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Fire Safety Inspection and Testing of Air Moving Systems

John H. Klote

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Fire Research
Gaithersburg, MD 20899

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Sponsored by:

General Services Administration
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U.S. DEPARTMENT OF COMMERCE, C. William Verity, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

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John H. Klote

Abstract

This paper discusses fire safety inspection and testing procedures for air moving systems. These systems include heating, ventilating and air conditioning systems; zoned smoke control systems; and pressurized stairwells. The detailed methods for inspection and testing presented in the appendices are initial efforts in the evolution of such methodology and it is anticipated that users will modify them to suit their needs.

Key words: acceptability, acceptance tests, air movement, field tests, pressurization, smoke control, ventilation systems.

1. INTRODUCTION

The fire-associated dangers of heating, ventilating and air conditioning systems (HVAC) are well known to the fire protection community. Penetrations through walls, floors and ceilings for air ducts can reduce the natural fire resistive nature of these building components. Fire dampers in such penetrations can restore a significant level of fire resistance. Smoke can be transported by an HVAC system to locations remote from the fire, thus endangering life and property. These fires can be located in a building space or within the HVAC system. The traditional approach to the smoke problem has been to shut down the HVAC system. Shutting down the HVAC system prevents it

from forcing smoke into the spaces it supplies. However, shutting down the HVAC system does not prevent smoke movement through the supply and return ducts, air shafts, and other building openings due to stack effect, buoyancy, or the wind. The concept of smoke control has evolved over the last two decades as one solution to this smoke problem. Smoke control uses pressure differences at building barriers produced by fans to limit smoke flow.

A smoke control manual by Klote and Fothergill (1983) was initially intended for use by designers of mechanical systems. However, the manual has been used extensively by fire protection professionals and code officials. An overview of smoke control technology with emphasis on recent advances was prepared by Klote (1987). Regardless of the care, skill and attention to detail with which an air moving system is designed, an acceptance inspection and test are needed as assurance that the system, as built, operates as intended.

This paper discusses fire safety inspection and testing methods for air moving systems which is part of a project sponsored by the General Services Administration (GSA) to develop commissioning procedures for HVAC systems. These systems may be HVAC systems with shut down capability only, HVAC systems with zoned smoke control capability, dedicated zoned smoke control systems, or pressurized stairwells. Detailed inspection and testing methods are presented in the appendices. These methods should be thought of as an initial effort to develop information which could be of use to engineers and code officials tasked with determining the acceptability of an air moving system. It is

anticipated that users will want to modify the methods to suit their specific needs.

2. ACCEPTANCE INSPECTION

Inspection consists of checking the system components which include ducts, materials within plenums, access openings in ducts for inspection, air filters, fans, heating equipment, cooling equipment, fire dampers, ceiling dampers, smoke dampers, and controls. System components should be checked to determine if they are in accordance with appropriate codes or with the contract documents. Typically, code officials check for compliance with local codes. Building owners and engineering and architectural firms also conduct inspections checking for compliance with the contract documents. The GSA conducts inspections generally checking for compliance with contract documents, and for this reason the approach presented in appendix A checks for compliance with the contract documents.

Because GSA requires that their HVAC systems be designed in accordance with NFPA 90A (1985), the inspection procedure was written around the specific requirements of NFPA 90A. It may seem confusing that the procedure was written for compliance with contract documents and also written around NFPA 90A. The reason for this approach can be best illustrated by an example. Section 3.j of appendix A, deals with checking the location, fire protection rating and installation of fire dampers. In a strict sense, it would be sufficient to indicate these items should be as specified in the contract package. However, this is so general that it would be of little help to

inspectors. The procedure of appendix A provides specific information in an attempt to help the inspector. It is indicated that the location of dampers should be checked with that specified in the contract documents. This is appropriate for GSA projects because the locations should be clearly marked on construction drawings which have been reviewed for compliance with NFPA 90A. Further, the procedure tells inspectors how to determine if a fire damper is of the proper rating and installation based on information from the damper standard, UL 555 (1979), which is referenced by NFPA 90A. Also, general information is provided about checking damper operation.

It is believed that the material of appendix A can be of general use beyond GSA as an example of an inspection method. The requirements of appendix A are consequences of its foundation in NFPA 90A, and these should not be considered as recommendations of the National Bureau of Standards.

3. ACCEPTANCE TESTING

The acceptance test procedures discussed in this section and presented in appendices B and C are based on recommendations of the proposed NFPA 92A (1987) and an overview of smoke control technology by Klote (1987). For zoned smoke control systems, one zone should be put into the smoke control mode, and the pressure differences at the boundaries of that zone should be measured. After smoke control operation in that zone has been deactivated, another zone should be tested in the same manner. This should be repeated until all smoke zones have been tested. Systems with automatic activation should be activated by putting an appropriate detector into alarm.

Many zoned smoke control systems will require adjustments of supply air flow rates or pressure relief vent openings to accommodate the particular leakage characteristics of the buildings in which they are located. These adjustments can be made in conjunction with the acceptance test. All measurements made during acceptance testing should be recorded and saved for inspection. A suggested approach for acceptance testing of zoned smoke control systems is presented in appendix B.

Pressurized stairwells have very different testing requirements than do zoned smoke control systems. With all stairwell doors closed, pressure differences across each stairwell door should be measured. Then one door should be opened, and pressure difference measurements made at each closed stairwell door. This should be repeated until the number of doors opened equals the number of doors required by the contract documents (or code authority) to be opened. A suggested approach to acceptance testing of pressurized stairwells is presented in appendix C.

It is believed that smoke bombs are inappropriate for acceptance testing of smoke control systems for reasons previously presented (Klote 1987). However, chemical smoke from smoke bombs can be useful for testing for smoke feedback into the supply system and for locating leakage paths in construction of smoke barriers.

4. REFERENCES

Klote, J.H. 1987. An Overview of Smoke Control Technology, submitted to ASHRAE Transactions.

Klote, J.H. and Fothergill, J.W. 1983. Design of Smoke Control Systems for Buildings, American Society of Heating, Refrigerating and Air-conditioning Engineers, Atlanta, GA.

NFPA 1985. Installation of Air Conditioning and Ventilating Systems, NFPA 90A-1985, Quincy, MA, National Fire Protection Assn.

NFPA 1987. Recommended Practice for Smoke Control Systems, proposed document NFPA 92A, Quincy, MA, National Fire Protection Assn.

UL 1979. Standard for Fire Dampers and Ceiling Dampers, UL 555-1979, Northbrook, IL, Underwriters Laboratories.

APPENDIX A FIRE SAFETY INSPECTION PROCEDURES FOR AIR MOVING SYSTEMS

1. Scope. The inspection procedures described in this appendix apply to the fire safety of systems for heating, ventilating, and air conditioning (HVAC) with or without smoke control capabilities or to systems only dedicated to controlling smoke in building fires. This procedure is intended for HVAC systems that are in accordance with the 1985 version of NFPA 90A. The levels of performance, standards, test methods and other requirements listed in this procedure are consequences its foundation in the 1985 version of NFPA 90A, and these are not recommendations of the National Bureau of Standards. This procedure is intended as an example inspection procedure, and it is anticipated that users will modify the procedure to suit their needs.

2. Reference standards

ASHRAE 15, Safety Code for Mechanical Refrigeration, is intended to assure the safe design, construction, installation, operation, and inspection of refrigeration systems. Among other safety features and precautions, this standard describes requirements of pressure-limiting devices and pressure-relief protection, including installation requirements of refrigeration piping and machinery room housing refrigerating equipment.

ASTM E136, Standard Method of Test for Noncombustibility of Elementary Materials - 1973(note: the standard been changed but version referenced here is that referenced by NFPA 90A), is a test method for determination of noncombustibility of elementary materials, to indicate those materials which

do not act to aid combustion or add appreciable heat to an ambient fire. It is not intended to apply to laminated or coated materials.

NBSIR 75-673, Development of a Fire Test Method for Flexible Connectors in Air Distribution Systems, is a test method which evaluates the fire performance of a flexible duct connector in terms of: (a) resistance of the flexible connectors to failure by direct fire penetration, (b) adequacy of attachment method of the flexible connector to the duct, and (c) effectiveness of the blocking (firestopping) of the penetration through a fire-rated floor and ceiling.

NFPA 31, Standard for the Installation of Oil Burning Equipment, applies to oil-fired stationary equipment including residential, commercial and industrial steam, hot water plants, and warm air heating plants.

NFPA 54 (ANSI Z223), National Fuel Gas Code, is a safety code which applies to the installation of fuel gas piping systems, fuel gas utilization equipment and related accessories. Among the areas this code addresses are piping design, piping materials, piping components, piping installation, piping testing, equipment installation, and equipment venting.

NFPA 70, National Electrical Code, applies to the installation of electric conductors and equipment within public and private buildings, and the code contains provisions considered necessary for safety to life and property. This code addresses wiring design, protection, methods, and materials. Also

addressed are electrical equipment, special occupancies, and communication systems.

NFPA 72E, Standard on Automatic Fire Detectors, provides basic minimum requirements for the performance of automatic fire detectors with the intent of ensuring timely warning for the purposes of life safety and property protection. The kinds of fire detectors addressed include heat sensing, smoke sensing, flame sensing, and gas sensing. The standard addresses installation, maintenance and testing of detectors.

NFPA 90A, Standard for the Installation of Air Conditioning and Ventilating Systems, prescribes minimum fire safety requirements for systems for the movement of environmental air within structures. This standard addresses aspects of fire safety for these systems in detail including definitions, system components, impact on fire integrity of building construction, and controls.

NFPA 255, Standard Method of Test of Surface Characteristics of Building Materials, is a method of testing the surface burning characteristics of building materials to determine comparative characteristics by evaluating the flame spread over the surface and the density of smoke produced.

NFPA 259, Standard Test Method for Potential Heat of Building Materials, is a test to determine, under controlled laboratory conditions, the heat released from a material under fire conditions.

UL 181, Standard for Factory-Made Air Ducts and Connectors, is a standard test method for air ducts and connector systems. The air ducts and connectors covered by this standard include preformed lengths of flexible or rigid ducts, materials in the form of boards for field fabrication of lengths of rigid ducts, and preformed flexible connectors. The method includes tests for surface burning characteristics, flame resistance, flame penetration, burning, corrosion resistance, mold resistance, temperature resistance, puncture resistance, static load resistance, impact resistance, erosion resistance, pressure resistance, collapse resistance, tension resistance, bending resistance, leakage resistance. Air ducts are classified as Class 0, Class 1 or Class 2. This standard requires that installation instructions be supplied by manufacturers.

UL 555, Standard for Fire Dampers and Ceiling Dampers, is a test method applicable to fire dampers and ceiling dampers intended for installation in floor-ceiling and roof-ceiling assemblies. The test method includes construction requirements and tests for fire endurance, hose-stream exposure, closing reliability, duct loading exposure, salt-spray exposure, and spring closing force. Fire dampers are rated at 3/4 hr, 1 hr, 1-1/2 hr, and 3 hr. Ceiling dampers are not assigned hourly ratings, but rather are assembly components designed for use in specific hourly rated resistive assembles. The standard requires that manufacturers supply installation instructions for these dampers.

UL 555S, Standard for Leakage Rated Dampers for Use in Smoke Control Systems, is a test method for leakage rated dampers intended for use in heating,

ventilating, and air conditioning systems. The test method includes construction requirements and tests for cycling, temperature degradation, duct loading exposure, salt-spray exposure, and air leakage. These smoke dampers are classified as 0, I, II, III, or IV leakage rated dampers, and they are tested at 250 °F or at an elevated temperature selected in increments of 100 °F above 250 °F.

UL 900, Standard for Test Performance of Fan Filter Units, presents test requirements of air filter units of both washable and throwaway types. Filter units are subjected to a flame-exposure test and a spot-flame test. Filter units are classified as either Class 1 or Class 2.

3. General inspection procedures:

a. Check ducts to verify that materials of duct construction are as specified. Ducts may be constructed of iron, steel, concrete, masonry or clay tile. For ducts constructed of other materials, check that they are Class 0 or Class 1 ducts as specified and that they are tested in accordance with UL 181, Standard for Factory-Made Air Ducts and Connectors. The duct class is imprinted on it by the manufacturer.

b. Check duct installation. Duct installation including the hangers must not reduce the fire resistance rating of structural members and of assemblies. Frequently, structural members and assemblies have fire protective coverings, such as drywall construction or a sprayed-on layer.

Check that ducts are installed in such a manner that these protective coverings are not damaged. Check that clearance from ducts to combustible construction is in accordance with NFPA 90A. In addition, check that where ducts pass through walls, floors, or partitions the openings in construction around the ducts are in accordance with NFPA 90A.

c. Check installation and materials of duct connectors and flexible duct connectors. Class 1 or Class 2 duct connectors tested in accordance with UL 181, Standard for Factory-Made Air Ducts and Connectors, may be used subject to limitations of NFPA 90A. The class is imprinted on the duct connector by the manufacturer. Duct connectors must not exceed 14 ft in length, and they must not pass through floors of buildings. Flexible duct connectors meeting a 1-hour fire exposure, as set forth in NBSIR 75-673, Development of a Fire Test Method for Flexible Connectors in Air Distribution Systems, may pass through one floor to connect ducts with air terminal units subject to the limitations of NFPA 90A including firestopping around openings. Flexible duct connectors must not exceed 14 ft in length. CAUTION: Because the characteristics of duct connectors and flexible duct connectors are different, one should not be substituted for the other.

d. Check duct coverings and linings to verify that their fire safety requirements are as specified. Coverings and linings must be in accordance with the requirements of NFPA 90A. Check that duct coverings do not conceal any service opening.

e. Check direct access and inspection provisions. A service opening or a telescoping or removable duct section are used for direct access and inspection. Check that a service opening or a telescoping or removable duct section is provided in ducts adjacent to fire dampers, smoke dampers and smoke detectors. Check that these access openings are identified with letters no less that 1/2 inch in height which identify the fire protection device within. Check that service openings are provided in horizontal ducts and plenums where required by contract documents.

f. Check plenums between ceilings and floors. Check materials exposed to air flow in these plenums to verify that these materials have smoke developed ratings not greater than 50 and are non-combustible or limited combustible except for electrical wiring, electrical equipment, optical fiber cable and pneumatic tubing. Check that electrical wiring and equipment in plenums is installed in accordance with NFPA 70, National Electrical Code. Check that optical fiber cable in plenums conforms to provisions of NFPA 70, National Electrical Code, or is listed as having adequate fire-resistant and low smoke producing characteristics. Check that pneumatic tubing for control systems is listed as having adequate fire-resistant and low smoke producing characteristics.

The following notes are provided for the convenience of the user of this inspection method, however, in matters of contract compliance or code requirements the definitions and wording of NFPA 90A apply:

1. A smoke developed rating of a material refers to a number or classification of a material obtained according to NFPA 255, Standard Method of Test of Surface Characteristics of Building Materials, which measures visible smoke.

2. A non-combustible material is a one which, in the form in which it is used and under the conditions anticipated, will not ignite, support combustion, or release flammable vapors when subjected to fire or heat. Many common materials such as iron, steel, aluminum, concrete, masonry and clay tile are non-combustible. Materials reported as non-combustible, when tested in accordance with ASTM E136, Standard Method of Test for Noncombustibility of Elementary Materials, are considered non-combustible materials.

3. A limited combustible material is one not complying with the requirements of a non-combustible material, which, in the form in which it is used, has a potential heat value not exceeding 3500 Btu/lb (see NFPA 259, Standard Test Method for Potential Heat of Building Materials) and complies with one of the following paragraphs (a) or (b). Materials which decrease in fire performance due to age or usage are considered combustible materials.

(a) Materials having a structural base of non-combustible material, with a surfacing not exceeding a

thickness of 1/8 inch which has a flame spread rating not greater than 50.

(b) Materials other than described in (a), having neither a flame spread rating greater than 25 nor evidence of continued progressive combustion, and of such composition that surfaces that would be exposed by cutting through the material on any plane would have neither a flame spread rating greater than 25 nor evidence of continued progressive combustion.

4. The flame spread rating of a material refers to a number or classification of a material obtained in accordance with NFPA 255, Standard Method of Test of Surface Characteristics of Building Materials.

g. Check air filters. Check air filters to verify that they have the classification required by the contract documents and that they have been rated in accordance with UL 900, Standard for Test Performance of Fan Filter Units.

h. Check that exposed fan inlets are protected with metal screens to prevent the entry of paper, trash, and similar foreign material.

i. Check that heating and cooling equipment is installed in accordance with manufacturers instructions and the following applicable standards:

Description	Standard
Mechanical refrigeration used with air duct systems	ASHRAE 15, Safety Code for Mechanical Refrigeration
Gas fired heating furnaces combined with cooling units in the same duct	NFPA 54 (ANSI Z223), National Fuel Gas Code
Oil fired heating furnaces combined with cooling units in the same duct	NFPA 31, Standard for the Installation of Oil Burning Equipment
Electrical duct heaters	Part F, Duct Heaters, of Article 424 of NFPA 70, National Electric Code

j. Check the location, fire protection rating and installation of fire dampers. Check that fire dampers are located at all places where they are required by the contract documents. Check the label attached to the fire dampers to verify that they meet the fire protection rating specified by the contract documents and that the damper has been tested in accordance with UL 555, Standard for Fire Dampers and Ceiling Dampers. Check that fire dampers have been installed in accordance with the conditions of their listing and the manufacturer's installation instructions which are supplied with the damper. Further check installation by removing fusible link (where applicable) and operating damper to verify that it fully closes. It is desirable to operate

dampers with normal air flow to assure that they are not held open by the air stream. Remember to reinstall all fusible links that have been removed during inspection.

k. Check the location, fire protection rating and installation of ceiling dampers. Check that ceiling dampers are located at all places where they are required by the contract documents. Check the label attached to the ceiling dampers to verify that they are appropriate for the floor-ceiling or roof-ceiling assembly in which they are used and that the damper has been tested in accordance with UL 555, Standard for Fire Dampers and Ceiling Dampers. Check that ceiling dampers have been installed in accordance with the conditions of their listing and the manufacturer's installation instructions which are supplied with the damper. Further check installation by removing fusible link (where applicable) and operating damper to verify that it fully closes. It is desirable to operate dampers with normal air flow to assure that they are not held open by the air stream. Remember to reinstall all fusible links that have been removed during inspection.

l. Check the location, fire protection classification and installation of smoke dampers. Check that smoke dampers are located at all places where they are required by the contract documents. Check the label attached to the smoke dampers to verify that they meet the leakage and temperature class specified by the contract documents and that the damper has been tested in accordance with UL 555S, Standard for Leakage Rated Dampers for Use in Smoke Control Systems. Check that smoke dampers have been installed in accordance with the conditions of their listing and the manufacturer's installation

instructions. During normal system operation, check that each smoke damper required by the contract documents to be closed is fully and tightly closed, and that each smoke damper required to be opened is fully opened.

m. Check the location, fire protection rating and installation of combination fire and smoke dampers. Check that combination fire and smoke dampers are located at all places where they are required by the contract documents. Check the label(s) attached to the combination fire and smoke dampers to verify that they meet the fire protection rating specified by the contract documents and that the damper has been tested in accordance with UL 555, Standard for Fire Dampers and Ceiling Dampers. Also, check the label to verify that they meet the leakage and temperature class specified by the contract documents and that the damper has been tested in accordance with UL 555S, Standard for Leakage Rated Dampers for Use in Smoke Control Systems. Check that combination fire and smoke dampers have been installed in accordance with the conditions of their listing and the manufacturer's installation instructions. Further check installation by removing fusible link (where applicable) and operating damper to verify that it fully closes. It is desirable to operate dampers with normal air flow to assure that they are not held open by the air stream. Remember to reinstall all fusible links that have been removed during inspection.

4. Controls for systems without smoke control capability:

a. Check manual controls. Check that each air distribution system has manually operated device(s) that will stop the operation of supply, return,

and/or exhaust fan(s) in an emergency, and that this device is located as specified. With the system in normal operating mode, operate each manual shutdown device, and check that all fans required by the contract documents to be stopped have actually stopped. Also, check that any smoke dampers required by the contract documents to be closed are fully and tightly closed.

b. Check automatic controls. If automatic shutdown capability is required, check that the air system has automatic shutdown capability. Check that detectors used to activate any automatic shutdown are located as specified, are of the type as specified, and are installed in accordance with NFPA 72E, Standard on Automatic Fire Detectors. Where applicable, check system shutdown by detectors located in supply duct, return duct, and by detector system installed in the building. With the system in normal operating mode, activate the detector (where applicable) in the return air stream. Check that all fans required by the contract documents to be stopped have actually stopped. Also, check that any smoke dampers required by the contract documents to be closed are fully and tightly closed.

5. Controls for systems with zoned smoke control capability:

a. Check manual controls. Check that devices required by the contract documents for manual activation and deactivation of the zoned smoke control system have been installed (a detailed check of the functioning of manual control is included in appendix B).

b. Check automatic controls. Check that devices required by the contract documents for automatic activation and deactivation of the zoned smoke control system have been installed (a detailed check of the functioning of automatic control is included in appendix B).

INSPECTION CHECK LIST - FIRE SAFETY IN HVAC SYSTEMS

Date_____
Inspection agent_____

NO.	DESCRIPTION	YES	NO	REMARKS
	General:			
1	All materials in plenums appropriate			
2	Air filters appropriate			
3	Fan inlets protected by screens			
4	Heating equipment installation appropriate			
5	Cooling equipment installation appropriate			
6	Manual controls installed			
7	Automatic controls installed			
	Ductwork:			
1	Duct material appropriate			
2	Duct installation appropriate			
3	Duct connectors appropriate			
4	Duct coverings appropriate			
5	Duct linings appropriate			
	Duct access and inspection provisions:			
1	Access at all required locations			
2	Access properly identified			
	Dampers:			
1	Fire dampers located where required			
2	Fire dampers of appropriate rating			
3	Fire dampers installed appropriately			
4	Ceiling dampers located where required			
5	Ceiling dampers of appropriate rating			
6	Ceiling dampers installed appropriately			
7	Smoke dampers located where required			
8	Smoke dampers of appropriate rating			
9	Smoke dampers installed appropriately			
10	Combination fire and smoke dampers located where required			
11	Combination fire and smoke dampers of appropriate rating			
12	Combination fire and smoke dampers installed appropriately			

COMMENTS:_____
_____
_____

INSPECTION CHECK LIST -
FIRE SAFETY CONTROLS IN HVAC SYSTEMS
WITHOUT SMOKE CONTROL CAPABILITIES

Date_____
Inspection agent_____

NO.	DESCRIPTION	YES	NO	REMARKS
	Manual shutdown:			
1	Appropriate fans stopped			
2	Appropriate smoke dampers fully and tightly closed			
	Automatic shutdown by return detector:			
1	Appropriate fans stopped			
2	Appropriate smoke dampers fully and tightly closed			
	Automatic shutdown by supply detector:			
1	Appropriate fans stopped			
2	Appropriate smoke dampers fully and tightly closed			
	Automatic shutdown by detector system:			
1	Appropriate fans stopped			
2	Appropriate smoke dampers fully and tightly closed			

COMMENTS:_____

APPENDIX B TEST PROCEDURES FOR ZONED SMOKE CONTROL SYSTEMS

1. Scope. The test procedures described in this appendix apply to zoned smoke control systems that are either dedicated systems or part of systems for heating, ventilating, and air conditioning (HVAC). These procedures should be thought of as an initial effort to develop information which could be of use to engineers and code officials tasked with determining the acceptability of a zoned smoke control system. It is anticipated that users will want to modify the methods to suit their specific needs.

2. General references:

ASHRAE manual "Design of Smoke Control Systems for Buildings" by Klote and Fothergill consolidates and systematically presents data and calculational procedures necessary to smoke control systems designers and discusses design criteria. Included are discussions of the driving forces of smoke movement, the principles of smoke control, calculation of effective flow areas, concept of symmetry, and design parameters. A computer program for analysis of smoke control systems is presented. Concepts of stairwell pressurization and zoned smoke control are presented.

NFPA 92A, Recommended Practice for Smoke Control Systems, is a draft document to be voted on by NFPA in November 1987. This document provides recommendations about design, installation, testing, operation, and maintenance of new and retrofitted mechanical air conditioning and ventilation systems for the control of smoke.

3. Emergency power:

If standby power or other emergency power has been provided for the operation of the zoned smoke control system, acceptance testing shall be conducted with emergency power and normal power.

4. Smoke control diagram:

Identify the exact location of each smoke control zone. If it is not part of the building plans, make a smoke control zone diagram of the building. This diagram should include the locations of all zone boundaries and of all doors in those boundaries.

5. Normal operation test:

With all building HVAC systems in normal operation, the zoned smoke control system shut off, and the smoke barrier doors closed; measure and record the pressure differences across each smoke barrier door. Evaluate these pressure differences to determine that they are appropriate for the balanced HVAC system.

6. Smoke mode test:

Each smoke zone is to be individually tested by performing the following sequence.

a. Activate smoke control system operation in the zone. This should be accomplished by putting one of the detectors into alarm that are intended to activate the smoke control system in that zone.

b. Check that the operation of fans is as required by the contract documents.

c. Check that the position of smoke dampers is as required by the contract documents. Also, check that any smoke dampers required to be closed are fully and tightly closed.

d. Check to verify that all doors required by the contract documents to be closed during smoke control system operation are fully closed and that they operate freely allowing use during evacuation without becoming jammed in their door frames. This should include doors in the boundary of the smoke zone being tested.

e. Measure and record pressure differences across all closed doors in the boundary of the smoke zone being tested. Pressure differences resulting from air flowing to the smoke zone being tested are to be recorded as positive values, and pressure differences resulting from air flowing from the smoke zone being tested are to be recorded as negative values.

f. Check that the measured pressure difference is within the acceptable range as defined in the contract documents. If the pressure difference is not

in the acceptable range, double check that the states of fans, dampers and doors is as required. If any of these were not as required, they should be fixed and the zone retested. After this, if the pressure difference is not acceptable, the flow rates of air to and from the smoke zones in question should be measured and adjusted as appropriate. If the pressure differences are too low after these actions, excessive air leakage paths in the construction should be filled, caulked or sealed as appropriate. (Often it is very difficult to locate leakage paths in buildings. Chemical smoke from smoke bombs can be used to find these leakage paths. The high pressure sides of smoke barriers are exposed to heavy concentrations of chemical smoke, while the low pressure side of the barrier is examined for smoke leakage that indicates the location of a leakage path. Exterior walls, interior partitions, floors and ceilings including areas above suspended ceilings must not be overlooked when hunting for excessive leakage areas.) Then the zone should be retested.

g. Test for smoke feedback into supply air. Place six smoke bombs (3 minute duration size) in a metal container, simultaneously ignite all bombs, and locate container near exhaust inlet in smoke zone being tested so that all of the chemical smoke produced by the bombs is drawn directly into the exhaust air stream. Check that air supplied to other zones of the building has no trace of chemical smoke. If chemical smoke is detected in this supply air, its path should be determined, the path should be blocked, and then the smoke feedback test should be conducted again. (The two most likely causes of smoke feedback are a leaky or partly opened return air damper and an outside air inlet located in the vicinity of the exhaust air outlet.)

h. Make sure that this zone has been returned to its normal setting before continuing to test other zones.

TEST WORK SHEET - ZONED SMOKE CONTROL SYSTEM

Date____________

Test agent______________

NORMAL OPERATION TEST

Doors in barriers of smoke control zone	Pressure Difference (inches water gage)	Flow Direction: From Zone	To Zone

TEST WORK SHEET - ZONED SMOKE CONTROL SYSTEM (continued)

Smoke Control Zone No._____
Date_____
Test agent_____

SMOKE MODE TEST

NO.	YES	NO	REMARKS
1. Fans operating appropriately			
2. Smoke dampers in required position			
3. Pass feedback test			

Doors in Boundary of Smoke Control Zone	Pressure Difference (inches of water gage)

COMMENTS:_____

APPENDIX C TEST PROCEDURES FOR STAIRWELL PRESSURIZATION SYSTEMS

1. Scope. The test procedures described in this appendix apply to systems for stairwell pressurization. These procedures should be thought of as an initial effort to develop information which could be of use to engineers and code officials tasked with determining the acceptability of a pressurized stairwell system. It is anticipated that users will want to modify the methods to suit their specific needs.

2. General references:

ASHRAE manual "Design of Smoke Control Systems for Buildings" by Klote and Fothergill consolidates and systematically presents data and calculational procedures necessary to smoke control systems designers and discusses design criteria. Included are discussions of the driving forces of smoke movement, the principles of smoke control, calculation of effective flow areas, concept of symmetry, and design parameters. A computer program for analysis of smoke control systems is presented. Concepts of stairwell pressurization and zoned smoke control are presented.

NFPA 92A, Recommended Practice for Smoke Control Systems, is a draft document to be voted on by NFPA in November 1987. This document provides recommendations about design, installation, testing, operation, and maintenance of new and retrofitted mechanical air conditioning and ventilation systems for the control of smoke.

3. Emergency power:

If standby power or other emergency power has been provided for the operation of the stairwell pressurization control system, acceptance testing shall be conducted with emergency power and normal power.

4. Normal operation test:

With all building HVAC systems in normal operation, any zoned smoke control systems shut off, and the stairwell doors closed; measure and record the pressure differences across each stairwell door. The sign convention for all pressure difference readings in the stairwell tests is: a pressure difference resulting from a flow from the stairwell is positive, and a pressure difference resulting from a flow to the stairwell is negative. Evaluate these pressure differences to determine that they are appropriate for the balanced HVAC system.

5. Stairwell pressurization test:

Activate the stairwell pressurization systems by putting a detector in alarm as required by the contract documents. Test each pressurized stairwell by conducting the following steps.

a. With all stairwell doors closed (except for the exterior ground floor door if it is required to be opened upon system activation), measure and record pressure differences across each closed stairwell door.

b. Open the exterior ground floor stairwell door (except if the exterior ground floor door is required to be opened upon system activation), and measure and record pressure differences across each closed stairwell door. For stairwells without a ground floor exterior door, another highly severe open door condition must be tested. This can be an exterior door not at the ground floor or a large flow path to the outside created by opening the stairwell door and other doors including an exterior building door.

c. Open an additional stairwell door, and measure and record pressure differences across each closed stairwell door. Repeat this step opening another door each time until the required number of doors is opened. The required number of doors is that number that must be opened during testing as stipulated in the applicable codes or contract documents.

d. With the required number of doors opened, check flow direction through open doorways using a 6 ft strip of tissue paper secured at the top of the door frame.

e. Check that the measured pressure difference is within the acceptable range as defined in the contract documents. If the pressure difference is not in the acceptable range, double check that the states of fans, dampers and doors is as required. If any of these were not as required, they should be fixed and the zone retested. After this, if the pressure difference is not acceptable, the flow rate of air to the stairwell in question should be measured and adjusted as appropriate. If the pressure differences are too low

after these actions, excessive air leakage paths in the construction should be filled, caulked or sealed as appropriate. (Often it is very difficult to locate leakage paths in buildings. Chemical smoke from smoke bombs can be used to find these leakage paths. The stairwell is filled with chemical smoke and pressurized, while the low pressure side of the stairwell barriers are examined for smoke leakage that indicates the location of a leakage path.) Then the zone should be retested.

TEST WORK SHEET - PRESSURIZED STAIRWELL SYSTEM

Doors Open________________

____

____

Stairwell No.____________

Date___________

Test agent_____________

PRESSURE DIFFERENCE MEASUREMENTS

Doors in Pressurized Stairwell	Pressure Difference (inches water gage)

TEST WORK SHEET - PRESSURIZED STAIRWELL SYSTEM (Continued)

Date_____
Test agent_____
Stairwell No._____

FLOW DIRECTION INDICATION

Doors Open in Pressurized Stairwell	Flow Direction: From Stair	To Stair

NBS-114A (REV. 2-8C)

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John H. Klote

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10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)*

This paper discusses fire safety inspection and testing procedures for air moving systems. These systems include heating, ventilating and air conditioning systems; zoned smoke control systems; and pressurized stairwells. The detailed methods for inspection and testing presented in the appendices are initial efforts in the evolution of such methodology and it is anticipated that users will modify them to suit their needs.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

acceptability; acceptance tests; air movement; field tests; pressurization; smoke control; ventilation systems

13. AVAILABILITY

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