NFPA 105

Recommended Practice for the Installation of Smoke-Control Door Assemblies

1999 Edition

NFPA®

National Fire Protection Association, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101
An International Codes and Standards Organization

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This edition of NFPA 105, *Recommended Practice for the Installation of Smoke-Control Door Assemblies*, was prepared by the Technical Committee on Fire Doors and Windows and acted on by the National Fire Protection Association, Inc., at its Fall Meeting held November 16–18, 1998, in Atlanta, GA. It was issued by the Standards Council on January 15, 1999, with an effective date of February 4, 1999, and supersedes all previous editions.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

This edition of NFPA 105 was approved as an American National Standard on February 4, 1999.

Origin and Development of NFPA 105

This recommended practice is the result of a multiyear project by the Technical Committee on Fire Doors and Windows and is based on the acknowledgment that smoke is the principal killer in destructive fires. Historically, fire doors have been permitted to have such clearances and deflections as would permit the passage of relatively great quantities of smoke. Those fire doors, when properly installed, have proven to be adequate barriers against the passage of fire, but improvement is needed to protect against the passage of smoke. This recommended practice was prepared to introduce parameters for door performance that will limit smoke spread through a door opening.

The 1993 edition was the third edition and replaced the 1989 edition. It made use of new information that recognized that smoke-control doors in buildings protected by automatic sprinklers will have substantially lower pressures created by a potential fire.

The 1999 edition includes modifications to Table 3-2.1 recognizing the pressure differentials caused by stack effect in elevator hoistways.

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NOTE: Membership on a committee shall not in and of itself constitute an endorsement of the Association or any document developed by the committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on the installation and maintenance of fire doors, windows, shutters, and other equipment used to restrict the spread of fire, including arrangements for automatic operation in case of fire. This includes installation to protect buildings against external fire and to restrict the spread of fire within buildings. Vault and record room doors are covered by the Technical Committee on Record Protection.

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NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Appendix A.

Information on referenced publications can be found in Chapter 4 and Appendix B.

Chapter 1 Introduction

1-1 Scope.

1-1.1 This recommended practice covers the use of door assemblies in openings where the passage of smoke is to be governed. These door assemblies are hereafter referred to as smoke-control door assemblies. Any specific known factors affecting any installations may require more stringent application of the recommendations in this recommended practice.

1-1.2 This recommended practice is primarily concerned with the effect of smoke on visibility. It does not contain an assessment of toxicity. While the use of smoke-control doors will be helpful in reducing the flow of airborne gases, it is not to be assumed that using this recommended practice obviates the concern over toxic combustion products.

1-2* Purpose. This recommended practice is intended to assist in the treatment of the problems associated with controlling the flow of smoke and gases through door openings in buildings.

1-3 General.

1-3.1 NFPA *101*®, *Life Safety Code*®, and building codes include specific requirements for smoke-control door assemblies and should be consulted in every instance. NFPA 80, *Standard for Fire Doors and Fire Windows*, should be followed when fire door assemblies are used as smoke-control door assemblies.

1-3.2 Consideration should be given to the leakage characteristics of adjacent wall, ceiling, and floor assemblies. It is generally considered to be of marginal benefit to install smoke-control door assemblies in locations where adjacent walls, ceilings, or floors do not effectively resist the passage of smoke. *(For additional information, see Design of Smoke Control Systems for Buildings.)*

1-3.3* When protecting against smoke migration into spaces of large volume, a reasonably tight-fitting door may be considered adequate because of the relatively long time it would take for such a space to become untenable due to smoke. Conversely, the average 8-ft (2.4-m) high by 4-ft to 6-ft (1.2-m to 1.8-m) wide corridor can become untenable in less than 2 minutes as shown in a test conducted in California entitled *Operation School Burning,* where the fire room door was open.

1-3.4 Depending on construction and on which side of the door the elevated temperature exists, the door might bow away from the stops at certain points. If the gasket is mounted such that it cannot move with the door, some gaps may occur between the door and the gaskets. Also, if the gaskets are on the outside of the door where the elevated temperature smoke occurs, there may be some detrimental effects to the gaskets, depending on the temperature and the length of time exposed. However, tests indicate that many gaskets, if properly installed and maintained, do a good job of reducing the smoke infiltration to a sufficient level to provide protection against smoke infiltration through the door assembly. In a fire condition, there would normally be a room of fire origin, and temperatures would be high in this area. Immediately outside the room of origin there might be warm smoke.

1-3.5 NFPA 252, *Standard Methods of Fire Tests of Door Assemblies*, permits a $1^3/_4$-in. (44-mm) thick door to deflect up to $2^5/_8$ in. (67 mm). This door deflection is unacceptable for smoke infiltration protection. Special recommendations are needed, therefore, for smoke-control door assemblies used in locations where fire exposure and hot smoke are expected.

NFPA 252 does not provide for measurements of leakage through fire door assemblies under the standard fire exposure conditions. Furthermore, door deflection might occur at elevated temperatures, depending on the door construction. It should be noted that fire doors are commonly tested under neutral or even negative pressure, whereas in typical fires, positive pressures exist over the upper one-half or two-thirds of the door. In view of the deflections permitted in NFPA 252, under fire exposure conditions, fire doors can allow considerable leakage unless special designs involving seals are used.

1-3.6* Smoke Temperature. Depending on the function of the door, its location in relation to the fire, and the movement of hot gases and air, door assemblies might be exposed to ambient or elevated smoke temperatures. For the purposes of this recommended practice, the following three temperature exposures are considered.

(a) *Ambient smoke temperature.* The temperature at the exposed face of the door is assumed to be at or near 75°F (24°C).

(b) *Warm smoke temperature.* The temperature at the exposed face of the door is assumed to be at or near 400°F (204°C).

(c) *Hot smoke temperature.* The temperature at the exposed face of the door is assumed to be in excess of 400°F (204°C).

1-3.7* Pressure differentials of at least 0.04 in. wg (10 Pa) are developed in the upper parts of rooms that are involved in fire. Considerably higher pressure differentials can exist in rooms, corridors, and stair enclosures due to the action of air-handling systems, stack effect, and wind. For the purposes of this recommended practice, pressures up to 0.30 in. wg (75 Pa) are considered.

In sprinklered buildings where the fire will be controlled, it is anticipated that the maximum pressure differential generated should not exceed 0.05 in. wg (12.5 Pa).

1-3.8* Smoke management systems both affect and are affected by smoke-control door assemblies. Pressurized stair enclosures, for example, are more easily engineered when leakage through the stair doors is reduced. In other areas, pressurization can inhibit smoke flow so that reasonably tight-fitting doors unrated for smoke protection may be entirely appropriate.

1-3.9 Smoke-control doors should take the entire smoke management system into account. The amount of leakage tolerable will vary according to the degree of compartmentation, whether smoke management systems are used, and whether the building is protected by sprinklers.

1-3.10 The required duration of smoke protection can be equated with the path of egress. Evacuation typically starts in a room, progresses through a corridor, perhaps passes through a smoke barrier or horizontal exit, and proceeds through an entrance to the exit, which can be a stair enclosure, exit passageway, or the exit discharge. As with fire door assemblies, the longest time of protection is generally required at the entrance to an exit enclosure or horizontal exit with shorter durations appropriate for preceding doors.

This arrangement should also be the case with smoke-control door assemblies. This arrangement is compatible with the protect-in-place concept as occupants are expected to be moved from one compartment to another for protection or, in some cases, protected in rooms other than the room of fire origin.

Occupancies not typical of this scenario include atria, malls, open office plans, and industrial occupancies. Areas of this sort can be adequately protected by reasonably tight-fitting doors without specific smoke-control door ratings because of the large volume of space involved.

1-3.11 Criteria for rating smoke-control door assemblies reflect several areas of compliance, which includes amount of door deflection, limitation of leakage at various temperatures, protection related to specific volumes of space, and duration of protection. Practicality, however, dictates against so many variables as to make each assembly different from another. It is likely then that smoke-control door assemblies for ambient and warm smoke temperature protection will be rated on the basis of a simple air infiltration test. An on-site verification should be required to determine that materials used are of the same construction as those tested and the installation is appropriate.

While not covered in this recommended practice, a rating for hot smoke protection should be in connection with a fire test and under label service with an in-plant follow-up inspection service. At this time, a nationally recognized standard test for measuring hot smoke temperature leakage does not exist.

1-3.12* Complete sealing of doors is not always desirable. A disadvantage of complete sealing is the difficulty to open or close doors because of the pressure differential. Some smoke management designs call for some areas to be pressurized. A small pressure acting across the full area of a door can exert sufficient force to make opening a door difficult. A seal must be first broken to equalize the pressure on both sides of the door before the door can be opened easily.

1-3.13 Twenty-minute smoke-control door assemblies do not require the hose stream portion of the test called for in NFPA 252, *Standard Methods of Fire Tests of Door Assemblies.* Some 20-minute fire door assemblies have been tested with the hose stream portion of the test. For the purposes of this document, either type of assembly is appropriate for use under Section 2-1.

Chapter 2 Guidelines

2-1 Fire Door Assemblies Used as Smoke-Control Doors.

2-1.1 The installation of fire door assemblies is covered by NFPA 80, *Standard for Fire Doors and Fire Windows.*

2-1.2 The addition of gasketing materials is also covered by NFPA 80.

2-1.3 If protection against leakage at elevated temperatures is desired, a suitable sealing system or gasketing should be provided that will allow the door to meet the performance criteria in Section 3-2.

2-1.4* Gasketing, if used, should not inhibit the closing and positive latching of the door. Satisfactory closing and latching of the door should be verified after any gasketing has been installed.

2-1.5 For pairs of fire doors used for smoke control, double egress doors with leaves that swing in opposite directions are recommended with either overlapping astragals or other tested methods that do not hinder free use of either leaf. Double egress doors do not hinder the free use of either leaf and a satisfactory seal is provided.

2-1.6 Pairs of fire doors swinging in the same direction should be provided with split or compensating astragals adjusted so that closing and positive latching is not inhibited. Gasketing may also be used if the doors have been so tested. Use of a center mullion is another alternative, provided the required units of exit width in the opening are maintained.

2-1.7 If automatic-closing fire doors are used in lieu of self-closing fire doors, the release device should be smoke actuated. Delay on closing after actuation should not exceed 10 seconds. Where appropriate, interconnect with other fire alarm, suppression, and detection systems.

2-1.8 Because louvers are normally subject to leakage, they should not be used. *(See 1-3.2 of NFPA 80.)*

2-2 Nonfire Door Assemblies Used as Smoke-Control Doors.

2-2.1 Doors used should be substantial and may include glazing.

2-2.2 Frames used should be smoke resistant *(see also 1-3.2)* and of sufficient strength to support an operating door.

2-2.3 Nonfire doors should only be used for controlling ambient and warm smoke. Nonfire doors used for controlling warm smoke should not be equipped with materials that would adversely affect the performance of the smoke-control door assembly at temperatures less than 400°F (204°C).

2-2.4* Doors should be self-closing or automatic-closing upon smoke detection.

Exception: It is recognized that some codes call for the use of 20-minute fire doors or their equivalent and waive the requirement for a door closer. These doors are still desired even though a label cannot be provided because of the omission of a required fire door assembly component. These doors are usually in room-to-corridor locations where protection against leakage at elevated temperatures may be desired.

2-2.5 Doors should be hinged in accordance with NFPA 80.

Exception: Double-acting doors may be used if they meet the performance criteria of Section 3-2.

2-2.6 Latches should be provided unless the anticipated pressures are such that the performance criteria *(see Section 3-2)* of the door assembly can be achieved without latching.

2-2.7 Gasketing, if used, should be of a type covered in NFPA 80, and should not inhibit the closing and positive latching of the door. Satisfactory closing and latching of the door should be verified after any gasketing has been installed.

2-2.8 Pairs of doors should be installed in accordance with the recommendations in 2-1.6 or 2-1.7.

2-2.9 Because louvers are normally subject to leakage, they should not be used. *(See 1-3.2 of NFPA 80.)*

2-2.10 Operating transoms should not be used. Fixed solid transom panels are permitted to be used.

2-2.11 Glazing should be sealed in place to minimize leakage. If glazing is used for doors described in the exception to 2-2.4, it should be labeled fire protection–rated glazing material and should be no larger than that tested in the door.

Chapter 3 Recommended Test

3-1 Air Leakage.

3-1.1 To determine leakage rates of a smoke-control door assembly that may be exposed to ambient or warm smoke temperatures, each side of the door assembly should be tested in accordance with UL 1784, *Air Leakage Tests of Door Assemblies.*

3-1.2* Depending on the type and functional use of the door assembly, an additional test should be conducted with an artificial seal applied at the bottom edge. Artificial sealing of the gap (or undercut), for example, with an impermeable sheet or tape, provides information on the extent of air leakage at the bottom gap and provides a better measure of anticipated leakage for doors given that they will be exposed to positive pressure in the upper part and to negative pressure in the lower part of a door. *(See Table 3-2.1.)*

3-1.3 The sequence of testing should follow the order in Table 3-1.3.

For the warm temperature measurement, the chamber air temperature should be increased so that it reaches 350°F (177°C) within 15 minutes. When stabilized at the prescribed air temperature [400°F ± 20°F (204°C ± 11°C)], the leakage rate should be measured at the four pressure differentials in sequence during a period not to exceed 30 minutes.

Exception: Where representative test data exist to verify that ambient temperature results in higher leakage rates, additional tests for warm temperature measurement need not be conducted.*

Table 3-1.3 Air Leakage Testing Sequence

Temperature	Pressure Differential (in. wg)	(Pa)
Ambient (75°F/24°C)	0.05	12.5
Ambient (75°F/24°C)	0.10	25
Ambient (75°F/24°C)	0.20	50
Ambient (75°F/24°C)	0.30	75
Warm (400°F/204°C)	0.05	12.5
Warm (400°F/204°C)	0.10	25
Warm (400°F/204°C)	0.20	50
Warm (400°F/204°C)	0.30	75

3-2 Performance Criteria.

3-2.1 To provide reasonable levels of performance for the door application indicated, air leakage rates should not exceed the values provided in Table 3-2.1 per ft^2 of door opening.

3-2.2 An engineering evaluation should be performed when the volume of the space to be protected is known so that the

Table 3-2.1 Allowable Air Leakage

Door Installation	Pressure Differential[1] (in. wg)	Temperature	Maximum Leakage (scfm/ft^2 door opening)
Room to corridor[1, 2]	0.10	Warm	3
Room to corridor (pressurized)	0.05	Warm	3
Area of refuge[1]	0.20	Warm	2
Elevator lobby[1]	0.10	Ambient	3
Elevator-pressurized hoistway	0.10	Warm	6
Elevator without lobby separation (not pressurized)			
≤50 ft	0.10	Warm	3
>50 ft and ≤100 ft	0.20	Warm	3
>100 ft	0.30	Warm	3
Cross corridor[1, 2]	0.05	Warm	1
Stair enclosure	0.10	Ambient	3
Stair enclosure (pressurized)	0.30	Ambient	11
Horizontal exit	0.05	Warm	1

For SI Units: 1 in. wg = 250 Pa; 1 scfm/ft^2 = 0.3 $m^3/min/m^2$.
[1]In fully sprinklered buildings, the pressure differential should be considered to be 0.05 in. wg.
[2]Tested with artificial bottom seal. However, in an actual installation, the bottom seal that was provided in the test may be omitted due to the neutral pressure plane being located in a fire condition approximately one-third of the way up from the bottom of the door.

values in Table 3-2.1 can be modified to restrict smoke leakage in terms of a specified smoke tenability level. The evaluation should include, but not be limited to, fuel load, pressurization, stack effect, the presence of smoke-control systems, and. construction as well as smoke leakage in assessing tenability.

3-3 Gasketing. Gasketing or seals used as part of smoke-control door assemblies should be classified and listed by an independent testing laboratory. Evaluations should indicate that the material investigated does not adversely affect the performance of fire doors. It should be helpful if such materials could also be evaluated according to temperature resistance. Lacking such evaluations, the manufacturer should be requested to indicate maximum temperatures under which its gasket material is effective. Resiliency, durability, and cycling should be considerations for acceptance of gaskets or seals.

Chapter 4 Referenced Publications

4-1 The following documents or portions thereof are referenced within this recommended practice and should be considered as part of its recommendations. The edition indicated for each referenced document is the current edition as of the date of the NFPA issuance of this recommended practice. Some of these documents might also be referenced in this recommended practice for specific informational purposes and, therefore, are also listed in Appendix B.

4-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 80, *Standard for Fire Doors and Fire Windows,* 1999 edition.

NFPA *101*®, *Life Safety Code*®, 1997 edition.

NFPA 252, *Standard Methods of Fire Tests of Door Assemblies*, 1995 edition.

NFPA film, *Operation School Burning*, Los Angeles Fire Department, 1959.

4-1.2 Other Publication.

4-1.2.1 UL Publication. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL 1784, *Air Leakage Tests of Door Assemblies,* 1990.

Appendix A Explanatory Material

Appendix A is not a part of the recommendations of this NFPA document but is included for informational purposes only. This appendix contains explanatory material, numbered to correspond with the applicable text paragraphs.

A-1-2 This recommended practice was written to be of assistance to authorities having jurisdiction and designers of building smoke management systems when smoke-control door assemblies are used as part of the system.

A-1-3.3 For the purposes of this recommended practice, smoke can be considered to be airborne particulates and gases resulting from combustion. Therefore, to understand smoke movement it is only necessary to understand air movement. Hot smoke, however, will be buoyant and will be located above the neutral plane in the fire compartment. As it moves away from the fire source, it will cool, lose its buoyancy, and become less stratified. Beyond the immediate influence of the fire, smoke will behave just as warm or cool air would behave. It will be driven by pressure differentials within the building or will follow air currents created by the heating, ventilating, and air-conditioning (HVAC) system in the building. Pressure differentials may be the result of the following:

(a) Fire pressure buildup, which would only drive the smoke out of the compartment or area of origin

(b) Stack effect due to temperature differentials between the interior and exterior of the building

(c) Wind

(d) Pressures created mechanically using HVAC systems, exhaust fans, supply (pressurization) fans, vents, and so forth

Therefore, to control smoke movement, a designer needs to control air movement. Leakage rates for smoke-control door assemblies can be established for different pressure differentials. Quantity of air movement through a door assembly can be determined and performance criteria established for the specific application.

Based on measurements reported in *Operation School Burning* and Technical Paper No. 341, "Factors in Controlling Smoke in High Buildings," it has been estimated that a tenable or tolerable smoke concentration limit corresponds to an optical density per meter within the range of 0.04 to 0.08. Since the maximum density of smoke generated in the fire area is considered to lie in the range of 4 to 8 optical density per meter, a tenable smoke atmosphere is sometimes assumed to correspond to 1 percent of the atmosphere in the immediate fire area.

A-1-3.6 Smoke-control door assemblies used in locations likely to be in close proximity to a fire can be exposed to elevated temperatures. These locations include doors separating rooms and corridors, and doors serving as smoke barriers or horizontal exits. Such doors, whether rated as fire doors or not, should restrict the passage of smoke that may be heated to a temperature of 400°F (204°C). In a fully sprinklered building, protection against elevated temperature smoke may not be necessary, and the criteria for protection against ambient temperature smoke may be appropriate.

Mention should be made of the effects of automatic sprinkler protection on smoke. The activation of an automatic sprinkler occurs early in a flaming fire condition, usually within 5 minutes or so after visible flaming is observed. Temperatures immediately drop to almost ambient, and smoke is driven to the floor and diffused throughout the available space. Smoke production rate is reduced as the fire size decreases and the temperature of the flame plume is reduced. The temperature of the smoke is also reduced to near ambient. Thus, in a sprinklered building it may be appropriate to treat smoke as if it were at or near ambient temperature. Fewer mitigating measures may be taken to control smoke movement since the production rate of smoke will be reduced. However, under a smoldering fire condition, sprinkler activation can be delayed and this, too, should be considered.

Fire door assemblies protecting stair enclosures and vestibules adjacent to stair enclosures, for example, are more likely to be exposed to ambient temperature smoke provided there are no combustible materials in the enclosure. These doors may form part of a control system involving pressurized stairwells or vestibules. The air leakage characteristics of such door assemblies are an essential part of smoke control design.

A-1-3.7 It has been determined from many full-scale fire tests of compartments that the maximum instantaneous pressure differential created by an uncontrolled fire can approach 0.15 in. wg (37.5 Pa). More typically, a pressure differential of 0.06 to 0.10 in. wg (15 to 25 Pa) is achieved over the period of most intense burning in light fire loading occupancies such as residential, health care, and business (offices).

In sprinklered buildings where the fire will be controlled, it is anticipated that the maximum pressure differential generated should not exceed 0.05 in. wg (12.5 Pa).

Typical stair pressurization systems can often result in pressure differentials as high as 0.25 to 0.50 in. wg (62.5 to 125 Pa) across the door assembly.

Stack effect can also play a major role in determining pressure that must be overcome in order to pressurize shafts, such as elevators and stairs, to prevent smoke infiltration. Pressure differentials between the exterior and unvented shafts can range from virtually nothing to as much as 0.5 to 1.0 in. wg (125 to 250 Pa) or more, depending on the location of the building neutral pressure plane, the height of the building, and the outside temperature.

The quantity of air movement through a door gap can be determined by the following general formula:

$$Q = KAP^{1/N}$$

where:

Q = volume flow rate of air

K = orifice coefficient for the gap around the door perimeter

A = area of the gap

P = pressure differential across the door

N = number between 1 and 2 that can be determined empirically

(For more information, see Handbook and Product Directory — 1997 Fundamentals.)

A-1-3.8 Many factors must be taken into consideration before smoke management systems can be developed. Fire load, smoke load, rate of heat release, rate of smoke release, geometry, height of building, ambient environmental conditions, HVAC systems, exhaust systems, compartmentation, occupancy type, occupant status, means of egress, volume of spaces, and fire alarm detection system are just some of the factors that must be considered before a designer can develop a total system approach to the smoke problem. A smoke-control door assembly is only one component of a total smoke control and management system. A smoke management system can either be active, passive, or a combination of both. Active systems are dynamic and generally use mechanical systems in conjunction with automatic activating devices, for example, a smoke exhaust system. Passive systems use built-in-place barriers, for example, a smoke-retardant barrier, that do not rely on mechanical systems to function. Both types of systems may be activated either automatically, manually, or a combination of both.

A-1-3.12 Door opening force is addressed in various standards on ingress for mobility-impaired people. Ease of egress is equally important. A designer of a smoke management system should be aware of the importance of door opening force, and should consider pressure-reducing measures, such as using vestibules and equalizing pressures through the use of multiple ducts.

A-2-1.4 If gasketing or other sealing system is used and protection against hot smoke is intended, noncombustible gasketing or a suitable sealing system that will not break down under hot smoke conditions for a 20-minute period should be considered.

A-2-2.4 In such situations, it is suggested that the authority having jurisdiction require regular fire drills or staff training sessions where manual closing of the door is a high priority portion of the drill or training session.

A-3-1.2 Temperature has a direct effect on pressure. When protecting against warm or hot smoke infiltration, this test method in itself may not be completely appropriate, but it provides a uniform and repeatable test method. It also provides a standard evaluation of an assembly for a pressurized application.

Concepts and proposed test methods have been developed and should be considered for measuring smoke leakage during exposure in the standard fire resistance test. One such draft, *The Measurement of Smoke Leakage of Door Assemblies During Standard Fire Test Exposures,* developed at the National Bureau of Standards' Center for Fire Research, should be reviewed.

A-3-1.3 Exception. Test data exists for certain door types demonstrating that air leakage at ambient temperatures is greater than warm air temperature leakage. In such instances the air leakage rate for ambient temperature could also apply for warm temperatures when additional tests are not conducted at elevated temperatures.

Appendix B Referenced Publications

B-1 The following documents or portions thereof are referenced within this recommended practice for informational purposes only and are thus not considered part of its recommendations. The edition indicated here for each reference is the current edition as of the date of the NFPA issuance of this recommended practice.

B-1.1 NFPA Publication. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA film, *Operation School Burning,* Los Angeles Fire Department, 1959.

B-1.2 Other Publications.

B-1.2.1 ASHRAE Publications. American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., 1791 Tullie Circle, N.E., Atlanta, GA 30329-2305.

Design of Smoke Control Systems for Buildings, 1992.

Handbook and Product Directory — 1997 Fundamentals.

B-1.2.2 NIST Publication. National Institute for Standards and Technology, Gaithersburg, MD 20899-0001.

NBSIR 80-2004, *The Measurement of Smoke Leakage of Door Assemblies During Standard Fire Test Exposures,* 1981.

B-1.2.3 National Research Council of Canada Publication. National Research Council of Canada, 1200 Montreal Road, Ottawa, Ontario, K1A 0R6.

Technical Paper No. 341, "Factors in Controlling Smoke in High Buildings," 1971.