2.2%                            | 2.1%                                | 2.2%                      | 12.2%              |
| Manufacturing facility                                     | 0.1%                                      | 0.0%                                | 2.5%                            | 2.1%                                | 1.7%                      | 6.4%               |
| Warehouse excluding cold storage                           | 0.1%                                      | 0.3%                                | 5.0%                            | 12.4%                               | 9.9%                      | 27.7%              |

\* Hospital, clinic, doctor's office, nursing home and development disability facility.

Note: Percentages are defined as non-confined fires with indicated area of origin divided by total non-confined and confined fires with any area of origin. Percentages sum left to right and may not equal totals in last column because of rounding. Fires reported as confined fires are excluded from the numerator because such fires could not be large enough to exceed the sprinkler design area. Statistics are based on structure fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Statistics exclude buildings under construction and fires with sprinklers not in fire area reported as reason for failure or ineffectiveness of automatic extinguishing equipment.

Source: NFIRS and NFPA survey.



Some properties have some very large rooms in which the sprinkler installation is designed to confine fire to a design area that is much smaller than the entire room. These rooms could include large assembly areas; sales, showroom, or performance areas; and storage areas.

Table A shows the percentage of fires, by property use, that begin in five types of rooms that *could* be large enough to have a design area smaller than the entire room. Many of these rooms will not be that large. All these rooms combined do not account for a majority of fires in any type of property, and only warehouses have more than about one-eighth of their fires in such rooms.

**Sprinklers are designed to confine a fire to the room of origin or the design fire area, whichever is smaller.**

Therefore, the benefits of sprinklers will tend to come in the following scenarios:

- A fire that would otherwise have spread beyond the room of fire origin will be confined to the room of origin, resulting in a smaller fire-damaged area and less property damage.
- A fire that would otherwise have grown larger than the design fire area in a room larger than that area will be confined to the design fire area, resulting in a smaller fire-damaged area and less property damage.
- A fire will be confined to an area smaller than the room or the design fire area, even though that degree of success goes beyond the performance assured by the design, resulting in a smaller fire-damaged area and less property damage.

Table 6 provides direct measurement of sprinkler effect involving the first scenario. For all structures combined, 74% have flame damage confined to room of origin when there is no automatic extinguishing equipment present. This rises to 95% of fires with flame damage confined to room of origin when any type of sprinkler is present.

As noted, for most rooms in most properties, effective performance is indicated by confinement of fire to the room of origin. For the few rooms where the design area is smaller than the room, a sprinkler system can be ineffective in terms of confining fire to the design area but still be successful in confining fire to the larger room of origin. Therefore, one might expect the percentage of fires with flame confined to room of origin to be slightly larger than the combined performance (operating effectively) for any given property use. Table B shows this is usually the case.

**Dry pipe sprinklers tend to have more sprinklers operating than wet pipe sprinklers.**

Table 7A shows the number of sprinklers operating by type of sprinkler system. Five or fewer heads operated in 97% of the wet pipe system activations and 89% of the dry pipe system activations.

Dry-pipe systems are much more likely to open more than one sprinkler than wet pipe systems (39% vs. 23% of fires). The likely reason is the designed time delay in tripping the dry pipe valve and passing water through the piping to the opened sprinklers. The delay permits fire to spread, which can mean a larger fire, requiring and causing more sprinklers to activate.

**Table B. Combined Sprinkler Performance vs.  
Sprinkler Success in Confining Fire to Room of Origin, by Property Use Group  
2003-2007 Structure Fires Reported to U.S. Fire Departments Where Sprinklers Were Present in Fire Area,  
Fire Was Large Enough to Activate Sprinklers, and Building Was Not Under Construction**

| <b>Property Use</b>                                                | <b>Percentage of Fires<br/>Where Sprinklers<br/>Operated Effectively<br/>(from Table 3A)</b> | <b>Percentage of Fires with<br/>Flame Damage Confined to<br/>Room of Origin</b> |
|--------------------------------------------------------------------|----------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|
| Public assembly                                                    | 90%                                                                                          | 95%                                                                             |
| Eating or drinking establishment                                   | 90%                                                                                          | 93%                                                                             |
| Educational                                                        | 68%                                                                                          | 98%                                                                             |
| Health care property*                                              | 87%                                                                                          | 99%                                                                             |
| Residential                                                        | 95%                                                                                          | 96%                                                                             |
| Home (including apartment)                                         | 94%                                                                                          | 97%                                                                             |
| Hotel or motel                                                     | 91%                                                                                          | 97%                                                                             |
| Dormitory or barracks                                              | 99%                                                                                          | 97%                                                                             |
| Store or office                                                    | 94%                                                                                          | 93%                                                                             |
| Grocery or convenience store                                       | 94%                                                                                          | 96%                                                                             |
| Laundry or dry cleaning or<br>other professional supply or service | 92%                                                                                          | 92%                                                                             |
| Service station or motor vehicle<br>sales or service               | 92%                                                                                          | 85%                                                                             |
| Department store                                                   | 95%                                                                                          | 92%                                                                             |
| Office building                                                    | 95%                                                                                          | 94%                                                                             |
| Manufacturing facility                                             | 86%                                                                                          | 87%                                                                             |
| Storage                                                            | 77%                                                                                          | 80%                                                                             |
| Warehouse excluding cold storage                                   | 77%                                                                                          | 79%                                                                             |
| All structures**                                                   | 91%                                                                                          | 95%                                                                             |

\* Nursing home, hospital, clinic, doctor's office, or development disability facility.

\*\* Includes some properties not separately listed above.

**Wet pipe sprinkler systems tend to have more sprinklers operating in fires in manufacturing facilities or warehouses than in other properties.**

Table 7B shows the number of wet pipe sprinklers operating by property use group. In warehouses or manufacturing facilities respectively, 69-70% of the fires in properties where wet pipe sprinklers operated had two or fewer sprinklers operating, which means 30-31% of the fires in properties had at least three sprinklers operating. Similarly, 89-90% had five or fewer sprinklers operating, which means 10-11% had at least six sprinklers operating. By contrast, in public assembly properties and stores and offices where wet pipe sprinklers operated, 87-90% of fires in properties had two or fewer sprinklers operating, which means only 10-13% of fires in properties had at least three sprinklers operating. Similarly, 95-96% had five or fewer sprinklers operating, which means only 4-5% had at least six sprinklers operating.

In homes (including apartments), 97% of fires in properties had two or fewer sprinklers operating.

### Effectiveness declines when more sprinklers operate.

When more than 1-2 sprinklers have to operate, this may be taken as an indication of less than ideal performance. Table 8 shows that the percentage of fires where performance is deemed effective decreases as the number of wet pipe sprinklers operating decreases, falling from 97% of fires when one sprinkler opens to 79% when more than 10 sprinklers open. At the same time, the number of sprinklers operating should not be used as an independent indicator of effectiveness because sprinklers are deemed effective in most fires where sprinklers operate, no matter how many sprinklers operate. Furthermore, most sprinkler installations are designed for control, not extinguishment, and anticipate that multiple sprinklers will be needed for control in some fire scenarios.

**Table C. Reasons for Failure or Ineffectiveness as Percentages of All Cases of Failure or Ineffectiveness, for All Structures and All Sprinklers**

| Reason                                                | Failure |       | Ineffectiveness |       | Combined |        |
|-------------------------------------------------------|---------|-------|-----------------|-------|----------|--------|
| System shut off                                       | 521     | (38%) | 0               | (0%)  | 521      | (38%)  |
| Wrong type of (inappropriate) system for type of fire | 197     | (14%) | 47              | (3%)  | 244      | (18%)  |
| Water discharged but did not reach fire               | 0       | (0%)  | 169             | (12%) | 169      | (12%)  |
| Lack of maintenance                                   | 148     | (11%) | 16              | (1%)  | 163      | (12%)  |
| Not enough water discharged                           | 0       | (0%)  | 121             | (9%)  | 121      | (9%)   |
| Manual interruption defeated system                   | 89      | (7%)  | 20              | (1%)  | 108      | (8%)   |
| System component damaged                              | 20      | (1%)  | 16              | (1%)  | 35       | (3%)   |
| Total                                                 | 974     | (72%) | 388             | (28%) | 1,362    | (100%) |

Source: Based on Tables 4A and 5A.

### Details on reasons for failure or ineffectiveness and how to address them.

The following potential reasons for failure or ineffectiveness are defined in the statistical database:

- System shut off (a reason for failure but not for ineffectiveness),
- Wrong type of (inappropriate) system for the type of fire,
- Agent discharged but did not reach fire (a reason for ineffectiveness but not for failure),
- Lack of maintenance [including corrosion or heads painted],
- Not enough agent discharged (a reason for ineffectiveness but not for failure),
- Manual intervention [defeated the system] (8%)
- System component damaged,
- Fire not in area protected [by the system] (excluded from analysis of failure and ineffectiveness)

NFPA has compiled published incidents (see Appendix D) that illustrate the different types of reasons for sprinkler failure or ineffectiveness, and NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, describes procedures to

address most of these reasons that involve maintenance of an existing sprinkler system. An exception is systems designed to NFPA 13D (the home sprinkler standard), for which maintenance, inspection, and testing requirements are much fewer, reflecting the greater inherent reliability of the simpler design, and are included in the NFPA 13D standard. When the reasons involve a need to modify the sprinkler system, procedures to trigger those changes are found in NFPA 1, *Fire Code*, and NFPA 1620, *Standard for Pre-Incident Planning*.

### **System shut off**

The NFPA incident compilation includes cases of systems shut off because of building status (e.g., vacant, being remodeled, still under construction) and cases of systems shut off because of system problems (e.g., leak in system, dirt in water supply for both building and system, damage from earlier forklift collision). NFPA 25 addresses all these circumstances under rules for dealing with impairments (Chapter 14). When the system is shut off or otherwise impaired, NFPA 25 requires use of a tag to provide a visible reminder that the system is out of service, close oversight of the schedule and steps required to correct the impairment, and appropriate practices to assure safety in the building while the impairment exists. NFPA 25 also addresses valve supervision using a tamper switch connected to a central alarm monitoring system.

### **Inappropriate system**

Statistically, this is the second leading reason for failure or ineffectiveness, after system shut off.

“Inappropriate” system can refer to the wrong type of agent (e.g., water vs. chemical agent or carbon dioxide), the wrong type of system for the same agent (e.g., wet pipe vs. dry pipe), or the wrong design for the same system and agent (e.g., a design adequate only for Class I commodities vs. a design adequate for any class of commodities). The NFPA compilation identifies cases where the system was inadequate for the hazard or where the fire overwhelmed the system with no further details available.

The NFPA 13, NFPA 13D and NFPA 13R standards for installation of automatic extinguishing equipment provide detailed requirements for selecting the right agent, the right system, and the right design, but this is all relative to conditions at the initial installation. The need for a change in system design can be identified during routine, periodic inspections in support of the local fire code or pre-incident planning. Section 13.3.3 of NFPA 1 requires the property owner or occupant to maintain the design level of performance and protection of the sprinkler system and to evaluate the adequacy of the installed system if there are any changes in occupancy, use, process, or materials. NFPA 1620 requires periodic review, testing, updating and refinement of the pre-incident plan. NFPA 1620 also states that a mismatch of sprinkler system with type or arrangement of protected commodities is a sprinkler system design deficiency that should be noted on the pre-incident plan.

### **Agent did not reach fire**

A number of conditions can result in this problem, but the most obvious one is a shielded fire. An incident identified in the NFPA compilation involved a convention center where a covering,



operating like a temporary ceiling, blocked the sprinklers from reaching the fire. Shielding can also occur if fire grows under furniture (as in a residential property or an office) or under equipment (as in a manufacturing facility) or in the lower portions of an array of objects (as in a store or warehouse).

An engineered solution to the problem is to place sprinklers under the shielding, as with in-rack sprinklers. The other principal alternative is to avoid arrangements where shielding and blocking are likely to occur. The periodic inspections needed to identify shielding and blocking situations and to correct such problems if discovered can be conducted as part of fire code inspections (e.g., in support of NFPA 1) or pre-incident planning (e.g., in accord with NFPA 1620.)

### **Lack of maintenance**

The NFPA compilation identifies an incident where a sprinkler was coated with cotton dust in a textile manufacturing plant and an incident where sediment built up in the system. NFPA 13 and NFPA 25 include requirements for special protection in settings or during activities with a high vulnerability to accumulation of dust, paint, or other substances, and NFPA 25 uses inspections to detect such accumulations when they occur.

### **Not enough agent discharged**

The NFPA incident compilation identifies several cases of fire overwhelming the sprinklers, but for most of these incidents, it was not reported whether the sprinkler system had problems affecting the flow or whether the system design was no longer adequate for the hazard being protected or whether some other problem was involved.

NFPA 25 uses inspections and testing to address all sources of problems affecting water flow or delivered density, including standpipes, hose systems, fire service mains, fire pumps, and water storage tanks. If the problem is a system no longer appropriate for the hazard below it, NFPA 1 and NFPA 1620 are relevant, as discussed above under “inappropriate system”.

NFPA 25 also provides a procedure for periodic investigation of pipes for obstructions (Chapter 13). Such obstructions can reduce water flow and result in a problem of not enough agent discharged.

### **Manual intervention**

NFPA standards for specific occupancies or for fire service operations provide guidance for fire protection and firefighting in a sprinklered building. These rules address the best use of fire suppression equipment in combination with fire sprinklers and the need to confirm that fire conditions no longer pose a threat before shutting off sprinklers.

### **System component damaged**

In the NFPA compilation of incidents of failure or ineffectiveness, the incidents involving component damage consist entirely of fires where automatic extinguishing equipment was

damaged by explosions or by ceiling, roof, or building collapse, nearly always as a consequence of fire. System component damage is the least frequently cited reason for sprinkler failure or ineffectiveness, which is consistent with the idea that the components are very reliable, absent a severe external cause like an explosion. Explosions are more severe than the design fires considered by NFPA 13, NFPA 13D, and NFPA 13R. NFPA 25 uses inspections and tests to detect less severe component damage.

### **Fire not in area protected**

Under fire incident coding rules, automatic extinguishing equipment is deemed to be present in a building only if it is present in the area of fire. Therefore, fires are removed from the operability and effectiveness analysis in the report if equipment was deemed to have failed or been ineffective because of fire outside area protected.

However, some areas may be unprotected even in a system that is described as having complete coverage. NFPA 13 has provisions for sprinkler protection of concealed spaces and exterior locations, but coverage of these areas is required only in certain defined situations. The NFPA compilation includes several incidents involving partial coverage by any definition but also several incidents where coverage was described as complete but was not provided for areas of fire origin or of early fire growth in concealed or void spaces, on balconies or other outside locations, or above sprinklers in manufacturing or storage facilities.

**Table D. Leading Areas of Origin for Fires in One- or Two-Family Homes  
Excluding Buildings Under Construction  
2003-2007 Structure Fires Reported to U.S. Fire Departments**

| <b>Area of Origin</b>                    | <b>Percent of Fires Where Wet-Pipe Sprinklers<br/>Were Present But<br/>Not Present in Fire Area</b> | <b>Percent of<br/>All<br/>Fires</b> |
|------------------------------------------|-----------------------------------------------------------------------------------------------------|-------------------------------------|
| Kitchen                                  | 32%                                                                                                 | 32%                                 |
| Wall assembly or concealed space         | 9%                                                                                                  | 3%                                  |
| Attic or concealed space above top story | 8%                                                                                                  | 3%                                  |
| Crawl space or substructure space        | 6%                                                                                                  | 2%                                  |
| Garage**                                 | 6%                                                                                                  | 3%                                  |
| Exterior balcony or unenclosed porch     | 5%                                                                                                  | 2%                                  |
| Courtyard, terrace or patio              | 5%                                                                                                  | 1%                                  |
| Laundry room or area                     | 4%                                                                                                  | 4%                                  |
| Exterior wall surface                    | 4%                                                                                                  | 3%                                  |
| Other area of origin                     | 21%                                                                                                 | 47%                                 |
| Total                                    | 100%                                                                                                | 100%                                |

\* These are only fires where the absence of sprinklers in the fire area was identified because that absence was cited as a reason for failure or ineffectiveness.

\*\* Excludes garages coded as separate building.

Source: NFIRS and NFPA survey.

This long-standing dilemma over how to describe a lack of coverage in concealed spaces and exterior locations has become more complicated with the emergence of specialized installation standards, such as NFPA 13D and NFPA 13R, that also exempt certain rooms from coverage.

Table D shows the leading areas of fire origin for one- and two-family home fires coded as sprinklers present but failed or ineffective because of no sprinkler in the fire area. In other words, sprinklers were present somewhere in the home but not in the area of origin. Percentage shares for all these areas of origin for one- and two-family home fires, regardless of sprinkler status, are also included for comparison.

One-third of fires with no sprinklers in the fire area were fires that began in the kitchen, an area that should be covered by sprinklers in any standard installation. However, concealed spaces and other structural areas, external areas, garages, and attics account for nearly half (43%) of the fires where sprinklers are present but not in the fire area. These same areas accounted for less than one-fifth (18%) of fires in dwellings in general.

**Table 3.**  
**Automatic Extinguishing Equipment Reliability and Effectiveness, by Property Use**  
**2003-2007 Structure Fires**

**A. All Sprinklers**

| Property Use                                      | When equipment is present, fire is large enough to activate equipment, and sprinklers were present in fire area |                                                  |                          |                                      |                                              |                                                      |
|---------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|--------------------------------------------------|--------------------------|--------------------------------------|----------------------------------------------|------------------------------------------------------|
|                                                   | Number of fires per year where extinguishing equipment was present                                              | Percent of fires too small to activate equipment | Number of fires per year | Percent where equipment operated (A) | Percent effective of those that operated (B) | Percent where equipment operated effectively (A x B) |
| All public assembly                               | 3,040                                                                                                           | 68%                                              | 910                      | 96%                                  | 94%                                          | 90%                                                  |
| Eating or drinking establishment                  | 1,380                                                                                                           | 54%                                              | 580                      | 97%                                  | 93%                                          | 90%                                                  |
| Educational property                              | 2,010                                                                                                           | 83%                                              | 320                      | 68%                                  | 100%                                         | 68%                                                  |
| Health care property*                             | 3,770                                                                                                           | 83%                                              | 620                      | 88%                                  | 98%                                          | 87%                                                  |
| Nursing home                                      | 1,910                                                                                                           | 80%                                              | 380                      | 83%                                  | 99%                                          | 82%                                                  |
| Residential                                       | 25,820                                                                                                          | 66%                                              | 8,440                    | 96%                                  | 99%                                          | 95%                                                  |
| Home (including apartment)                        | 20,130                                                                                                          | 62%                                              | 7,290                    | 95%                                  | 99%                                          | 94%                                                  |
| Hotel or motel                                    | 1,790                                                                                                           | 69%                                              | 520                      | 92%                                  | 99%                                          | 91%                                                  |
| Dormitory or barracks                             | 1,550                                                                                                           | 81%                                              | 290                      | 99%                                  | 100%                                         | 99%                                                  |
| Rooming or boarding house                         | 950                                                                                                             | 82%                                              | 150                      | 97%                                  | 99%                                          | 96%                                                  |
| Board and care home                               | 790                                                                                                             | 85%                                              | 110                      | 98%                                  | 100%                                         | 98%                                                  |
| Store or office                                   | 4,660                                                                                                           | 64%                                              | 1,580                    | 96%                                  | 99%                                          | 94%                                                  |
| Grocery or convenience store                      | 1,010                                                                                                           | 64%                                              | 340                      | 97%                                  | 97%                                          | 94%                                                  |
| Laundry or dry cleaning                           | 340                                                                                                             | 59%                                              | 130                      | 96%                                  | 96%                                          | 92%                                                  |
| Service station or motor vehicle sales or service | 170                                                                                                             | 40%                                              | 100                      | 97%                                  | 95%                                          | 92%                                                  |
| Department store                                  | 560                                                                                                             | 68%                                              | 170                      | 95%                                  | 99%                                          | 95%                                                  |
| Office                                            | 1,170                                                                                                           | 75%                                              | 280                      | 95%                                  | 100%                                         | 95%                                                  |
| Manufacturing facility                            | 3,740                                                                                                           | 48%                                              | 1,850                    | 93%                                  | 93%                                          | 86%                                                  |
| All storage                                       | 920                                                                                                             | 48%                                              | 470                      | 79%                                  | 97%                                          | 77%                                                  |
| Warehouse excluding cold storage                  | 510                                                                                                             | 43%                                              | 280                      | 80%                                  | 97%                                          | 77%                                                  |
| All structures**                                  | 44,310                                                                                                          | 65%                                              | 14,630                   | 93%                                  | 97%                                          | 91%                                                  |

\* Nursing home, hospital, clinic, doctor's office, or development disability facility.

\*\* Includes some properties not listed separately above.

Note: These are percentages of fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Percentages are based on estimated total fires reported in NFIRS Version 5.0 with the indicated type of automatic extinguishing system and system performance not coded as fire too small to activate systems. Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to fail if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. Property use classes are shown only if they accounted for at least 100 projected fires per year with the specific type of automatic extinguishing equipment present.

Source: NFIRS and NFPA survey.



**Table 3. (Continued)**  
**Automatic Extinguishing Equipment Reliability and Effectiveness, by Property Use**  
**2003-2007 Structure Fires**

**B. Wet Pipe Sprinklers Only**

| Property Use                                      | When equipment is present, fire is large enough to activate equipment, and sprinklers were present in fire area |                                                  |                          |                                      |                                              |                                                      |
|---------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|--------------------------------------------------|--------------------------|--------------------------------------|----------------------------------------------|------------------------------------------------------|
|                                                   | Number of fires per year where extinguishing equipment was present                                              | Percent of fires too small to activate equipment | Number of fires per year | Percent where equipment operated (A) | Percent effective of those that operated (B) | Percent where equipment operated effectively (A x B) |
| All public assembly                               | 2,570                                                                                                           | 70%                                              | 730                      | 97%                                  | 97%                                          | 94%                                                  |
| Eating or drinking establishment                  | 1,110                                                                                                           | 57%                                              | 460                      | 97%                                  | 97%                                          | 94%                                                  |
| Educational property                              | 1,800                                                                                                           | 85%                                              | 250                      | 75%                                  | 100%                                         | 75%                                                  |
| Health care property*                             | 3,270                                                                                                           | 83%                                              | 520                      | 90%                                  | 99%                                          | 89%                                                  |
| Nursing home                                      | 1,600                                                                                                           | 81%                                              | 300                      | 85%                                  | 99%                                          | 84%                                                  |
| Residential                                       | 23,370                                                                                                          | 64%                                              | 7,920                    | 96%                                  | 100%                                         | 96%                                                  |
| Home (including apartment)                        | 18,220                                                                                                          | 61%                                              | 6,840                    | 96%                                  | 99%                                          | 96%                                                  |
| Hotel or motel                                    | 1,620                                                                                                           | 70%                                              | 470                      | 88%                                  | 99%                                          | 87%                                                  |
| Dormitory or barracks                             | 1,290                                                                                                           | 77%                                              | 290                      | 99%                                  | 100%                                         | 99%                                                  |
| Rooming or boarding home                          | 850                                                                                                             | 79%                                              | 150                      | 97%                                  | 99%                                          | 96%                                                  |
| Store or office                                   | 4,070                                                                                                           | 64%                                              | 1,390                    | 96%                                  | 99%                                          | 95%                                                  |
| Grocery or convenience store                      | 880                                                                                                             | 64%                                              | 300                      | 97%                                  | 97%                                          | 95%                                                  |
| Laundry or dry cleaning                           | 300                                                                                                             | 57%                                              | 130                      | 96%                                  | 96%                                          | 92%                                                  |
| Service station or motor vehicle sales or service | 160                                                                                                             | 40%                                              | 90                       | 97%                                  | 95%                                          | 92%                                                  |
| Department store                                  | 480                                                                                                             | 69%                                              | 140                      | 95%                                  | 99%                                          | 94%                                                  |
| Office                                            | 1,030                                                                                                           | 74%                                              | 260                      | 96%                                  | 99%                                          | 96%                                                  |
| Manufacturing facility                            | 3,210                                                                                                           | 49%                                              | 1,540                    | 96%                                  | 92%                                          | 89%                                                  |
| All storage                                       | 710                                                                                                             | 48%                                              | 360                      | 84%                                  | 98%                                          | 82%                                                  |
| Warehouse excluding cold storage                  | 420                                                                                                             | 45%                                              | 230                      | 85%                                  | 97%                                          | 83%                                                  |
| All structures**                                  | 39,110                                                                                                          | 65%                                              | 13,000                   | 95%                                  | 98%                                          | 92%                                                  |

\* Nursing home, hospital, clinic, doctor's office, or development disability facility.

\*\* Includes some properties not listed separately above.

Note: These are percentages of fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Percentages are based on estimated total fires reported in NFIRS Version 5.0 with the indicated type of automatic extinguishing system and system performance not coded as fire too small to activate systems. Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to fail if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. Property use classes are shown only if they accounted for at least 100 projected fires per year with the specific type of automatic extinguishing equipment present.

Source: NFIRS and NFPA survey.

**Table 3. (Continued)**  
**Automatic Extinguishing Equipment Reliability and Effectiveness, by Property Use**  
**2003-2007 Structure Fires**

**C. Dry Pipe Sprinklers Only**

| Property Use                     | When equipment is present, fire is large enough to activate equipment, and sprinklers were present in fire area |                                                  |                          |                                      |                                              |                                                      |
|----------------------------------|-----------------------------------------------------------------------------------------------------------------|--------------------------------------------------|--------------------------|--------------------------------------|----------------------------------------------|------------------------------------------------------|
|                                  | Number of fires per year where extinguishing equipment was present                                              | Percent of fires too small to activate equipment | Number of fires per year | Percent where equipment operated (A) | Percent effective of those that operated (B) | Percent where equipment operated effectively (A x B) |
| All public assembly              | 190                                                                                                             | 60%                                              | 70                       | 94%                                  | 76%                                          | 71%                                                  |
| Eating or drinking establishment | 90                                                                                                              | 46%                                              | 40                       | 100%                                 | 69%                                          | 69%                                                  |
| Residential                      | 1,880                                                                                                           | 82%                                              | 320                      | 92%                                  | 98%                                          | 90%                                                  |
| Home (including apartment)       | 1,350                                                                                                           | 81%                                              | 250                      | 89%                                  | 98%                                          | 88%                                                  |
| Store or office                  | 420                                                                                                             | 65%                                              | 140                      | 91%                                  | 99%                                          | 90%                                                  |
| Manufacturing facility           | 410                                                                                                             | 45%                                              | 210                      | 90%                                  | 95%                                          | 86%                                                  |
| All storage                      | 190                                                                                                             | 49%                                              | 90                       | 57%                                  | 97%                                          | 55%                                                  |
| Warehouse excluding cold storage | 80                                                                                                              | 26%                                              | 60                       | 43%                                  | 96%                                          | 41%                                                  |
| All structures*                  | 3,810                                                                                                           | 70%                                              | 1,100                    | 83%                                  | 95%                                          | 79%                                                  |

\* Includes some properties not listed separately above.

Note: These are percentages of fires reported to U.S. municipal fire departments and so exclude fires reported only to federal or state agencies or industrial fire brigades. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Percentages are based on estimated total fires reported in NFIRS Version 5.0 with the indicated type of automatic extinguishing system and system performance not coded as fire too small to activate systems. Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. Property use classes are shown only if they accounted for at least 100 projected fires per year with the specific type of automatic extinguishing equipment present.

Source: NFIRS and NFPA survey.

**Table 3. (Continued)**  
**Automatic Extinguishing Equipment Reliability and Effectiveness, by Property Use**  
**2003-2007 Structure Fires**

**D. Dry Chemical Systems Only**

| Property Use                        | Number of fires<br>per year where<br>extinguishing<br>equipment was<br>present | Percent of fires<br>too small to<br>activate<br>equipment | When equipment is present, fire is large enough to activate<br>equipment, and sprinklers were present in fire area |                                               |                                                          |                                                                  |
|-------------------------------------|--------------------------------------------------------------------------------|-----------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------|-----------------------------------------------|----------------------------------------------------------|------------------------------------------------------------------|
|                                     |                                                                                |                                                           | Number of fires<br>per year                                                                                        | Percent where<br>equipment<br>operated<br>(A) | Percent<br>effective of<br>those that<br>operated<br>(B) | Percent where<br>equipment<br>operated<br>effectively<br>(A x B) |
| All public assembly                 | 3,060                                                                          | 63%                                                       | 1,020                                                                                                              | 69%                                           | 75%                                                      | 51%                                                              |
| Eating or drinking<br>establishment | 2,230                                                                          | 63%                                                       | 730                                                                                                                | 68%                                           | 75%                                                      | 51%                                                              |
| Residential                         | 570                                                                            | 50%                                                       | 300                                                                                                                | 94%                                           | 95%                                                      | 89%                                                              |
| Store or office                     | 890                                                                            | 56%                                                       | 330                                                                                                                | 82%                                           | 75%                                                      | 61%                                                              |
| Grocery or<br>convenience store     | 630                                                                            | 66%                                                       | 170                                                                                                                | 92%                                           | 73%                                                      | 67%                                                              |
| All structures*                     | 5,930                                                                          | 61%                                                       | 2,060                                                                                                              | 74%                                           | 81%                                                      | 60%                                                              |

\* Includes some properties not listed above.

Note: "Dry chemical systems" may include some wet chemical systems, because there is no category designated for wet chemical systems. These are percentages of fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Percentages are based on estimated total fires reported in NFIRS Version 5.0 with the indicated type of automatic extinguishing system and system performance not coded as fire too small to activate systems. Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to fail if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. Property use classes are shown only if they accounted for at least 100 projected fires per year with the specific type of automatic extinguishing equipment present.

Source: NFIRS and NFPA survey.

**Table 3. (Continued)**  
**Automatic Extinguishing Equipment Reliability, by Property Use**  
**2003-2007 Structure Fires**

**E. Carbon Dioxide Systems Only**

| Property Use                     | Number of fires per year where extinguishing equipment was present | Percent of fires too small to activate equipment | When equipment is present, fire is large enough to activate equipment, and sprinklers were present in fire area |                                      |                                              |  | Percent where equipment operated effectively (A x B) |
|----------------------------------|--------------------------------------------------------------------|--------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|--------------------------------------|----------------------------------------------|--|------------------------------------------------------|
|                                  |                                                                    |                                                  | Number of fires per year                                                                                        | Percent where equipment operated (A) | Percent effective of those that operated (B) |  |                                                      |
| All public assembly              | 220                                                                | 50%                                              | 100                                                                                                             | 37%                                  | 93%                                          |  | 34%                                                  |
| Eating or drinking establishment | 160                                                                | 52%                                              | 70                                                                                                              | 39%                                  | 91%                                          |  | 35%                                                  |
| Manufacturing facility           | 180                                                                | 3%                                               | 160                                                                                                             | 99%                                  | 93%                                          |  | 93%                                                  |
| All structures*                  | 710                                                                | 43%                                              | 360                                                                                                             | 83%                                  | 94%                                          |  | 79%                                                  |

**F. Foam Systems Only**

| Property Use                     | Number of fires per year where extinguishing equipment was present | Percent of fires too small to activate equipment | When equipment is present, fire is large enough to activate equipment, and sprinklers were present in fire area |                                      |                                              |  | Percent where equipment operated effectively (A x B) |
|----------------------------------|--------------------------------------------------------------------|--------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|--------------------------------------|----------------------------------------------|--|------------------------------------------------------|
|                                  |                                                                    |                                                  | Number of fires per year                                                                                        | Percent where equipment operated (A) | Percent effective of those that operated (B) |  |                                                      |
| All public assembly              | 320                                                                | 66%                                              | 70                                                                                                              | 96%                                  | 69%                                          |  | 66%                                                  |
| Eating or drinking establishment | 230                                                                | 63%                                              | 50                                                                                                              | 95%                                  | 69%                                          |  | 66%                                                  |
| All structures*                  | 670                                                                | 66%                                              | 160                                                                                                             | 97%                                  | 84%                                          |  | 81%                                                  |

\* Includes some properties not listed separately above.

Note: These are percentages of fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Percentages are based on estimated total fires reported in NFIRS Version 5.0 with the indicated type of automatic extinguishing system and system performance not coded as fire too small to activate systems. Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to fail if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. Property use classes are shown only if they accounted for at least 100 projected fires per year with the specific type of automatic extinguishing equipment present.

Source: NFIRS and NFPA survey.



**Table 3. (Continued)**  
**Automatic Extinguishing Equipment Reliability, by Property Use**  
**2003-2007 Structure Fires**

**G. Halogen Systems Only**

| Property Use                     | When equipment is present, fire is large enough to activate equipment, and sprinklers were present in fire area |                                                  |                          |                                      |                                              |                                                      |
|----------------------------------|-----------------------------------------------------------------------------------------------------------------|--------------------------------------------------|--------------------------|--------------------------------------|----------------------------------------------|------------------------------------------------------|
|                                  | Number of fires per year where extinguishing equipment was present                                              | Percent of fires too small to activate equipment | Number of fires per year | Percent where equipment operated (A) | Percent effective of those that operated (B) | Percent where equipment operated effectively (A x B) |
| All public assembly              | 210                                                                                                             | 65%                                              | 50                       | 100%                                 | 93%                                          | 93%                                                  |
| Eating or drinking establishment | 150                                                                                                             | 65%                                              | 40                       | 100%                                 | 91%                                          | 91%                                                  |
| All structures*                  | 380                                                                                                             | 59%                                              | 110                      | 96%                                  | 92%                                          | 88%                                                  |

\* Includes some properties not listed separately above.

Note: These are percentages of fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Percentages are based on estimated total fires reported in NFIRS Version 5.0 with the indicated type of automatic extinguishing system and system performance not coded as fire too small to activate systems. Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to fail if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. Property use classes are shown only if they accounted for at least 100 projected fires per year with the specific type of automatic extinguishing equipment present.

Source: NFIRS and NFPA survey.

**Table 4.**  
**Reasons for Failure to Operate When Fire Was Large Enough to Activate Equipment**  
**and Equipment Was Present in Area of Fire, by Property Use**  
**Based on Indicated Estimated Number of 2003-2007 Structure Fires per Year**

**A. All Sprinklers**

| Property Use                        | System<br>shut off | Inappropriate<br>system for<br>type of fire | Lack of<br>maintenance | Manual<br>intervention<br>defeated system | System<br>component<br>damaged | Total<br>fires<br>per year |
|-------------------------------------|--------------------|---------------------------------------------|------------------------|-------------------------------------------|--------------------------------|----------------------------|
| All public assembly                 | 61%                | 6%                                          | 9%                     | 21%                                       | 3%                             | 32                         |
| Eating or drinking<br>establishment | 60%                | 0%                                          | 17%                    | 23%                                       | 0%                             | 17                         |
| Residential                         | 35%                | 43%                                         | 3%                     | 16%                                       | 2%                             | 377                        |
| Home (including<br>apartment)       | 46%                | 34%                                         | 2%                     | 14%                                       | 5%                             | 357                        |
| Store or office                     | 64%                | 7%                                          | 17%                    | 10%                                       | 1%                             | 70                         |
| Manufacturing facility              | 62%                | 4%                                          | 13%                    | 18%                                       | 4%                             | 123                        |
| Storage                             | 83%                | 2%                                          | 4%                     | 5%                                        | 5%                             | 96                         |
| All structures*                     | 53%                | 20%                                         | 15%                    | 9%                                        | 2%                             | 974                        |

\* Includes some properties not listed separately above.

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire, unclassified or unknown. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Property use groups are shown only if there were at least 10 fires per year involving failure to operate and 10 fires per year involving operation not effective.

Source: NFIRS and NFPA survey.

**Table 4. (Continued)**  
**Reasons for Failure to Operate When Fire Was Large Enough to Activate Equipment**  
**and Equipment Was Present in Area of Fire, by Property Use**  
**2003-2007 Non-Confined and Confined Structure Fires**

**B. Wet Pipe Sprinklers Only**

| Property Use                        | System<br>shut off | Inappropriate<br>system for<br>type of fire | Lack of<br>maintenance | Manual<br>intervention<br>defeated system | System<br>component<br>damaged | Total<br>fires<br>per year |
|-------------------------------------|--------------------|---------------------------------------------|------------------------|-------------------------------------------|--------------------------------|----------------------------|
| Public assembly                     | 67%                | 4%                                          | 8%                     | 20%                                       | 0%                             | 23                         |
| Eating or drinking<br>establishment | 67%                | 0%                                          | 13%                    | 20%                                       | 0%                             | 14                         |
| Residential                         | 43%                | 30%                                         | 4%                     | 21%                                       | 2%                             | 297                        |
| Home (including<br>apartment)       | 57%                | 18%                                         | 3%                     | 19%                                       | 5%                             | 264                        |
| Store or office                     | 70%                | 5%                                          | 8%                     | 17%                                       | 0%                             | 54                         |
| Manufacturing<br>facility           | 57%                | 7%                                          | 11%                    | 19%                                       | 6%                             | 60                         |
| All structures*                     | 52%                | 17%                                         | 10%                    | 18%                                       | 2%                             | 704                        |

**C. Dry Pipe Sprinklers Only**

| Property Use   | System<br>shut off | Inappropriate<br>system for<br>type of fire | Lack of<br>maintenance | Manual<br>intervention<br>defeated system | System<br>component<br>damaged | Total<br>fires<br>per year |
|----------------|--------------------|---------------------------------------------|------------------------|-------------------------------------------|--------------------------------|----------------------------|
| All structures | 65%                | 19%                                         | 5%                     | 6%                                        | 5%                             | 185                        |

\* Includes some properties not listed separately above.

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire, unclassified or unknown. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Property use groups are shown only if there were at least 10 fires per year involving failure to operate and 10 fires per year involving operation not effective.

Source: NFIRS and NFPA survey.

**Table 4. (Continued)**  
**Reasons for Failure to Operate When Fire Was Large Enough to Activate Equipment**  
**and Equipment Was Present in Area of Fire, by Property Use**  
**Based on Indicated Estimated Number of 2003-2007 Structure Fires per Year**

**D. Dry Chemical Systems Only**

| Property Use                     | System shut off | Inappropriate system for type of fire | Lack of maintenance | Manual intervention defeated system | System component damaged | Total fires per year |
|----------------------------------|-----------------|---------------------------------------|---------------------|-------------------------------------|--------------------------|----------------------|
| Public assembly                  | 13%             | 2%                                    | 80%                 | 3%                                  | 1%                       | 320                  |
| Eating or drinking establishment | 14%             | 2%                                    | 78%                 | 5%                                  | 1%                       | 235                  |
| Residential                      | 0%              | 0%                                    | 100%                | 0%                                  | 0%                       | 14                   |
| Store or office                  | 5%              | 5%                                    | 79%                 | 4%                                  | 7%                       | 59                   |
| Grocery or convenience store     | 9%              | 20%                                   | 22%                 | 18%                                 | 32%                      | 13                   |
| All structures*                  | 11%             | 2%                                    | 76%                 | 10%                                 | 2%                       | 542                  |

**E. Carbon Dioxide Systems Only**

| Property Use   | System shut off | Inappropriate system for type of fire | Lack of maintenance | Manual intervention defeated system | System component damaged | Total fires per year |
|----------------|-----------------|---------------------------------------|---------------------|-------------------------------------|--------------------------|----------------------|
| All structures | 4%              | 0%                                    | 90%                 | 0%                                  | 6%                       | 60                   |

\* Includes some properties not listed above.

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire, unclassified or unknown. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Property use groups are shown only if there were at least 10 fires per year involving failure to operate and 10 fires per year involving operation not effective.

Source: NFIRS and NFPA survey.



**Table 5.**  
**Reasons for Ineffectiveness When Fire Was Large Enough to Activate Equipment**  
**and Equipment Was Present in Area of Fire, by Property Use**  
**Based on Indicated Estimated Number of 2003-2007 Structure Fires per Year**

**A. All Sprinklers**

| <b>Property Use</b>              | <b>Agent did not reach fire</b> | <b>Not enough agent released</b> | <b>Inappropriate system for type of fire</b> | <b>Manual intervention defeated system</b> | <b>System component damaged</b> | <b>Lack of maintenance</b> | <b>Fires per year</b> |
|----------------------------------|---------------------------------|----------------------------------|----------------------------------------------|--------------------------------------------|---------------------------------|----------------------------|-----------------------|
| All public assembly              | 45%                             | 48%                              | 4%                                           | 3%                                         | 0%                              | 0%                         | 55                    |
| Eating or drinking establishment | 49%                             | 46%                              | 5%                                           | 0%                                         | 0%                              | 0%                         | 41                    |
| Residential                      | 31%                             | 12%                              | 21%                                          | 4%                                         | 16%                             | 15%                        | 54                    |
| Home (including apartment)       | 35%                             | 8%                               | 14%                                          | 2%                                         | 23%                             | 16%                        | 50                    |
| Store or office                  | 50%                             | 16%                              | 10%                                          | 16%                                        | 0%                              | 8%                         | 20                    |
| Manufacturing facility           | 46%                             | 35%                              | 4%                                           | 9%                                         | 1%                              | 5%                         | 127                   |
| Storage                          | 38%                             | 13%                              | 0%                                           | 25%                                        | 24%                             | 0%                         | 12                    |
| All structures*                  | 43%                             | 31%                              | 12%                                          | 5%                                         | 4%                              | 4%                         | 388                   |

\* Includes some properties not listed separately above.

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Property use groups are shown only if there were at least 10 fires per year involving failure to operate and 10 fires per year involving operation not effective.

Source: NFIRS and NFPA survey.

**Table 5. (Continued)**  
**Reasons for Ineffectiveness When Fire Was Large Enough to Activate Equipment**  
**and Equipment Was Present in Area of Fire, by Property Use**  
**Based on Indicated Estimated Number of 2003-2007 Structure Fires per Year**

**B. Wet Pipe Sprinklers Only**

| <b>Property Use</b>              | <b>Agent did not reach fire</b> | <b>Not enough agent released</b> | <b>Inappropriate system for type of fire</b> | <b>Manual intervention defeated system</b> | <b>System component damaged</b> | <b>Lack of maintenance</b> | <b>Total fires per year</b> |
|----------------------------------|---------------------------------|----------------------------------|----------------------------------------------|--------------------------------------------|---------------------------------|----------------------------|-----------------------------|
| Public assembly                  | 60%                             | 20%                              | 11%                                          | 9%                                         | 0%                              | 0%                         | 18                          |
| Eating or drinking establishment | 62%                             | 24%                              | 14%                                          | 0%                                         | 0%                              | 0%                         | 13                          |
| Residential                      | 39%                             | 4%                               | 22%                                          | 4%                                         | 20%                             | 9%                         | 48                          |
| Home (including apartment)       | 39%                             | 3%                               | 14%                                          | 3%                                         | 26%                             | 15%                        | 43                          |
| Store or office                  | 55%                             | 10%                              | 14%                                          | 21%                                        | 0%                              | 0%                         | 15                          |
| Manufacturing facility           | 49%                             | 33%                              | 5%                                           | 9%                                         | 0%                              | 4%                         | 114                         |
| All structures*                  | 47%                             | 25%                              | 15%                                          | 6%                                         | 4%                              | 3%                         | 303                         |

**C. Dry Pipe Sprinklers Only**

| <b>Property Use</b> | <b>Agent did not reach fire</b> | <b>Not enough agent released</b> | <b>Inappropriate system for type of fire</b> | <b>Manual intervention defeated system</b> | <b>System component damaged</b> | <b>Lack of maintenance</b> | <b>Total fires per year</b> |
|---------------------|---------------------------------|----------------------------------|----------------------------------------------|--------------------------------------------|---------------------------------|----------------------------|-----------------------------|
| All structures      | 16%                             | 60%                              | 3%                                           | 3%                                         | 3%                              | 14%                        | 45                          |

\* Includes some properties not listed above.

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Property use groups are shown only if there were at least 10 fires per year involving failure to operate and 10 fires per year involving operation not effective.

Source: NFIRS and NFPA survey.

**Table 5. (Continued)**  
**Reasons for Ineffectiveness When Fire Was Large Enough to Activate Equipment**  
**and Equipment Was Present in Area of Fire, by Property Use**  
**Based on Indicated Estimated Number of 2003-2007 Structure Fires per Year**

**D. Dry Chemical Systems Only**

| <b>Property Use</b>              | <b>Agent did not reach fire</b> | <b>Not enough agent released</b> | <b>Inappropriate system for type of fire</b> | <b>Manual intervention defeated system</b> | <b>System component damaged</b> | <b>Lack of maintenance</b> | <b>Total fires per year</b> |
|----------------------------------|---------------------------------|----------------------------------|----------------------------------------------|--------------------------------------------|---------------------------------|----------------------------|-----------------------------|
| Public assembly                  | 72%                             | 19%                              | 2%                                           | 2%                                         | 0%                              | 5%                         | 178                         |
| Eating or drinking establishment | 72%                             | 19%                              | 2%                                           | 2%                                         | 0%                              | 4%                         | 122                         |
| Residential                      | 21%                             | 69%                              | 0%                                           | 10%                                        | 0%                              | 0%                         | 17                          |
| Store or office                  | 44%                             | 45%                              | 6%                                           | 0%                                         | 2%                              | 3%                         | 68                          |
| Grocery or convenience store     | 81%                             | 10%                              | 10%                                          | 0%                                         | 0%                              | 0%                         | 43                          |
| All structures*                  | 57%                             | 34%                              | 2%                                           | 2%                                         | 0%                              | 3%                         | 291                         |

**E. Carbon Dioxide Systems Only**

| <b>Property Use</b> | <b>Agent did not reach fire</b> | <b>Not enough agent released</b> | <b>Inappropriate system for type of fire</b> | <b>Manual intervention defeated system</b> | <b>System component damaged</b> | <b>Lack of maintenance</b> | <b>Total fires per year</b> |
|---------------------|---------------------------------|----------------------------------|----------------------------------------------|--------------------------------------------|---------------------------------|----------------------------|-----------------------------|
| All structures      | 49%                             | 51%                              | 0%                                           | 0%                                         | 0%                              | 0%                         | 17                          |

\* Includes some properties not listed separately above.

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire, unclassified or unknown. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Property use groups are shown only if there were at least 10 fires per year involving failure to operate and 10 fires per year involving operation not effective.

Source: NFIRS and NFPA survey.

**Table 6.**  
**Extent of Flame Damage,**  
**for Sprinklers Present vs. Automatic Extinguishing Equipment Absent**  
**2003-2007 Structure Fires**

| Property Use                                                       | Percentage of fires confined to room of origin<br>excluding structures under construction<br>and sprinklers not in fire area |                                   |
|--------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|
|                                                                    | With no<br>automatic<br>extinguishing<br>equipment                                                                           | With<br>sprinklers<br>of any type |
| Public assembly                                                    | 77%                                                                                                                          | 95%                               |
| Fixed-use amusement or recreation place                            | 74%                                                                                                                          | 96%                               |
| Variable-use amusement or recreation place                         | 84%                                                                                                                          | 97%                               |
| Religious property                                                 | 74%                                                                                                                          | 96%                               |
| Library or museum                                                  | 85%                                                                                                                          | 97%                               |
| Eating or drinking establishment                                   | 76%                                                                                                                          | 93%                               |
| Educational                                                        | 90%                                                                                                                          | 98%                               |
| Health care property*                                              | 92%                                                                                                                          | 99%                               |
| Residential                                                        | 76%                                                                                                                          | 96%                               |
| Home (including apartment)                                         | 76%                                                                                                                          | 97%                               |
| Hotel or motel                                                     | 87%                                                                                                                          | 97%                               |
| Dormitory or barracks                                              | 94%                                                                                                                          | 97%                               |
| Store or office                                                    | 71%                                                                                                                          | 93%                               |
| Grocery or convenience store                                       | 77%                                                                                                                          | 96%                               |
| Laundry or dry cleaning or other<br>professional supply or service | 81%                                                                                                                          | 92%                               |
| Service station or motor vehicle<br>sales or service               | 62%                                                                                                                          | 85%                               |
| Department store                                                   | 75%                                                                                                                          | 92%                               |
| Office building                                                    | 77%                                                                                                                          | 94%                               |
| Manufacturing facility                                             | 69%                                                                                                                          | 87%                               |
| Storage                                                            | 32%                                                                                                                          | 80%                               |
| Warehouse excluding cold storage                                   | 50%                                                                                                                          | 79%                               |
| All structures**                                                   | 74%                                                                                                                          | 95%                               |

\* Nursing home, hospital, clinic, doctor's office, or development disability facility.

\*\* Includes some properties not listed separately above.

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Calculations exclude fires with unknown or unreported extent of flame damage. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system.

Source: NFIRS and NFPA survey.



**Table 7.**  
**Number of Sprinklers Operating**  
**2003-2007 Structure Fires**

**A. By Type of Sprinkler**

| Number of<br>Sprinklers<br>Operating | <b>Percentage of structure fires where<br/>that many sprinklers operated</b> |                     |                                 |                           |
|--------------------------------------|------------------------------------------------------------------------------|---------------------|---------------------------------|---------------------------|
|                                      | <b>Wet<br/>pipe</b>                                                          | <b>Dry<br/>pipe</b> | <b>Other type<br/>sprinkler</b> | <b>All<br/>sprinklers</b> |
| 1                                    | 77%                                                                          | 61%                 | 39%                             | 75%                       |
| 2 or fewer                           | 89%                                                                          | 74%                 | 53%                             | 87%                       |
| 3 or fewer                           | 92%                                                                          | 79%                 | 65%                             | 91%                       |
| 4 or fewer                           | 95%                                                                          | 86%                 | 88%                             | 94%                       |
| 5 or fewer                           | 97%                                                                          | 89%                 | 90%                             | 96%                       |
| 6 or fewer                           | 98%                                                                          | 90%                 | 95%                             | 97%                       |
| 7 or fewer                           | 98%                                                                          | 90%                 | 96%                             | 97%                       |
| 8 or fewer                           | 98%                                                                          | 90%                 | 96%                             | 98%                       |
| 9 or fewer                           | 98%                                                                          | 90%                 | 96%                             | 98%                       |
| 10 or fewer                          | 99%                                                                          | 92%                 | 98%                             | 98%                       |
| 20 or fewer                          | 99%                                                                          | 96%                 | 99%                             | 99%                       |

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Percentages are based on fires where sprinklers were reported present and operating and there was reported information on number of sprinklers operating. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

**Table 7. (Continued)  
Number of Sprinklers Operating  
2003-2007 Structure Fires**

**B. Wet Pipe Sprinklers, by Property Use Group**

| Number of<br>Sprinklers<br>Operating | Percentage of structure fires where<br>that many wet pipe sprinklers operated |      |                   |                    |                           |                                        |
|--------------------------------------|-------------------------------------------------------------------------------|------|-------------------|--------------------|---------------------------|----------------------------------------|
|                                      | Public<br>assembly                                                            | Home | Hotel<br>or motel | Store or<br>office | Manufacturing<br>facility | Warehouse<br>excluding<br>cold storage |
| 1                                    | 72%                                                                           | 90%  | 87%               | 67%                | 49%                       | 47%                                    |
| 2 or fewer                           | 90%                                                                           | 97%  | 94%               | 87%                | 69%                       | 70%                                    |
| 3 or fewer                           | 92%                                                                           | 98%  | 96%               | 91%                | 79%                       | 76%                                    |
| 4 or fewer                           | 95%                                                                           | 99%  | 99%               | 94%                | 86%                       | 78%                                    |
| 5 or fewer                           | 96%                                                                           | 99%  | 100%              | 95%                | 89%                       | 90%                                    |
| 6 or fewer                           | 97%                                                                           | 99%  | 100%              | 97%                | 92%                       | 93%                                    |
| 7 or fewer                           | 97%                                                                           | 99%  | 100%              | 97%                | 93%                       | 94%                                    |
| 8 or fewer                           | 99%                                                                           | 100% | 100%              | 97%                | 94%                       | 94%                                    |
| 9 or fewer                           | 99%                                                                           | 100% | 100%              | 98%                | 94%                       | 95%                                    |
| 10 or fewer                          | 99%                                                                           | 100% | 100%              | 98%                | 96%                       | 95%                                    |
| 20 or fewer                          | 100%                                                                          | 100% | 100%              | 98%                | 98%                       | 97%                                    |

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Percentages are based on fires where sprinklers were reported present and operating and there was reported information on number of sprinklers operating. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

**Table 8.**  
**Sprinkler Effectiveness Related to**  
**Number of Sprinklers Operating**  
**2003-2007 Structure Fires**

| Number of<br>Sprinklers<br>Operating | <b>Percent of structure fires where sprinklers are effective</b> |                     |                           |                                        |
|--------------------------------------|------------------------------------------------------------------|---------------------|---------------------------|----------------------------------------|
|                                      | All sprinklers<br>All structures                                 | Wet pipe sprinklers |                           | Warehouse<br>excluding<br>cold storage |
|                                      |                                                                  | All<br>structures   | Manufacturing<br>facility |                                        |
| 1                                    | 97%                                                              | 98%                 | 93%                       | 95%                                    |
| 2                                    | 94%                                                              | 96%                 | 93%                       | 100%                                   |
| 3 to 5                               | 91%                                                              | 93%                 | 92%                       | 99%                                    |
| 6 to 10                              | 87%                                                              | 86%                 | 85%                       | 88%                                    |
| More than 10                         | 79%                                                              | 74%                 | 75%                       | 90%                                    |
| Total                                | 96%                                                              | 96%                 | 91%                       | 96%                                    |

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Percentages are based on fires where sprinklers were reported present and operating and there was reported information on number of sprinklers operating. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.





## Automatic Extinguishing Equipment Impact

A number of approaches can be and have been used to quantify the impact and value of sprinklers and other automatic extinguishing systems. These approaches may be grouped into the following three types:

- Reduction in life loss per fire or property loss per fire;
- Reduction in the likelihood of large fire size or severity, such as fire spread beyond room of origin, multiple deaths, or large property loss; and
- Qualitative judgments as “effective” or “satisfactory” by fire investigators or others completing incident reports, already discussed in the previous section.

### Sprinkler Reduction in Loss of Life in Fire

**For 2003-2007 home fires, the death rate per 100 fires was 83% lower with wet pipe sprinklers than with no automatic extinguishing equipment.**

Table 9 shows fire death rate reductions for various property use groups. Only the statistics for homes (including apartments) are based on enough fatal fires, both with and without sprinklers, for reasonable confidence in the results. Even the home fire statistics are volatile because of the influence of confined fires, where details on sprinkler presence and performance are not required and rarely provided.

Manufacturing facilities show a small reduction in an already low death rate, while warehouses show no reduction. Warehouses illustrate the statistical problem of analyzing impact when there are very few fatal fires. Total fire deaths in sprinklered warehouses in 2003-2007 are estimated from projections based on only four fatal incidents. The most severe was an explosion in a fireworks warehouse that killed three people. When an initial explosion precedes the fire, sprinklers cannot save people even if the explosion does not knock out the sprinklers, as can easily happen. The second most severe was an intentional fire using flammable liquids as accelerants. That fire killed two people, and there were few details. In particular, we cannot tell from the coded records whether either or both of the victims might have been the arsonists, killed early in the fire before sprinklers could activate, or whether the area of origin – an unclassified storage area – might have been outside the range of the sprinklers, which if true should have excluded the incident as no sprinklers in initial fire area. The third fatal fire was in a building under major renovation. The analysis excludes buildings under construction, but buildings under major renovation can present the same challenge to fire protection, depending on the scale of the renovation and the location of the fire origin. The fourth fatal fire was a three-story facility, with a fourth level below grade, storing agricultural products, which suggests the possibility of a dust explosion. A total of 75 sprinklers opened but sprinklers were said to have failed to operate due to manual intervention; this indicates some confusion on incident details or how to code them.

The factors that make fatal injury possible even when sprinklers are present and operate would include the following, including those shown in Table 10:

1. Victims whose actions or lack of action add to their risk by prolonging their exposure to fire conditions, such as victims who (a) act irrationally; (b) return back into the building after safely escaping; (c) are unable to act to save themselves, such as people who are bedridden or under restraint; or (d) are engaged in firefighting or rescue;
2. Victims of fires that are beyond the design limits of the system, such as fires that were (a) so close that the victim is deemed “intimate with ignition” (a victim condition no longer shown in the data but most closely approximated by “victim in area of fire origin”; they constituted 93% of fatal victims when sprinklers operated vs. 53% of total victims, in Table 10); (b) very fast, such as explosions or flash fires; or (c) outside the sprinkler-protected area, such as fires originating on exterior areas of the building; and
3. Victims who are or may be unusually vulnerable to fire effects, such as (a) older adults, age 65 or older (who constituted 50% of fatal victims when sprinklers operated vs. 28% of total victims, in Table 10), or (b) people who are in poor health before fire begins.

**Absent these conditions, NFPA has no record of a fire killing 3 or more people in a completely sprinklered building where the system was properly operating.**

Appendix C lists fires after 1970 with three or more deaths in a completely sprinklered building where the system was properly operating and the fire began in the sprinkler-protected interior of the building. Each is marked by the condition that accounted for the large life loss, either explosion or flash fire, which is the most common condition, or firefighting.

The statement says it excludes systems that were not “properly operating.” Nearly all the systems that were present in multiple-death fires but not properly operating have been systems damaged by explosions. An exception, where poor installation or maintenance was involved, was a 1990 Alabama board and care facility fire where the water supply was insufficient to support the sprinklers.

The 2010 edition of NFPA 13 adds a clarifying sentence to the scope section of the standards: “This standard is written with the assumption that the sprinkler system shall be designed to protect against a single fire originating within the building.”

There are dangers in statements that rely on all-or-nothing statistics. Until 1981, NFPA had no record of a fatal fire involving *any* number of deaths in fully sprinklered hotels or motels. In fact, though, sprinklers cannot be expected to exclude all deaths under these circumstances.

### **Sprinkler Reduction in Loss of Property in Fire**

**For most property uses, the property damage rate per reported structure fire is 40-70% lower than in properties with no automatic extinguishing equipment when wet pipe sprinklers are present in structures that are not under construction, after excluding cases of failure or ineffectiveness because of a lack of sprinklers in the fire area.**

Table 11 shows smaller reductions for manufacturing facilities (22%) and warehouses (7%).

Estimates exclude a reported \$100 million loss in one California single family home fire, which appears to be a badly miscoded fire loss, based on other available details on the property.

The warehouse situation is a fairer indication of the limitations of sprinklers but also of the limitations of these statistical comparisons. Roughly half of the 2003-2007 estimate of total direct property damage in warehouses with wet pipe sprinklers, excluding buildings under construction and sprinklers not in fire area, comes from projections from six fires, each involving \$5.2-\$8.5 million in direct property damage. All six incidents are also included in NFPA's Fire Incident Data Organization (FIDO) database, which provides some additional details not included in NFIRS. Between the NFIRS coding and the FIDO data, we can say that in two of the six fires, sprinklers failed to operate because they had been shut off before fire began. Another two fires showed sprinklers operating effectively to contain and control fire, but high loss still resulting because of the inaccessible location of the fire, either inside rack storage where the racks blocked sprinklers or deep seated in palletized storage, where the stored goods blocked sprinklers. Of the other two fires, one was in a facility with no recent maintenance and an impaired sprinkler system. The other involved a large fire load and, according to news accounts, water problems that delayed firefighting operations for roughly an hour. This last incident also involved by far the largest warehouse of the six, with a footprint of 600,000 square feet in a 4-story building.

Focusing on the first two incidents, Table 3B showed that warehouses excluding cold storage have a lower operational percentage than nearly all other property uses – operation in 85% of fires where sprinklers were present in fire area and fire was large enough to activate equipment, compared to 95% for all structures combined. While not shown in Table 4B because there were too few incidents of ineffective operation to display, the reasons for sprinkler failure in warehouses excluding cold storage were dominated by system shut off, which accounted for 90% of failures.

With respect to the last four incidents, there is reason to believe that sprinklers are more common in warehouses that are larger and have higher values per square foot. It takes a substantial warehouse to permit a fire location too deep in storage to be reached by sprinklers that are operating effectively to contain fire, and the last incident involved a warehouse with 2.4 million square feet. This can mean that the average loss per fire in a sprinklered warehouse will not be a good estimate of the predicted average loss per fire if sprinklers were added to the unsprinklered warehouses, as our calculations implicitly assume. The use of average loss in unsprinklered warehouses as a proxy for average loss in sprinklered warehouses in the absence of sprinklers, as is done in this analysis, will produce a misleadingly low baseline for comparison and so a misleadingly low estimated reduction.

Generalizing from the warehouse analysis and the long-standing NFPA statement about sprinkler effectiveness in preventing catastrophic multiple death fires, one can say that *sprinklers cannot be expected to prevent large loss if the large loss was attributable to partial coverage, explosion or flash fire, system shutoff, or the loss of the system before or early in the fire to collapse or collision*. However, there are other circumstances that also can lead to a large loss:

- Sprinkler design may not be appropriate to the hazard being protected. In the simplest form, the contents may be capable of supporting a larger, more intense fire than the sprinkler system can handle. The problem may be insufficient sprinkler density or insufficient water flow, which in turn may reflect the system's design, its age and maintenance, or its supporting water supply. Unlike explosions and flash fires, fire loads can be addressed by appropriate design, installation, maintenance, and operation. And although the effectiveness statement could be phrased to require a fully code-compliant installation, fire incident reports rarely have enough detail to confirm code compliance, and large property-loss fires are less likely than large life-loss fires to receive the detailed fire investigations that could confirm such details.
- The nature or configuration of contents may be sufficient to create a large loss even when sprinkler performance is deemed successful. Some bulk goods can shield a deep-seated fire from sprinklers. Rack storage may shield fires from ceiling sprinklers, although in-rack sprinklers should be sufficient to address such problems. High-piled stock may block sprinklers or even permit fire spread on the tops of contents above the sprinklers. And some areas – such as clean rooms – have contents so sensitive and valuable that even a small fire can produce a large financial loss.
- A fire with a sufficient number of different points of origin can overwhelm any sprinkler system. This could also be an exception to the life-saving effectiveness statement, although it has not been found to be the deciding factor in any multiple-death fire to date. It has been the deciding factor for at least one large-loss fire. Multiple points of origin can occur deliberately in an arson fire, but they can occur unintentionally or naturally, as when an outside fire spreads to numerous entry points in and on a building.

**Table 9.**  
**Estimated Reduction in Civilian Deaths per Thousand Fires**  
**Associated With Wet Pipe Sprinklers, by Property Use**  
**2003-2007 Structure Fires**

| <b>Property Use</b>              | <b>Without<br/>automatic<br/>extinguishing<br/>equipment</b> | <b>With<br/>wet pipe<br/>sprinklers</b> | <b>Percent<br/>reduction</b> |
|----------------------------------|--------------------------------------------------------------|-----------------------------------------|------------------------------|
| All public assembly              | 0.6*                                                         | 0.0                                     | 100%                         |
| Eating or drinking establishment | 0.5*                                                         | 0.0                                     | 100%                         |
| Educational                      | 0.0                                                          | 0.0                                     | NA                           |
| Health care property**           | 4.6                                                          | 1.3                                     | 72%                          |
| Residential                      | 7.7                                                          | 1.5                                     | 80%                          |
| Home (including apartment)       | 7.8                                                          | 1.3                                     | 83%                          |
| Hotel or motel                   | 4.3                                                          | 0.9                                     | 79%                          |
| Dormitory or barracks            | 3.0                                                          | 0.5                                     | 83%                          |
| Rooming or boarding house        | 7.8                                                          | 1.6                                     | 80%                          |
| Board and care home              | 7.5                                                          | 2.4                                     | 68%                          |
| Store or office                  | 0.9                                                          | 0.2                                     | 75%                          |
| Manufacturing facility           | 1.0                                                          | 0.7                                     | 25%                          |
| Warehouse excluding cold storage | 1.2                                                          | 9.8                                     | No reduction                 |

NA – Not applicable because both death rates are estimated as zero.

\* The Station nightclub fire is not included in the NFIRS database. If it were, the estimates for public assembly without automatic extinguishing equipment and for eating or drinking establishments without automatic extinguishing equipment would be much higher.

\*\*Nursing home, hospital, clinic, doctor's office, or development disability facility.

Note: These are national estimates of structure fires reported to U.S. municipal fire departments, based on fires reported in NFIRS Version 5.0, and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures exclude fires with sprinkler status unknown or unreported, partial sprinkler systems not in fire area, and structures under construction; and reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system.

Source: NFIRS and NFPA survey.



**Table 10.**  
**Characteristics of Fatal Victims**  
**When Wet Pipe Sprinklers Operate vs. All Conditions**  
**2003-2007 Structure Fires**

| Victim Characteristic                                                 | Percent of fire fatalities                                              |                                      |
|-----------------------------------------------------------------------|-------------------------------------------------------------------------|--------------------------------------|
|                                                                       | When wet pipe sprinklers operate, excluding sprinklers not in fire area | No automatic extinguishing equipment |
| Victim in area of fire origin, whether or not involved in fire origin | 93%                                                                     | 53%                                  |
| Clothing on fire, whether or not while escaping                       | 30%                                                                     | 7%                                   |
| Victim age 65 or older                                                | 50%                                                                     | 28%                                  |
| Victim returned to fire, unable to act, or acted irrationally         | 37%                                                                     | 19%                                  |

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fire reported only to Federal or state agencies or industrial fire brigades. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

**Table 11.**  
**Estimated Reduction in Average Direct Property Damage per Fire**  
**Associated With Wet Pipe Sprinklers, by Property Use**  
**2003-2007 Structure Fires**

| <b>Property Use</b>              | <b>Without<br/>automatic<br/>extinguishing<br/>equipment</b> | <b>With wet pipe<br/>sprinklers</b> | <b>Percent<br/>reduction</b> |
|----------------------------------|--------------------------------------------------------------|-------------------------------------|------------------------------|
| All public assembly              | \$37,000                                                     | \$16,000                            | 56%                          |
| Eating or drinking establishment | \$42,000                                                     | \$12,000                            | 71%                          |
| Educational                      | \$18,000                                                     | \$7,000                             | 63%                          |
| Health care property*            | \$8,000                                                      | \$3,000                             | 63%                          |
| Residential                      | \$16,000                                                     | \$5,000                             | 68%                          |
| Home (including apartment)       | \$17,000                                                     | \$4,000                             | 74%                          |
| Hotel or motel                   | \$19,000                                                     | \$9,000                             | 54%                          |
| Dormitory or barracks            | \$6,000                                                      | \$1,000                             | 81%                          |
| Rooming or boarding house        | \$15,000                                                     | \$8,000                             | 50%                          |
| Board and care home              | \$5,000                                                      | \$2,000                             | 54%                          |
| Store or office                  | \$44,000                                                     | \$26,000                            | 40%                          |
| Manufacturing                    | \$76,000                                                     | \$59,000                            | 22%                          |
| Warehouse excluding cold storage | \$101,000                                                    | \$95,000                            | 7%                           |

\*Nursing home, hospital, clinic, doctor's office, or development disability facility.

Note: These are national estimates of structure fires reported to U.S. municipal fire departments, based on fires reported in NFIRS Version 5.0, and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures exclude fires with sprinkler status unknown or unreported, partial sprinkler systems not in fire area, and structures under construction; and reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. Direct property damage is estimated to the nearest thousand dollars and has not been adjusted for inflation. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system.

Source: NFIRS and NFPA survey.



## Other Issues

Much of the resistance to wider use of sprinklers stems from a cluster of concerns that are not so much issues as myths. Most Americans have had little contact with sprinkler systems outside of their portrayal in movies and television shows, where sprinklers all too often are portrayed inaccurately. For instance, activation by common heat sources, activation of all sprinklers if any one is activated, even drowning or swimming in the water released by sprinklers, all have been portrayed in film versions of sprinkler activation.

### Water Damage from Sprinklers in the Absence of Fire

Sprinkler systems can release water in the absence of fire, but the best available evidence indicates that this is a small source of loss compared to fire losses. For home sprinklers in particular, the threat from non-fire water damage is negligible.

Sprinkler systems are carefully designed to activate early in a real fire but not to activate in a non-fire situation. Each sprinkler reacts only to the fire conditions in its area. Water release in a fire is generally much less than would occur if the fire department had to suppress the fire, because later action means more fire, which means more water is needed. According to a 15-year study done in Scottsdale, Arizona, on average, a fire sprinkler will use 25 gallons of water per minute to control a home fire as compared to the estimated 250 gallons used by firefighters.<sup>7</sup>

Unintentional release of water in a non-fire activation of a sprinkler appears to be less likely and much less damaging, according to the best available evidence, than is unintentional water release involving other parts of a building's plumbing and water supply, which tend to be both more frequent and more costly per incident.<sup>8</sup> Maryatt's study of sprinklers in Australia and New Zealand found water damage from non-fire accidental discharges added only 25% to the fire losses suffered by sprinklered buildings.<sup>9</sup> If sprinklers reduced average fire loss by only 20%, then combined fire and water damage in fire and non-fire incidents would be unchanged. (A 20% reduction means the sprinklered fire loss is 80% of the unsprinklered fire loss. Adding 25% for water damage adds 25% of 80%, which is 20%.  $80\% + 20\% = 100\%$ .) As previously noted, however, sprinklers reduce average fire loss by much more than 20%.

Another set of estimates based on recent U.S. experience can be developed from more recent data on water damage from sprinkler systems in the absence of fire. These estimates generally agree with the earlier estimates cited above.

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<sup>7</sup> Home Fire Sprinkler Coalition, *Automatic Sprinklers, A 15-Year Study, Scottsdale, Arizona*, available at <http://www.homefiresprinkler.org/hfsc.html>.

<sup>8</sup> Walter W. Maybee, "a Brief History of fire Protection in the United States, Atomic Energy Commission, 1947-1975", paper presented to the NFPA Fall Meeting, 1978. Paper is not limited to or focused on power plants and like facilities.

<sup>9</sup> H.W. Maryatt, *Fire: A Century of Automatic Sprinkler Protection in Australia and New Zealand, 1886-1986*, 2<sup>nd</sup> edition, Victoria, Australia: Australian Fire Protection Association, 1988, p. 435.

**Table E. Non-Fire Sprinkler Activations  
by Major Property Use Group, 2003**

| Property Use                                                | Reported incidents |        |
|-------------------------------------------------------------|--------------------|--------|
| Commercial properties (public assembly, stores and offices) | 15,900             | (36%)  |
| Manufacturing facilities                                    | 6,800              | (15%)  |
| Homes (one- or two-family dwellings, apartments)            | 4,700              | (11%)  |
| Warehouses excluding cold storage                           | 4,100              | (9%)   |
| Other property use groups                                   | 12,500             | (28%)  |
| Total                                                       | 44,000             | (100%) |

Note: Projections from NFIRS to national estimates are based on non-fire emergency responses estimated by Michael Karter from the 2003 Fire Loss Experience Survey.

Source: Unpublished analysis by Jennifer D. Flynn, NFPA Fire Analysis and Research Division, January 2008.

**Table F. Non-Fire Sprinkler Activations  
by Likelihood of Water Release and Major Property Use Group**

| Type of Activation<br>(Based on:)                                                           | Commercial properties<br>(726 incidents) | Manufacturing facilities<br>(206 incidents) | Homes<br>(292 incidents) | Warehouses<br>excluding cold storage<br>(165 incidents) |
|---------------------------------------------------------------------------------------------|------------------------------------------|---------------------------------------------|--------------------------|---------------------------------------------------------|
| <u>No Water Released</u>                                                                    | 50%                                      | 55%                                         | 50%                      | 50%                                                     |
| Definitely no water released except dry pipe system charging or release to drain or outside | (45%)                                    | (48%)                                       | (46%)                    | (44%)                                                   |
| Activation with no mention of water flow outside system                                     | (5%)                                     | (7%)                                        | (4%)                     | (6%)                                                    |
| <u>Possibly Water Released</u>                                                              | 50%                                      | 45%                                         | 50%                      | 50%                                                     |
| Break or damage to component                                                                | (29%)                                    | (30%)                                       | (27%)                    | (38%)                                                   |
| Activation with mention of water flow release outside system                                | (8%)                                     | (4%)                                        | (14%)                    | (5%)                                                    |
| Leak                                                                                        | (5%)                                     | (2%)                                        | (2%)                     | (1%)                                                    |
| Freezing                                                                                    | (7%)                                     | (6%)                                        | (6%)                     | (6%)                                                    |
| Nearby heat                                                                                 | (2%)                                     | (2%)                                        | (1%)                     | (1%)                                                    |
| Total                                                                                       | 100%                                     | 100%                                        | 100%                     | 100%                                                    |
| Confirmed water release outside system                                                      | 16%                                      | 7%                                          | 21%                      | 12%                                                     |

Source: Analysis of uncoded narratives from reported incidents in Austin (TX), Minnesota, and Massachusetts.



Jennifer Flynn analyzed the number of reported emergency responses in 2003 by U.S. fire department where the reason for the response was either (a) non-fire unintentional sprinkler activation or (b) non-fire sprinkler activation from a malfunction or failure of the system. The year 2003 was the last one for which the public release file of NFIRS included non-fire incidents (because the complete file grew too large for practical storage for release in and after 2004), and earlier years involved less participation in NFIRS Version 5.0 and so a narrower base for statistical analysis. Four property use groups accounted for nearly three-fourths of the reported non-fire sprinkler incidents. See Table E.

A sprinkler system can “activate” with no damaging release of water outside the sprinkler system. The most common example is a dry-pipe system that activates by flowing water into the pipes but does not release water outside the system. Such an activation would register as an activation in a centrally monitored system and could result in a fire department response.

To estimate the fraction of incidents where water is released, an exploratory data analysis was conducted on the uncoded narratives for one year of non-fire sprinkler incidents from Austin, TX (thanks to Karyl Kinsey) and the states of Minnesota and Massachusetts (thanks to Nora Gierok and Derryl Dion). Table F shows the results, separating incidents confirmed as no water outside the system and, among incidents where water release was possible, those with water release outside the system confirmed.

If the confirmed water release percentages shown in Table F are applied to the non-fire sprinkler incidents in Table E, and the resulting water-damage incidents are compared to the 2003-2006 annual average number of fires where sprinklers were present in the same properties, then one can obtain a basis for comparison. Non-fire sprinkler incidents with confirmed water release outside the system, as a percentage of fire incidents where sprinklers operated, were as follows:

- 34% for commercial properties,
- 13% for manufacturing facilities,
- 5% for homes, and
- 25% for warehouses excluding cold storage.

While the NFIRS reports do not include any estimates of dollar damage, only a handful of incidents mentioned extensive water damage. It seems likely that the average damage per non-fire sprinkler incident is considerably less than the average damage per fire incident in sprinklered properties. Even without any such adjustment, the percentages above are comparable to the estimates from Marryatt cited earlier.

Also, the Minnesota and Massachusetts incidents that dominate the combined data base probably reflect a bigger problem with freezing conditions than is true for the country as a whole. Roughly half of the commercial property confirmed water release incidents and roughly half of the warehouse incidents involved either freezing as a cited factor or a month of occurrence during December to February. Therefore, these two percentages would probably be somewhat lower if data with representative weather conditions were available.

Whatever the actual rate for these incidents, many of them can be readily prevented by better design or safer practices. Common factors in component breaks are:

- Exposure to freezing conditions,
- Damage from forklifts or other large vehicles,
- Misuse of sprinklers, notably their use as hangers or as a base for anchoring hangers,
- Damage by construction or similar workers,
- Vandalism or horseplay in the vicinity of sprinklers, and
- Damage from impact by large doors.

Non-fire activations can also be prevented by better design or safer practices. Common factors in such activations are:

- Proximity to very high levels of ambient heat, like that produced by certain manufacturing processes,
- Testing or maintenance not conducted according to standard, resulting in water surge or alarm activation.

### **Do People Want Sprinklers?**

In surveys, many people say they do not want sprinklers. The question is why. The answer is often some type of misinformation, like the ones related to water damage, already discussed.

One myth has to do with aesthetics. Again, when people outside the fire community think of sprinklers, they may think of the exposed pipe and sprinkler arrays that are common in some large manufacturing facilities. Inconspicuously mounted sprinklers, which are already common in offices and hotels and are available for homes, need to be better publicized.

A second myth has to do with the risk of death, serious injury or significant property damage in fire. This was the principal reason cited by people without smoke alarms 30 years ago, when most people still did not have smoke alarms, to explain why they did not have smoke alarms. If sprinklers are an excellent solution to a problem you (wrongly) think you do not have, then that would naturally reduce your interest in sprinklers and your sense of their value.

A third myth has to do with the affordability of sprinklers. Sprinklers are not inexpensive, although their effectiveness, documented earlier, means most people will find them cost-effective. This often can be incorporated into reduced insurance costs and incentives applied by community planners in new developments.

A 2008 study, conducted by Newport Partners under sponsorship of the Fire Protection Research Foundation, developed comprehensive and all-inclusive cost estimates for 30 diverse house plans in 10 communities.<sup>10</sup> Cost per sprinklered square foot ranged from

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<sup>10</sup> Newport Partners, *Home Fire Sprinkler Cost Assessment – Final Report*, Fire Protection Research Foundation, Quincy, MA, September 2008, pp. iv and 6.

\$0.38 to \$3.66, with an average (mean) of \$1.61 and a median of \$1.42. Variables associated with higher cost systems included:

- Extension use of copper piping instead of CPVC or PEX plastic;
- On-site water supply (such as well water) instead of municipal water supply;
- Local requirements to sprinkler areas, like garages or attics, where coverage is not required under NFPA 13D;
- Local sprinkler ordinances in effect for less than five years, or too brief a time for market acceptance, increased competition, and resulting lower prices to take hold; and
- Local sprinkler permit fees that are higher than the norm.

Many people are not aware how much the cost of sprinkler systems and the cost of installing them have been reduced in recent years as a result of continued innovation in the industry. When people say they are not interested in sprinklers for cost reasons, they may well be reacting to an inflated notion of those costs.

A 1977 survey done for the U.S. Fire Administration, back when only 22% of U.S. homes had smoke alarms, found that 74% of households with smoke alarms were very concerned about fire compared to only 45% of households that had no smoke alarms and no intention of obtaining smoke alarms. For households without smoke alarms, whether or not they intended to obtain smoke alarms, the leading reason cited for not having obtained one was no perception of need (don't need one – 16%; no interest in one – 16%) and the second leading reason was cost (too expensive – 23%; not worth the money – 1%). These are the same reasons, in the same order, cited today by people not intending to obtain home fire sprinklers today.<sup>11</sup>

In survey after survey, we find that people's perceptions and reasoning align for consistency with their actions. It is impossible today to believe that a large segment of the public once objected to smoke alarms on the basis of cost, but early in their adoption, it was true. The more people learn about home fire sprinklers, the more they are attracted to them, and there is no reason to expect this trend to stop.

In fact, there is evidence that many homeowners are getting past these dated perceptions and moving on to more fact-based and positive views of home fire sprinklers. The Home Fire Sprinkler Coalition sponsored a December 2005 survey by Harris Interactive®.<sup>12</sup> Among the findings were that 45% of homeowners considered a sprinklered home more desirable than an unsprinklered home, that 69% believe a fire sprinkler system increases the value of a home, that 38% say they would be more likely to purchase a new home with sprinklers than one without, and that 43% would be more likely to have home fire sprinklers installed if the cost could be included in the mortgage. These read like the emerging perceptions of a nation that sees value for the cost of home fire sprinklers and sees ways to handle that cost within their home-buying budget.

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<sup>11</sup> Based on 2007 slide presentation of results of NAHB National Survey, conducted August 14-15, 2006, by Public Opinion Strategies, #06811.

<sup>12</sup> See a summary of findings in a press release at <http://www.homefiresprinkler.org/release/HarrisPoll.html>.



## Concluding Points

Fire sprinklers are highly reliable and effective elements of total system designs for fire protection in buildings. They save lives and property, producing large reductions in the number of deaths per thousand fires, in average direct property damage per fire, and especially in the likelihood of a fire with large loss of life or large property loss.

Excluding fires too small to activate a sprinkler and cases of failure or ineffectiveness because of a lack of sprinklers in the fire area, sprinklers operated in 93% of reported structure fires and operated effectively in 91% of fires. More than half (53%) of the failures occurred because the system had been shut off.

There are certain fire situations where even a complete sprinkler system will have limited impact: (a) Explosions and flash fires that may overpower the system; (b) Fires that begin very close to a person (e.g., clothing ignition) or unusually sensitive and expensive property (e.g., an art gallery) where fatal injury or substantial property loss can occur before sprinklers can react; and (c) Fires that originate in unsprinklered areas (e.g., concealed wall spaces) or adjacent properties (e.g., exposure fires), which may grow to unmanageable size outside the range of the sprinkler system. These situations can arise when (a) sprinkler standards are based on design fires less severe than explosions or flash fires, as is the case for explosions in the NFPA 13, NFPA 13D, and NFPA 13R standards; (b) sprinkler objectives are defined in terms of a design fire area larger than the distance implied by a victim intimate with ignition; or (c) sprinkler standards exclude certain potential areas of fire origin from their definition of complete coverage, which is typically but not always the case.

Sprinkler systems are so effective that it can be tempting to overstate just how effective they are. For example, some sprinkler proponents have focused too narrowly on the reliability of the components of the sprinkler system itself. If this were the only concern in sprinkler performance, then there would be little reason for concern at all, but human error is a relevant problem.

On the other hand, human error is not a problem unique to sprinklers. In fact, all forms of active and passive fire protection tend to show more problems with human error than with intrinsic mechanical or electrical reliability.

It is important for all concerned parties to (a) distinguish between human and mechanical problems because they require different strategies; (b) include both as concerns to be addressed when deciding when and how to install, maintain, and rely on sprinklers and other automatic extinguishing systems; (c) strive to use performance analysis in assessing any other element of fire protection; and (d) remember that the different elements of fire protection support and reinforce one another and so must always be designed and considered as a system.

Because sprinkler systems are sophisticated enough to require competent fire protection engineering and function best in buildings where there is a complete integrated system of



fire protection, it is especially important that proper procedures be used in the installation and maintenance of sprinkler systems. This means careful adherence to the relevant standards: NFPA 13, *Standard for the Installation of Sprinkler Systems*; NFPA 13D, *Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes*; NFPA 13R, *Standard for the Installation of Sprinkler Systems in Residential Occupancies Up to and Including Four Stories in Height*; and NFPA 25, *Standard for the Inspection, Testing and Maintenance of Water-Based Fire Protection Systems*.

Because sprinkler systems are so demonstrably effective, they can make a major contribution to fire protection in any property. NFPA 101®, *Life Safety Code*; NFPA 1, *Fire Code*; and NFPA 5000®, *Building Construction and Safety Code*, have required sprinklers in all new one- and two-family dwellings, all nursing homes, and many nightclubs since the 2006 editions. The 2009 edition of the *International Residential Code* also added requirements for sprinklers in one- or two-family dwellings, effective January 2011. This protection can be expected to increase in areas that adopt and follow these revised codes.

## **Appendix A.**

### **How National Estimates Statistics Are Calculated**

The statistics in this analysis are estimates derived from the U.S. Fire Administration's (USFA's) National Fire Incident Reporting System (NFIRS) and the National Fire Protection Association's (NFPA's) annual survey of U.S. fire departments. NFIRS is a voluntary system by which participating fire departments report detailed factors about the fires to which they respond. Roughly two-thirds of U.S. fire departments participate, although not all of these departments provide data every year. Fires reported to federal or state fire departments or industrial fire brigades are not included in these estimates.

NFIRS provides the most detailed incident information of any national database not limited to large fires. NFIRS is the only database capable of addressing national patterns for fires of all sizes by specific property use and specific fire cause. NFIRS also captures information on the extent of flame spread, and automatic detection and suppression equipment. For more information about NFIRS visit <http://www.nfirs.fema.gov/>. Copies of the paper forms may be downloaded from [http://www.nfirs.fema.gov/documentation/design/NFIRS\\_Paper\\_Forms\\_2008.pdf](http://www.nfirs.fema.gov/documentation/design/NFIRS_Paper_Forms_2008.pdf).

NFIRS has a wide variety of data elements and code choices. The NFIRS database contains coded information. Many code choices describe several conditions. These cannot be broken down further. For example, area of origin code 83 captures fires starting in vehicle engine areas, running gear areas or wheel areas. It is impossible to tell the portion of each from the coded data.

#### **Methodology may change slightly from year to year.**

NFPA is continually examining its methodology to provide the best possible answers to specific questions, methodological and definitional changes can occur. *Earlier editions of the same report may have used different methodologies to produce the same analysis, meaning that the estimates are not directly comparable from year to year.*

#### **NFPA's fire department experience survey provides estimates of the big picture.**

Each year, NFPA conducts an annual survey of fire departments which enables us to capture a summary of fire department experience on a larger scale. Surveys are sent to all municipal departments protecting populations of 50,000 or more and a random sample, stratified by community size, of the smaller departments. Typically, a total of roughly 3,000 surveys are returned, representing about one of every ten U.S. municipal fire departments and about one third of the U.S. population.

The survey is stratified by size of population protected to reduce the uncertainty of the final estimate. Small rural communities have fewer people protected per

department and are less likely to respond to the survey. A larger number must be surveyed to obtain an adequate sample of those departments. (NFPA also makes follow-up calls to a sample of the smaller fire departments that do not respond, to confirm that those that did respond are truly representative of fire departments their size.) On the other hand, large city departments are so few in number and protect such a large proportion of the total U.S. population that it makes sense to survey all of them. Most respond, resulting in excellent precision for their part of the final estimate.

The survey includes the following information: (1) the total number of fire incidents, civilian deaths, and civilian injuries, and the total estimated property damage (in dollars), for each of the major property use classes defined in NFIRS; (2) the number of on-duty firefighter injuries, by type of duty and nature of illness; (3) the number and nature of non-fire incidents; and (4) information on the type of community protected (e.g., county versus township versus city) and the size of the population protected, which is used in the statistical formula for projecting national totals from sample results. The results of the survey are published in the annual report *Fire Loss in the United States*. To download a free copy of the report, visit <http://www.nfpa.org/assets/files/PDF/OS.fireloss.pdf>.

### **Projecting NFIRS to National Estimates**

As noted, NFIRS is a voluntary system. Different states and jurisdictions have different reporting requirements and practices. Participation rates in NFIRS are not necessarily uniform across regions and community sizes, both factors correlated with frequency and severity of fires. This means NFIRS may be susceptible to systematic biases. No one at present can quantify the size of these deviations from the ideal, representative sample, so no one can say with confidence that they are or are not serious problems. But there is enough reason for concern so that a second database -- the NFPA survey -- is needed to project NFIRS to national estimates and to project different parts of NFIRS separately. This multiple calibration approach makes use of the annual NFPA survey where its statistical design advantages are strongest.

Scaling ratios are obtained by comparing NFPA's projected totals of residential structure fires, non-residential structure fires, vehicle fires, and outside and other fires, and associated civilian deaths, civilian injuries, and direct property damage with comparable totals in NFIRS. Estimates of specific fire problems and circumstances are obtained by multiplying the NFIRS data by the scaling ratios. Reports for incidents in which mutual aid was given are excluded NFPA's analyses.

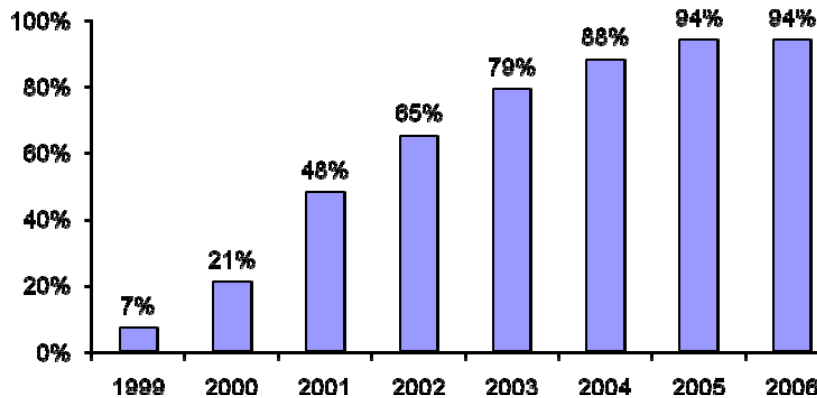
Analysts at the NFPA, the USFA and the Consumer Product Safety Commission developed the specific basic analytical rules used for this procedure. "The National Estimates Approach to U.S. Fire Statistics," by John R. Hall, Jr. and Beatrice Harwood, provides a more detailed explanation of national estimates. A

copy of the article is available online at <http://www.nfpa.org/osds> or through NFPA's One-Stop Data Shop.

Version 5.0 of NFIRS, first introduced in 1999, used a different coding structure for many data elements, added some property use codes, and dropped others. The essentials of the approach described by Hall and Harwood are still used, but some modifications have been necessary to accommodate the changes in NFIRS 5.0.

Figure 1 shows the percentage of fires originally collected in the NFIRS 5.0 system. Each year's release version of NFIRS data also includes data collected in older versions of NFIRS that were converted to NFIRS 5.0 codes.

**Figure 1. Fires Originally Collected in NFIRS 5.0 by Year**



For 2002 data on, analyses are based on scaling ratios using only data originally collected in NFIRS 5.0:

$$\frac{\text{NFPA survey projections}}{\text{NFIRS totals (Version 5.0)}}$$

For 1999 to 2001, the same rules may be applied, but estimates for these years in this form will be less reliable due to the smaller amount of data originally collected in NFIRS 5.0; they should be viewed with extreme caution.

NFIRS 5.0 introduced six categories of confined structure fires, including:

- cooking fires confined to the cooking vessel,
- confined chimney or flue fires,
- confined incinerator fire,
- confined fuel burner or boiler fire or delayed ignition,
- confined commercial compactor fire, and
- trash or rubbish fires in a structure with no flame damage to the structure or its contents.

Although causal and other detailed information is typically not required for these incidents, it is provided in some cases (typically 10-20%). Some analyses, particularly those that examine cooking equipment, heating equipment, fires caused by smoking materials, and fires started by playing with fire, may examine the confined fires in greater detail. Because the confined fire incident types describe certain scenarios, the distribution of unknown data differs from that of all fires. Consequently, allocation of unknowns must be done separately.

Some analyses of structure fires show only non-confined fires. In these tables, percentages shown are of non-confined structure fires rather than all structure fires. This approach has the advantage of showing the frequency of specific factors in fire causes, but the disadvantage of possibly overstating the percentage of factors that are seldom seen in the confined fire incident types.

Other analyses include entries for confined fire incident types in the causal tables and show percentages based on total structure fires. In these cases, the confined fire incident type is treated as a general causal factor.

For most fields other than Property Use, NFPA allocates unknown data proportionally among known data. This approach assumes that if the missing data were known, it would be distributed in the same manner as the known data. NFPA makes additional adjustments to several fields. *Casualty and loss projections can be heavily influenced by the inclusion or exclusion of unusually serious fire.*

*In the formulas that follow, the term “all fires” refers to all fires in NFIRS on the dimension studied.*

**Factor Contributing to Ignition:** In this field, the code “none” is treated as an unknown and allocated proportionally. For Human Factor Contributing to Ignition, NFPA enters a code for “not reported” when no factors are recorded. “Not reported” is treated as an unknown, but the code “none” is treated as a known code and not allocated. Multiple entries are allowed in both of these fields. Percentages are calculated on the total number of fires, not entries, resulting in sums greater than 100%. Although Factor Contributing to Ignition is only required when the cause of ignition was coded as: 2) unintentional, 3) failure of equipment or heat source; or 4) act of nature, data is often present when not required. Consequently, any fire in which no factor contributing to ignition was entered was treated as unknown.

In some analyses, all entries in the category of electrical failure or malfunction (factor contributing to ignition 30-39) are combined and shown as “electrical failure or malfunction.” This category includes:

- 31. Water-caused short circuit arc;
- 32. Short-circuit arc from mechanical damage;
- 33. Short-circuit arc from defective or worn insulation;



- 34. Unspecified short circuit arc;
- 35. Arc from faulty contact or broken connector, including broken power lines and loose connections;
- 36. Arc or spark from operating equipment, switch, or electric fence;
- 37. Fluorescent light ballast; and
- 30. Electrical failure or malfunction, other.

**Type of Material First Ignited (TMI).** This field is required only if the Item First Ignited falls within the code range of 00-69. NFPA has created a new code “not required” for this field that is applied when Item First Ignited is in code 70-99 (organic materials, including cooking materials and vegetation, and general materials, such as electrical wire, cable insulation, transformers, tires, books, newspaper, dust, rubbish, etc..) and TMI is blank. The ratio for allocation of unknown data is:

(All fires – TMI Not required)  
(All fires – TMI Not Required – Undetermined – Blank)

**Heat Source.** In NFIRS 5.0, one grouping of codes encompasses various types of open flames and smoking materials. In the past, these had been two separate groupings. A new code was added to NFIRS 5.0, which is code 60: “Heat from open flame or smoking material, other.” NFPA treats this code as a partial unknown and allocates it proportionally across the codes in the 61-69 range, shown below.

- 61. Cigarette;
- 62. Pipe or cigar;
- 63. Heat from undetermined smoking material;
- 64. Match;
- 65. Lighter: cigarette lighter, cigar lighter;
- 66. Candle;
- 67 Warning or road flare, fuse;
- 68. Backfire from internal combustion engine. Excludes flames and sparks from an exhaust system, (11); and
- 69. Flame/torch used for lighting. Includes gas light and gas-/liquid-fueled lantern.

In addition to the conventional allocation of missing and undetermined fires, NFPA multiplies fires with codes in the 61-69 range by

All fires in range 60-69  
All fires in range 61-69

The downside of this approach is that heat sources that are truly a different type of open flame or smoking material are erroneously assigned to other categories. The grouping “smoking materials” includes codes 61-63

(cigarettes, pipes or cigars, and heat from undetermined smoking material, with a proportional share of the code 60s and true unknown data.

**Equipment Involved in Ignition (EII).** NFIRS 5.0 originally defined EII as the piece of equipment that provided the principal heat source to cause ignition if the equipment malfunctioned or was used improperly. In 2006, the definition was modified to “the piece of equipment that provided the principal heat source to cause ignition.” However, much of the data predates the change. Individuals who have already been trained with the older definition may not change their practices. To compensate, NFPA treats fires in which EII = NNN and heat source is not in the range of 40-99 as an additional unknown.

To allocate unknown data for EII, the known data is multiplied by

All fires

(All fires – blank – undetermined – [fires in which EII =NNN and heat source <>40-99])

In addition, the partially unclassified codes for broad equipment groupings (i.e., code 100, - heating, ventilation, and air conditioning, other; code 200- electrical distribution, lighting and power transfer, other; etc.) were allocated proportionally across the individual code choices in their respective broad groupings (heating, ventilation, and air conditioning; electrical distribution, lighting and power transfer, other; etc.). Equipment that is totally unclassified is not allocated further. This approach has the same downside as the allocation of heat source 60 described above. Equipment that is truly different is erroneously assigned to other categories.

In some analyses, various types of equipment are grouped together.  
(Confined fire incident types are not discussed here)

| Code Grouping                  | EII Code | NFIRS definitions                          |
|--------------------------------|----------|--------------------------------------------|
| Central heat                   | 132      | Furnace or central heating unit            |
|                                | 133      | Boiler (power, process or heating)         |
| Fixed or portable space heater | 131      | Furnace, local heating unit, built-in      |
|                                | 123      | Fireplace with insert or stove             |
|                                | 124      | Heating stove                              |
|                                | 141      | Heater, excluding catalytic and oil-filled |
|                                | 142      | Catalytic heater                           |

|                                                    |     |                                                  |
|----------------------------------------------------|-----|--------------------------------------------------|
|                                                    | 143 | Oil-filled heater                                |
| Fireplace or chimney                               | 121 | Fireplace, masonry                               |
|                                                    | 122 | Fireplace, factory-built                         |
|                                                    | 125 | Chimney connector or vent connector              |
|                                                    | 126 | Chimney – brick, stone or masonry                |
|                                                    | 127 | Chimney-metal, including stovepipe or flue       |
| Wiring, switch or outlet                           | 210 | Unclassified electrical wiring                   |
|                                                    | 211 | Electrical power or utility line                 |
|                                                    | 212 | Electrical service supply wires from utility     |
|                                                    | 214 | Wiring from meter box to circuit breaker         |
|                                                    | 216 | Electrical branch circuit                        |
|                                                    | 217 | Outlet, receptacle                               |
|                                                    | 218 | Wall switch                                      |
|                                                    |     |                                                  |
| Power switch gear or overcurrent protection device | 215 | Panel board, switch board, circuit breaker board |
|                                                    | 219 | Ground fault interrupter                         |
|                                                    | 222 | Overcurrent, disconnect equipment                |
|                                                    | 227 | Surge protector                                  |
| Lamp, bulb or lighting                             | 230 | Unclassified lamp or lighting                    |
|                                                    | 231 | Lamp-tabletop, floor or desk                     |
|                                                    | 232 | Lantern or flashlight                            |
|                                                    | 233 | Incandescent lighting fixture                    |
|                                                    | 234 | Fluorescent light fixture or ballast             |
|                                                    | 235 | Halogen light fixture or lamp                    |
|                                                    | 236 | Sodium or mercury vapor light fixture or lamp    |
|                                                    | 237 | Work or trouble light                            |
|                                                    | 238 | Light bulb                                       |
|                                                    | 241 | Nightlight                                       |
|                                                    | 242 | Decorative lights – line voltage                 |
| Cord or plug                                       | 243 | Decorative or landscape lighting – low voltage   |
|                                                    | 244 | Sign                                             |
|                                                    | 260 | Unclassified cord or plug                        |

|                                       |     |                                               |
|---------------------------------------|-----|-----------------------------------------------|
|                                       | 261 | Power cord or plug, detachable from appliance |
|                                       | 262 | Power cord or plug- permanently attached      |
|                                       | 263 | Extension cord                                |
| Torch, burner or soldering iron       | 331 | Welding torch                                 |
|                                       | 332 | Cutting torch                                 |
|                                       | 333 | Burner, including Bunsen burners              |
|                                       | 334 | Soldering equipment                           |
| Portable cooking or warming equipment | 631 | Coffee maker or teapot                        |
|                                       | 632 | Food warmer or hot plate                      |
|                                       | 633 | Kettle                                        |
|                                       | 634 | Popcorn popper                                |
|                                       | 635 | Pressure cooker or canner                     |
|                                       | 636 | Slow cooker                                   |
|                                       | 637 | Toaster, toaster oven, counter-top broiler    |
|                                       | 638 | Waffle iron, griddle                          |
|                                       | 639 | Wok, frying pan, skillet                      |
|                                       | 641 | Breadmaking machine                           |

**Item First Ignited.** In most analyses, mattress and pillows (item first ignited 31) and bedding, blankets, sheets, and comforters (item first ignited 32) are combined and shown as “mattresses and bedding.” In many analyses, wearing apparel not on a person (code 34) and wearing apparel on a person (code 35) are combined and shown as “clothing.” In some analyses, flammable and combustible liquids and gases, piping and filters (item first ignited 60-69) are combined and shown together

**Area of Origin.** Two areas of origin: bedroom for more than five people (code 21) and bedroom for less than five people (code 22) are combined and shown as simply “bedroom.”

**Rounding and percentages.** The data shown are estimates and generally rounded. An entry of zero may be a true zero or it may mean that the value rounds to zero. Percentages are calculated from unrounded values. It is quite possible to have a percentage entry of up to 100%, even if the rounded number entry is zero. The same rounded value may account for a slightly different percentage share. Because percentages are expressed in integers and not carried out to several decimal places, percentages that appear identical may be associated with slightly different values.

**Inflation.** Property damage estimates are not adjusted for inflation unless so indicated.

## Appendix B

### Data Elements in NFIRS 5.0 Related to Automatic Extinguishing Systems

#### **M1. Presence of Automatic Extinguishment System**

This is to be coded based on whether a system was or was not present in the area of fire and is designed to extinguish the fire that developed. (The latter condition might exclude, for example, a range hood dry chemical extinguishing system from being considered if the fire began in a toaster.)

Codes:

- |   |                                           |
|---|-------------------------------------------|
| N | None Present                              |
| 1 | Present                                   |
| U | Undetermined (restored to coding in 2004) |

#### **M2. Type of Automatic Extinguishment System**

If multiple systems are present, this is to be coded in terms of the (presumably) one system designed to protect the hazard where the fire started. This is a required field if the fire began within the designed range of the system. It is not clear whether questions might arise over a system that is not located in the area of fire origin but has the area of fire origin within its designed range; this has to do with the interpretation of the “area” of fire origin.

Codes:

- |   |                             |
|---|-----------------------------|
| 1 | Wet pipe sprinkler          |
| 2 | Dry pipe sprinkler          |
| 3 | Other sprinkler system      |
| 4 | Dry chemical system         |
| 5 | Foam system                 |
| 6 | Halogen type system         |
| 7 | Carbon dioxide system       |
| 0 | Other special hazard system |
| U | Undetermined                |

#### **M3. Automatic Extinguishment System Operation**

This is designed to capture the “operation and effectiveness” of the system relative to area of fire origin. It is also said to provide information on the “reliability” of the system. The instructions say that “effective” does not necessarily mean complete extinguishment but does mean containment and control until the fire department can complete extinguishment.



Codes:

- 1 System operated and was effective
- 2 System operated and was not effective
- 3 Fire too small to activate the system
- 4 System did not operate
- 0 Other
- U Undetermined

#### **M4. Number of Sprinklers Operating**

The instructions say this is not an indication of the effectiveness of the sprinkler system. The instructions do not explicitly indicate whether this data element is relevant if the automatic extinguishment system is not a sprinkler system (as indicated in M2). The actual number is recorded in the blank provided; there are no codes.

#### **M5. Automatic Extinguishment System Failure Reason**

This is designed to capture the (one) reason why the system “failed to operate or did not operate properly.” The instructions also say that this data element provides information on the “effectiveness” of the equipment. It is not clear whether this is to be completed if the system operated properly but was not effective.

Text shown in brackets is text shown in the instructions but not on the form. Note that for code 4, the phrase “wrong” is replaced by “inappropriate” in the instructions; the latter term is more precise and appropriate, although it is possible for the type of fire to be unexpected in a given occupancy.

Codes:

- 1 System shut off
- 2 Not enough agent discharged [to control the fire]
- 3 Agent discharged but did not reach [the] fire
- 4 Wrong type of system [Inappropriate system for the type of fire]
- 5 Fire not in area protected [by the system]
- 6 System components damaged
- 7 Lack of maintenance [including corrosion or heads painted]
- 8 Manual intervention [defeated the system]
- 0 Other \_\_\_\_\_ [Other reason system not effective]
- U Undetermined

**Appendix C**  
**Multiple-Death Fires in Fully Sprinklered Properties**  
**(Excluding Incidents Where Sprinklers Were Not Operational at Time of Fire)**  
**1971-Present**

| <b>Month and<br/>Year</b> | <b>Property Use</b>              | <b>State</b>   | <b>Deaths*</b> | <b>Explosion<br/>or flash<br/>fire</b> | <b>Firefighting</b> |
|---------------------------|----------------------------------|----------------|----------------|----------------------------------------|---------------------|
| December 1971             | Chemical manufacturer            | New York       | 3              | X                                      |                     |
| April 1975                | Metal recycling plant            | Oregon         | 3 (1)          | X                                      | X                   |
| January 1976              | Aerosol packaging plant          | Indiana        | 5              | X                                      |                     |
| November 1976             | Gum factory                      | New York       | 6              | X                                      |                     |
| June 1979                 | Ink manufacturer                 | California     | 3              | X                                      |                     |
| March 1980                | Paper products warehouse         | Idaho          | 5 (3)          |                                        | X                   |
| July 1980                 | Metal products manufacturer      | New York       | 11             | X                                      |                     |
| October 1981              | Aerosol packaging plant          | Massachusetts  | 5              | X                                      |                     |
| September 1982            | Textile mill                     | North Carolina | 4 (4)          |                                        | X                   |
| July 1983                 | Supermarket                      | Florida        | 5              | X                                      |                     |
| December 1983             | Vehicle parts repair             | New York       | 7 (5)          | X                                      |                     |
| December 1984             | Recycle steam plant              | Ohio           | 3              | X                                      |                     |
| February 1985             | Furniture manufacturer           | Virginia       | 4              | X                                      |                     |
| December 1985             | Shopping mall                    | California     | 4              | X                                      |                     |
| April 1986                | Industrial park                  | California     | 9              | X                                      |                     |
| February 1993             | Office complex                   | New York       | 6              | X                                      |                     |
| April 1995                | Office building                  | Oklahoma       | 168            | X                                      |                     |
| November 1997             | Toy manufacturer                 | California     | 4              | X                                      |                     |
| February 1999             | Chemical manufacturer            | Pennsylvania   | 5              | X                                      |                     |
| February 1999             | Iron foundry                     | Massachusetts  | 3              | X                                      |                     |
| February 2001             | Particleboard manufacturer       | Pennsylvania   | 3              | X                                      |                     |
| May 2002                  | Rubber reclamation manufacturer  | Mississippi    | 5              | X                                      |                     |
| February 2003             | Insulation products manufacturer | Kentucky       | 7              | X                                      |                     |
| July 2003                 | Fireworks warehouse              | Texas          | 3              | X                                      |                     |
| April 2004                | Plastic products manufacturer    | Illinois       | 5              | X                                      |                     |

X – Indicates whether explosion or flash fire and/or firefighting was the factor that allowed multiple deaths in spite of the presence of operational sprinklers with complete coverage.

\* “Multiple-death fires are here defined as fires with 3 or more civilian or firefighter deaths. Numbers in parentheses indicate the number of firefighter deaths in the total. The 9/11 attack on the World Trade Center involved an initial flash fire from the ignited jet fuel, but it is excluded here because the impact of the airplanes rendered the sprinklers non-operational before fire began.



## **Appendix D**

### **Selected Incidents**

The following published incidents are detailed examples reinforcing the need for proper inspection and testing maintenance programs and reflect the analysis discussed in the reliability and effectiveness section of the report. The collection may not be representative of all fires in terms of relative frequency or specific circumstances.

Included are short articles from the “Firewatch” column in *NFPA Journal* and incidents from the large-loss and catastrophic fires report. It is important to remember that this is anecdotal information. Anecdotes show what can happen; they are not a source to learn about what typically occurs.

NFPA’s Fire Incident Data Organization (FIDO) identifies significant fires through a clipping service, the Internet and other sources. Additional information is obtained from the fire service and federal and state agencies. FIDO is the source for articles published in the “Firewatch” column of the *NFPA Journal*.

## NOT IN AREA PROTECTED

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b>      | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                    | <b>Fire Protection<br/>Systems</b>                                                                                                                                                                                                                                                                                                                                       | <b>Fire<br/>Development</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | <b>Contributing<br/>Factors and<br/>Other Details</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|-----------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| New Jersey<br>\$7,100,000<br>September, 2005<br>1:41 p.m. | This four-story eight-unit condominium was of unprotected wood-frame construction and covered 4,225 square feet (392 square meters). The building was occupied. | There was completed coverage smoke detection equipment. The alarms sounded, but with a delay due to the fire's area of origin. There was a complete coverage wet-pipe sprinkler system present. There was no coverage in the area of ignition (outside). Upon arrival, the fire department pumped into the sprinkler system, but there was no effect on the fire spread. | This exposure fire began in the engine compartment of a car parked in a garage under the condominium structure. The garages were separated by wood latticework that allowed the fire to spread through the eight garages that contained vehicles, boats, and propane grills. The fire spread up cedar siding and through the truss floor assembly of the condominium units above. The fire spread to several other buildings in the condominium complex. At least 35 fire departments responded to fight the fire. | The day of the fire was very hot and humid, with a wind of 15 to 20 miles per hour (24 to 32 kilometers per mile). There had been no rain for three weeks, causing the siding to be very dry. One side of the structure was on a bay, forcing firefighters to hand lay fire hoses. The open-web truss construction of floors and roof allowed for rapid spread. Twenty-four firefighters and three civilians were treated for heat exhaustion and other injuries. The loss was \$6,000,000 to structures and \$1,100,000 to contents. |

Stephen G. Badger, 2006, "2005 Large-Loss Fires and Explosions in the United States", *NFPA Journal*, November/December, 72.



| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b> | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                                                                                      | <b>Fire Protection<br/>Systems</b>                                                                                                                                                | <b>Fire<br/>Development</b>                                                                                                                            | <b>Contributing<br/>Factors and<br/>Other Details</b>                          |
|------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| Georgia<br>\$6,000,000<br>July, 2003<br>5:50 p.m.    | This 7-story university library of protected noncombustible construction covered 200,000 square feet (18,580 square meters). There was an older (the original) building attached and the building was open and operating at the time of the fire. | A partial coverage smoke detection system was present and it activated, notifying the fire department. There was partial coverage wet-pipe system, but not in the area of origin. | This incendiary fire was set in a second-story storage area. The fire was contained to the floor of origin. An arson arrest has been made in the case. | Loss to the building was \$1,000,000 and loss to the contents was \$5,000,000. |

Stephen G. Badger, November, 2004, *Large-Loss Fires in the United States 2003*, 29.

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b> | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                             | <b>Fire Protection<br/>Systems</b>                                                                                                                                                                    | <b>Fire<br/>Development</b>                                                                                                                                                                                          | <b>Contributing<br/>Factors and<br/>Other Details</b>                   |
|------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|
| Texas<br>\$5,220,000<br>March, 2003<br>12:05 a.m.    | This three-story, single-family dwelling of protected wood-frame construction covered 14,585 square feet (1,354 square meters) and was occupied when the fire broke out. | A partial coverage smoke detection system present operated and a partial coverage sprinkler system was present. The type and operation weren't reported, but the system wasn't in the area of origin. | The cause is undetermined. Arriving firefighters found a fire in the ceiling between the first and second story, which spread rapidly in voids throughout the house. Firefighters were forced to a defensive attack. | Loss to the house was \$3,250,000 and loss to contents was \$1,970,000. |

Stephen G. Badger November, 2004, *Large-Loss Fires in the United States 2003*, 25.

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b>    | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                                   | <b>Fire Protection<br/>Systems</b>                                                                                                                                                                                                                                                                                                                                     | <b>Fire<br/>Development</b>                                                                                                                                                                                                                             | <b>Contributing<br/>Factors and<br/>Other Details</b>                                                                                                                         |
|---------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Virginia<br>\$12,823,900<br>February, 2003<br>4:45 a.m. | This 4-story senior citizen apartment house of protected wood-frame construction contained 100 units and covered 23,536 square feet (2,186 square meters). Of the 100 units, 81 were occupied. | There was a complete coverage combination heat and smoke detection equipment. The system operated but it wasn't in the area of origin. An arriving police officer activated a manual pull station to sound the alarm. There was a complete coverage wet-pipe sprinkler system but one head operated. This system also was not in the area of origin (outside balcony). | The cause of this fire is undetermined and it originated on a third-story balcony. The fire spread up the exterior and entered the attic through roof soffits. The fire spread horizontally then down to the apartments on the fourth and third floors. | The balconies were of combustible materials, allowing for ignition. Two firefighters were injured. Loss to the building was \$9,823,900 and loss to contents was \$3,000,000. |

Stephen G. Badger, 2004, "Large-Loss Fires for 2003", *NFPA Journal*, November/December, 56.

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b>    | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                         | <b>Fire Protection<br/>Systems</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | <b>Fire<br/>Development</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                     | <b>Contributing<br/>Factors and<br/>Other Details</b>                                                                                                                                                                                                                                                                                                                                            |
|---------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Colorado<br>\$28,000,000<br>November, 2000<br>8:47 p.m. | Seven-story hotel of protected noncombustible construction that covered 96,000 square feet (8,918.7 square meters). The hotel was operating at the time of the fire. | Although the hotel's complete-coverage smoke and heat detection system wasn't in the area of ignition, it operated. The hotel also had a complete-coverage wet-pipe sprinkler system. The fire began in a void and burned through the unprotected area. When the system activated, 31 sprinklers opened, causing a drop in pressure and overwhelming the system. Firefighters pumped water into the standpipes that fed both the sprinkler system and the standpipe hose connections, but pressure was inadequate. | The fire began in a second-floor fireplace and ignited a build-up of creosote, causing the vent pipe in the soffit near the fifth floor to separate. The unsupported chimney fell into the chase, allowing fire to spread throughout the void. Firefighters, who were already at the hotel on a medical call, heard the smoke alarms and discovered fire in the chase. Upon investigation, they found flames spreading rapidly through the concealed space above the top floor. | The concealed space above the top-floor ceiling was undivided, allowing the fire to burn the length of the building. Combustible exterior siding contributed to the fire's spread outside the building. It's believed that the fire burned undetected for up to three hours. Two firefighters were injured. Structural loss came to \$19 million, and contents loss is estimated at \$9 million. |

Stephen G. Badger, 2001, "Large-Loss Fires of 2000", *NFPA Journal*, November/December, 64.

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b> | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                          | <b>Fire Protection<br/>Systems</b>                                                                                                                                                                                                                                                                       | <b>Fire<br/>Development</b>                                                                                                                                                                      | <b>Contributing<br/>Factors and<br/>Other Details</b>                                                           |
|------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|
| Ohio<br>\$60,000,000<br>August, 2000<br>4:05 p.m.    | Three-story steel manufacturing plant was of unprotected ordinary construction covering 355,320 square feet (33,010 square meters) and was in full operation at the time of the fire. | There was no automatic detection equipment present. A wet-pipe sprinkler system was present; the extent of the coverage was not reported. The system was not a factor as the fire was in the attic and roof area, above the system. An early collapse of the roof did damage the branch and trunk lines. | No information reported on the cause. Firefighters made an initial interior attack but were forced to withdraw due to roof and ceiling collapse. Operations were switched to a defensive attack. | Three firefighters were injured. Losses totaled \$40,000,000 to the structure and \$20,000,000 to the contents. |

Stephen G. Badger, November, 2002, *Large-Loss Fires in the United States 2001*, 11.

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b> | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                                            | <b>Fire Protection<br/>Systems</b>                                                                                                                                                                                                                 | <b>Fire<br/>Development</b> | <b>Contributing<br/>Factors and<br/>Other Details</b>                                                                   |
|------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|-------------------------------------------------------------------------------------------------------------------------|
| Hawaii<br>\$10,000,000<br>April, 2000<br>8:13 a.m.   | A 16-story office building of fire-resistive construction that covered 58,564 square feet (5,440 square meters). Although the building was closed for the weekend a few occupants were in the building. | Smoke detectors and manual pull stations of unknown type activated and alerted the occupants. The extent of the system's coverage wasn't reported. A partial-coverage wet-pipe sprinkler system wasn't in the area of the fire and didn't operate. | Undetermined.               | Twelve firefighters were injured. Fire loss was listed as \$8 million to the structure and \$2 million to the contents. |

Stephen G. Badger, 2001, "Large-Loss Fires of 2000", *NFPA Journal*, November/December, 63.

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b>   | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                                                  | <b>Fire Protection<br/>Systems</b>                                                                                                                                                                                                                            | <b>Fire<br/>Development</b>                                                    | <b>Contributing<br/>Factors and<br/>Other Details</b>                                                                |
|--------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|
| Pennsylvania<br>\$25,000,000<br>May, 2000<br>8:00 a.m. | General product warehouse of unprotected noncombustible construction. The building was 40 feet (12 meters) high and covered 400,000 square feet (37,161 square meters). Its operating status wasn't reported. | The warehouse had no automatic detection system. Automatic suppression equipment had been installed, but only in two sections of the warehouse, and the fire originated elsewhere. By the time the system activated, the fire was too large for it to handle. | The fire's cause is still under investigation. No other details were reported. | One firefighter was injured. Fire loss was listed as \$15 million to the structure and \$10 million to the contents. |

Stephen G. Badger, 2001, "Large-Loss Fires of 2000", *NFPA Journal*, November/December, 62.



### **Propane Gas Grill Fire Spreads from Apartment Balcony, Wisconsin**

A propane gas grill on a fourth-floor balcony leaked fuel, which ignited, and the resulting fire spread to the apartment building roof.

The four-story building, constructed of wood framing with a brick veneer, housed several apartments on the second, third, and fourth floors. Retail businesses were located on the first floor, and there was a parking garage in the basement. Smoke alarms were installed throughout, and there were heat detectors in the attic and mechanical rooms. Manual pull stations were located on every floor. A residential wet-pipe sprinkler system installed in compliance with NFPA 13R, *Installation of Sprinkler Systems in Residential Occupancies Up To and Including Four Stories in Height*, was operational at the time of the fire.

The fire began when the occupant of the fourth-floor unit started a propane grill on her balcony in preparation for cooking. She had only had the grill for about a month and had difficulty lighting the grill due to a faulty igniter switch. To start the grill, she resorted to either matches or lighted pieces of paper.

As she waited for the grill to warm up, the woman got a phone call and after five minutes shut off the grill. When she returned 45 minutes later, she restarted the grill again using a match when the igniter didn't work. Once the fire was going, however, she noticed flames near the neck of the propane cylinder. Although she immediately turned the burners off, the fire still burned at the cylinder. The woman called 911 to report the fire, then returned to the balcony to find that the fire had spread to the floor.

The woman tried to control the fire, but the flames continued to spread, so she left the apartment with her 4-year-old son. On the way out, she told occupants of the building she met in the stairwell about the fire but failed to activate a pull station that would have alerted the entire building.

Attempts by two occupants to control the fire with a portable extinguisher knocked down about 70 percent of the blaze, but failed to extinguish the flames that soon reached the ceiling of the balcony.

Responding to the 7:13 p.m. call, firefighters found fire on the top floor. Shortly after their arrival, they saw fire rolling across the fourth-floor ceiling. They later discovered fire in the eaves, but didn't realize fire was in the attic above them. Then firefighters discovered there was no standpipe connection available, they lowered ropes from a fourth-floor window and pulled a hose line up.

A second alarm was sounded as firefighters fought for more than two hours to control the fire.

Investigators determined that the fire began when a propane gas leak was ignited by the grill's burners. The fire then spread to combustible wood framing and roof supports, through the vinyl and aluminum covered soffits.

The residential sprinkler system in the apartment operated, but the fire spread in the attic. Eventually, the ceiling collapsed. Fire spread from the deck into the fourth floor was reduced by the sprinkler system, which didn't extend to the attic and roof.

The building suffered a \$2 million loss. There were no injuries during the fire.

Kenneth J. Tremblay, 2000, "Firewatch," *NFPA Journal*, July/August, 18.

### **Neon Signs Ignite Wood Siding in Strip Mall, Arkansas**

Flames traveled along a strip mall's open exterior façade before firefighters extinguished it. Although sprinklers and a fire wall kept the flames from entering the main building, damage was estimated at nearly \$1 million.

The 15 retail stores in a single-story shopping center were of wood-frame construction. Each store had an individual fire detection system, and a wet-pipe sprinkler system had been installed throughout the building. The stores were closed for the night when the fire broke out.

A passerby discovered the blaze and called 911 on his mobile phone at 1:50 a.m. When firefighters arrived, they found the façade engulfed in flames and used a deck gun to extinguish the blaze. The wood-frame façade was sheathed in wood siding and affixed with a neon sign for each occupancy. Unfortunately, it was open from one end to the other with no separation.

The fire heavily damaged the facade, although three sprinklers and a fire wall kept flames from entering the stores. Investigators determined that one of the neon signs, which had recently been replaced, short circuited and ignited the siding.

The building, which had an estimated value of \$750,000, suffered \$650,000 in damage. Damage to the contents, valued at \$300,000, came to \$250,000.

Kenneth J. Tremblay, 2000, "Firewatch," *NFPA Journal*, September/October, 23.

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b>  | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                                                              | <b>Fire Protection<br/>Systems</b>                                                                                                                                                                                                                     | <b>Fire<br/>Development</b>                                                                                                                                                                                                                                                                                                              | <b>Contributing<br/>Factors and<br/>Other Details</b>                                                              |
|-------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------|
| Illinois<br>\$15,000,000<br>August, 1999<br>5:47 a.m. | This one-story warehouse for palletized cardboard cartons was of unprotected ordinary construction with a ground floor area of 140,000 square feet (13,006 square meters). When the fire broke out, the plant was closed. | The plant didn't have any automatic detection equipment. It did have a complete coverage wet-pipe sprinkler system, which activated and sounded an alarm. The sprinklers were ineffective, however, because the fire spread above the sprinkler heads. | The fire originated at ceiling level above the sprinklers system and spread through the wood truss roof. The cause was undetermined. Firefighters initiated an offensive attack. While venting the roof, firefighters found it to be spongy and evacuated the entire building. Soon after the roof collapsed. No injuries were reported. | The collapsing roof broke cross feeds to the sprinkler system. The open truss area contributed to the fire spread. |

Stephen G. Badger and Thomas Johnson, 2000, "1999 Large-Loss Fires and Explosions", *NFPA Journal*, November/December, 88.

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b>     | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                                                              | <b>Fire Protection<br/>Systems</b>                                                                                                                                                                                           | <b>Fire<br/>Development</b>                                                                                                                                                                                                                                                                                                                                                                                                                                           | <b>Contributing<br/>Factors and<br/>Other Details</b>                                                                                                                                                                                                                                                            |
|----------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Wisconsin<br>\$5,000,000<br>September, 1999<br>6:11 p.m. | This one-story wood product manufacturing plant was of protected, ordinary construction and covered a ground-floor area of 100,000 square feet (9,290 square meters). The plant was in operation at the time of the fire. | The plant had no automatic detection equipment but did have a complete coverage wet-pipe sprinkler system. Although the sprinklers operated and sounded an alarm, they were ineffective because the fire started above them. | Workers performing roofing operations ignited a small fire in the roofing materials. The workers thought they completely extinguished the fire and left the area two hours later. A fire broke out approximately one hour later in the Styrofoam insulation between the upper and lower plywood roof decks. Firefighters initiated an interior attack on the fire until conditions deteriorated and they withdrew to a defensive attack. One firefighter was injured. | Fire department notification of the initial fire was delayed almost three hours. The water supply in the area was limited. Firefighters had trouble getting to the fire building. Railroad tracks on one side of the building and a lake on two other sides limited firefighters accessibility to only one side. |

Stephen G. Badger and Thomas Johnson, 2000, "1999 Large-Loss Fires and Explosions", *NFPA Journal*, November/December, 88.

## SHUT OFF

### **Two Intentional Fires in Foreclosed Home, Arizona**

An intentionally set fire substantially damaged the second floor of a large, single-family house. Although the house, which was under foreclosure, had a fire sprinkler system, it failed to operate because the water had been shut off due to nonpayment.

The two-story wood-frame home, which covered approximately 5,900 square feet (548 square meters), was vacant at the time of the fire. All it contained was some trash and an upholstered couch. Hardwired smoke detectors were located in the common areas and bedrooms, but they had been disabled by lack of electricity.

A neighbor noticed the fire and called 911 at 11:58 p.m. Firefighters arrived minutes later to find heavy smoke and flames coming from the second floor, and extinguished the blaze using a tower ladder and several monitor nozzles.

Investigators found evidence that a door had been forced open before the firefighters arrived. They also determined that an accelerant poured on the second floor and in the first floor hallway had been ignited by an unknown ignition source. The fire consumed some of the remaining contents before it spread through structural floor and ceiling voids to the attic.

The home, valued at \$1 million, incurred \$200,000 in damage.

Two nights later, the house was destroyed by a second fire. By the time firefighters were summoned to the property at 8:05 p.m., flames were visible on both floors of the structure, and they had to use more than 160,000 gallons (606,000 liters) of water to extinguish the blaze.

Investigators found that the lock on the natural gas supply valve had been broken and that valves on the gas line in the laundry room had been opened before an accelerant poured in a first-floor hallway was ignited. The fire spread up the open stairs and vented through the roof, which had been opened during the previous fire.

Ken Tremblay, 2009, "Firewatch", *NFPA Journal*, September/October, 24.

### **Large-Loss Fire Involving Former Mill Building, Massachusetts**

Dollar Loss: \$26,000,000

Month: July 2007

Time: 4:14 am

#### **Property Characteristics and Operating Status:**

This three-story, irregularly-shaped former mill building was used by 56 mercantile businesses and covered 350,000 square feet (32,500 square meters). It was of unprotected ordinary construction. The building was closed at the time of the fire.



#### Fire Protection Systems:

There was no smoke detection equipment present. There was a full-coverage combination wet- and dry-pipe sprinkler system. A sprinkler valve in the area of ignition was padlocked shut, allowing the fire to quickly overwhelm the rest of the system. The fire department was not notified that the system was shut down.

#### Fire Development:

Investigators believe the fire started after welding was done in the basement the day before, without a permit from the fire department.

#### Contributing Factors and Other Details:

Several code noncompliance issues, such as the welding and shutting down the sprinkler system, contributed to the fire. Four hundred firefighters from 78 fire departments in two states responded to this fire. Nine firefighters were injured. The loss was estimated at \$16,000,000 to the structure and \$10,000,000 to the contents.

Stephen G. Badger, 2008, " *Large-Loss Fires in the United States in 2007*", *NFPA Fire Analysis and Research*, Quincy, MA

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b> | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                                                                                      | <b>Fire Protection<br/>Systems</b>                                                                                                                                                               | <b>Fire<br/>Development</b>                                                                                                                 | <b>Contributing<br/>Factors and<br/>Other Details</b>                                                       |
|------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|
| Maryland<br>\$11,000,000<br>May, 2005<br>7:00 p.m.   | This storage complex consisted of a one-story vacant warehouse of unprotected ordinary construction and a second warehouse of unprotected noncombustible construction and covered 100,000 square feet (9,290 square meters). The site was closed. | There was no detection equipment present. There was a complete coverage dry-pipe sprinkler system present. The system was not operational, as it had been shut down when building became vacant. | This was an incendiary fire. The fire caused a complete collapse of the older brick building and fire damage to the steel storage building. | Four firefighters were injured. The loss was \$10,000,000 to the structure and \$1,000,000 to the contents. |

Stephen G. Badger, 2006, "Large-Loss Fires for 2005", *NFPA Journal*, November/December, 68.

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b> | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                             | <b>Fire Protection<br/>Systems</b>                                                                                                                                                                                                                                                                                                                                                                    | <b>Fire<br/>Development</b>                                                                          | <b>Contributing<br/>Factors and<br/>Other Details</b> |
|------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|-------------------------------------------------------|
| Illinois<br>\$20,000,000<br>April, 2005<br>6:00 p.m. | This one-story paper products manufacturing plant was of protected noncombustible construction and covered 243,000 square feet. The plant was at full operation when the fire broke out. | There was a partial coverage combination smoke and heat detection system present. The system was not located in the area of origin and it was not reported if the system activated. There was a complete coverage wet-pipe sprinkler system present. The flow from this system was not sufficient. The main switch to the fire pump was found shut off. How or when it was shut off was not reported. | An incendiary fire was set in the rolled paper storage area. This fire is still under investigation. | None Reported.                                        |

Stephen G. Badger, 2003, "Large-Loss Fires for 2002", *NFPA Journal*, November/December, 77.

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b> | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                                                                | <b>Fire Protection Systems</b>                                                                                                                                             | <b>Fire Development</b>                                                                                                                                                                                                                                                                      | <b>Contributing<br/>Factors and<br/>Other Details</b>                                                                                            |
|------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|
| Texas<br>\$11,000,000<br>August, 2004<br>5:56 p.m.   | This four-story 100-unit apartment building was of unprotected wood-frame construction covering 32,000 square feet. The building was under construction at the time. Some workers were at the site when the fire broke out. | There was no detection equipment yet installed. There was a complete coverage wet-pipe sprinkler present but it was shut down before the fire due to a leak in the system. | A fire of unknown cause broke out on the second level of the building. Wind helped spread the fire throughout the units in the section of the building that was still in the framing phase. The fire spread to a parking garage then ignited a structure on the opposite side of the street. | Despite openings not yet protected by fire-rated doors, fire walls were effective in limiting the spread of fire. Two firefighters were injured. |

Stephen G. Badger, 2005, "Large-Loss Fires for 2004", *NFPA Journal*, November/December, 44.

## School Fire Spreads Due to Sprinkler Shut-Off, California

Fire heavily damaged an unoccupied school, because the water supply to the sprinkler system was shut off, allowing the fire to spread to the attic.

The single-story, wood-framed elementary school, which was 60 feet (18 meters) by 60 feet (18 meters), contained five classrooms, two work rooms, two bathrooms, and two mechanical rooms. The building had a peaked roof with a skylight in the middle. Although the property had sprinklers, the building's well, which supplied its water, was shut-down due to dirt in the system. There was also no fire detection system.

When neighbors saw smoke from the school at 7:07 p.m., they called 911 and activated the fire alarm on the building. Nine minutes later, arriving firefighters found smoke and flames coming from the roof and fire at one end of the interior hallway. They stretched hoselines to the building, entered, and began extinguishment.

Several fire companies coordinated a fire attack and ventilation strategy to extinguish the blaze, which had spread to the attic and roof before it even damaged the classrooms below.

One of the building's heating units was found within inches of the wall of origin. No other potential heat sources were found in the area.

Because there was no detection system or operating sprinkler system, the fire burned undetected into concealed spaces.

The structure, valued at \$1 million, sustained an estimated \$400,000 in direct property damage. Contents were valued at \$150,000 and sustained \$60,000 in damage.

Kenneth J. Tremblay, 2000, "Firewatch," *NFPA Journal*, July/August, 20.

| Location,<br>Dollar Loss,<br>Date,<br>Time           | Property<br>Characteristics and<br>Operating Status                                                                                                                                              | Fire Protection Systems                                                                                                                                                                     | Fire Development                                                                                                                                        | Contributing<br>Factors and<br>Other Details |
|------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|
| Colorado<br>\$15,000,000<br>April, 1999<br>2:58 p.m. | This two-story single-family home had a ground-floor area of more than 5,000 square feet (464 square meters). The type of construction wasn't reported. No one was home when the fire broke out. | The house had an automatic detection system of unknown type and coverage, which operated. It also had a residential set-pipe sprinkler system, but it had been shut down during remodeling. | A light fixture in a closet ignited structural members. No details on the fire's subsequent growth and spread were reported. No injuries were reported. | None reported.                               |

Stephen G. Badger and Thomas Johnson, 2000, "1999 Large-Loss Fires and Explosions", *NFPA Journal*, November/December, 93.

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b>     | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                                                                                                            | <b>Fire Protection Systems</b>                                                                                                     | <b>Fire Development</b>                                                                                                                                                                                                                                                                            | <b>Contributing<br/>Factors and<br/>Other Details</b>                                                      |
|----------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|
| Massachusetts<br>\$10,000,000<br>June, 1999<br>3:37 p.m. | The warehouse in which the main losses occurred was in an old mill complex and stored new commercial dryers. The ground-floor area wasn't reported. The building in which the fire originated was a vacant one-story structure of unprotected, wood-frame construction. | No information was reported on automatic detection equipment. The warehouse's sprinkler system had been shut down before the fire. | Investigators believe that smoking materials caused the fire, which started in grass outside. The fire spread to a wood-frame dye house then to the warehouse. More than 250 firefighters responded from 24 cities and towns. Crews managed to contain the fire to approximately half the complex. | If the sprinkler system hadn't been shut down, it could have extinguished the fire in its incipient stage. |

Stephen G. Badger and Thomas Johnson, 2000, "1999 Large-Loss Fires and Explosions", *NFPA Journal*, November/December, 88, 90.

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b> | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                                                                                                                                                      | <b>Fire Protection Systems</b>                                                                                                                   | <b>Fire Development</b>                                                                        | <b>Contributing<br/>Factors and<br/>Other Details</b> |
|------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|-------------------------------------------------------|
| Oregon<br>\$13,522,500<br>August, 1999<br>4:13 a.m.  | This five-story apartment building with businesses on the lower level was under construction at the time of the fire. It was of protected, wood-frame construction and covered a ground-floor area of more than 50,000 square feet (4,645.0 square meters). There was no one at the site when the fire broke out. | No information was reported on automatic detection equipment. The building had a wet-pipe sprinkler that had been shut down during construction. | The only information reported was that this was an incendiary fire. No injuries were reported. | None reported.                                        |

Stephen G. Badger and Thomas Johnson, 2000, "1999 Large-Loss Fires and Explosions", *NFPA Journal*, November/December, 95.

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b>        | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                                                                                                                                                                         | <b>Fire Protection Systems</b>                                                                                                                                                                                                                                                                                                       | <b>Fire Development</b>                                                                                                                                                                                                                                                                                                                                         | <b>Contributing<br/>Factors and<br/>Other Details</b>                                                                                                                                        |
|-------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Washington<br>\$7,000,000<br>December,<br>1999<br>3:23 a.m. | This 12-foot (3.7 meter) retail tool store was of unprotected, ordinary construction with a ground-floor area of 102,000 square feet (9,475.8 square meters). The store of origin, which was one of six businesses in the strip mall, covered a ground-floor area of 32,400 square feet (3,010 square meters). The store was closed. | No information was reported on automatic detection equipment. The entire strip mall had a shared wet-pipe sprinkler system, which had been disabled in the store of origin by a prior forklift incident. The sprinkler in the adjoining business helped control fire spread. There was also a dry-pipe system in a dry storage area. | Cardboard boxes containing plastic tarps failed and fell from rack storage, landing within a foot (.03 meters) of a heater. The propane heater was set up to help dry out the stock made wet by the sprinkler incident earlier in the day. The heater ignited the boxes and the blower pushed the burning embers into other storage. No injuries were reported. | With the sprinkler system disabled, there was no water flow alarm to notify the fire department, allowing the fire to burn a long time before the neighboring business' sprinkler activated. |

Stephen G. Badger and Thomas Johnson, 2000, "1999 Large-Loss Fires and Explosions", *NFPA Journal*, November/December, 91.

#### **Large-Loss Fire Warehouse Fire, Alabama**

Dollar Loss: \$5,000,000

Date: October 1997

Time: Not reported.

##### **Property Characteristics and Operating Status:**

This one-story general item warehouse was of unprotected, wood-frame construction with a ground-floor area of 297,000 square feet (28,000 square meters). It was in operation when the fire broke out.

##### **Fire Protection Systems:**

The building had no automatic detection system. It did have a complete-coverage dry-pipe sprinkler system, but the system didn't operate because it was out of service undergoing repair.

##### **Fire Development:**

The crew members of a passing fire department EMS transport unit discovered the fire when they noticed a large smoke plume in the air. The fire, which spread rapidly through



paper and wood and involved some pesticides, was allowed to burn to reduce the toxicity of involved areas. Its cause and origin are undetermined.

Contributing Factors:  
None were reported.

Stephen G. Badger and Thomas Johnson, 1998, 1997 Large-Loss Fires and Explosions, *NFPA Journal*, November/December, 88.

### **Large-Loss Warehouse Fire, Texas**

Dollar Loss: \$45,000,000

Time: 10:31 a.m.

Month: November 1993

#### **The Building:**

The warehouse was used to store baled and rolled paper, and plastics. The single-story structure was of unprotected noncombustible construction with a ground-floor area of 500,000 square feet. It was operating at the time.

#### **Detection and Suppression Systems:**

The warehouse was not equipped with automatic detectors, but it did contain a complete wet-pipe sprinkler system.

#### **The Fire:**

Fire investigators believe that loose scrap paper became lodged in a forklift that was being used to move bales of paper. The paper caused the forklift to overheat and ignite the baled paper. Workers discovered the fire and notified the fire department using 911. Fire fighters attempted an interior fire attack, but they were forced out of the warehouse after the roof started to show signs of collapse. The entire warehouse and its contents were destroyed.

#### **Contributing Factors and Other Details:**

The water supply to the sprinkler system had been turned off due to a leak in the supply pipe for the system.

Large undivided areas, tons of combustible paper storage, and open overhead doors contributed to the rapid spread of fire throughout the warehouse.

Michael J. Sullivan, 1994, "Property Loss Rises in Large-Loss Fires" *NFPA Journal*, November/December, 95.

## INOPERATIVE

### **Delayed Alarm Leads to \$2 Million Loss, Texas**

A plastic manufacturing plant was completely destroyed when a cutting torch ignited cardboard, plastics, and other trash, and the fire spread rapidly to storage. A delay in fire department notification and a disabled sprinkler contributed to the huge loss.

The two-story plant had a steel frame, with a metal deck roof and masonry walls. It was 200 feet (61 meters) long and 400 feet (122 meters) wide. A wet-pipe system was inoperable, and its owners had been issued a notice to repair by fire officials. There were no smoke alarms, and the building was operating at the time of the fire.

Employees were using a cutting torch to remove a metal gate and overhead door assembly on a loading dock when the torch came into contact with the combustible trash. The resulting fire spread quickly while the employees tried to control it with hand-held extinguishers before calling the fire department.

The department received a 911 call from the plant manager at 10:35 A.M. Arriving 2 ½ - minutes later, the first company saw “a wall of fire” at one corner of the building.

Two firefighters and two civilians were injured during the incident. The structure, valued at \$1 million, and contents, valued at \$1 million, were a total loss.

Kenneth J. Tremblay, 2000, “Firewatch,” *NFPA Journal*, May/June, 38.

## WRONG TYPE OF SYSTEM

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b>  | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                                                                                                     | <b>Fire Protection Systems</b>                                                                                                                                                  | <b>Fire Development:</b>                                                             | <b>Contributing<br/>Factors and<br/>Other Details</b> |
|-------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|-------------------------------------------------------|
| Arizona<br>\$100,000,000<br>August, 2000<br>4:58 p.m. | The fire broke out in a warehouse containing a home and garden supply company and a pharmaceuticals distribution company. The construction and height of the structure weren't reported. Employees were working in one of the companies when the fire broke out. | No information was available on automatic detection equipment. A sprinkler system, whose type and extent of coverage weren't known, wasn't adequate for the stored merchandise. | Due to litigation, officials are releasing no information on the fire's development. | None reported.                                        |

Stephen G. Badger, 2001, "Large-Loss Fires of 2000", *NFPA Journal*, November/December, 61.

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b> | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                                                      | <b>Fire Protection Systems</b>                                                                                                                                                                                                                                              | <b>Fire Development:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | <b>Contributing<br/>Factors and<br/>Other Details</b>                                                                                                                                                                                                                                              |
|------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Georgia<br>\$7,300,000<br>March, 1999<br>1:23 p.m.   | This two-story general storage warehouse of protected noncombustible construction covered a ground-floor area of 75,000 square feet (6,967.5 square meters). The warehouse was operating at the time of the fire. | The warehouse didn't have an automatic detection system. It did have a wet-pipe sprinkler system, but its coverage wasn't known. The system operated but wasn't effective because it hadn't been maintained well and because it wasn't designed for the commodities stored. | Because investigators believe that toxic materials were present, they suspended investigation of this fire before determining a cause. The fire broke out in an unoccupied area. With a rapid fire spread due to 700 to 1,000 tons (635 to 907.2 metric tons) of group A plastics and a delay in notifying the fire department, an interior fire attack wasn't possible. By the time the fire department arrived, flames had consumed 100 feet (30.5 meters) of the building. No injuries were reported. | The sprinkler system was poorly maintained and not appropriate for the commodities stored. It took awhile for someone to discover the fire because it started in a remote, unoccupied area. The person who discovered the fire called others in the building before notifying the fire department. |

Stephen G. Badger and Thomas Johnson, 2000, "1999 Large-Loss Fires and Explosions", *NFPA Journal*, November/December, 88.

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b>     | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                                                                                                              | <b>Fire Protection Systems</b>                                                                                                                                                                                                                                                                           | <b>Fire Development:</b>                                                                                                                                   | <b>Contributing<br/>Factors and<br/>Other Details</b>                                                   |
|----------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|
| Pennsylvania<br>\$6,000,000<br>August, 1999<br>5:57 p.m. | This approximately 50-foot (15.2 meters) steel manufacturing building was of unprotected, noncombustible construction with a ground-floor area of 20,000 square feet (1,858 square meters). Although the plant was closed for the night, maintenance workers were inside. | The plant didn't have any automatic detection equipment, but it did have a partial coverage wet-pipe sprinkler system. The sprinklers were ineffective because of missing heads and the fact that the system wasn't designed for this hazard. The system outside the area did help stop the fire spread. | Investigators haven't determined the cause of this fire, but they believe it started in a dip-tank area. Six firefighters were injured fighting the blaze. | The poorly maintained sprinkler system wasn't designed for the hazard involved, and heads were missing. |

Stephen G. Badger and Thomas Johnson., 2000, "1999 Large-Loss Fires and Explosions", *NFPA Journal*, November/December, 85-86.

## SYSTEM COMPONENT DAMAGE

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b>     | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                                                                             | <b>Fire Protection<br/>Systems</b>                                                                                                                                                              | <b>Fire<br/>Development</b>                                                                   | <b>Contributing<br/>Factors and<br/>Other Details</b>                                                                          |
|----------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| Indiana<br>\$10,000,000<br>September, 2005<br>11:59 p.m. | This outdoor furniture and cushion manufacturing plant was of unprotected ordinary construction and had a ground floor area of 279,000 square feet (25,919 square meters). The height was not reported. The plant was in full operation. | There was no detection equipment present. There was a complete coverage combination wet- and dry-pipe sprinkler system. The system operated but risers were heavily damaged by a roof collapse. | The fire broke out in a woodworking area. The ignition sequence is still under investigation. | Over the years, the building had many additions and multiple roofs that firefighters had to work through to reach to the fire. |

Stephen G. Badger, 2006, "Large-Loss Fires for 2005", *NFPA Journal*, November/December, 70.

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b>  | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                                               | <b>Fire Protection<br/>Systems</b>                                                                                                                                                                                                                              | <b>Fire<br/>Development</b>                                                                                                                                                                | <b>Contributing<br/>Factors and<br/>Other Details</b> |
|-------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|
| Missouri<br>\$5,000,000<br>October, 2005<br>2:42 p.m. | This two-story food preparation plant was under construction. It was of protected noncombustible construction. The ground floor area was not reported. Workmen were on location with ongoing construction. | There was unreported coverage smoke detection equipment present. The system had been shut off due to construction work. There was an unreported coverage wet-pipe sprinkler system present. The system was damaged during the explosion and it did not operate. | An explosion and fire occurred when a natural gas valve was installed in the kitchen area and left in the open position and uncapped. The source of ignition is still under investigation. | One person died and 15 were injured in the explosion. |

Stephen G. Badger, 2006, "Large-Loss Fires for 2005", *NFPA Journal*, November/December, 69-70.



| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b> | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                            | <b>Fire Protection Systems</b>                                                                                                                                                                | <b>Fire Development</b>                                                                                                                                                                                                                                                                                                                 | <b>Contributing<br/>Factors and<br/>Other Details</b>                                                                                                             |
|------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Indiana<br>\$5,000,000<br>April, 2004<br>7:45 a.m.   | This two-story foam products vinyl coating plant was of protected non-combustible construction and covered 20,000 square feet. The plant was in full operation at the time of the fire. | There was no automatic detection equipment present. There was a complete coverage wet-pipe sprinkler system. The system did not operate due to damage to its supply line during an explosion. | A small explosion occurred in or around an automatic spray booth where vinyl was sprayed onto foam. The cause is still under investigation. A second and larger explosion occurred, blowing out walls and collapsing the roof. A fire broke out in two of the paint booths. The fire was contained to this area by the fire department. | Five civilians suffered various injuries related to the explosion and fire. Damage to the structure was estimated at \$1,500,000 and \$3,500,000 to the contents. |

Stephen G. Badger, November, 2005, "Large-Loss Fires in the United States 2004", 22.

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b>          | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                      | <b>Fire Protection Systems</b>                                                                                                                                                                                                               | <b>Fire Development</b>                                                                                                                                                                                        | <b>Contributing<br/>Factors and<br/>Other Details</b>                                                      |
|---------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|
| North Carolina<br>\$9,000,000<br>December, 2003<br>12:24 p.m. | This one-story plastics item manufacturing plant of heavy timber construction covered 18,000 square feet (1,672 square meters) and was in full operation at the time of the fire. | No automatic detection equipment was present. A complete coverage wet-pipe sprinkler system was present and operated but it was ineffective due to damage from a collapse that caused a large loss of water to other sections of the system. | Welding on a piece of machinery ignited a pile of polyester waste on the floor. Employees attempted to extinguish the blaze with hand-held extinguishers but were unsuccessful against a large spreading fire. | Three firefighters were injured and loss to building was \$5,000,000 and loss to contents was \$4,000,000. |

Stephen G. Badger, 2004, "Large-Loss Fires for 2003", *NFPA Journal*, November/December, 52.

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b> | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                                                             | <b>Fire Protection Systems</b>                                                                                                                                                                                                                                               | <b>Fire Development</b>                                                                                                                                                                                                        | <b>Contributing<br/>Factors and<br/>Other Details</b>                                                                                                                                                                     |
|------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Wisconsin<br>\$17,000,000<br>July, 2002<br>9:23 p.m. | This 110-foot-high magazine printing plant with automated rack storage retrieval was of unprotected noncombustible construction and covered 61,600 square feet. The plant was in full operation when the fire broke out. | There was a complete coverage smoke detection system present but its installation was not yet complete. There was a complete coverage wet-pipe sprinkler system present. A building collapse prior to the fire damaged and rendered useless the sprinkler system and risers. | A building collapse caused stored magazine paper to come in contact with a broken 400-watt metal halide light bulb. Fire then spread rapidly throughout the collapsed structure. The reason for the collapse was not reported. | The paper contents and windy conditions contributed to rapid fire spread. The suppression system was damaged in the collapse and did not operate. The collapse also blocked alleyways, hampering firefighting operations. |

Stephen G. Badger, 2003, "2002 Large-Loss Fires", *NFPA Journal*, November/December, 77.

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b>  | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                                 | <b>Fire Protection Systems</b>                                                                                                                                                                                                                                                                                                                                                                                                                                     | <b>Fire Development</b>                                                                                                                                                                                                                                                                                                                                                                       | <b>Contributing<br/>Factors and<br/>Other Details</b>      |
|-------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------|
| Mississippi<br>\$16,070,001<br>May, 2002<br>6:00 p.m. | This one-story rubber reclaiming plant was of unprotected noncombustible construction and covered 60,000 square feet. The plant was in full operation at the time of the fire and explosion. | There was a complete coverage heat detection system present. This system did not operate because an explosion destroyed a large portion of it. There was a local suppression system in the drying system, which operated but was not effective. There was a complete coverage wet-pipe sprinkler system present. The system was damaged by the explosion and was not effective in the area of origin but did control the fire in the area unaffected by the blast. | A fire in a rubber dust particle drying system was not fully extinguished by the dryer's suppression system, allowing the fire to extend through a vent pipe located above the roof. Embers ignited accumulated rubber dust on the roof. The fire then spread to the bagging station where a rubber dust explosion occurred throughout the plant, igniting more rubber dust and combustibles. | Five civilians were killed and seven injured in this fire. |

Stephen G. Badger, 2003, "2002 Large-Loss Fires", *NFPA Journal*, November/December, 77.

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b>   | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                                   | <b>Fire Protection Systems</b>                                                                                                                                          | <b>Fire Development</b>                                                                                                                                                                                                                                                 | <b>Contributing<br/>Factors and<br/>Other Details</b> |
|--------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|
| Kansas<br>\$15,000,000<br>September, 2002<br>2:26 p.m. | This 70-foot-high alcohol distillery was of unprotected noncombustible construction. The area covered was not reported. The plant was in full operation at the time of the explosion and fire. | There was no automatic detection system present. There was a partial coverage wet sprinkler system present. It was not effective due to damage caused by the explosion. | A manhole cover door left open in a lower vapor chamber of a still allowed vapors to escape into the still house. An unknown ignition source caused an explosion that ruptured additional pipes, allowing a large amount of grain alcohol to flow and continue to burn. | Four civilians were injured in this fire.             |

Stephen G. Badger, 2003, "2002 Large-Loss Fires ", *NFPA Journal*, November/December, 78.

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b>     | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                                                                    | <b>Fire Protection<br/>Systems</b>                                                                                                                                                                           | <b>Fire<br/>Development</b>                                                                                                                                           | <b>Contributing<br/>Factors and<br/>Other Details</b>                                                         |
|----------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|
| Virginia<br>\$40,000,000<br>September, 2001<br>9:40 a.m. | Five-story office building of protected noncombustible construction was in full operation at the time. The building covered a ground floor area of approximately 1.3 million square feet (approximately 123,500 square meters). | There was a complete coverage smoke detection system present. There was a partial coverage wet-pipe sprinkler system. These systems were overwhelmed by the massive explosion, fire and structural collapse. | A hijacked commercial airliner crashed into the side of the office building and exploded on impact. Burning jet fuel ignited standard office furniture and materials. | One hundred and eighty-nine civilians were killed and 99 building occupants and 12 firefighters were injured. |

Stephen G. Badger, November, 2002, "Large-Loss Fires in the United States 2001", 29.

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b>  | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                     | <b>Fire Protection<br/>Systems</b>                                                                                                                                                                                        | <b>Fire<br/>Development</b>                                                                                                                                                                    | <b>Contributing<br/>Factors and<br/>Other Details</b> |
|-------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|
| Minnesota<br>\$10,000,000<br>March, 2001<br>5:08 a.m. | Two-story wood products manufacturing plant of unprotected wood frame construction was in full operation at the time the fire broke out. The ground floor area was not reported. | There was no automatic detection equipment present. A dry-pipe sprinkler system was present. The extent of coverage was not reported. A ceiling collapse preceding the fire damaged the system, rendering it ineffective. | A roof collapse caused by a heavy snow load is believed to have caused wires to spark and ignite dust that had accumulated above the ceiling. The fire then spread to pallets of wood product. | None reported.                                        |

Stephen G. Badger, November, 2002, "Large-Loss Fires in the United States 2001", 13-14.

| <b>State,<br/>Date,<br/>Time of Alarm,<br/>Dollar Loss</b> | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                                     | <b>Fire Protection<br/>Systems</b>                                                                                                                                                                                                                                                                                     | <b>Fire Development</b>                                                                                                                                                                            | <b>Contributing<br/>Factors and<br/>Other Details</b>                        |
|------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|
| Michigan.<br>March, 2001<br>8:11 a.m.<br>\$5,500,000       | One-story plastic products manufacturing plant of protected ordinary construction covering 44,160 square feet (4,103 square meters) was in full operation at the time of the explosion and fire. | There was a partial coverage smoke detector system that was not in the area of the explosion and it did not activate. There was a complete coverage wet-pipe sprinkler system present. This system was damaged by the explosion and roof collapse. Water flowing from the severed branch main did extinguish the fire. | A fire on a forklift vehicle in this plant impinged on the propane cylinder on the vehicle. The cylinder exploded. The explosion collapsed the wall and roof of the plant and caused a small fire. | Losses totaled \$4,000,000 to the structure and \$1,500,000 to the contents. |

Stephen G. Badger, November, 2002, "Large-Loss Fires in the United States 2001", 16.

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b>     | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                                                                                                                  | <b>Fire Protection Systems</b>                                                                                                                                                                                                                                                                                              | <b>Fire Development</b>                                                                                                                                                               | <b>Contributing<br/>Factors and<br/>Other Details</b>                           |
|----------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|
| Michigan<br>\$650,000,000<br>February, 1999<br>1:00 p.m. | This six-story power plant at an automobile manufacturing complex was of protected, noncombustible construction and covered a ground-floor area of 80,874 square feet (7,513.2 square meters). The plant was in full operation at the time of the explosion and ensuing fire. | The power plant didn't have automatic detection equipment. There was a partial area coverage wet-pipe sprinkler system. The areas covered weren't reported. This system did activate but wasn't able to contain or extinguish the fire due to the extreme circumstances and damage to the system by the explosion and fire. | A build-up of natural gas in a boiler was ignited by an undetermined source. The explosion heavily damaged the building. Six civilians died in the blast and another 38 were injured. | According to investigators, several safety devices were removed or inoperative. |

Stephen G. Badger and Thomas Johnson, 2000, "1999 Large-Loss Fires and Explosions", *NFPA Journal*, November/December, 95-96.

| <b>Location,<br/>Date,<br/>Time of<br/>Alarm,<br/>Number of<br/>Deaths</b> | <b>Occupancy Type<br/>and Use,<br/>Construction Type,<br/>Number of Stories,<br/>and Operating<br/>Status</b> | <b>Detection<br/>Systems</b>                                 | <b>Suppression<br/>Systems</b>                                                | <b>Fire Origin and<br/>Path</b>                                                                                                            | <b>Contributing<br/>Factors and<br/>Other Details</b> |
|----------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------|-------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|
| Michigan<br>November, 1999<br>9:00 p.m.<br>Five                            | Convalescent home; protected ordinary construction; one story; full operation.                                | The building had smoke alarms and heat detectors throughout. | The wet-pipe sprinkler system in the basement was destroyed in the explosion. | The fire started in the boiler room. A small initial explosion was followed by another. Other details of the ignition remain undetermined. | The occupants had no time to react to the explosion.  |

Robert S. McCarthy, 2000, "1999 Catastrophic Multiple-Death Fires", *NFPA Journal*, September/October, 59.

## LACK OF MAINTENANCE

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b>      | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                 | <b>Fire Protection Systems</b>                                                                                                                                                                                                                                                                                                                                                                                                                                  | <b>Fire Development</b>                                                                                                                                                                                                                                                                                                                                                        | <b>Contributing<br/>Factors and<br/>Other Details</b>                                                                                                                                                |
|-----------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| South Carolina<br>\$8,000,000<br>March, 2005<br>6:53 a.m. | Four-story textile manufacturing plant of heavy timber construction covering 67,500 square feet (6,271 square meters) was in full operation at the time this fire broke out. | There was a complete coverage detection system of an unreported type. This system was out of service for an unreported reason at the time of the fire. A complete coverage wet-pipe sprinkler system was present. The system operated but was ineffective due to lack of maintenance. The sprinkler heads were coated with cotton dust. There were pressurized water and ABC extinguishers present, which the employees used to extinguish the fire in a baler. | A fire originating in a baler was believed extinguished by the employees. The cause was not reported. When firefighters arrived and investigated they found the fire had extended to the second floor. Firefighters attempted an interior attack, but conditions deteriorated rapidly and walls started to collapse, so all firefighters were withdrawn to a defensive attack. | Three firefighters were injured. Holes in the floor on the second story allowed the fire to extend to the second story. Losses totaled \$5,000,000 to the structure and \$3,000,000 to the contents. |

Stephen G. Badger, November, 2002, "Large-Loss Fires in the United States 2001", 14.

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b> | <b>Property Characteristics<br/>and Operating Status</b>                                                                                                                                                                                      | <b>Fire Protection Systems</b>                                                                                                                                                                                                                                                                                                                                                                                                          | <b>Fire Development</b>                                                                                                                                                                                                                                                             | <b>Contributing<br/>Factors and<br/>Other Details</b> |
|------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|
| California<br>\$6,000,000<br>July, 1999<br>7:25 p.m. | This four-story furniture showroom of protected, non-combustible construction covered a ground-floor area of approximately 44,000 square feet (4,087.5 square meters). The showroom was closed but construction workers were in the building. | The building had no automatic detection system but did have a partial-coverage sprinkler system. Sprinklers helped control fire spread on the second and third floors but weren't effective on the fourth floor because of sediment in the system. Firefighters found sediment blocking several heads. The building also had portable extinguishers and a stand pipe system. Investigators believe that workers used the extinguishers. | Molten slag came in contact with furniture during welding operations and ignited a fire. The fire spread out the second-floor windows and into the third floor. Flames then breached a ceiling and entered the fourth floor where there was a flashover. No injuries were reported. | Sediment blocked sprinklers on the fourth floor.      |

Stephen G. Badger and Thomas Johnson, 2000, "1999 Large-Loss Fires and Explosions", *NFPA Journal*, November/December, 92.



## OBSTRUCTED WATER FLOW

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b>  | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                    | <b>Fire Protection<br/>Systems</b>                                                                                                                                                                                          | <b>Fire<br/>Development</b>                                                                                                                                                                                                                                                                                                                                           | <b>Contributing<br/>Factors and<br/>Other Details</b>                                                                                                                                                                                                                                                                                                                             |
|-------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Arizona<br>\$8,000,000<br>December, 2004<br>7:33 p.m. | This two-story convention center was of protected non-combustible construction. The ground floor area was not reported. The center was fully operating at the time of the fire. | There was a smoke detection system present that operated and alerted the occupants. The coverage was not reported. There was a wet-pipe sprinkler system present. The system did activate with over 30 heads flowing water. | Heat from a halogen light ignited walnut dust used in filming a collapse scene in a mine for a movie. The fire ignited polyurethane beams and walls of a cave and extended to the cave roof. A covering over the movie set prevented water from the sprinkler from reaching the seat of the fire but the sprinkler flow did prevent the fire's spread beyond the set. | Original reports were that one worker was missing. A primary search was initiated but the worker was located unharmed. Visibility was zero as firefighters attempted an initial fire attack. Firefighters were warned initially of loose rattlesnakes at the movie set. The snakes were corralled by an animal handler and posed no threat to the firefighters and harmed no one. |

Stephen G. Badger, 2005, "Large-Loss Fires for 2004", *NFPA Journal*, November/December, 49.

## WATER FLOW ISSUES

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b> | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                                | <b>Fire Protection<br/>Systems</b>                                                                                                                                                                                                                                                                                   | <b>Fire<br/>Development</b>                                                                                                                                                                                                                                                                                                                                                                                                                                     | <b>Contributing<br/>Factors and<br/>Other Details</b>                                                                                                                                          |
|------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Iowa<br>\$250,000,000<br>February, 2000<br>7:02 a.m. | One-story machinery storage warehouse of unprotected non-combustible construction covering 990,000 square feet (91,974 square meters) was in full operation at the time the fire broke out. | There was no automatic detection equipment. A system was in the process of being installed. A wet-pipe sprinkler system was present. The extent of the coverage was not reported. This system activated but was not effective because of a water flow problem. The cause of the problem is still being investigated. | A fire of unknown cause broke out in the shipping/receiving area of this warehouse. Responding firefighters reported a large column of smoke from a distance away. With the sprinkler system activated, firefighters made an interior attack. Walls without openings within the warehouse hindered firefighters in reaching the fire. When large areas of the roof began to collapse and high rack storage failed, firefighters withdrew to a defensive attack. | Five firefighters were injured. The water supply was far below the fire flow requirements. A tanker shuttle was set up to assist until late in the day when the water problems were corrected. |

Stephen G. Badger, November, 2002, "Large-Loss Fires in the United States 2001", 17.

## OTHER

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b> | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                        | <b>Fire Protection Systems</b>                                                                                                                                                                           | <b>Fire Development</b>                                                                                                                                                                                           | <b>Contributing<br/>Factors and<br/>Other Details</b>                                                                                                    |
|------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|
| Texas<br>\$18,000,000<br>December, 2005<br>2:06 p.m. | This was a cotton storage facility of unprotected noncombustible construction was operating. The height and area were not reported. | No information on detection equipment was reported. There was a sprinkler system in the building. The coverage and type was not reported. The system operated but was overwhelmed by the spreading fire. | This was an exposure fire. A welder working in a livestock auction facility unintentionally ignited hay in a pen. The fire spread to grass and then across a road to cotton bales, and into the storage building. | High winds spread the fire very rapidly. Embers blowing from the fire ignited several smaller fires in town. Ten fire departments were called to assist. |

Stephen G. Badger, 2006, "Large-Loss Fires for 2005", *NFPA Journal*, November/December, 72.

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b>       | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                                                 | <b>Fire Protection Systems</b>                                                                                                                                                                                                                                                                                                                                                         | <b>Fire Development</b>                                                                                                                                                                                            | <b>Contributing<br/>Factors and<br/>Other Details</b>                      |
|------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|
| Louisiana<br>\$11,000,000<br>September, 2005<br>12:57 p.m. | This L-shaped, one-story mall of unprotected ordinary construction had a floor area of 100,000 square feet (929 square meters) and contained 110 stores and eateries. The operating status was not reported. | There was smoke detection equipment present. The coverage and operation was not report. There was a wet-pipe sprinkler system of unreported coverage. The system did operate as designed until pressure was lost to the system. By the time the fire department re-established water flow and pressure to the systems the fire had overwhelmed the system and 100 sprinklers operated. | This incendiary fire was set in a show room of a mall store in wearing apparel. The fire spread to and destroyed 15 stores in one wing of the building, and caused smoke and water damage to the rest of the mall. | The loss was \$8,000,000 to the structure and \$3,000,000 to the contents. |

Stephen G. Badger, November, 2006, "Large-Loss Fires In The United States 2005," 25.

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b> | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                                            | <b>Fire Protection<br/>Systems</b>                                                                                                                                           | <b>Fire<br/>Development</b>                                                                                                                                                                                                                                                                                                                                                                                                                         | <b>Contributing<br/>Factors and<br/>Other Details</b>                                                                                                                                                                                                                                                                               |
|------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Oregon<br>\$23,013,625<br>July, 2005<br>12:42 p.m.   | This one-story sawmill was of heavy-timber construction and covered a ground floor area of more than 100,000 square feet (9,290 square meters). The mill was at full operation at the time of the fire. | There was no detection equipment present. There was an unreported coverage wet-pipe sprinkler system present. The system operated but was overpowered by the spreading fire. | The fire originated in the area of an electric motor above a dryer. The exact heat source and first materials ignited were still under investigation. The fire burned in hidden areas until it spread to the heavy timber bowstring truss roof construction. Several interior attacks were attempted but the fire was very deep-seated and firefighters were withdrawn for an exterior attack. Shortly after this, there was a structural collapse. | There was a long delay in notifying the fire department while workers attempted to extinguish the fire. Firefighters were told upon arrival the fire was out, but on investigation, firefighters found a deep-seated fire. Three firefighters were injured. The loss was \$5,013,000 to the structure and \$18,000,625 to contents. |

Stephen G. Badger, 2006, "Large-Loss Fires for 2005", *NFPA Journal*, November/December, 70.

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b> | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                | <b>Fire Protection Systems</b>                                                                                                                                                                                             | <b>Fire Development</b>                                                                                                            | <b>Contributing<br/>Factors and<br/>Other Details</b>                                                                                                                                     |
|------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Georgia<br>\$50,000,000<br>May, 2004<br>4:25 a.m.    | This one-story chemical manufacturing plant was of protected ordinary construction and covered 400,000 square feet. The plant was in operation at the time. | There was no automatic detection equipment present. There was a complete coverage wet-pipe sprinkler system present. The system activated but was overpowered by the spreading fire. The reason for this was not reported. | A fire broke out when a chemical reaction occurred in the warehouse area of the plant. The chemicals involved were not identified. | Very heavy smoke covered the area, causing local officials to evacuate many downwind of the fire. Damage to the structure was estimated at \$20,000,000 and \$30,000,000 to the contents. |

Stephen G. Badger, 2005, "Large-Loss Fires for 2004", *NFPA Journal*, November/December, 46.

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b>  | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                   | <b>Fire Protection Systems</b>                                                                                                                                        | <b>Fire Development</b>    | <b>Contributing<br/>Factors and<br/>Other Details</b>                                                                                                                                                                    |
|-------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Illinois<br>\$6,800,000<br>October, 2003<br>4:03 a.m. | This three-story warehouse containing tires was of heavy timber construction and covered 150,000 square feet (13,935 square meters). The warehouse was closed for the weekend. | No automatic detection equipment was present. A complete coverage wet-pipe sprinkler system was present and operated, but was ineffective due to the large fire load. | The cause is undetermined. | Fire growth was extremely fast due to the fire load. Firefighters were forced to withdraw to a defensive attack. Two firefighters were injured. Loss to the building was \$800,000 and loss to contents was \$6,000,000. |

Stephen G. Badger, 2004, "Large-Loss Fires for 2003", *NFPA Journal*, November/December, 57.

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b> | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                             | <b>Fire Protection Systems</b>                                                                                                                                                                                  | <b>Fire Development</b>                                                                                                                                                                                                                                                     | <b>Contributing<br/>Factors and<br/>Other Details</b>                                                                                                                                          |
|------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Oregon<br>\$8,501,000<br>March, 2004<br>8:21 a.m.    | This one-story petroleum recycling plant was of heavy-timber, construction and covered 186,900 square feet. The plant was in full operation at the time. | No information was reported on any detection equipment. There was a complete coverage dry-pipe sprinkler system present. The system operated, but its rate of application was insufficient to control the fire. | A spark from an oxy/acetylene cutting torch fell into an open sludge-oil pit and ignited the contents instantaneously. The fire grew out of control quickly despite the activation of the sprinkler system. The fire spread through several businesses inside the building. | Firefighters reported insufficient water pressure in hydrants originally. Two firefighters were injured. Damage to the structure was estimated at \$3,000,000 and \$5,501,000 to the contents. |

Stephen G. Badger, 2005, "Large-Loss Fires for 2004", *NFPA Journal*, November/December, 47.

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b>   | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                                             | <b>Fire Protection Systems</b>                                                                                                                                                                    | <b>Fire Development</b>                                                     | <b>Contributing<br/>Factors and<br/>Other Details</b> |
|--------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|-------------------------------------------------------|
| Colorado<br>\$30,000,000<br>December, 2002<br>8:47a.m. | This 24-foot-high, one-story general products warehouse was of protected ordinary construction and covered a ground floor area of 120,415 square feet. The warehouse was closed at the time of the fire. | There was no automatic detection system present. There was a complete coverage wet-pipe system present. The system did activate but was ineffective when it was overwhelmed by the fire's growth. | Several incendiary fires were set in this warehouse to cover up a burglary. | One firefighter and four civilians were injured.      |

Stephen G. Badger, 2003, "2002 Large-Loss Fires", *NFPA Journal*, November/December, 78.



| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b>  | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                        | <b>Fire Protection<br/>Systems</b>                                                                                                                                                         | <b>Fire<br/>Development</b>                                                       | <b>Contributing<br/>Factors and<br/>Other Details</b> |
|-------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-------------------------------------------------------|
| Indiana<br>\$27,000,000<br>October, 2002<br>3:00 a.m. | This one-story steel manufacturing plant was of unprotected ordinary construction. The ground floor area was not reported. The plant was in full operation at the time of the fire. | There was no automatic detection system present. There was a complete coverage sprinkler system of unreported type present. The system operated but was overwhelmed by the spreading fire. | The fire originated in a hanging natural gas furnace and swept through the plant. | None Reported.                                        |

Stephen G. Badger, 2003, "2002 Large-Loss Fires", *NFPA Journal*, November/December, 77.

| <b>Location,<br/>Dollar Loss,<br/>Date,<br/>Time</b> | <b>Property<br/>Characteristics and<br/>Operating Status</b>                                                                                                                 | <b>Fire Protection<br/>Systems</b>                                                                                                                                                                                          | <b>Fire<br/>Development</b>                                                                                                                                                                                                             | <b>Contributing<br/>Factors and<br/>Other Details</b>                                                                                                               |
|------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Montana<br>\$7,000,000<br>January, 2002<br>9:40 p.m. | This two-story lumber warehouse was of unprotected noncombustible construction and covered a ground floor area of 9,000 square feet. The warehouse was closed for the night. | There were no automatic detection or suppression systems present. An exposure building did have a dry-pipe sprinkler system, but this was overcome and ineffective when the fire attacked that structure from the exterior. | This incendiary fire was set in available combustible materials. The building was fully engulfed in fire when the fire department arrived, forcing them to go to an exterior attack. The fire spread to several warehouses in the area. | Because of the remote location, the fire burned undetected for some time. Faulty hydrants and dead-end mains impeded water supply. Three firefighters were injured. |

Stephen G. Badger, November, 2003, "Large-Loss Fires in the United States 2002", 17.

| <b>Location,<br/>Date,<br/>Time of Alarm,<br/>Number of Deaths</b> | <b>Occupancy Type<br/>and Use,<br/>Construction<br/>Type, Number<br/>of Stories, and<br/>Operating<br/>Status</b> | <b>Detection<br/>Systems</b> | <b>Suppression<br/>Systems</b>                                       | <b>Fire Origin<br/>and Path</b>                                                              | <b>Contributing<br/>Factors and Other<br/>Details</b>                                                                                                                                                                                                                                                                                               |
|--------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|------------------------------|----------------------------------------------------------------------|----------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Michigan<br>February, 1999<br>1:00 p.m.<br>Six                     | Industrial power<br>plant;<br>unprotected non-<br>combustible<br>construction; six<br>stories; full<br>operation. | None.                        | The power<br>plant had a<br>partial wet-pipe<br>sprinkler<br>system. | An<br>undetermined<br>source<br>ignited an<br>accumulation<br>of natural gas<br>in a boiler. | According to the<br>state OSHA report,<br>several safety<br>devices at the plant<br>had been defeated<br>or removed, and<br>there were no<br>written procedures<br>posted for shutting<br>down the boiler.<br>Sprinklers were<br>unable to control<br>the fire caused by<br>the explosion.<br>Thirty-eight<br>workers were<br>injured in the blast. |

Robert S. McCarthy, 2000, "1999 Catastrophic Multiple-Death Fires", *NFPA Journal*, September/October, 59.

January 8,

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## **Study on the Life Cycle Cost of Portable Fire Extinguishers**

Richard W. Bukowski, P.E., FSFPE

RJA undertook this project to determine the cost of portable fire extinguishers over their life cycle, estimated to be 24 years, including purchase, installation, and all service requirements. This analysis may be used to determine the value of portable fire extinguishers in commercial properties. The study methodology utilized the accepted international standard, *Standard for Measuring Life Cycle Costs of Buildings and Building Systems, ASTM E0917-05*. This analysis can be used to estimate the total economic impact of the provision of portable extinguishers in accordance with NFPA 10 in any size facility for any assumed rate of return. Here, the discount (interest) rate used is 5%, which is typical for equipment investment analyses.

Typical costs of procurement, periodic inspection, maintenance, and testing as required by NFPA 10 were obtained from publically available sources and include initial (or replacement) cost and costs associated with required on-site servicing. Required monthly inspections are assumed to be performed by employees at a typical loaded salary rate and annual maintenance, periodic recharge, and hydrostatic testing required to be performed by certified professionals is assumed to be done on site.

NFPA 10 requires that for Class A hazards, an extinguisher must be within a 75 foot travel distance of any point; which is not directly useful in assessing cost. Most cost estimating guides (e.g., Means) express costs in cost per square foot of floor area. To determine a reasonable value for number of extinguishers per floor area, the floorplans of a dozen health care facilities ranging in size from 33,000 sq. ft. to 560,000 sq. ft. and

requiring from 15 to 420 extinguishers, were examined. This resulted in a range of 1500 to 2000 sq. ft. per extinguisher. Note that NFPA-10 allows these extinguishers to cover no more than 6,000 square feet, so the cost per foot can vary significantly.

Actual inspection, maintenance and testing costs gathered for this study consist of a fixed service charge per facility per visit and a per extinguisher charge. To distribute the per visit charge over multiple extinguishers, costs per extinguisher were determined as 10% of the costs for 10 extinguishers per facility.

Because actual costs vary depending on many factors, including the facility size and geographic location, costs are reported as a range, following conservative assumptions in each case. Obtaining a cost per square foot was accomplished by using the actual number of extinguishers required in each health care facility divided by their gross floor area.

Based on the actual health care facility extinguisher location drawings, the annual cost per square foot for procurement, installation, and all required inspection, testing, and maintenance over a 24 year life (all paid at the time of purchase) ranged from \$.015 to \$.04 per square foot per year. If a facility was able to maximize extinguisher coverage at 6,000 square feet per extinguisher, the annual cost per foot would range from .005 to \$.01. While unlikely that any facility can achieve the maximum permitted coverage, this calculation is provided for comparative purposes.

