VM-1 Smoke Management Application Guide

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Contact information

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Content

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Caution: Caution messages advise you of possible equipment damage. They tell you which actions to take or to avoid in order to prevent the damage.

Note: Note messages advise you of the possible loss of time or effort. They describe how to avoid the loss. Notes are also used to point out important information that you should read.

Chapter 1
Fire geometry and smoke movement in buildings

Summary

This chapter introduces the basics of smoke development and control. Theory of smoke management and building equipment for smoke control are covered along with requirements for the installation of an effective VM-1 smoke control system (SCS).

Content

Introduction to the fire problem

Architectural factors in the spread of smoke

Smoke is considered the primary hazard that puts occupants of buildings at risk during a fire. Heat from fire, while an important threat, is usually confined to the area of fire origin. In contrast, smoke readily spreads from the area of fire origin to adjacent rooms or spaces and to parts of a building remote from the origin of the fire. Smoke can contaminate escape routes including stairs and elevators, rendering them unusable and resulting in occupants who are trapped in or near the fire due to their inability to escape.

More people in building fires are exposed to the hazards of smoke than to heat. Smoke is a particularly serious hazard in buildings requiring long egress times for complete evacuation. As buildings increase in height the hazard to occupants increases also, with the time for a high building to maintain tenability being less than the building's actual evacuation time.

From a smoke management standpoint, a high-rise building is one in which evacuation time of able-bodied and mobility-impaired occupants is considered excessive. Model building and fire codes typically classify high-rise buildings as those with the highest floor 75 feet or more above grade. Local modifications to the nationally recognized codes in some areas classify high-rise buildings as being six or more floors or as little as 50 feet above grade. The lower height classifications for high-rise buildings are often based upon the height which fire department aerial ladders can reach. Buildings classified as high-rise buildings typically require the installation of automatic sprinklers.

Early high-rise buildings did not impose major smoke hazard problems in fires due to noncombustible or limited combustible construction materials and extensive compartmentation. Since the 1950s, changes in construction materials, building designs, and occupancy practices have resulted in increased fire loads.

Fire compartment size has increased with central core service areas and open floor plans. Combustible furnishings, interior linings, ceiling tiles, partitions, and thermal and electrical insulation in modern buildings have increased the fire load compared to earlier buildings. Modern materials, such as plastics, generate dense toxic smoke, which increases the threat to occupants in a fire.

In 1963, John Portman, an architect and developer, introduced modern large building atriums as a building element in the 23-story Hyatt Regency hotel in Atlanta, Georgia. Atrium buildings, which provide large interior spaces, have gained in popularity to the point of being used in nearly all types of occupancies.

Atriums in hotels, malls, hospitals and office buildings interconnect floor spaces and create new problems in confining fire and smoke movement. In the late 1960s, building and fire code officials in North America recognized the increased fire hazards created by atriums and universally required the installation of automatic sprinkler systems in larger atriums and adjacent spaces.

Fire and smoke in an atrium initially moves and performs similar to a fire in an open outdoor area with heat and smoke rising and spreading towards the ceiling. However, with the interaction of automatic sprinklers, mechanical air movement, and the atrium ceiling, the atrium and adjacent floor spaces can quickly become contaminated with smoke. Occupants relying upon egress paths using exits or enclosed stairs through atriums are dependent upon the ability to use these spaces in the early stages of a fire event. Smoke control systems are a critical element in the common space evacuation scenario.

Smoke management

Smoke management is one of the primary tools used in the built environments for containing the effects of fire. Smoke management includes all methods that can be used alone or in combination to modify smoke movement for the benefit of occupants or firefighters, or to reduce property damage. The mechanisms of compartmentation, dilution, airflow, pressurization, and buoyancy are used alone or in combination to manage smoke conditions in fires.

Smoke control is a subset of the smoke management discipline. Smoke control systems are commonly defined as engineered systems that use mechanical fans to produce airflow and pressure differences across smoke barriers to limit and direct smoke movement.

Both NFPA 101, *Life Safety Code,* and NFPA 90A, *Standard for the Installation of Air-Conditioning and Ventilating Systems,* recognize that smoke control may be either active or passive.

The passive approach recognizes the long-standing compartmentation concept, which requires that fans shut down and fire/smoke dampers in ductwork close under fire conditions. The active approach, which applies NFPA 92A criteria, utilizes the building's heating, ventilating, and air conditioning (HVAC) systems to create differential pressures to prevent smoke migration from the fire area and to exhaust the products of combustion to the outside. Active smoke control systems use passive barrier components to create zones or areas for effective smoke movement as an essential component.

Products of combustion

Fire

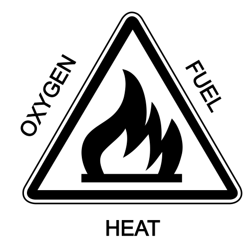
As a fire burns, it:

- Generates heat
- Changes major portions of the burning material or fuel from its original chemical composition to other compounds which include carbon dioxide, carbon monoxide, and water
- Transports a portion of the unburned fuel as soot or other material that may or may not have undergone chemical change

The fire triangle, used to explain the components that make up fire, is important in understanding smoke control systems. The oxygen leg of the triangle is always present and will allow combustion to take place. The heat leg of the triangle, which presents the ignition source, is limited or controlled in most built environments. Smoke control systems designed to protect people from the effects of fire are installed in environments with low or ordinary hazard contents in the protected space. What there is to burn (the fuel leg) will dictate to a large degree the kinds of fire that can be expected in an area. The size, location, and character of the fans and other components in an engineered smoke control system must consider the fuel loading for an area.

The nature of the fuel only affects the quantity of smoke produced in relation to the size of the fire and depends upon what is burning and the rate at which it is burning. Evaluating and limiting what there is to burn helps in the determination of what kinds of smoke will be produced for a given fire or area.

Figure 1: The fire triangle



Smoke

Smoke produced in a fire varies from fire to fire and over time in the same fire. In examining smoke development, the constituent parts of smoke will therefore fluctuate. The plume of hot gases above a fire has many parts that can be placed into one of three general groups:

- Hot vapors and gases given off by the burning material
- Unburned decomposition and condensation matter (may be light colored to black and sooty)
- A quantity of air heated by the fire and entrained in the rising plume

The cloud surrounding most fires and called *smoke* consists of a well-mixed combination of these three groups and will contain gases, vapors, and dispersed solid particles.

The volume of smoke produced, its density, and its toxicity depend upon the material that is burning and its geometry. The nature of the fuel only affects the quantity of smoke produced in as far as the size of the fire depends on what is burning and the rate at which it is burning.

Smoke movement

Smoke can behave very differently in tall buildings when compared to low buildings. In low buildings, the influences of the fire, including heat, convective movement, and fire pressures, can be the major factors that cause smoke movement. Tall buildings have the effects found in small buildings combined with smoke and heat movement by convection and radiation upwards. Accepted engineering approaches to smoke removal and venting practices reflect these influences.

A major cause of fire spread across the floor of a building is heat radiated downwards from the layer of hot gases beneath the ceiling. Roof venting will limit fire spread because it limits the spread of hot gases under the roof. In the alternative, if the major cause of fire spread is due to flame progressing sideward, at floor level and through readily combustible material, roof venting will less readily limit fire spread. Roof venting, addressed in NFPA 204, *Standard for Smoke and Heat Venting*, will only slow sideward movement because it limits the extent to which heat is radiated downward and is only one factor in the sideward development of a fire.

All fires produce smoke and the movement of smoke follows the same pattern as the overall air movement within a building. Very simply, a smoke control system needs to be able to inhibit the flow of smoke within a building.

Smoke movement is determined by two central factors in a fire. These are:

- Smoke's buoyancy due to the entrainment of hot gases which are less dense than the surrounding air
- Normal air movement inside a building, which may have nothing to do with the fire, but which can carry smoke around a building in a positive way

The magnitude of these two smoke-moving factors will depend upon particular circumstances and will vary throughout a building. In general, the smoke closer to the fire poses the greatest risk. The movement caused by the smoke's mobility is due to pressure differentials developed by the:

- Expansion of the gases as they are heated by the fire
- Difference in density of the hot gases above the flames
- Cooler air which surrounds the fire

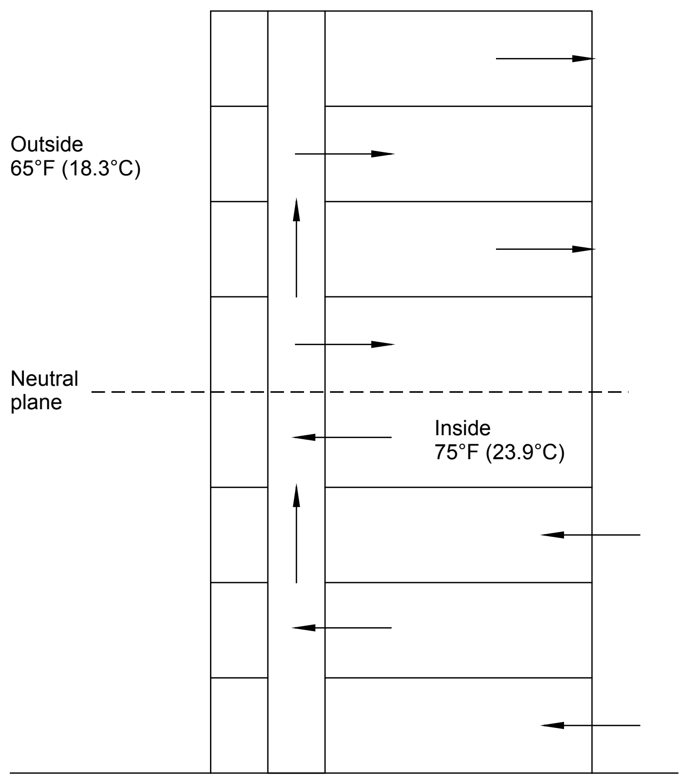
Air movement in a building in nonfire conditions can be caused by three separate factors: stack effect, wind load, or HVAC (mechanical) systems. In a fire, these same factors are equally influential.

Stack effect

The stack effect is the pressure differential due to the air inside a building being at a different temperature from the air outside the building. Stack effect will cause the air inside the building to move upwards or downwards, depending upon whether the air inside the building is warmer or cooler than the air outside the building.

Air within a building has a tendency to rise because it is warmer and less dense than the outside air. The taller a building is and the greater the temperature differences between the building interior and exterior are, the greater the tendency for air to rise in the building's shafts. See Figure 2.

Figure 2: Normal stack effect

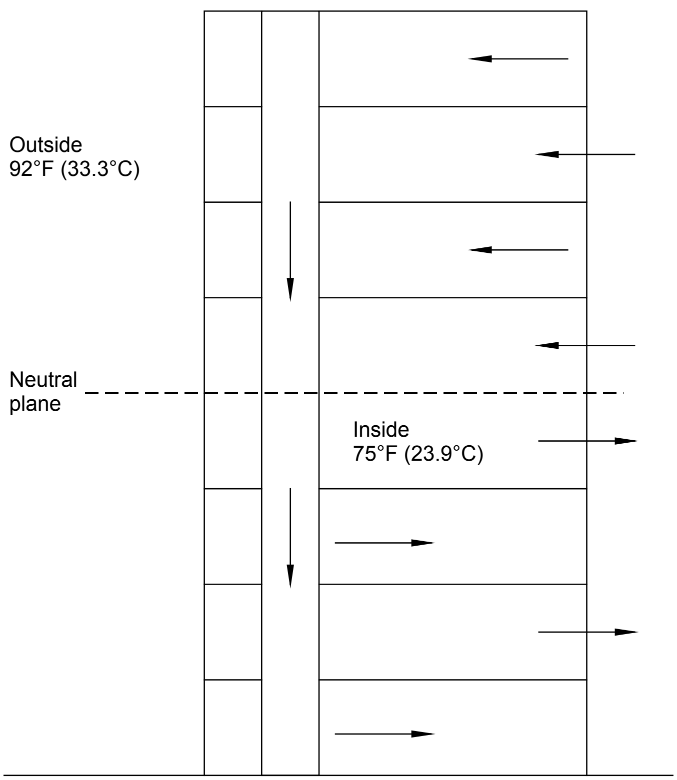


The opposite is true when the outside temperature is warmer than the temperature inside the building, causing a downward movement of air within building shafts. This is referred to as reverse stack effect.

In a building with reverse stack effect, only relatively cool smoke will follow the downward tendency of air into a shaft. If a smoldering fire occurs on a floor above the neutral plane during a reverse stack effect condition, the smoke will travel into and down the shaft and deposit itself on the floors below the neutral plane. In the case of hot smoke, buoyancy forces can counteract normal reverse stack effect causing the smoke to move up a shaft. See Figure 3.

The neutral plane of a building or space is defined as the elevation where the hydrostatic pressure inside the building equals the outside pressure. Normally the neutral plane is located near the midpoint of the building, but can occur at any floor and depends upon building design. The neutral plane of a building should be determined prior to the design of a smoke control system. ASHRAE's *Design of Smoke Management Systems* contains methods for calculating the neutral plane of a building or space.

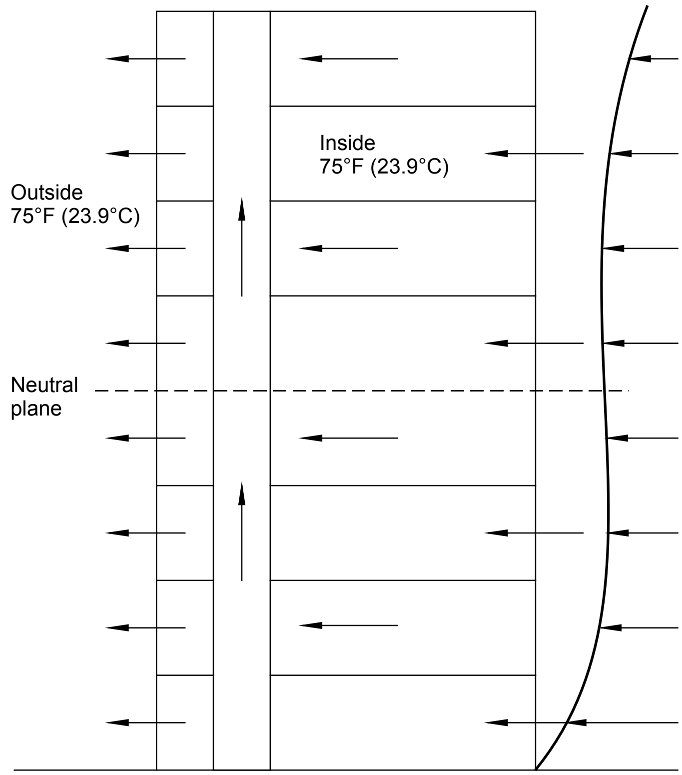
Figure 3: Reverse stack effect



Wind load

All buildings are to some extent *leaky* and wind penetration through these leaks contributes to internal air movement. Wind can have a dramatic effect on smoke movement depending upon the wind speed and direction, the characteristics of the surrounding terrain (including the shielding effect of adjacent buildings), and the building shape and height. See Figure 4below.

Figure 4: Wind effects on a building



In fires if a window breaks or is left open in a fire compartment, it has an effect on smoke movement. If the opening is on the windward side of the building, the wind causes a buildup of pressure in the fire compartment and forces smoke throughout the floor and possibly to other floors. Pressures caused by the wind in this condition can be large and easily dominate smoke movement through the building.

If the opening is on the leeward side of the building, the reverse is true. The negative pressure created by the wind vents the smoke from the fire compartment, greatly reducing the smoke movement through the building.

HVAC systems

Mechanical air handling systems inside a building condition and move air under normal conditions and can affect the movement of smoke in a fire. Before we reached our current understanding of smoke movement in buildings, most HVAC Systems were shut down when fires occurred for two primary reasons:

- The HVAC system rapidly advanced smoke movement from the room of fire origin to every area the system served.

- The HVAC system supplied air to the room of origin and thus had the potential to help accelerate the fire.

An HVAC system may aid in the detection of fire in its early stages when area smoke detection is not provided. The HVAC system can transport smoke from an unoccupied area to one where smoke detection or occupants are present and can then alert others of the fire.

Once fire is detected, HVAC systems installed in accordance with NFPA 90A and utilizing an internal smoke detector will shut down fans and dampers or provide a special smoke control mode. NFPA 90A-3-4 contains damper shutdown provisions. NFPA 90A-4-4 contains provisions for smoke detectors when area detectors are not used in air distribution systems:

- Downstream of air filters and ahead of any branch connections in air supply systems having a capacity greater than 2000 cfm (944 L/s)
- At each story prior to the connection to a common return and prior to any recirculation or fresh air inlet connections in air return systems having a capacity greater than 15,000 cfm (7,080 L/s) and serving more than one story

Note: See NFPA 72 for guidance on installing smoke detectors used in smoke control systems.

If neither of the NFPA 90A steps are taken, the HVAC system will transport smoke to every area that a system serves; putting occupants in peril, damaging property, and possibly inhibiting fire fighting.

Shutting down fans does not prevent smoke movement through supply and return air ducts, air shafts, and other building openings due to stack effect, buoyancy, and wind. Installation of smoke dampers for use when the system is shut down will help inhibit smoke movement in this case. Again, NFPA 90A contains damper requirements that are referenced by building and fire codes, standards, or guidelines used in the design and installation of smoke management systems.

Additional contributing factors

Thermal expansion: In addition to stack effect, buoyancy, and HVAC factors, the energy released by a fire can cause smoke movement due to thermal expansion.

In a fire compartment with only one opening to the building, air will flow into the compartment and hot smoke will flow out. For a fire compartment with open doors and windows, the movement of smoke due to expansion is negligible. However, the effects of expansion should be taken into consideration for tightly sealed compartments where fires can occur.

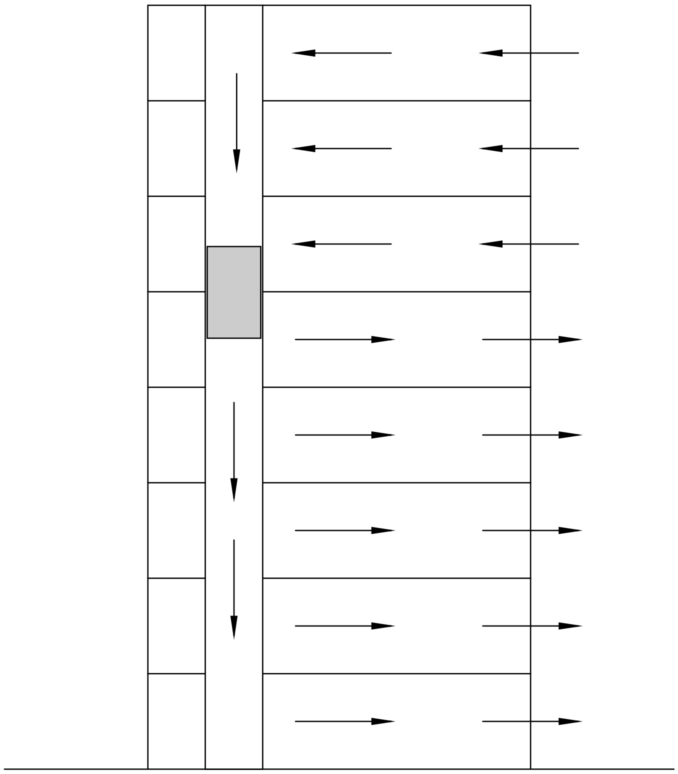
It is possible for the volume of smoke to almost triple in size when temperatures over 1,000°F (538°C) are reached. For tightly sealed compartments the buildup of pressure resulting from expansion causes smoke movement through any leakage paths in the walls or around doors.

Elevator piston effect: Vertical shafts for elevators can be significant contributors to smoke movement in a building when no control measures are in place.

The downward movement of an elevator car in a shaft produces temporary pressure increase in the area below the car and a temporary pressure decrease in the area above the car. The reverse is true for an upward moving elevator car. The temporary pressure increase tends to move air out of the elevator shaft and into the floors. The temporary pressure decrease tends to move air from the floors and into the elevator shaft. See Figure 5 on page 7.

Pressure differences, due to the piston effect, are greater in single car elevator shafts as compared to multiple car shafts. In a multiple car shaft there is usually more room to the left and right of the moving car to allow for pressure relief.

Figure 5: Elevator piston effects



Automatic sprinkler systems: Automatic sprinklers are nearly always dictated as a component of large space or tall building fire protection.

In designing a smoke control system, the size of the expected fire must be determined as a base for sizing the air handling equipment for smoke control. Escape routes must be kept usable for extended periods of time and this means that the size of the fire must be limited to ensure that the smoke control system will not be overwhelmed by a growing fire.

Automatic sprinklers are essential in order to limit the size of a possible fire. Sprinklers can affect smoke in two ways:

- Sprinklers can, by the discharge of water spray through the smoke layer, bring the smoke down to a low level
- By cooling the smoke, automatic sprinklers can reduce smoke buoyancy and slow down the movement of smoke through roof or ceiling vents

Automatic suppression systems are an integral part of many fire protection designs, and the efficacy of such systems in controlling building fires is well documented. Klote and Milke, in *Design of Smoke Management Systems,* point out that:

"while it is important to recognize that while the functions of fire suppression and smoke management are both desirable fire safety features; they should not be readily substituted for each other."

One of the best ways to address the smoke problem in a fire is to prevent or reduce smoke production. To the extent that a suppression system slows the burning rate, it reduces the smoke problem. For fires that are suppressed rather than extinguished, some smoke is produced. This smoke can move through a building due to varied driving forces as discussed in general in this chapter. Well-designed smoke management systems can maintain tenable conditions along critical escape routes, but will have little effect on the fire.

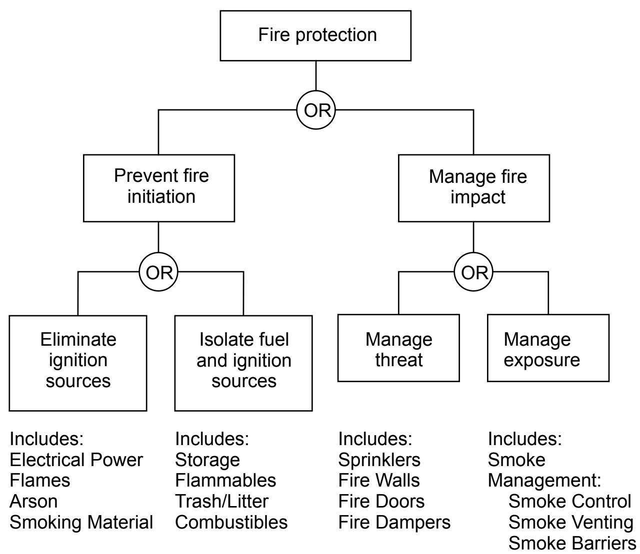
Where automatic sprinklers are installed, the determination of the fire size for smoke control calculations is based upon a limited fire spread, typically 9.8 ft. x 9.8 ft. (3 m x 3 m).

Principles of smoke control

Fire protection approaches

Smoke management is only one component of an overall building fire protection system. The two basic approaches to fire protection are to prevent fire ignition and to manage fire impact when a fire does occur. Figure 6 shows a simplified decision tree for fire protection. The building occupants and managers have the primary role in preventing fire ignition. The building design team may incorporate features into the building to assist the occupants and managers in this effort. Because it is impossible to completely prevent ignition, managing fire impact has assumed a significant role in fire protection design.

Figure 6: Simplified fire protection decision tree



Smoke management mechanisms

Mechanisms for managing smoke impact include:

- Compartmentation in the form or walls, floors, doors and other barriers
- Dilution (also known as smoke purging, smoke removal, smoke exhaust, or smoke extraction)
- Airflow in the form of large flow rates and used primarily in subway, railroad, and highway tunnels
- Pressurization using mechanical fans under NFPA 92A
- Buoyancy effects that employ mechanical systems when ceiling heights exceed 33 ft.(10 m)

Design factors

Many factors affect the design of a smoke control system. Before the actual mechanical design of the system can proceed, the potential constraints on the system must be determined and the design criteria established.

Unique factors in the design of a smoke control system include:

- Occupancy type and characteristics
- Evacuation plans
- Areas of refuge
- Occupant density and distribution
- Human life support requirements (medical facilities)
- Detection and alarm systems (exclusive of smoke control)
- Fire department response to fire emergencies in the building
- Fixed fire suppression systems
- Type of HVAC systems (in place or proposed)
- Energy management systems and controls
- Building security provisions
- Status of doors in a fire emergency
- Potential fire sources
- Internal compartmentation and architectural characteristics
- Building leakage paths
- Exterior building temperatures
- Wind velocity and effects

All of these factors funnel into a consideration of how much smoke will be present in an expected fire. The amount of smoke, expressed as smoke density, can reduce visibility, trap occupants in the building, prevent escape, and expose occupants over an extended period of time to toxic and irritant gases which could become lethal.

The ASHRAE manual *Design of Smoke Management Systems* contains guidelines for designers who wish to provide active smoke control systems for buildings. Smoke control systems are intended to provide systems that exhaust smoke from the immediate fire area, and provide pressurized outside air to adjacent areas, access corridors, and stairwells. It is fully recognized that this approach would apply more to large HVAC units servicing individual floors or large systems with volume control dampers at each floor. The integrity of the HVAC/smoke control system must be at a level that will maintain safe exit routes with sufficient exiting time for building occupants to either leave or move to designated safe refuge areas.

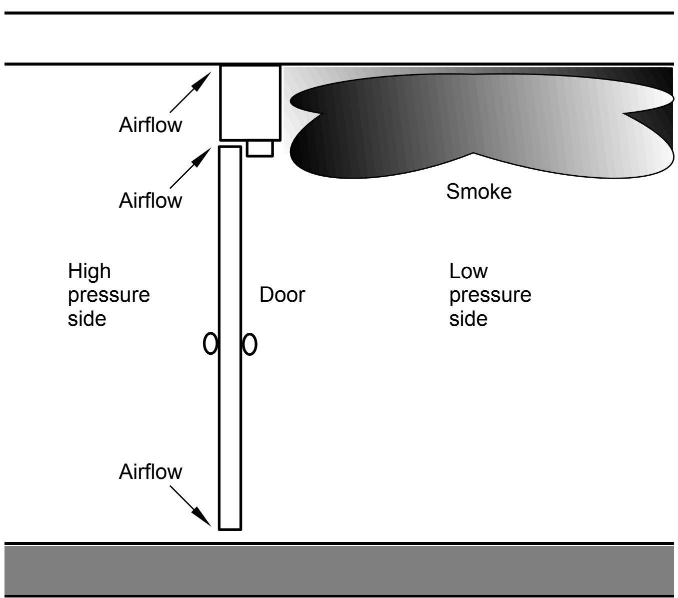
Smoke zones

A building or area is typically divided into several zones. Zones are delineated by fire or smoke barrier walls or horizontally with floor ceiling assemblies. A smoke zone, as used in this guide, is simply the area where the fire is located. The two basic principles for containing smoke within a smoke zone are pressurization and airflow.

Pressurization

Pressurization develops positive and negative pressure differences across zone boundaries in order to control smoke movement and is the most desirable means of controlling smoke movement. See Figure 7 below.

Figure 7: Pressurization

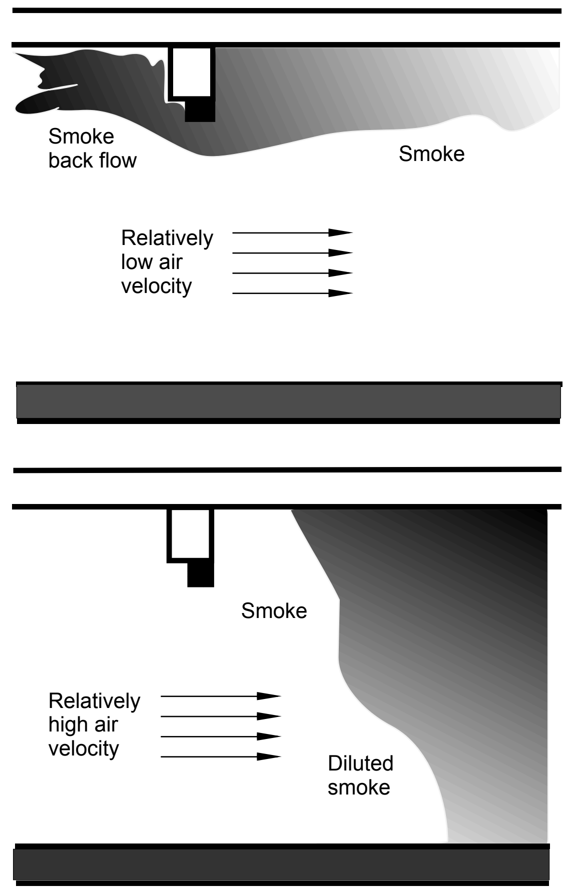


Pressurization creates pressure differences across partitions that separate the smoke zone from other zones or areas. This is typically accomplished by creating higher pressure in the nonfire or smoke areas. Airflow will occur through construction cracks at floor to ceiling slabs, around unsealed conduit and pipe openings, and around doors that act as the primary barriers to smoke movement from a smoke zone. Pressure differences must be sufficient to contain the smoke in the smoke zone and simultaneously allow doors leading to safety to be opened.

Airflow

Airflow by itself can control smoke levels and movement if the air velocity is high enough to overcome the tendency of smoke to migrate to other zones. This approach is typically used to prevent the flow of smoke down corridors or through open doorways, as shown in Figure 8 below. The airflow approach to smoke control requires large quantities of air and is therefore not practical for most applications.

Figure 8: Airflow



Purging

Purging may be used as a supplement to airflow or pressurization methods in smoke control systems. When there is a concern over smoke movement through open doors into a protected area, outside air can be introduced into the space. Purging uses an exhaust inlet near the ceiling and a supply inlet commonly in the lower half of a wall. The supply and exhaust points are placed far enough apart to prevent the supply air from blowing directly into the exhaust without the benefit of entraining smoke-filled air. Purging is commonly used in smoke-proof stairwells that contain a vestibule between the occupant space and the stairs.

With any of the methods used for smoke zones, pedestrian door opening forces must be considered. The pressure differences between barriers are important not only in the force to open the door, but also the force necessary to overcome the door closer. NFPA 101, the *Life Safety Code* establishes a maximum force of 30 lbf (133.35 N) to set a door in motion that is an accepted benchmark for designers. Occupants must be able to open doors leading to escape routes while the smoke control system is in operation.

Types of systems

Smoke management utilizing active and passive methods in combination to modify smoke movement must be engineered into a system that is focused upon property or people protection. While passive methods of smoke management do exist (see NFPA 204), dynamic smoke control systems using mechanical equipment to meet design goals dominate. NFPA 92B, *Guide for Smoke Management Systems in Malls, Atria, and Large Areas,* provides methodologies for determining smoke development in large spaces. NFPA 92A, *Recommended Practice for Smoke control Systems*, is used for the design, installation, testing, operation, and maintenance of systems for smoke control.

A VM-1 smoke control system (SCS) when installed and programmed in accordance with this design manual and the criteria set forth by the smoke control system designer will help to:

- Provide a tenable environment in evacuation routes during the time necessary to evacuate people from the area
- Restrict the movement of smoke from the fire area
- Assist in protecting life and property
- Maintain tenable conditions in nonfire areas that will enable fire personnel to conduct search and rescue operations in addition to attacking the seat of the fire

A VM-1 SCS should be designed, installed, and maintained such that the system will remain effective during evacuation of the protected areas. Other considerations determined by the smoke control system designer may dictate that a system should remain effective for longer periods. Areas to evaluate in determining VM-1 SCS integrity are:

- Reliability of power sources
- Arrangement of power distribution
- Location, and methods of protection for VM-1 system panels
- Building occupancy type

The design, installation, testing, operation, and maintenance of new and retrofitted mechanical air conditioning and ventilation systems for the control of smoke will require the involvement of several interdependent disciplines or parties:

System designer. Building equipment and controls are the responsibility of the system designer. The system designer:

- Determines the type of smoke control system to be used
- Defines the size of the expected or design fire
- Performs tenability calculations
- Establishes and defines smoke zones based on building barriers and determines the sizing of fans and location of dampers

The system designer may be an architect, engineer, or fire protection professional knowledgeable in the theory and application of smoke management and control. The system designer creates a specification used by the VM-1 SCS designer to create the smoke control system. The specification defines how the total system must operate under fire or smoke conditions.

VM-1 SCS designer. Smoke control system operation is the responsibility of the VM-1 fire alarm and smoke control system designer. The specifications for operation of a smoke control system define the methods of fire/smoke detection for a particular area and the resulting outputs for smoke removal or control functions that must take place. Control functions performed by a VM-1 panel include the startup and shutdown of HVAC or exhaust fans, smoke damper closure, and door closure.

Authority having jurisdiction (AHJ). The AHJ, typically a fire official, is important in the determination of firefighter control station locations and final acceptance and testing of the smoke control system. Involvement of the AHJ early in a project helps to ensure that the system requirements (typically NFPA 92A) will be met by the total system design. The AHJ can establish clear pass/fail criteria for a completed system before detail design work begins.

Smoke control systems

Systems for controlling smoke movement in a building can be divided into two separate types: shaft protection and floor protection.

The vertical transfer of smoke to the upper stories of a building from a fire on a lower floor occurs mostly from shafts versus leakage through openings in floor construction. Vertical smoke spread accounts for 95 percent or more of the upward movement of smoke in high-rise building fires. Shaft protection can be further divided into stairwell pressurization systems and elevator hoistway systems.

Floor protection encompasses several variations of zoned smoke control. Use of a particular system or combination of systems is dependent upon building and fire code requirements, as well as specific occupancy and life safety goals established by the system designer.

For either type of smoke control system, electrical and mechanical equipment or components can be classified as dedicated or nondedicated.

Smoke control components must be capable of continuous use at the maximum temperatures expected during a fire, based upon calculations performed by the smoke control system designer. Most smoke control systems will be designed with a primary goal of maintaining a tenable environment for occupants outside the fire area for zoned smoke control and within atriums or large spaces. This goal is achieved by exhausting smoke from a building, limiting fire growth, or for atrium smoke control systems, preventing accumulations of smoke below a six-foot height along egress paths.

Dedicated

Dedicated smoke control systems are independent systems for air-movement and are not used for any other purpose under normal building operating conditions. Upon activation, dedicated systems operate specifically to perform a smoke control function.

Dedicated systems have the following advantages:

- System design and control functions are less likely to be modified during maintenance
- Operation and control of the system is less complex with system controls typically routed only to the VM-1 SCS and the firefighter's smoke control station (FSCS)
- Independent of other building systems, dedicated systems are less likely to be affected by changes in other building systems

Dedicated systems have several recognized disadvantages:

- Dedicated systems are more costly
- Component failures may go undetected for a long time
- Dedicated systems often require more building space for installation
- Automatic weekly self-testing of dedicated smoke control systems must be programmed with consideration for weather conditions

Nondedicated

Nondedicated smoke control systems share or use components with other building systems including the HVAC system for a floor, area, or zone. Smoke control system activation suspends normal operation of HVAC and other shared components for use in achieving smoke control objectives.

Nondedicated systems have the following advantages:

- Equipment costs are shared
- Component failures of equipment needed for smoke control are more apparent due to their use for daily services
- Smoke control system components do not require additional building space

Nondedicated smoke control systems have three recognized disadvantages:

- System control may involve complex interlocks with shared equipment used for HVAC or energy management
- Inadvertent modification of HVAC controls or equipment affecting smoke control functionality is more likely to occur
- Other building system modification may interfere with smoke control system operation

HVAC systems

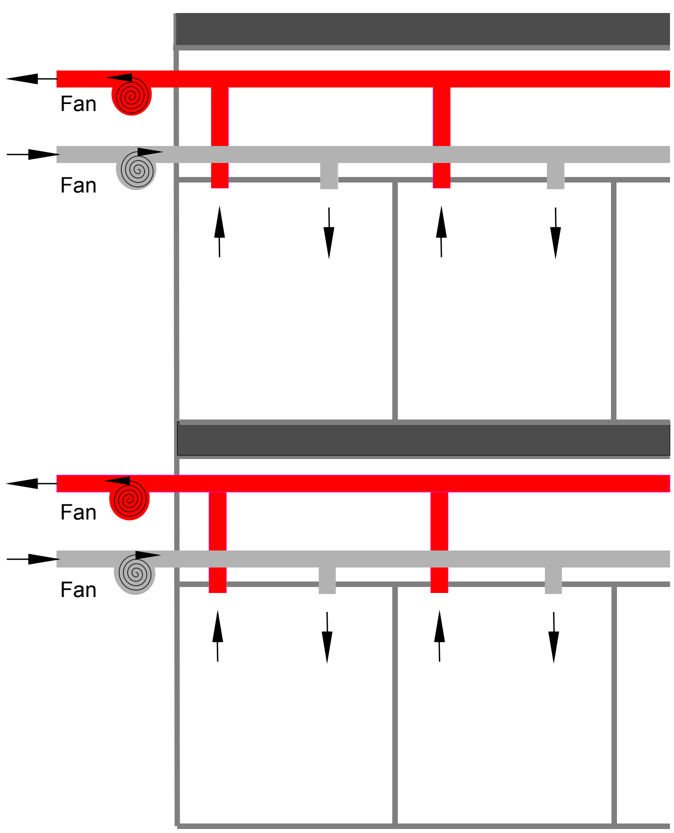
Commercial heating, ventilating, and air conditioning (HVAC) systems can usually be adapted for smoke control use. In order to meet smoke control reliability and tenability criteria established in NFPA 92A, an HVAC system must be capable of supplying outside air to the protected space, returning air from the protected space, and exhausting air from a protected space to the outside.

An HVAC system can be as simple as a fan in a housing (such as a roof-mounted exhaust fan) or a complex system with ductwork, supply air outlets, return air inlets, fresh air intakes, humidifiers, filters, heating and cooling coils, preheat coils, and dampers.

Individual floor units

Air handling units serve a single floor or area. Units can have separate supply and exhaust fans. The smoke control system designer must verify that the units are capable of providing sufficient outside air and an exhaust capability for the expected fire condition. See Figure 9.

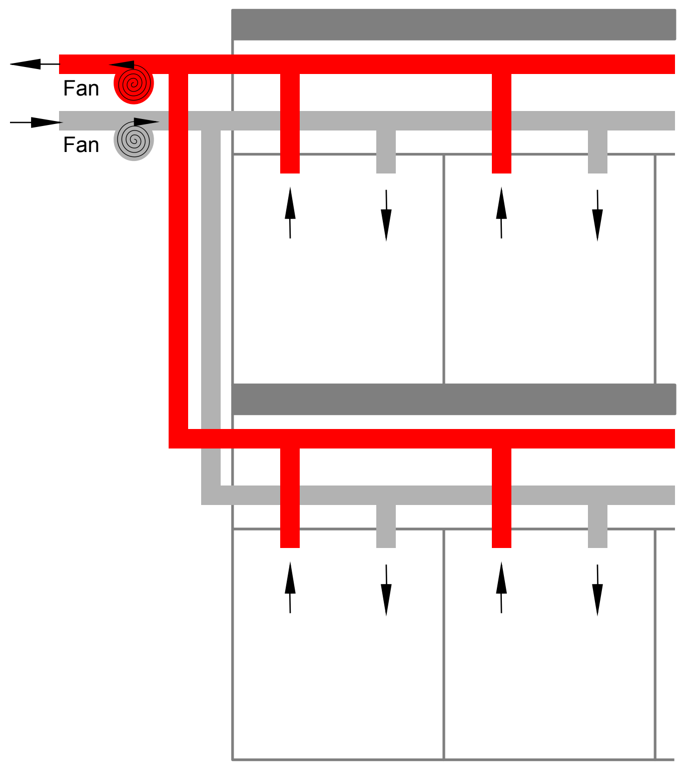
Figure 9: Individual floor units



Induction units

Induction-type air handling units are usually used in conjunction with a central HVAC system, which supplies high-pressure air to the induction units. Induction units are located around the outside of a building and are used to condition the air for areas around the perimeter of a building. Room air is then drawn into the induction unit, mixed with the primary air from the central system, and returned to the room. Induction units servicing a fire area should be shut down or have the primary air from the central system isolated. See Figure 10.

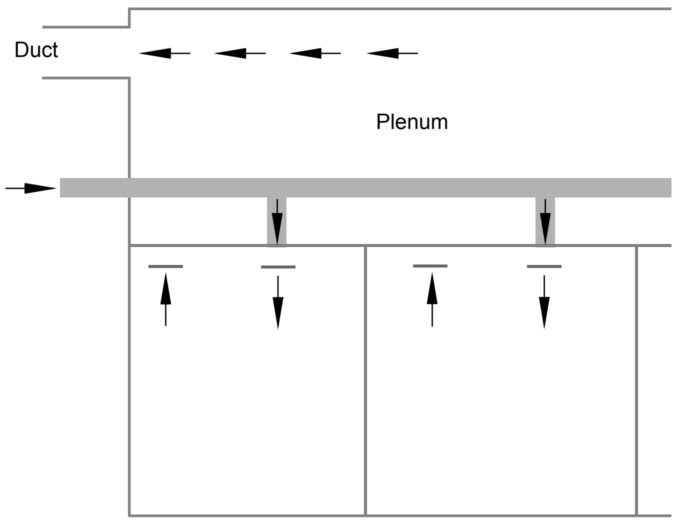
Figure 10: Induction units for central HVAC system



Ductwork

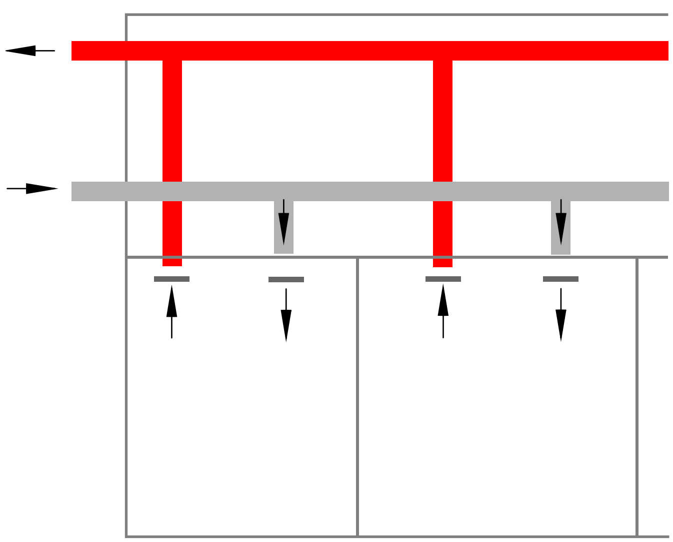
Ductwork is constructed of a variety of materials including steel, aluminum, concrete, and masonry. Ductwork usually connects the fans with the areas to be served. Air travels from the supply fan through the supply ducts into the building. Return air is often pulled through the plenum space above the ceiling as shown in Figure 11 on page 13.

Figure 11: Supply ductwork with plenum return



Ductwork, however, can be used for the return air as well, as shown in Figure 12. In most commercial buildings today, both the supply and the return ductwork (where used) is typically located in the area above a suspended ceiling. Return air ductwork is required from the smoke zone boundary to exhaust fans when routed through other zones.

Figure 12: Ducted return



Multiple-zone systems

Multiple-zone systems are similar to dual duct systems in that they have separate heating and cooling coils located in a separate compartment. The difference in these systems is that multiple-zone systems mix the air at the unit and supply the mixture through low-pressure ducts to each space served.

Dual duct systems

Dual duct systems have parallel heating and cooling coils, each located in a separate compartment. Systems of this type also have separate ducts to supply hot and cold air from each coil compartment into mixing boxes. The mixing boxes are used to mix the hot and cold air to be supplied to the area served. See Figure 13 on page 14.

Variable air volume systems

Variable air volume (VAV) systems usually supply central cooling only. The individual areas served by this type of system will reheat the air near or in the area being served or have other sources of heating. Some VAV systems connect a bypass from the intake side of a supply fan to the outlet side of a supply fan, as shown in Figure 14 on page 14, to reduce supply air volumes and pressure in the ductwork. Such bypasses must be closed for smoke control applications to ensure sufficient pressurization of protected areas.

Fan-powered terminals

Fan-powered terminals are used in conjunction with VAV systems to provide the reheat capability of cool air being supplied to a particular area and to circulate air within the space. Terminal fans servicing a fire area must be shut off for smoke control applications. During a fire condition, terminal fans serving other areas may continue to operate normally.

Figure 13: Dual duct system

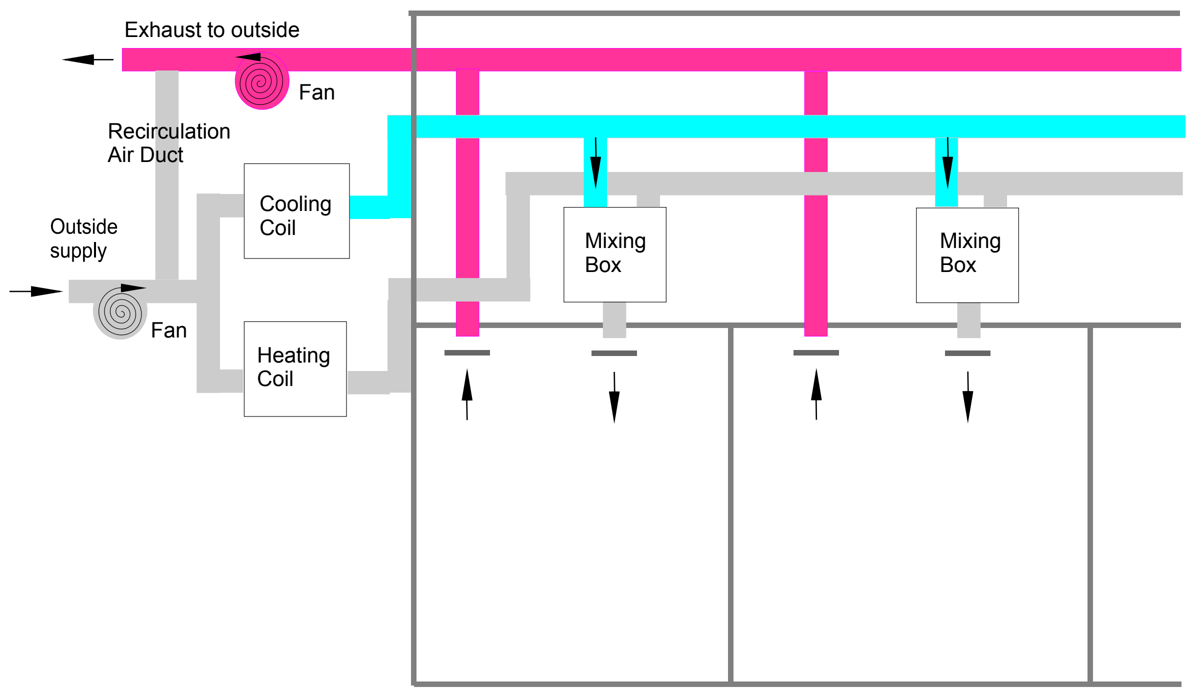
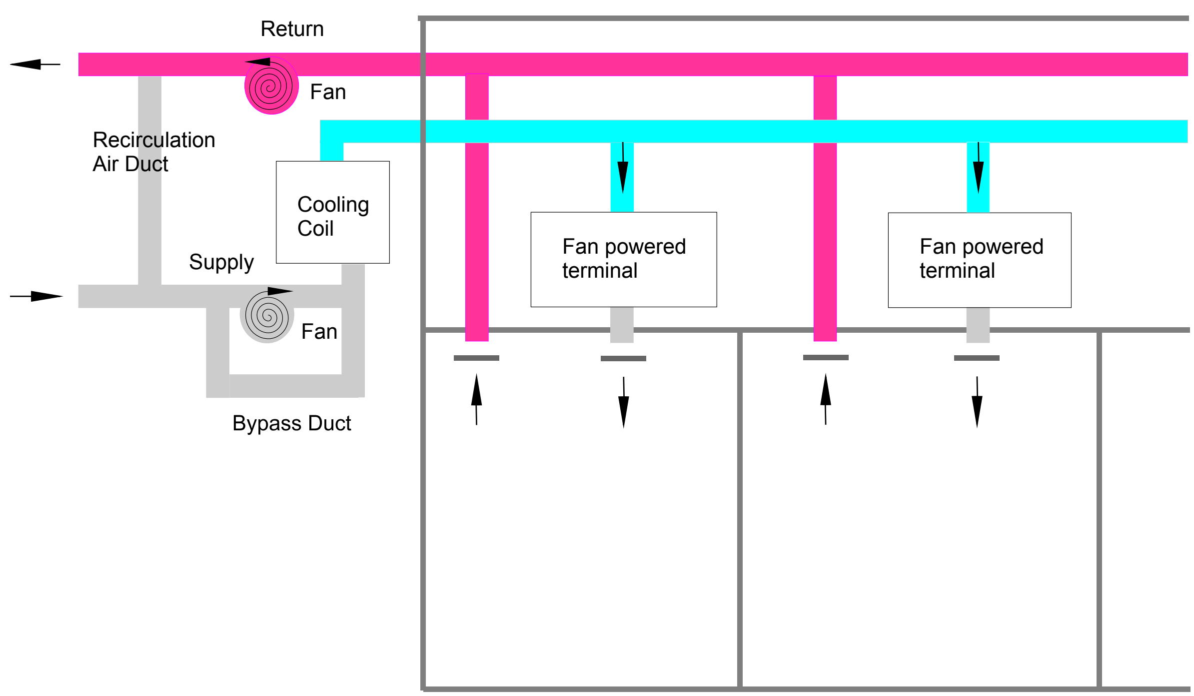


Figure 14: Variable air volume (VAV) system with fan powered terminals

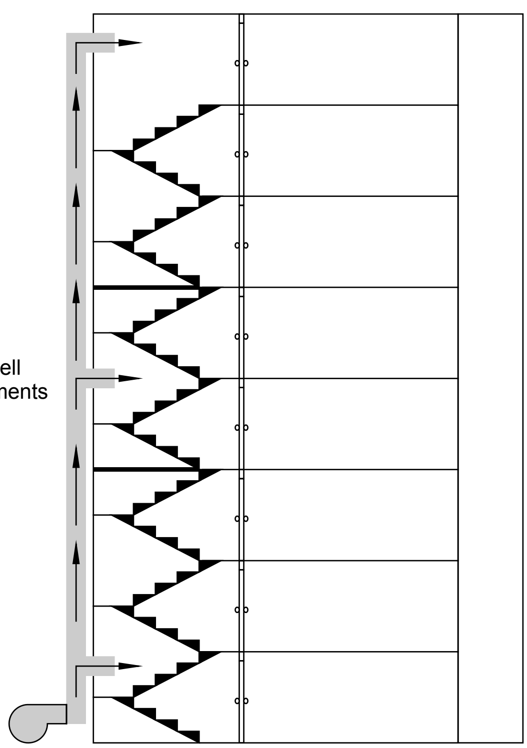


Stairwell pressurization systems

Stairwell pressurization systems are built with the intent of keeping stairs clear of smoke in order to assist in the evacuation of occupants. Stairwell pressurization systems are commonly dedicated smoke control systems. Activation of stairwell systems can be by automatic or manual means.

Stairwell pressurization systems can be from a single injection point into the tower or multiple injection points. Single injection systems are commonly used for eight or fewer stories. Multiple injection systems (see Figure 15 below) provide several supply inlets in the stairwell. Compartmentation of the stairwell can also be used in a pressurized design to maintain stair tenability. Pressurization systems may operate throughout the fire event, offering refuge for firefighters as they enter or leave the fire floor.

Figure 15: Compartmentation of a pressurized stairwell



A fire in a multiple story building will develop a positive pressure in the fire area until ventilation occurs, often due to the opening of a door or the failure of window glass. The positive pressures developed by a fire can enter a stair as occupants leave the fire floor and reduce the usefulness of the stair for escape. The design objective of achieving a higher pressure in the stair than is found on the fire floor is usually achieved by a single dedicated fan in the stairwell.

Life safety and fire codes require stairwells to be isolated from the building they serve, making the use of shared building HVAC systems unlikely or prohibited. Dedicated HVAC systems for stairwell pressurization systems are also used with modulating dampers controlled by static sensors at each doorway or at selected points in a stairwell.

For pressurizing a stairwell, the smoke control system designer must define the number of doors expected to be open at any one time and design air flows which compensate for the open doors. If more than the expected or design number of doors is opened, the pressure in the stairwell may drop below that of the fire floor and smoke will be able to enter the tower.

Power requirements for smoke control system operation must consider the total number of systems or zones in operation. For example, if there are two stairwells with pressurization, they will both operate in a fire event and power must be available for both tower systems. If a smoke control zone on the fire floor will also operate, then the three separate smoke control systems must be powered and operable from the FSCS.

Automatic operation of one of a building's fire alarm systems should cause all stair pressurization fans to start. Where an engineering and life safety analysis determines that the configuration of the building is such that only certain stairs need pressurization, programming of the smoke control system will need to be tailored to various fire scenarios.

A smoke detector should be provided in the air supply to the pressurized stairwell. Smoke drawn into the stairwell from the exterior of the building will be detected and fans will then shut down. Detectors selected for fan flow monitoring should be within the air velocity ranges specified in the detector's installation sheet.

The firefighter's smoke control station (FSCS) must contain a manual override, to be operated by an authorized person, to restart fans should they shut down due to the operation of smoke detectors installed in the stairwell. The authorized person may determine that a lesser hazard exists from smoke entering the fan than smoke migrating into the tower from the fire floor and override fan shutdown based upon exterior smoke entry.

Vestibules: Stairwells can also be built with a vestibule that may include an air handling system. The vestibule may serve a pressurized stair or it can be in lieu of a pressurized stair, operating under the same criteria as a pressurized stairwell for smoke control. Even nonpressurized vestibules have the advantage of putting two doors between the building interior and a stairwell, which can help to limit smoke migration into a stair. Vestibule pressurization controls are addressed in much the same manner as stair pressurization systems by the smoke control system.

Elevator smoke control

Elevator smoke control systems are of two types. The first focuses on providing tenability and survivability of the elevator system in order that it can be used for occupant evacuation. Figure 16 diagrams two design alternatives. Exhaust of the fire floor, smoke-tight elevator lobbies, and the closing of elevator doors after automatic recall are other design alternatives which are less often chosen. Elevators traditionally have not been used for fire evacuation due to the “chimney effect” of the shafts in a fire.

In the last decade, due in part to increased demands for egress of mobility-impaired occupants and driven by the Americans with Disabilities Act (ADA), elevators have increasingly been looked upon as a possible avenue for fire escape. First, Canada developed standards for “hardened” elevators for egress and then in the US the NFPA *Life Safety Code* included elevators as an alternate egress component from areas of refuge. Smoke control for elevators used as an egress system components must provide tenability for the expected time needed for evacuation.

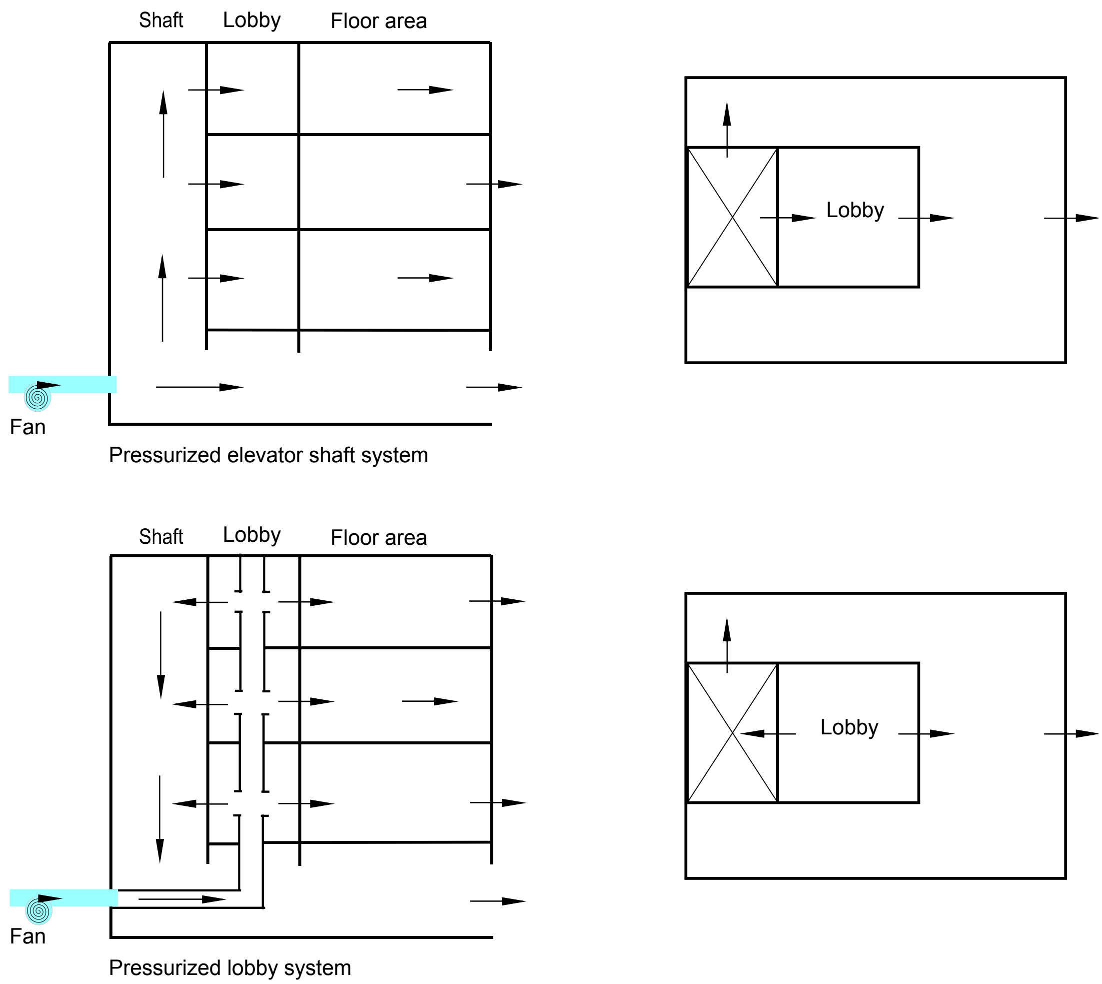
The second type of elevator smoke control system is intended to prevent or limit smoke flow to other floors by way of the hoistway. Elevators without enclosed lobbies must have a smoke control system that develops a pressure difference within the hoistway that is greater than the sum of the fire and other building effects. The smoke control system designer will calculate pressures, flow rates, and vent sizes for the elevator shaft to determine fan size.

Elevator recall is based upon ASME/ANSI A17.1, *Safety Code for Elevators and Escalators*. The standard requires that elevator doors open and remain open after elevators are recalled. This requirement results in a large opening into the elevator hoistway, greatly increasing airflow requirements for pressurization. NFPA 80, *Standard for Fire Doors and Other Opening Protectives,* permits closing of elevator doors after a predetermined time when required by the AHJ. Local requirements for the operation of pressurized shafts should therefore be determined and incorporated into the system design.

Table 8.11 of NFPA's *Smoke Movement and Control in High-rise Buildings* contains both elevator shaft and lobby pressurization system calculation formulas. John M. Klote, who worked with the author of this NFPA reference book, includes the same methodologies and several examples, in his ASHRAE book, *Design of Smoke Management Systems*.

Elevator recall systems return the elevators to the lobby or an adjacent floor when smoke is detected in an elevator lobby or when the fire alarm system is activated. Elevator doors can open at the recall location and remain open or revert to the closed position. The smoke control system designer must adjust airflow for the door position.

Figure 16: Elevator pressurization systems



Zoned smoke control systems

For larger area or multiple floor buildings, the smoke control system should be divided into zones based upon the expected fire scenario. Activation of a smoke control zone will be by automatic or manual means. A smoke detection system will automatically activate the VM-1 smoke control system.

Detector spacing should follow spacing of smoke detector requirements contained in the *Signature Series Intelligent Smoke and Heat Detectors Bulletin* (P/N 270145). The bulletin also contains design information on detector placement with respect to stratification, partitions, exposed solid joists, exposed beams, sloped ceilings, and high air-movement areas.

Automatic actuation of a zoned smoke control system can simultaneously exhaust a fire/smoke area and supply air to other areas. Detector locations, however, must coordinate with the operation of the smoke control zone to detect smoke before it migrates to another zone. Smoke control system programming will limit automatic activation to the first zone that detects smoke.

A waterflow switch or heat detector serving a smoke zone can be used to activate the zoned smoke control system where all piping or wiring of the devices is in the smoke zone. For example, a sprinkler system serving an atrium cannot have branch sprinkler lines serving an office area adjacent to the atrium and not a part of the same smoke control zone.

Atriums

Initially, fires in atriums (or large spaces) will perform like fires in outside areas due to the size and height of the space where the fire occurs. Upper levels of high ceilings or tall atriums collect heat and smoke with little or no downward radiation. Atriums and large spaces cannot easily restrict the movement of smoke using barriers or overcoming fire pressures. Common atrium or large space areas using smoke management systems include shopping malls, convention centers, airport terminals, sports arenas, and warehouses.

For large spaces, smoke management consists of exhausting smoke from the space. Exhausting smoke tends to restrict smoke spread to a plume above the fire and a smoke layer just below the ceiling of the space. The exhaust approach creates a lower level “smoke-free” layer that allows occupants to safely egress and for firefighters to see and attack the seat of a fire more readily. Providing smoke management for large spaces is a unique challenge for two reasons.

First, without any barriers in the interior, extensive smoke propagation occurs readily throughout the entire space. Consequently, a significant number of people in the space may be exposed to the smoke. Further, a substantial portion of the space can become contaminated by the smoke, resulting in significant property damage.

Second, large unprotected openings between the atrium and adjacent spaces can result in fire and smoke movement into the atrium due to a fire outside the atrium. Adjacent spaces, such as stores in a shopping mall, are called communicating spaces and may open directly to the atrium or may connect through a corridor or another open passageway. In the last several years code limitations on the number of levels with communicating spaces open to an atrium have been changed to allow all levels in an atrium to have open communicating spaces. Required airflow for smoke venting in an atrium or large space must consider the effect of communicating space fires.

How a large space functions, location of egress routes, and the development of hazardous conditions from expected fire scenarios demands a tailoring of smoke management systems for each application. However, the technical fundamentals of smoke production and spread are the same for all of these spaces. A shopping mall smoke management design will focus on assuring egress paths are available, while a warehouse smoke management design will focus on the stored materials.

Parameters that may have an impact on the design of a smoke management system in a large space include:

- Ceiling height
- Fuel load
- Use of the space
- Separation of communicating spaces from the protected space

Smoke control system components

Controls

The smoke control system must fully coordinate smoke control system functions between the:

- VM-1 fire alarm system
- Automatic sprinkler system
- Firefighter smoke control station (FSCS)
- Systems related HVAC energy management
- Building smoke control equipment

Operation of the smoke control system either as a component of the VM-1 fire alarm system or as a stand-alone VM-1 smoke control system panel from a centralized location will be the most common applications.

Fire department suppression mobilization for large buildings may be from a loading dock in a high-rise building or at the main entrance of large buildings. An FSCS at the point of fire department mobilization or near the exterior of the building will often be required by codes or standards in addition to the VM-1 smoke control system.

Building main control/security center

Larger, more complex buildings and office or educational campuses contain centralized energy management and security centers. These control points for building systems or access may be located off the main lobby of a high-rise, in the center of a large building, or freestanding on a campus. The location and monitoring of the fire alarm control panel from these points is both practical and common. Installation of the VM-1 smoke control system in one of these centers is logical.

The trained personnel who monitor other fire and building systems can also be trained for smoke control system monitoring and operation. The building's main control or security center could also serve as the location of the FSCS, if acceptable to the AHJ.

Firefighter's smoke control station

The FSCS, where required, is located according to direction from the AHJ. The FSCS must provide full monitoring and manual control capability over all smoke control system functions including a graphic annunciator panel.

The FSCS should be designed to have the highest priority control over all smoke control systems and equipment. Where manual controls are also provided at other building locations (such as the main control/security center) for use of smoke control systems, the control mode selected from the FSCS should prevail. The design of the FSCS must be such that control actions from this point will override or bypass other building controls such as Hand-Off-Auto and Start/Stop switches located on fan motor controllers, freeze detection devices, and duct smoke detectors.

FSCS controls should not override or bypass devices and controls intended to protect against electrical overloads, provide for personnel safety, or prevent major system damage. These include overcurrent protection devices, electrical disconnect switches, high-limit static pressure switches, and combination fire/smoke dampers beyond their degradation temperature classifications.

FSCS nondedicated system fan motor controller switches do not need to be bypassed when:

- Located in mechanical or electrical equipment rooms
- Inaccessible to the general public
- Operation of such a switch will result in a trouble condition at the building's main control center

The VM-1 SCS, to be effective, should include an FSCS series graphic annunciator with a building diagram that indicates the type and location of all smoke control equipment. The building areas affected by the equipment, including barrier walls, should also be clearly indicated (Figure 17).

The actual status of system components that are activated or capable of activation for smoke control should be clearly indicated at the FSCS smoke control station. Status indication is for on and off status of each individual fan having a capacity of 2,000 cfm (944 L/s) or more and used for smoke control. The ON status should be sensed by pressure difference as a confirmation of airflow. Damper position status is also often required by UUKL and NFPA 92B.

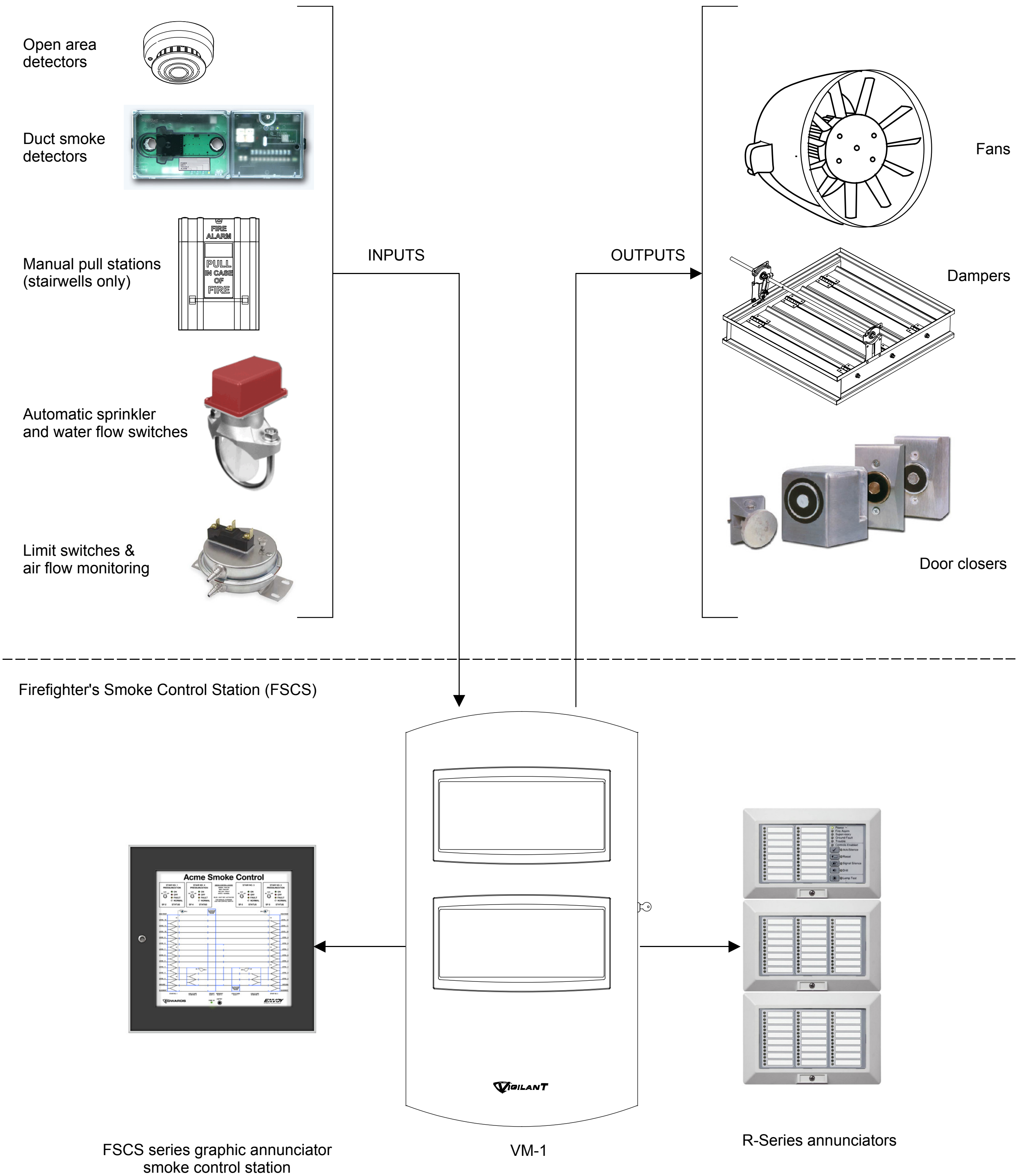
HVAC system controls

Initial design of HVAC system controls or modification of existing HVAC controls to incorporate smoke control system requirements must include assigning the highest priority to the smoke control mode.

Dedicated smoke control systems, while not utilizing HVAC fans and controls, will sometimes require the shutdown of the building HVAC equipment in addition to the closing of dampers interconnected to the HVAC system.

Nondedicated fire systems will use HVAC components and control systems. HVAC control systems use pneumatic, electric, electronic, and programmable logic-based control units. All of these control systems can be adapted to provide the necessary logic and control sequences to configure HVAC systems for smoke control. Programmable electronic logic or microprocessor based control units for HVAC systems which also provide other building control and monitoring functions are readily adapted to provide the necessary logic and control sequences for an HVAC system's smoke control mode of operation.

Figure 17: Input and output components



Smoke control system activation and deactivation

Smoke control system activation is the initiation of the operational mode of a smoke control system. Deactivation is the cessation of the operational mode of the smoke control system and return of HVAC control to the building environmental control center. Smoke control systems usually are activated automatically but can be manually initiated under conditions deemed appropriate as a part of the smoke control system design. Under all operating conditions, the smoke control system must be capable of manual override.

Loss of building power should be evaluated to determine if the smoke control system design would function as intended. The evaluation must consider the position (open or shut) of smoke dampers upon loss of power and when the fan systems the dampers served are shutdown.

Automatic activation or deactivation of a smoke control system includes all initiating circuit action that results in the operation of one or more smoke control zones without manual intervention. Automatic activation will usually come from smoke detectors and waterflow switches.

Smoke control system activation should begin immediately upon receipt of an activation command. Sequencing of smoke control components (fans, dampers, ducts, and louvers) is necessary to prevent physical damage to the equipment. Over-pressurization of a duct due to early or improper damper operation could result in damage to the duct and an inability to effectively control smoke in a zone.

NFPA 92A, *Recommended Practice for Smoke control Systems*, establishes the maximum response time for individual components to reach a fully operational mode. Fans must reach the specified flow rate within 60 seconds and confirm the state has been reached at the smoke control panel and the FSCS. Completion of smoke damper travel to either the fully open or the fully closed state must be accomplished within 75 seconds of signal initiation.

Note: Local codes, like UBC, may specify other times. Check all applicable codes and use the time limit required.

Initiating circuits

Smoke control system initiating circuits may contain the same alarm initiating devices found in a standard VM-1 fire alarm system and initiating device circuit (IDC). Alarm signal initiating devices used for smoke control may also serve a dual-purpose, initiating alarm notification or control functions required under NFPA 72. A smoke control system initiating device, when activated, initiates predetermined system sequences.

Detection

Smoke control system initiation using smoke detectors is most common. Since the goal of smoke control systems is most often to maintain tenability in a zone or space, heat or flame-type detection is not considered responsive enough for use in a smoke control system. Heat detectors in maintenance or similar rooms incidental to the area protected or locations where smoke detectors cannot be effectively installed may be connected to the smoke control system.

Detection using either photoelectric or ionization spot type smoke detectors should be based upon the space protected. Smoke development and travel are influenced by ceiling configuration and height, burning characteristics of materials, fuel arrangement, room geometry, and HVAC systems installed.

Some large volume spaces, such as atriums, have been reported to experience temperatures of up to 200°F (93.3°C) because of solar loads. Detectors in these areas need to be capable of operating in this day-to-day environment. Installation sheets for detectors contain operating temperature ranges for detectors. Signature Series smoke detectors should be installed in accordance with the requirements contained in the *Signature Series Intelligent Smoke and Heat Detectors Applications Bulletin* (270145).

Concerns over smoke stratification and detector access in large or high ceiling areas, such as atriums, is increasingly leading designers to specify projected beam-type smoke detectors. Projected beam detectors work on the principle of light obscuration. A beam of infrared light is transmitted across the protected area and is monitored by a receiver. Smoke particles entering the beam path can either absorb or scatter the beam of light, causing a reduction in light received. When the reduction in light received reaches a threshold, an alarm signal is generated.

Since both absorption and scattering of light cause a reduction in the light sensed at the receiver, projected beam detectors work well for both smoldering and fast-flaming fires.

Projected-beam detectors are normally installed parallel and within 20 in. (0.508 m) of the ceiling except when high ceilings or smoke stratification are a design consideration. Projected beam detectors have an operating range of 30 to 330 ft. (9.1 to 100.6 m).

Manual pull stations

Manual pull stations are placed in buildings for occupant use in reporting fires and notifying other occupants. Manual pull stations are not normally used to activate smoke control systems, but may be used for stairwell pressurization systems. With manual pull stations there is a greater likelihood of a person signaling an alarm from a station outside the smoke zone in which the fire is occurring and thereby pressuring and venting the wrong areas.

Automatic sprinkler and specialized extinguishing systems

The same criteria that dictate the installation of a smoke control system are likely to also dictate the installation of an automatic extinguishing system. Most model codes will require automatic sprinklers for large or tall buildings.

In the design of the smoke control systems, the size of the expected fire must be determined in order to establish exhaust flows for the smoke generated. Automatic sprinkler systems are designed to contain or control fires, thus limiting the size of an expected fire and the amount of smoke generated. Smoke control system designers utilize the limiting of fire size and spread due to automatic sprinklers as an important element in sizing HVAC systems and fans for smoke control.

Automatic sprinkler systems can be utilized to activate a smoke control zone, provided the flow switch for the sprinkler system serves only fire sprinklers in the smoke control zone. For new buildings, the coverage areas of sprinkler systems must be coordinated with smoke zone areas to ensure applicability.

Manual controls

For smoke control, manual activation or deactivation refers to the means available to an authorized person to activate one of the smoke control functions. Manual fire alarm pull stations are not in this category. Manual controls will be at the FSCS in a location directed by the AHJ.

Smoke control output circuits

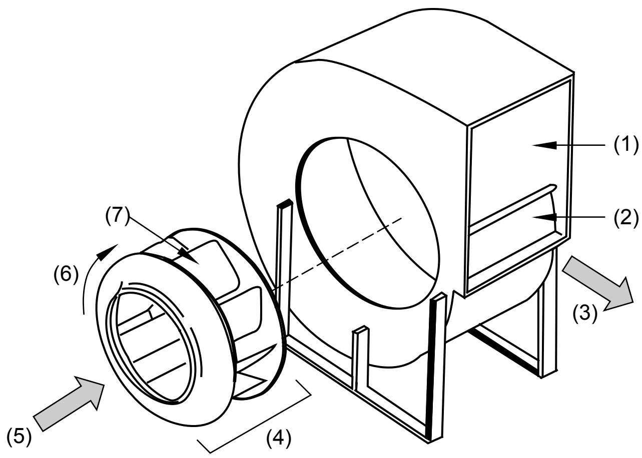
Smoke control system output circuits may contain some of the same output modules and devices found in a standard VM-1 fire alarm system. Output commands for a smoke control zone include the startup or shutdown of fans, damper operation, vent or louver operation, and door or barrier operation. Sequencing of each action is critical in the proper functioning of a smoke control system. Dampers may need to reach fully open or fully closed position prior to fan startup. Fans may also need to rundown or stop prior to damper movement.

Fans

HVAC fans are classified as either centrifugal or axial. Fan performance and economics are major factors in the type of fan for an application. Forward-curved fans are used for low-pressure applications including residential furnaces and packaged air-conditioning equipment. Airfoil and backward-curved fans are used for general-purpose HVAC applications, and airfoil fans are usually limited to large systems where the energy savings are significant. Radial fans are used when high pressures are needed. New building installations using fans for smoke control will consider the emergency operation parameters when selecting the HVAC system fans.

Centrifugal fans: Centrifugal fans (see Figure 18) are subdivided into forward-curved, backward-curved, and airfoil. Forward-curved centrifugal fans rotate at a relatively low speed. They are generally used to produce high flow rates and low static pressures. Backward-curved fans rotate at about twice the speed of forward-curved fans and have a higher efficiency. Both forward-curved and backward-curved impeller blades are single-width blades.

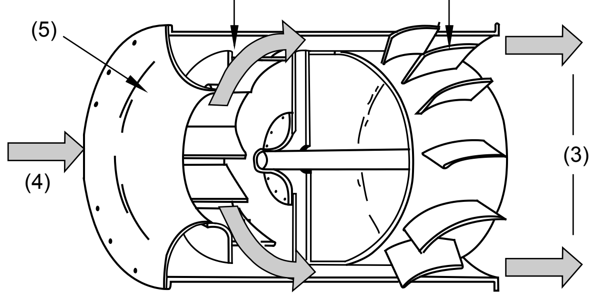
Figure 18: Centrifugal fans



(1) Outlet area
(2) Cut off
(3) Airflow OUT
(4) Impeller wheel rotor
(5) Airflow IN
(6) Impeller rotation direction
(7) Blade fins

Airfoil fans: Airfoil fans are simply backward-curved fans with blades of varying thickness to improve fan efficiency. Airfoil blades are based upon the same technology that is used to design airplane wings. Tubular centrifugal fans (see Figure 19) are an exception to the classification. They have single width impeller blades and straightening vanes at the discharge. Tubular centrifugal fans are used in low-pressure HVAC applications, often as return air fans.

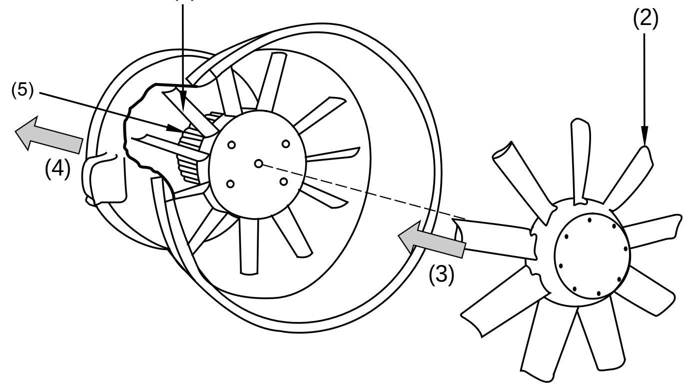
Figure 19: Tubular centrifugal fan



(1) SW centrifugal fan wheel
(2) Straightening vanes
(3) Airflow OUT
(4) Airflow IN
(5) Streamline inlet

Axial fans: Axial fans (see Figure 20) are subdivided as propeller fans, tubeaxial fans, and vaneaxial fans. Axial fans are designed to achieve high flow rates at low pressures. Common uses for axial fans include kitchen and rest room exhaust, stairwell or elevator pressurization, and space ventilation. Propeller fans are susceptible to adverse pressure conditions that would include opposing wind loads from the exterior. Unlike centrifugal fans, the backward rotation of an axial fan normally results in backward flow at a reduced airflow rate.

Figure 20: Axial fan



(1) Guide vane
(2) Blade
(3) Airflow IN
(4) Airflow OUT
(5) Motor

Exhaust fans for smoke control are selected to operate in the design conditions of the smoke and fire. While dilution with ambient air can significantly cool down the fire temperature reaching fans, there are also instances where the direct effects of the fire will be on the smoke control equipment.

HVAC systems with the capacity, outlets, grill locations and flow rates are suitable for smoke control. For HVAC systems, a means must be provided to prevent the supply system from operating until the exhaust flow has been established to avoid pressurization of the fire/smoke area. In colder locations where the introduction of outside air into the space due to inadvertent operation or testing could damage contents, consideration should be given towards heating the makeup air.

Fans must reach their specified flow rate within 60 seconds and confirm the state has been reached at the smoke control panel and the FSCS.

Dampers

Dampers in air-moving systems are used to balance and control airflow, relieve excess pressure, and resist fire or smoke passage. Fire, smoke, or ceiling dampers are the three types of dampers used in buildings.

Fire dampers are used for the protection of openings in walls, partitions, or floors and are rated at 1-1/2 to 3 hours. Fire dampers are installed in accordance with UL 555, *Standard for Safety Fire Dampers*. A fire damper does not prevent the leakage of smoke through the opening and is normally released by a fusible link.

Smoke dampers resist the passage of smoke and protect openings in smoke barriers or as a part of engineered smoke control systems. Smoke dampers are installed in accordance with UL 555S*, Standard for Safety Leakage Rated Dampers for Use in Smoke control Systems*. Combination fire/smoke dampers will have a fire resistance rating and meet both UL 555 and UL 555S.

Ceiling dampers or other methods for protecting openings in floor/roof-ceiling assemblies are installed in accordance with UL 555C*, Standard for Safety Ceiling Dampers*.

Fire and ceiling dampers are designed to close upon the operation of a fusible link. When dampers are part of an engineered smoke control system the temperature rating of the fusible links must be 50 degrees above the maximum smoke control system designed operating temperature with some additional qualifiers found in UL 555S.

With the remote operation of dampers for the engineered smoke control system, dampers must have provisions that allow them to re-close automatically upon reaching the damper's maximum degradation temperature as defined in UL 555S.

Completion of smoke damper travel to either the fully open or the fully closed state must be accomplished within 75 seconds and be confirmed at the FSCS.

Note: Local codes may require different response times for smoke dampers. See “System response time” on page 42.

Louvers and vents

Various combinations of louvers, vents, and nonrated dampers can be used as a part of a smoke control system. These venting methods are used to prevent over-pressurization of stairwells, elevator shafts and smoke zones. Vents can provide relief using barometric dampers with adjustable counterweights or electric or pneumatic motor-operated dampers.

Venting in stairwell and some atrium smoke control systems may use side-swinging doors that open to the exterior in lieu of louvers or vents. Exterior doors produce a constant-supply air rate, a recognized advantage in the design of stair systems on several fronts, including a requirement in the *Supplement to the National Building Code of Canada*. Exterior door opening is a method of reducing pressure fluctuations in the stairwell in the same way in which louvers and vents are used.

Movable louvers may be used in elevator or stairwell pressurization systems and must be interconnected to the smoke control system to ensure that they open in the proper sequence. Movable louvers may also be used for some building or zoned smoke control systems. For whichever device is selected, there should be a capability to close the opening should smoke begin to enter through it.

Doors for makeup air

The simplest method of introducing makeup air into an area is via direct openings to the outside using doors and louvers, which can be opened upon system activation. For new construction, the architectural designer, in concert with the smoke control system designer, can place these opening below the expected smoke layer. For locations where such openings are impractical, a powered supply system will likely be used.

Door and wall closers

In the last decade, several manufacturers have developed rolling or bifold door and wall systems, which can be used to create a smoke zone, isolate elevator shafts, lobbies, or areas of refuge.

Smoke barriers, other than side swinging doors, are supplied by a small number of manufacturers. The Won-Door Co. has received a door and a wall rating for their bifold system; McKeon Rolling Door has a rolling/swinging door combination; and SmokeGuard Corp. has an elevator opening protective. Listing directories for buildings materials contain specifics about these products.

Each of these barrier systems depends upon smoke detection for operation and where used is an important part of establishing and maintaining smoke control zones.

Panel and component operation

Panel functions

This chapter provides general information on the techniques used to evaluate the physical characteristics of smoke movement through buildings as a basis for designing smoke control systems. Mechanical system components consisting primarily of fans and dampers are determined, sized, and located by the smoke control system designer. The smoke control system designer is an engineer, architect, or competent person, usually on the building owner's design team.

The VM-1 smoke control system designer should not establish smoke zones and airflow requirements as a part of the design unless they are competent in HVAC system and smoke movement analysis. The VM-1 smoke control system panel functions are therefore based upon requirements established by the smoke control system designer.

Detection of a fire or smoke condition is the same for a VM-1 smoke control system panel and the standard VM-1 fire alarm panel. Outputs from the smoke control system are focused upon two areas:

- Removing or reducing smoke from an area or zone
- Compartmentalizing a smoke zone

Smoke control system functions do not include the alerting of the occupants or fire department of the event; this is performed by the fire alarm panel.

A VM-1 smoke control system panel can be a stand-alone panel or integrated into a VM-1 fire alarm panel. The decision to incorporate smoke control system functions into the VM-1 fire alarm panel should be accepted as a part of the design process by the building owner and local AHJ requirements. There are some jurisdictions currently requiring a stand-alone smoke control system under their building and fire codes.

Control system supervision and instrumentation

Every smoke control system must have a means of ensuring it will operate if needed. The means will vary according to the complexity and importance of the system. Supervision devices can include:

- The presence of operating power downstream of all circuit disconnects
- End-to-end supervision of wiring, equipment, and devices in a manner that includes provisions for positive confirmation of activation, periodic testing, and manual override operation
- Positive confirmation of fan activation by means of duct pressure, airflow, or equivalent sensors that respond to loss of operating power, problems in the power or control circuit wiring, airflow restrictions, and failure of the belt, shaft coupling, or motor itself
- Positive confirmation of damper operation by contact, proximity, or equivalent sensors that respond to loss of operating power or compressed air, problems in the power control circuit, or pneumatic lines, and failure of the damper actuator, linkage, or damper itself
- Other devices or means as appropriate

Energy management systems

Energy management systems, particularly those that cycle supply, return, and exhaust fans for energy conservation, must be overridden when they control or may operate in conflict with the smoke control system. Smoke control is an emergency mode of operation and is to take priority over all energy management and other non-emergency control modes.

Materials

Materials used for systems supplying smoke control are to conform to NFPA 90A, *Standard for the Installation of Air-Conditioning and Ventilating Systems*, and its referenced standards.

Duct materials should be designed and selected to convey hot smoke, withstand any additional pressure (either positive or negative) by the supply and exhaust fans when operating in a smoke control mode. Ducts must maintain their structural integrity during the period when they are designed to operate. Special high-temperature ratings for smoke exhaust fans are not normally necessary.

Electrical power requirements

All electrical installations must meet the requirements of NFPA 70, *National Electrical Code*, in addition to building code requirements. Normal electrical power serving air conditioning systems will generally have sufficient reliability for nondedicated zoned smoke control systems.

Standby power for dedicated smoke control systems and their control systems should be adequate for the expected duration of a fire event.

Programming functions

Regardless of the type of smoke control system installed, the control and programming device functions will fall into three general categories:

- The operation of fans: turning ON or OFF
- The operation of compartmenting components (dampers, doors, louvers, walls, or windows): to OPEN or CLOSE
- The toggling of HVAC system components from their normal, nonfire condition: AUTO or AUTO OFF

From the two control categories the monitoring or status of smoke control equipment will also be needed or required.

Verification of devices results in a confirmation of:

- An ON (fan) or OPEN (dampers, etc.) condition
- An OFF (fan) or CLOSED (dampers, etc.) condition

Control and monitoring functions will fall into one of the categories shown in Table 1 for fans or compartmenting devices. Monitoring will take the form of a control panel LCD or annunciator LED. Table 1 provides a list of control actions and the devices they monitor.

Table 1: Control and monitoring functions

Control action	Resulting control or LED status
AUTO OFF	Overrides normal HVAC Controls
Turn Fan OFF	Only when Fan is OFF
Turn Fan OFF	Only when Fan is ON
Turn Fan OFF	Fan is ON & OFF
Turn Fan ON	Only when Fan is OFF
Turn Fan ON	Only when Fan is ON
Turn Fan ON	When Fan is ON & OFF
Turn Fan ON & OFF	Only when Fan is OFF
Turn Fan ON & OFF	Only when Fan is ON
Turn Fan ON & OFF	Only when Fan is ON & OFF
CLOSE Damper*	When Damper is CLOSED
CLOSE Damper*	When Damper is OPEN
CLOSE Damper*	When Damper is OPEN & CLOSED
OPEN Damper*	When Damper is CLOSED
OPEN Damper*	When Damper is OPEN
OPEN Damper*	When Damper is OPEN & CLOSED
OPEN & CLOSE Damper*	Damper is CLOSED
OPEN & CLOSE Damper*	When Damper is OPEN
OPEN & CLOSE Damper*	When Damper is OPEN & CLOSED
AUTO ON	Returns HVAC to normal operation

* For this table, damper is used to denote any compartmenting device.

For each of the control actions in Table 1 the verification of the result is displayed at a monitoring point. For example, a controlling action to “Turn Fan ON or OFF” with a monitoring requirement to verify “Only when Fan is ON” results in the capability to turn the fan ON or OFF when a fire is detected. In addition, verification when the fan is turned on in response to a fire will occur, usually in the form of an LED at the VM-1 smoke control panel.

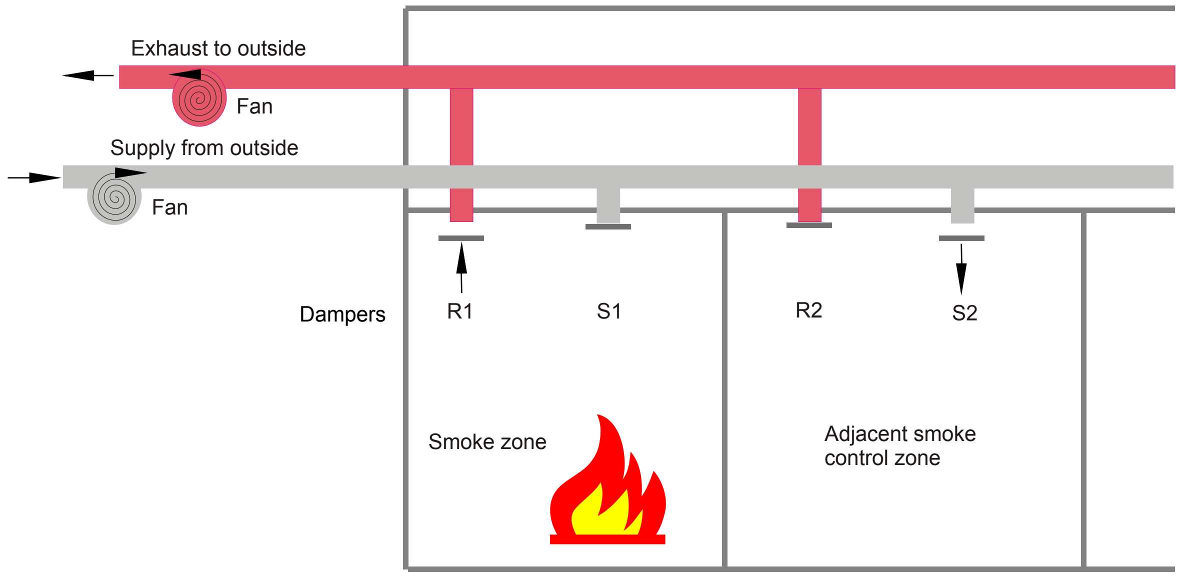
Note: Typically for a nondedicated HVAC fan, when the fan is in its normal or auto operating state, there will be suppression of the LED monitor point.

Control and monitoring examples

For Figure 21 on page 27 both fans and dampers are used for smoke control. There are two zones for the multiple zone arrangement. In the example, there is a supply and return vent for each area with dampers located at each vent and the system is equipped with mechanical exhaust.

The smoke control system designer has determined that in the event of a fire, the smoke zone must be placed under a negative pressure and adjacent zones must have positive pressures to prevent smoke intrusion.

Figure 21: Smoke control using fans and dampers



Depressurization of the smoke zone is accomplished by closing the supply damper (S1), verifying the exhaust damper (R1) is open, and turning on the return air fan. Pressurization of the adjacent area is accomplished by closing the exhaust damper (R2) and opening the supply damper (S2) while starting the supply fan.

The steps in controlling and monitoring the Figure 21 smoke control system example upon fire detection are found in Table 2 below.

Table 2: Smoke control sequencing for Figure 21

Control action	Monitor-LED indication
AUTO OFF	Overrides normal HVAC controls
Open Damper R1	Only when Damper R1 is OPEN
Close Damper S1	Only when Damper S1 is CLOSED
Start Return Fan	Return Fan ON
Close Damper R2	Only when Damper R2 is CLOSED
Open Damper S2	Only when Damper S2 is OPEN
Start Supply Fan	Supply Fan ON

The Control Sequencing in Table 1 will be discussed in detail as it applies to a VM-1 smoke control system in Chapters 2 and 3.

Additional reading

"Air Conditioning and Ventilating Systems," William A. Schmidt, *NFPA Fire Protection Handbook*, eighteenth edition.

Design of Smoke Management Systems, John H. Klote and James A. Milke.

"Emergency Movement," Harold E. Nelson and H.E. MacLennan, *The SFPE Handbook of Fire Protection Engineering*, second edition.

Fire Alarm Signaling Systems, Richard W. Bukowski and Robert J. O'Laughlin.

"Movement of People," Jake Pauls, *The SFPE Handbook of Fire Protection Engineering*, second edition.

ASME/ANS A17.1 *Safety Code for Elevators and Escalators*

NFPA 92A, *Recommended Practice for Smoke-Control Systems.*

NFPA 92B, *Guide for Smoke Management Systems in Malls, Atria, and Large Areas.*

NFPA 70, *National Electrical Code*

NFPA 72, *National Fire Alarm and Signaling Code*

NFPA 80, *Standard for Fire Doors and Other Opening Protectives*

NFPA 101, *Life Safety Code* (Chapter 6)

NFPA 204, *Standard for Smoke and Heat Venting*

BOCA, *Business Object Component Architecture International*

UBC, *Uniform Building Code*

SBC, *Standard Building Code*

IBC, *International Building Code*

UL 864, UUKL section for Smoke Control System Equipment

Signature Series Intelligent Smoke and Heat Detectors Bulletin (P/N 270145)

“Smoke Movement in Buildings,” John H. Klote and Harold E. Nelson *NFPA Fire Protection Handbook*, eighteenth edition.

Smoke Movement and Control in High-rise Buildings, George T. Tamura.

Smoke control in Fire Safety Design, E.G. Butcher and A.C. Parnell

“Commissioning Smoke Management Systems,” ASHRAE Guideline 5-1994, *American Society of Heating, Refrigerating and Air-conditioning Engineers*, Inc, 1791 Tullie Circle, NE, Atlanta, GA, 30329

Chapter 2
Smoke control system hardware

Summary

The VM-1 smoke control system hardware components are described in this chapter as a part of a VM-1 fire alarm network or as a stand-alone system with an annunciator panel for firefighter use.

Content

The VM-1 smoke control system

The VM-1 smoke control system is designated in this manual as the SCS. The SCS consists of fans, dampers, and other controls included in a typical VM-1 installation. The VM-1 firefighter's smoke control station is designated in this manual as the FSCS.

The SCS and the FSCS include an LCD and annunciator strips, which are common to the VM-1 fire alarm network. The FSCS may also include one of the following graphic-based smoke control stations, which are not a part of the VM-1 network:

- FSCS-1 graphic annunciator smoke control station
- FSCS-2 graphic annunciator smoke control station
- FSCS-3 graphic annunciator smoke control station
- FSCS-4 graphic annunciator smoke control station

Important: Do not confuse the FSCS series graphic annunciators or their model names with the FSCS (firefighter's smoke control station).

The SCS and the FSCS are able to receive fire alarm inputs and perform predetermined control functions. Control functions include opening or closing doors, dampers, and barriers. Other control functions include shutting down or starting up fans to limit smoke spread beyond the area of origin.

The SCS may be designed and installed as a stand-alone system or integrated into the standard VM-1 fire alarm network panels. NFPA 92A contains performance criteria for the design of a smoke control system. The integrity of a smoke control system can be accomplished with smoke control components mounted in an VM-1 fire alarm panel which also provides for occupant notification, off-premises notification, and other NFPA 72 alarm system requirements not common to smoke control functions.

To meet NFPA 92A design criteria, some jurisdictions may require a panel for the SCS separate from the fire alarm system. Confirmation of the ability to integrate smoke control system components into the fire alarm panel should be made with the owner and the authority having jurisdiction (AHJ) prior to installation.

The FSCS graphic annunciator panel must indicate the routing of fire alarm devices connected to the SCS as required by NFPA 72. Operational power for dampers, fans, and their related components are critical to the operation of the smoke control system and should be on building emergency power. NFPA 92A recommends connection to emergency power for critical smoke control components, while local the AHJ may require emergency power for all system components.

Stand-alone

An VM-1 SCS designed and installed independent of any fire alarm system requirements constitutes a stand-alone smoke control system. This type of application is most suitable for:

- Applications where the SCS also serves as the FSCS
- Multiple building facilities or business campus environments
- Single zone systems like stairwells, elevator shafts, and vertical shafts

The AHJ in some jurisdictions may require the SCS be installed as a stand-alone fire protection component.

Integrated

The VM-1 SCS utilizes many components found in an VM-1 fire alarm network and may even share the same cabinet. The SCS may also share VM-1 components like the CPU module. In such cases, comply with the performance requirements of NFPA 92A in the programming of shared components.

Firefighter smoke control station

The FSCS, where required, provides graphical monitoring and manual control over the smoke control system. The FSCS must have priority over all smoke control system components shared with an HVAC system. Where manual controls are also provided at other building locations for management of smoke control systems, the control mode selected from the FSCS is to have override or bypass capability over other building controls. Building controls such as Hand-Off-Auto and Start/Stop switches located on fan motor controllers, freeze detection devices, and duct smoke detectors typically must be overridden or bypassed in order to ensure the FSCS can be used to contain or control smoke movement.

The override exception is where fan control capability switches for nondedicated smoke control system fans (i.e. HVAC) are located in electrical equipment or mechanical rooms accessible only to authorized personnel. In addition to authorized access, the operation of one of these motor controller switches must cause a trouble annunciation at the building's main control center, in order that the FSCS need not override or bypass these switches.

The FSCS must not override or bypass devices and controls, designed to:

- Protect against electrical overloads
- Provide for personnel safety
- Prevent major system damage

Controls not to be overridden include:

- Overcurrent protection devices
- Electrical disconnect switches
- High-limit static pressure switches
- Combination fire/smoke dampers beyond their UL 555 degradation temperature classifications

The FSCS must display a building diagram that clearly indicates the type and location of all smoke control equipment. At a minimum, the FSCS should indicate the following:

- The actual status of the system components and equipment which are activated or capable of activation for smoke control are to be indicated at the FSCS graphic annunciator.
- Status indication for each fan having a capacity of 2,000 cfm (944 L/s) or more is to include on and off conditions. The "ON" status should be sensed by pressure difference at the design smoke control airflow.
- Damper position at smoke barriers and other critical locations are to be confirmed by positive means.

VM-1 smoke control system design considerations

Dedicated

Dedicated smoke control system mechanical components such as fans and dampers are used only for smoke control. Design and sizing of fans and other components is focused upon static pressure control, safety devices, and sizing to manage the required smoke control air flows.

Dedicated smoke control systems include stairwell pressurization, smoke shaft exhaust systems, elevator shaft pressurization systems, and atrium smoke control systems. Controls for dedicated smoke control systems will be more straightforward since fans and dampers will likely be under the sole control of the SCS.

Stairwell pressurization systems

Stairwell pressurization systems are designated as either *compensated* or *noncompensated.*

Compensated systems have control provisions which react to changes in airflow in order to maintain a specific static pressure level. Depending upon the height of the stairwell, sensors and exhaust dampers will adjust air flows for pressure losses due to doors opening in the stairwell. Current designs place sensors and exhaust damper controls at every third floor in mid or high-rise buildings.

An SCS design for compensated systems must provide for control of fans and dampers at multiple points in a compensated system. Fans are typically VAV type or contain bypass ducts around the fan. Stairwells of 8 floors or less may be compensated with only fans at the top or bottom of the stairwell and dampers on the opposite end.

Noncompensated systems do not have static pressure control provisions. Fans and dampers or vents are designed and programmed to operate at a set pressure for the stairwell.

Stairwell pressurization fan air intakes must be located in a manner that helps to ensure that smoke from a building fire is not drawn into the stairwell. The air intakes will supply all of the air to the stairwell and therefore requires a duct smoke detector which will shut down the fan if smoke is detected and the FSCS must have a detector override for the fan.

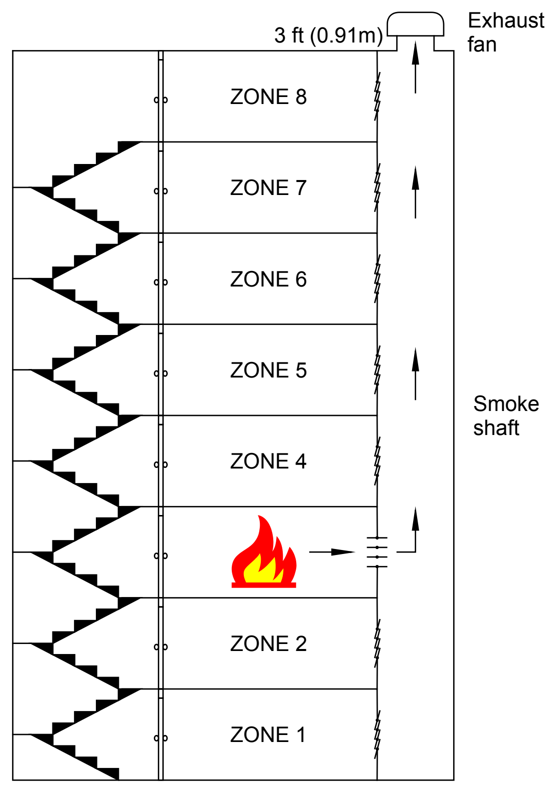
A relief damper for a pressurized stairwell, operable from the FSCS should be located at the top of the stairwell to prevent over-pressurization in addition to venting any smoke which may enter the stairwell. Damper relief is set by the Building Smoke control System Designer, normally at not less than 2,500 cfm (1,180 L/s) with a differential pressure of 0.15 inches (37,035 Pa) of water. The FSCS designer should anticipate a control point for the relief damper.

Smoke shaft exhaust systems

Smoke, as covered in Chapter 1, has a tendency to move upward in a building. Buildings may be designed with a smoke shaft as a mechanical method of exhausting smoke from a selected floor. A smoke shaft serving a smoke zone will assist a smoke control system by reducing smoke spread and static pressures on the fire floor which have a tendency to push smoke into adjacent zones or to other floors.

Smoke shaft systems consist of an exhaust fan mounted on the top of a vertical shaft which runs up the entire height of a structure. The shaft is constructed of fire rated material and connects to each floor through an FSCS and SCS operable combination fire/smoke dampers. Dampers are normally kept closed with the damper on the fire floor opening upon detection of fire followed by the startup of the shaft fan. The fire/smoke dampers, which connect each zone to the smoke shaft are to be reopening, within the limits of NFPA 90A-3-4.5, to allow for operation from the FSCS if their temperature activating mechanism causes them to automatically close and mechanical venting is needed. The smoke fan's discharge must be a minimum of 3 feet (0.9144 m) above the roof level or deck.

Figure 22: Smoke shaft system



Elevator shaft pressurization systems

Elevator shaft pressurization systems are similar in concept to stairwell pressurization systems, but of two types. The first is the pressurization of the elevator system in order that it may be used for occupant evacuation. In the second type, the pressurization of the elevator shaft prevents or limits smoke spread from the fire floor into the shaft. Meeting ADA area of refuge and egress requirements in tall buildings will often bring elevator shaft pressurization into a building's life safety system design.

The Building Smoke control System Designer must evaluate the possible effect of positive elevator pressurization upon a smoke zone's ability to maintain a negative pressure.

Elevator car movement, as reviewed in Chapter 1, may present additional challenges in maintaining shaft pressurization.

Elevator smoke control will involve the turning on of one or more pressurization fans and controlling the static pressure within the elevator shaft. Design approaches today inject air into the shaft near the main floor with air flow upward to a relief damper at the top of the shaft. Dampers are typically of the barometric type in order to effectively maintain a higher static pressure in the elevator shaft.

Atrium smoke control systems

Atrium smoke control, another dedicated smoke control type, focuses upon exhausting smoke products at a rate which will maintain tenability and help preserve visibility at lower levels of the atrium. Atrium smoke control systems are governed by NFPA 92B, *Guide for Smoke Management in Malls, Atria, and Large Areas*.

Smoke removal fans at the ceiling must typically provide the greater of six air changes per hour or 40,000 cfm (18,800 L/s). Very large atriums must have a ceiling exhaust system capable of at least four changes per hour.

Supply air openings for diluting and exhausting smoke are located on the lowest or next to lowest level and are sized the design air flow requirements. Larger atriums may also have fans for supplying makeup air. Openings for supply air may consist of louvers, dampers, rolling doors, and pedestrian doors as specified by the smoke control system designer. Operation of supply air doors or dampers from the FSCS is required.

Detection of a fire in an atrium is via smoke detectors mounted on the ceiling, and under floor projections in the atrium. Beam type detectors are often specified for larger or taller spaces.

The atrium smoke control system fans and dampers are normally off or closed. Sequencing of supply openings with fan startup is part of the VM-1 SCS. Static pressure control may be, but typically is not, a part of system operation.

For each of the dedicated system types the final goal is to create a pressure differential of 0.15 in. to 0.45 in. of water (37.4 Pa to 112.05 Pa) across a door opening or on either side of a barrier.

For dedicated systems, the building smoke control system designer will establish the size of fans, dampers, and vents. The sequencing of fan operation and damper controls will also be defined for the VM-1 SCS designer/installer.

Nondedicated

Nondedicated mechanical system components are commonly a part of the building HVAC system. HVAC systems are used for smoke control to create differential pressures between the smoke zone and adjacent zones or areas.

Differential pressurization is typically achieved by providing adjacent zones with full supply air (100 percent from the outside) without any return or exhaust in the adjacent zone. The smoke zone air supply is stopped and full exhaust of the zone to the outside is implemented to relieve fire generated pressures or create a negative pressure in the smoke zone.

Nondedicated smoke control systems include single zone HVAC systems with direct outside air and direct exhaust air, single zone systems with common outside air and common exhaust air, central HVAC systems, dual duct HVAC systems, multi-zone HVAC systems, and variable air volume systems. Key FSCS settings criteria for each of these system types and smoke control operating positions for devices follow.

Single zone HVAC systems with direct outside air and direct exhaust air

Single zone HVAC systems most often serve one floor or a portion of a floor in a multistory building and are readily adaptable to smoke control use.

Several zones will be used to limit smoke spread by creating differential pressures around a fire.

See Table 3 on page 34 for control settings.

Single zone systems with common outside air and common exhaust air

Single zone systems with common outside and exhaust air receive their outside air from a common outside air system and are found in multiple floor buildings. HVAC controls are provided within individually zoned systems.

Single zone HVAC systems can be effectively used to provide smoke control when smoke dampers are located at barriers to limit smoke spread.

See Table 4 on page 34 for control settings.

Central HVAC systems

Central HVAC systems are most often used in multiple floor buildings with a single HVAC system providing service for 6 to 20 floors.

Conditioned air is supplied to each floor via large vertical shafts with each HVAC zone having reheat provisions.

Damper positioning is the key component in isolating smoke control zones in these systems.

Control of static pressures in large vertical shafts supplying or exhausting air is necessary to prevent duct collapse or rupture during smoke control events.

See Table 5 below for control settings.

Table 3: Single zone smoke control settings with direct outside air and direct exhaust air

Smoke zone	Adjacent zones	Remote zones
Supply fan OFF	Supply fan ON	Maintain HVAC operation while power supply is available without impacting fire area smoke control operations
Return fan ON	Return fan OFF	
Exhaust air damper OPEN	Exhaust air damper CLOSED	
Return air damper CLOSED	Return air damper CLOSED	
Outside air damper CLOSED	Outside air damper OPEN	
Reset static pressure control to maximize air flow and prevent duct failure	Reset static pressure control to maximize air flow and prevent duct failure	

Table 4: Single zone smoke control settings with common outside air and exhaust ducts

Smoke zone	Adjacent zones	Common outside and exhaust air system	Common remote zones
Supply fan OFF	Supply fan ON	Supply fan ON*	Supply fan OFF
Return fan ON*	Return fan OFF*	Return fan ON*	Return fan OFF*
Exhaust air damper OPEN	Exhaust air damper CLOSED	Exhaust air damper OPEN	Exhaust air damper CLOSED
Supply air damper CLOSED	Supply air damper OPEN	Outside air damper OPEN	Supply air damper CLOSED
Return air damper CLOSED	Return air damper CLOSED	Reset static pressure control to maximize air flow and prevent duct failure	

* If no return fan is present, dampers are still positioned as indicated.

Table 5: Central system smoke control settings

Smoke zone	Adjacent zones	Central system	Remote zones on central system
		Supply fan ON	
		Return fan ON	
Exhaust air damper OPEN	Exhaust air damper CLOSED	Exhaust air damper OPEN	Exhaust air damper CLOSED
Supply air damper CLOSED	Supply air damper OPEN	Outside air damper OPEN	Supply air damper CLOSED
		Return air damper CLOSED	
		Reset static pressure control to maximize air flow and prevent duct failure	

Dual duct HVAC systems

Dual duct HVAC systems provide a central source of conditioned air through a hot supply duct and a cold supply duct serving multiple zones. Each zone has mixing boxes to control room temperatures.

Configuring for smoke control of dual duct HVAC systems utilizes mixing box air flows for pressurization.

Cold air ducts are often relied upon for air supply due to their larger size.

See Table 6 below for control settings.

Multi-zone HVAC systems

Multi-zone HVAC systems provide separate air mixes for each HVAC zone with multi-zone units.

Most systems are limited to about 12 zones due to energy efficiency considerations.

For smoke control, multi-zone systems maximize air to zones designated for pressurization around the fire. Cold air ducts are often relied upon for air supply due to their larger size.

See Table 7 below for control settings.

Variable air volume systems (VAV)

VAV systems serve multiple building zones with conditioned air at required volumes.

Terminal units in each building zone contain dampers to control air volume and may contain fans and heating coils.

Damper positioning and controlling of supply and return fans to provide maximum air volume are needed for smoke control applications using VAV systems.

Static pressure controls must be reset to permit maximum air flow without duct collapse or rupture.

See Table 8 on page 36 for control settings.

Table 6: Dual duct smoke control settings

Smoke zone	Adjacent zones	Dual duct central system	Remote zones on same dual duct system
		Supply fan ON	
		Return fan ON	
Exhaust air damper OPEN	Exhaust air damper CLOSED	Exhaust air damper OPEN	Exhaust air damper CLOSED
Hot duct damper CLOSED	Exhaust air damper CLOSED	Outside air damper OPEN	Hot duct damper CLOSED
Cold duct damper CLOSED	Hot duct damper CLOSED	Return air damper CLOSED	Cold duct damper CLOSED
	Cold duct damper CLOSED	Reset static pressure control to maximize air flow and prevent duct failure	

Table 7: Multi-zone smoke control settings

Smoke zone	Adjacent zones	Multi-zone central system	Remote zones on same multi-zone system
		Supply fan ON	
		Return fan ON	
Exhaust air damper OPEN	Exhaust air damper CLOSED	Exhaust air damper OPEN	Exhaust air damper CLOSED
Supply air damper CLOSED	Supply air damper OPEN	Outside air damper OPEN	Supply air damper CLOSED
		Return air damper CLOSED	
		Reset static pressure control to maximize air flow and prevent duct failure	

Table 8: VAV smoke control settings

Smoke zone	Adjacent zones	Central VAV system	Remote zones on same central system
		Supply fan ON	
		Return fan ON	
Exhaust air damper OPEN	Exhaust air damper CLOSED	Exhaust air damper OPEN	Exhaust air damper CLOSED
Supply air damper CLOSED	Supply air damper OPEN	Outside air damper OPEN	Supply air damper CLOSED
	Terminal unit discharge damper OPEN	Return air damper CLOSED	
		Reset static pressure control to maximize air flow and prevent duct failure	

FSCS firefighter smoke control station

The FSCS, where required, is most often located in the building's fire command center. The FSCS is a remotely networked panel, which also contains an FSCS series graphic annunciator. Where the fire command center is also located in the building's central security center, an SCS with a graphic annunciator may also serve as the FSCS.

The FSCS series graphic annunciator, with network support hardware, is capable of providing both monitoring and manual control of smoke control system components. The graphic annunciator, when combined to the correct Signature Series modules, can be used by firefighters to start and stop fans and open and close dampers for smoke control. The system, while designed primarily for occupant protection and egress, can be used by firefighters to exhaust smoke and allow for effective fire attack and extinguishment by manual means.

VM-1 SCS

Smoke control systems, which are not interconnected as part of an VM-1 fire alarm network panel, constitute a stand-alone system. The descriptions of components which follow address a stand-alone smoke control system, but can also be applied to a FACP function with the smoke control system components sharing common inputs and hardware in the VM-1 fire alarm network panel.

Table 9: VM-1 components

Model	Description
CAB6B	Control panel back box
VMD(G/R)	Control panel door
VM-CPU	CPU main board and dual loop controller
C-CPUD	CPU daughter card
VM-LCD	LCD user interface
PS10-4B	Power supply
VM-NOC	Network option card, RS-485, 8 nodes, max.
VM-NOCF	Network option card, fiber optic, 8 nodes, max.
VM-ETH1	Ethernet adapter card
VM-DACT	Dual line dialer
VM-SLCXB	Signaling line loop controller expansion card
CLA-PS10	Class A NAC adapter card
D12LS-VM	Annunciator strip with 12 LED-switch groups. Each group consists of one switch and one programmable LED (amber, red, blue, or green) over an amber LED
VMI-PMI	Paging microphone interface
VM-MFK	Firefighter's telephone kit
ACHS	Audio channel selector cards
CDR-3	Coder module
RPM	Reverse polarity module
CTM	City tie module
GCI	Graphic annunciator interface card
GCI-NB	Graphic annunciator interface card
GCIX	Graphic annunciator expander card

FSCS series graphic annunciator

Description

The FSCS series graphic annunciator provides detailed information on the location of dampers, barriers, and fans. The graphic annunciator may display a single smoke zone, a floor, or an entire building. Panel control functions, tailored to firefighter smoke control needs, include the actual status of smoke control equipment and components, which are capable of activation. LED confirmation of individual fans sensed by pressure difference and indications of damper position can be designed into the graphic annunciator, the companion LCD display, and the LED switches. The FSCS series graphic annunciator receives its power from the VM-1 network.

Table 10: FSCS series graphic annunciator components

Model	Description
EV1B	Back box, 24 × 18 × 3.5 in. (610 × 458 × 89 mm)
EV2B	Back box, 24 × 24 × 3.5 in. (610 × 610 × 89 mm)
EV3B	Back box, 24 × 36 × 3.5 in. (610 × 915 × 89 mm)
EV4B	Back box, 36 × 48 × 3.5 in. (914 × 1219 × 89 mm)
3-EVRMF	Graphic annunciator inner door mounting bracket
EVZSLED	In-graphic LED, red, yellow, or green
EVZSBLED	In-graphic LED, blue
EVZSWLED	In-graphic LED, white
EVSC3-21	Two-position toggle switch
EVSC3-22	Two-position toggle switch
EVSC3-32	Three-position toggle switch
EVSC3-33	Three-position toggle switch
EVSC3R-21	Two-position rotary switch
EVSC3R-22	Two-position rotary switch
EVSC3R-32	Three-position rotary switch
EVSC3R-33	Three-position rotary switch
EVSC3R-44	Four-position rotary switch
EVKE	Enable key switch
EVPLED	Power LED
EVTLED	Trouble LED
EVSSLED	Signal silence LED
EVTS	Trouble silence switch
EVDRILL	Drill switch
EVLT	Lamp test push button
GCI	Graphic annunciator interface card
GCI-NB	Graphic annunciator interface card
GCIX	Graphic annunciator expander card

Fan control and monitor circuit

Figure 23 on page 38 shows a typical fan control and monitor circuit. During normal operation, the fan (item 1) is off and may be turned on by either the HVAC system or by the automatic fire detection system. During alarm operation, the automatic fire detection system activates the GSA-IO module (item 5), which energizes relay K1 and connects the line voltage to the fan.

The GSA-IO module (item 5) also monitors the air flow switch (item 2) used to signal when the fan reaches the required output capacity. The GSA-IO module activates a Monitor event when the switch closes or a Trouble event if the switch fails to close in the time allowed.

The GSA-IO module (item 6) monitors the air flow switch (item 3) used to signal when the fan is not operating. The GSA-IO module activates a Monitor event when the switch closes or a Trouble event if the switch fails to close in the time allowed.

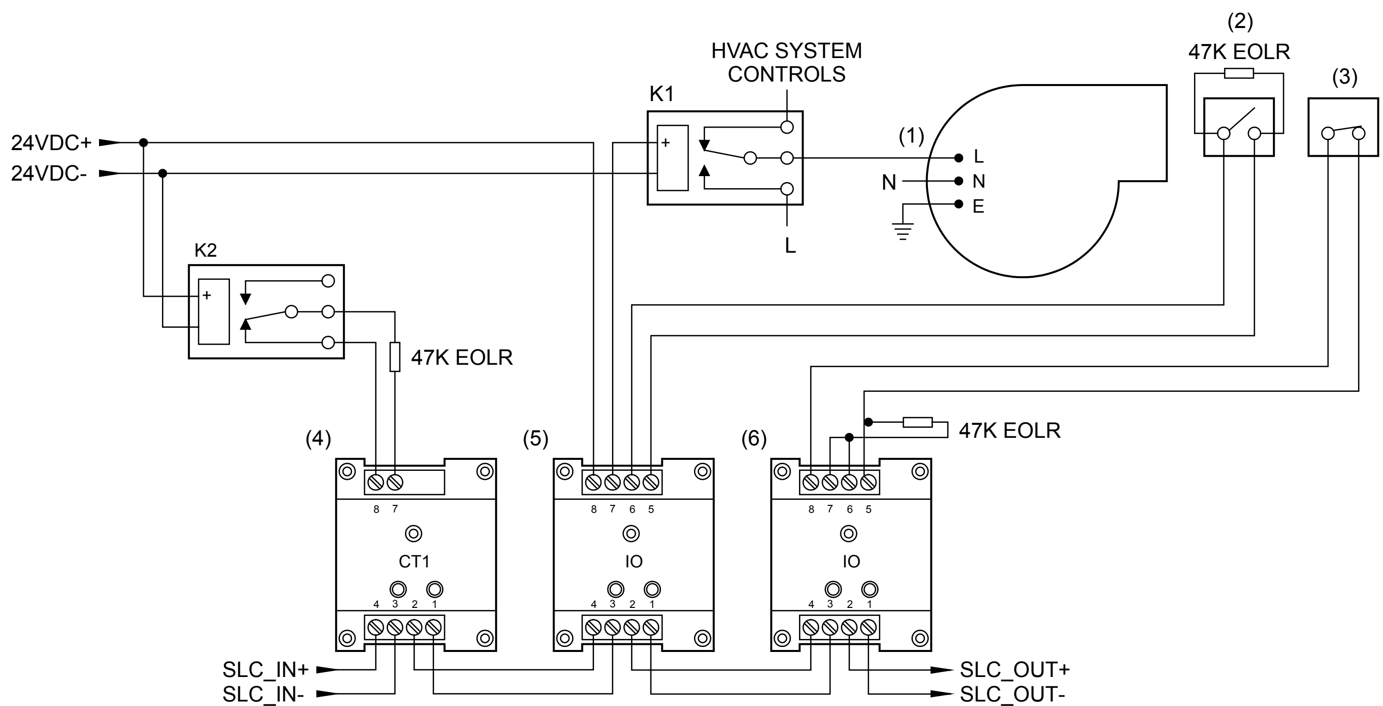
The GSA-CT1 module monitors the end-of-line power supervision relay (K2) and activates a Trouble event on loss of 24 VDC.

Notes

- Install relay K1 ahead of the HVAC system controller.
- The NFPA 72 Code requires that the wire distance between control devices and air handling units (AHUs) does not exceed 36 in. (91.44 cm).
- 24 VDC is from a regulated and filtered power supply that is UL/ULC Listed for fire protective signaling service.

- Set the Timer option on each GSA-IO module for the amount of time required for the fan to reach the required output but not more than 60 seconds.
- At startup, activate GSA-IO module (item 6).

Figure 23: Typical fan control and monitor circuit



Damper control and monitor circuit

Figure 24 on page 39 shows a typical damper control and monitor circuit. During normal operation, the damper is closed and may be opened by either the HVAC system or by the automatic fire detection system. During alarm operation, the automatic fire detection system activates the GSA-IO module (item 3), which energizes relay K1 and connects the line input voltage to the damper actuator (item 1).

The GSA-IO module (item 3) monitors the open limit switch on the damper actuator and activates a Monitor event when the switch closes or a Trouble event if the switch fails to close in the time allowed.

The GSA-IO module (item 4) monitors the closed limit switch on the damper actuator and activates a Monitor event when the switch closes or a Trouble event if the switch fails to close in the time allowed.

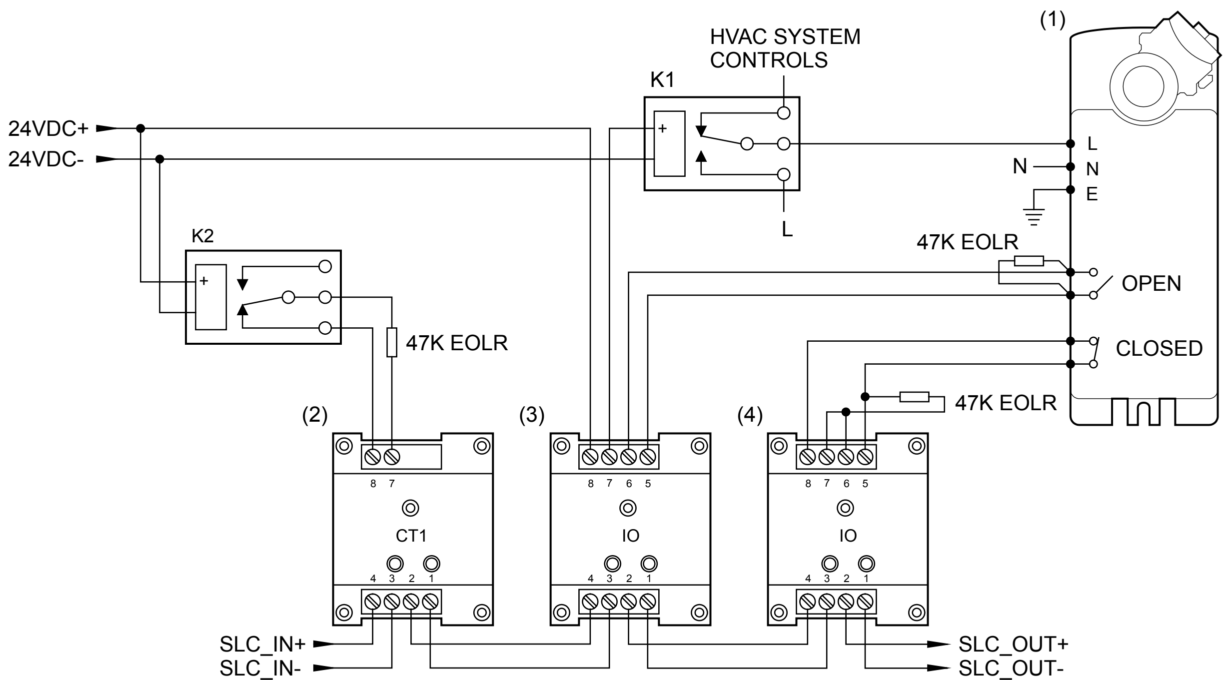
The GSA-CT1 module (item 2) monitors the end-of-line power supervision relay (K2) and activates a Trouble event on loss of 24 VDC.

Notes

- Install relay K1 ahead of the HVAC system controller.
- The NFPA 72 Code requires that the wire distance between control devices and air handling units (AHUs) does not exceed 36 in. (91.44 cm).
- 24 VDC is from a regulated and filtered power supply that is UL/ULC Listed for fire protective signaling service.

- Set the Timer option on the GSA-IO module for the amount of time required for the damper actuator to open or close, whichever is greater, but not more than 75 seconds.
- At startup, activate GSA-IO module (item 4).

Figure 24: Typical damper control and monitor circuit



Chapter 3
Smoke control system programming

Summary

This chapter provides information and procedures required to write correlations for smoke control system functions.

Content

Smoke control considerations and sequencing

System response time

Smoke control activation is to be initiated immediately after receipt of an appropriate automatic or manual activation command. Smoke control systems activate individual components such as fans and dampers in a sequence necessary to prevent physical damage to equipment. The total response time for individual components to achieve operational mode should remain within the limits set in NFPA 92A as a base requirement:

- 60 seconds for fan operation at smoke system design rate
- 75 seconds for isolating damper travel

The Uniform Building Code (UBC), one of the three model building codes in use in the US, establishes more restrictive limits on smoke control system response times. Section 905.14 of the UBC requires individual components to achieve their desired operating mode according to device:

Table 11: UBC response time requirements

Component	Response time
Control air isolation valves	Immediately
Smoke damper closing	15 seconds
Smoke damper openings	15 seconds maximum
Fan starting (energizing)	15 seconds maximum
Fan stopping (de-energizing)	Immediately
Fan volume modulation	30 seconds maximum
Pressure control modulation	15 seconds maximum
Temperature control safety override	15 seconds maximum
Positive indication of status	15 seconds maximum

Note: Local codes may require different response times.

System event processing bandwidth

The demand placed on the system event processing bandwidth cannot exceed 75% of the system response time requirement. If any of the bandwidth demands described below exceeds 75% of the system response time limit requirement, call Application Engineering for support.

Signature loop bandwidth demand

Each Signature loop can support a sustained rate of two events per second. Estimate the Signature loop bandwidth demand using the formula below.

$Ln[x] / 2 < TL \times 0.75$

where:

- Ln[x] is the number of events triggered by the operation on each loop [x]
- TL is the time limit

CPU board bandwidth demand

Each CPU board can support a sustained rate of 16 events per second. Estimate the CPU board bandwidth demand using the formula below.

$Cn[y] / 16 < TL \times 0.75$

where:

- Cn[y] is the number of events triggered by the operation on CPU board [y]
- TL is the time limit

Network bandwidth demand

The VM life safety network can support a sustained rate of 16 events per second at 38400 baud. Estimate the network bandwidth demand using the formula below.

$Nn / 16 < TL \times 0.75$

where:

- Nn is the total number of events triggered by the operation across the entire network
- TL is the time limit

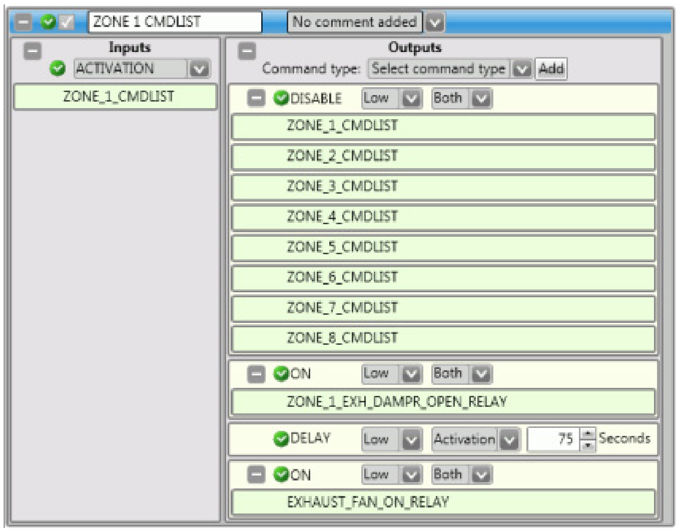
Activating the smoke control system

The fire detection system activates the smoke control system automatically when smoke is detected in a smoke control zone. A waterflow switch or heat detector can also activate the smoke control system as long as their piping and wiring are exclusive to the smoke control zone.

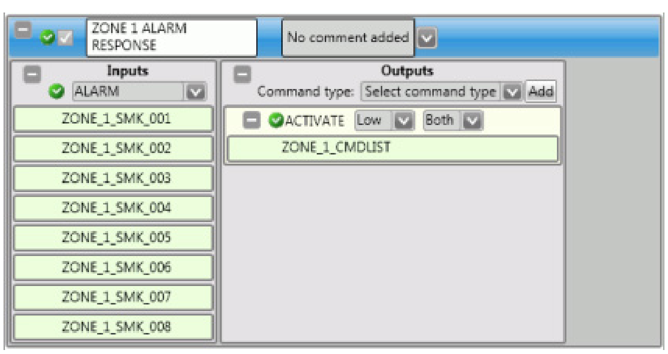
Only the response from the first active smoke control zone is used to automatically set damper positions and turn fans on or off according to the design of the smoke control system. After that, dampers and fans are controlled manually at the firefighters smoke control station (FSCS).

One way to prevent subsequent automatic responses from overriding the FSCS is by using command lists and the Disable command. The correlations below demonstrate using this approach on a smoke shaft exhaust system (see Figure 22 on page 32).

First, write a correlation like the one below for each smoke control zone. Note that the command list for zone 1 opens the damper for zone 1, the command list for zone 2 opens the damper for zone 2, and so on.



Second, write a correlation like the one below to activate the command lists.



Another method is to have all the smoke detectors in each smoke control zone activate a separate AND group, and then include commands in the active AND group's response to disable all of the other AND groups.

Interlocking fans and dampers

Interlocking is a way to prevent equipment damage by opening and closing dampers, and turning fans on and off in the proper sequence. For example, turning a supply fan on before the supply dampers are open may damage the supply duct and inhibit the smoke control system's ability to effectively control smoke.

The correlation inputs and outputs shown below can be used to create correlations that demonstrate how to program an exhaust fan interlock. Refer to Figure 23 on page 38 and Figure 24 on page 39.

Name: `EXHAUST FAN INTERLOCK – CORR 1`

Inputs:

```
Startup
```

Outputs:

```
ON, Low, Both, EXHAUST_FAN_OFF_RELAY
ON, Low, Both,
ZONE_1_EXH_DAMPR_CLOSE_RELAY
```

Name: `EXHAUST FAN INTERLOCK – CORR 2`

Inputs:

```
Alarm, ZONE_1_SMK_001
Alarm, ZONE_1_SMK_002
Alarm, ZONE_1_SMK_003
Alarm, ZONE_1_SMK_004
Alarm, ZONE_1_SMK_005
Alarm, ZONE_1_SMK_006
Alarm, ZONE_1_SMK_007
Alarm, ZONE_1_SMK_008
```

Outputs:

```
ON, Low, Activation,
ZONE_1_EXH_DAMPR_OPEN_RELAY
OFF, Low, Activation,
ZONE_1_EXH_DAMPR_CLOSE_RELAY
OFF, Low, Restoration,
EXHAUST_FAN_ON_RELAY
ON, Low, Restoration,
EXHAUST_FAN_OFF_RELAY
```

Name: `EXHAUST FAN INTERLOCK - CORR 3`

Inputs:
`Monitor, ZONE_1_EXH_DAMPR_OPEN_RELAY`

Outputs:
`ON, Low, Both, EXHAUST_FAN_ON_RELAY`
`OFF, Low, Both, EXHAUST_FAN_OFF_RELAY`

Name: `EXHAUST FAN INTERLOCK – CORR 4`

Inputs:
`Monitor, EXHAUST_FAN_OFF_RELAY`

Outputs:
`OFF, Low, Both,`
`ZONE_1_EXH_DAMPR_OPEN_RELAY`
`ON, Low, Both,`
`ZONE_1_EXH_DAMPR_OPEN_RELAY`

Indicating fan and damper status

The FSCS is required to provide LEDs for indicating fan and damper status. Typically, the LEDs are disabled until the FSCS has control of the smoke control system.

The correlation inputs and outputs shown below can be used to create correlations that demonstrate how to program fan and damper status indicators.

Name: `FSCS STATUS LEDS - CORR 1`

Inputs:
`Startup`

Outputs:
`Disable, Low, Both, FSCS_SW/LED_STRIP_2`

Name: `FSCS STATUS LEDS - CORR 2`

Inputs:
`Alarm, <all smoke control smoke detectors>`

Outputs:
`Enable, Low, Both, FSCS_SW/LED_STRIP_2`

Name: `FSCS STATUS LEDS - CORR 3`

Inputs:
`Monitor, SUPPLY_DAMPER_OPEN_RELAY`

Outputs:
`Steady, Low, Both, SUPPLY_DAMPER_OPEN_LED`

Name: `FSCS STATUS LEDS - CORR 4`

Inputs:
`Trouble, SUPPLY_DAMPER_OPEN_RELAY`

Outputs:
`Steady, Low, Both, SUPPLY_DAMPER_TRBL_LED`

Name: `FSCS STATUS LEDS - CORR 5`

Inputs:
`Monitor, SUPPLY_DAMPER_CLOSE_RELAY`

`Outputs:`
`Steady, Low, Both,`
`SUPPLY_DAMPER_CLOSE_LED`

Name: `FSCS STATUS LEDS - CORR 6`

Inputs:
`Trouble, SUPPLY_DAMPER_CLOSE_RELAY`

Outputs:
`Steady, Low, Both, SUPPLY_DAMPER_TRBL_LED`

`Steady, Low, Both, SUPPLY_DAMPER_TRBL_LED`

Name: `FSCS STATUS LEDS - CORR 7`

Inputs:
`Monitor, SUPPLY_FAN_ON_RELAY`

Outputs:
`Steady, Low, Both, SUPPLY_FAN_ON_LED`

Name: `FSCS STATUS LEDS - CORR 8`

Inputs:
`Trouble, SUPPLY_FAN_ON_RELAY`

Outputs:
`Steady, Low, Both, SUPPLY_FAN_TRBL_LED`

Name: `FSCS STATUS LEDS - CORR 9`

Inputs:
`Monitor, SUPPLY_FAN_OFF_RELAY`

Outputs:
`Steady, Low, Both, SUPPLY_FAN_OFF_LED`

Name: `FSCS STATUS LEDS - CORR 10`

Inputs:
`Trouble, SUPPLY_FAN_OFF_RELAY`

Outputs:
`Steady, Low, Both, SUPPLY_FAN_TRBL_LED`

Controlling fans and dampers manually

The FSCS is required to provide switches for controlling fans and dampers manually. Typically, the switches are disabled until the FSCS has control of the smoke control system.

The correlation inputs and outputs shown below can be used to create correlations that demonstrate how to program manual controls for a supply fan and supply damper. Refer to Figure 23 on page 38 and Figure 24 on page 39.

Name: `FSCS MANUAL CONTROLS - CORR 1`

Inputs:
`Startup`

Outputs:
```
Disable, Low, Both, FSCS_SW/LED_STRIP_1
Steady, Low, Both, SUPPLY_FAN_AUTO_SW_LED
Steady, Low, Both,
SUPPLY_DAMPER_AUTO_SW_LED
```

Name: `FSCS MANUAL CONTROLS - CORR 2`

Inputs:
```
Alarm, <all smoke control smoke
detectors>
```

Outputs:
`Enable, Low, Both, FSCS_SW/LED_STRIP_1`

Name: `FSCS MANUAL CONTROLS - CORR 3`

Inputs:
`Switch, SUPPLY_FAN_ON_SW`

Outputs:
```
LEDOFF, High, Both,
SUPPLY_FAN_AUTO_SW_LED
STEADY, High, Both, SUPPLY_FAN_ON_SW_LED
ON, Low, High, SUPPLY_FAN_ON_RELAY
```

Name: `FSCS MANUAL CONTROLS - CORR 4`

Inputs:
`Switch, SUPPLY_FAN_OFF_SW`

Outputs:
```
LEDOFF, High, Both,
SUPPLY_FAN_AUTO_SW_LED
STEADY, High, Both, SUPPLY_FAN_OFF_SW_LED
OFF, High, Both, SUPPLY_FAN_ON_RELAY
ON, High, Both, SUPPLY_FAN_OFF_RELAY
```

Name: `FSCS MANUAL CONTROLS - CORR 5`

Inputs:
`Switch, SUPPLY_DAMPER_OPEN_SW`

Outputs:
```
LEDOFF, High, Both,
SUPPLY_DAMPER_AUTO_SW_LED
STEADY, High, Both,
SUPPLY_DAMPER_OPEN_SW_LED
ON, High, Both, SUPPLY_DAMPER_OPEN_RELAY
```

Name: `FSCS MANUAL CONTROLS - CORR 6`

Inputs:
`Switch, SUPPLY_DAMPER_CLOSE_SW`

Outputs:
```
LEDOFF, High, Both,
SUPPLY_DAMPER_AUTO_SW_LED
STEADY, High, Both,
SUPPLY_DAMPER_CLOSE_SW_LED
OFF, High, Both, SUPPLY_DAMPER_OPEN_RELAY
ON, High, Both, SUPPLY_DAMPER_CLOSE_RELAY
```

Resetting the FSCS

The correlation inputs and outputs shown below can be used to create a correlation that demonstrates how to program a switch on the FSCS to perform a system reset.

Name: `RESET`

Inputs:

```
Switch, Cab01_Ann01_Exp01_SW01
```

Outputs:

```
ENABLE, Low, Both, All_Cabinets
```

Weekly self-testing

The correlation inputs and outputs shown below can be used to create a correlation that demonstrates how to program an automatic weekly self-test for a dedicated smoke control systems (i.e. stairwell pressurization systems).

Name: `WEEKLY SELF TEST 1`

Inputs:

```
Timecontrol, FAN_TEST_ZONE_W
```

Outputs:

```
ON, High, Both, ZONE_W_SUPPLY_DAMPER_OPEN
OFF, Low, Both, ZONE_W_SUPPLY_DAMPER_AUTO
STEADY, Low, Both,
ZONE_W_SUPPLY_DAMPER_ON_LED
DELAY, Low, Activation, 60 seconds
ON, High, Both, ZONE_W_SUPPLY_FAN_ON
OFF, High, Both, ZONE_W_SUPPLY_FAN_AUTO
STEADY, Low, Both,
ZONE_W_SUPPLY_FAN_ON_LED
```

HVAC and system control examples

Dedicated systems

Table 12 lists the sequence for a dedicated smoke control system.

Table 12: Dedicated smoke control stair tower

	Smoke control sequence commands	Objective
1	Open supply air dampers for smoke control	Provide a fresh air source to dilute smoke which may enter stair
2	Open exhaust air dampers for smoke zone	Outlet vent for air in stair
3	Start stair tower smoke exhaust fan	Pull air through exhaust damper
4	Monitor air flow and damper position at panel	Confirms system operation

Single zone smoke control systems with direct outside air and direct exhaust air

Table 13 lists the sequence for a single zone smoke control system with direct outside air and direct exhaust air.

Table 13: Single zone smoke control systems with direct outside air and direct exhaust air

	Smoke control sequence commands	Objective
1	AUTO OFF	Override all HVAC controls
2	Stop the smoke zone HVAC supply fan (Where fire is detected)	Reduce pressure development
3	Stop designated adjacent zone HVAC return fans	Keep out smoke
4	Close smoke zone supply air dampers	Stop smoke spread
5	Close adjacent zone return air dampers	Keep out smoke
6	Open exhaust dampers for smoke zone	Vent fire and develop negative pressure in smoke zone

	Smoke control sequence commands	Objective
7	Open outside air dampers for adjacent zone	Develop positive pressure and keep out smoke
8	Close exhaust dampers of adjacent zone systems	Develop positive pressure
9	Start smoke zone return fan	Maintain negative pressure
10	Start adjacent zone supply fan	Maintain positive pressure
11	Reset the static pressure control (if present) to maximum allowable value for all systems under active VM-1 SCS control	Monitoring and control
12	Monitor air flow and damper position at panel	Confirms system operation

Single zone smoke control with common outside air and exhaust air

Table 14 lists the sequence for a single zone smoke control system with common outside air and exhaust ducts.

Table 14: Single zone smoke control with common outside air and exhaust ducts

	Smoke control sequence commands	Objective
1	AUTO OFF	Override HVAC system
2	Stop the smoke zone HVAC supply fan (Where fire is detected)	Reduce pressure development
3	Close smoke zone supply air dampers	Isolate smoke zone
4	Stop designated adjacent zone HVAC return fans	Limit smoke spread
5	Close exhaust dampers of adjacent zone systems	Limit smoke spread
6	Stop supply and return fans of all remote zone systems on common outside air and exhaust ducts	Prevent smoke extension
7	Open (fully) common outside air damper	Allow for fresh air entry
8	Open (fully) common exhaust damper	Allow for exhausting smoke
9	Close return air dampers for the smoke zone	Prevent smoke back-flow and create negative pressure
10	Close return air dampers for adjacent zones	Keep out smoke
11	Open smoke zone exhaust damper	Vent smoke, create negative pressure
12	Turn on smoke zone return air fan	Vent smoke, create negative pressure in fire area
13	Open supply air dampers on adjacent zones	Provide fresh air
14	Turn on adjacent zone supply fans	Create positive pressure in zone
15	Turn on common system supply fan (if not previously activated)	Create positive pressure in zone
16	Turn on common system exhaust fan (if not previously activated)	Vent smoke, create negative pressure in fire area
17	Reset the static pressure control (if present) to maximum allowable value for all systems under active VM-1 SCS control	Monitoring and control
18	Monitor air flow and damper position at panel	Confirms system operation

Central system smoke control

Table 15 lists the sequence for a central system smoke control system.

Table 15: Central system smoke control

	Smoke control sequence commands	Objective
1	AUTO OFF	Overrides HVAC controls
2	Open central system outside exhaust air dampers	Reduce pressure development in smoke zone
3	Open central system outside supply air dampers	Limit smoke spread
4	Close central system return air dampers	Limit smoke spread
5	Close smoke zone supply air damper	Isolate smoke development
6	Open smoke zone exhaust air damper	Reduce pressure development
7	Close adjacent zone exhaust air dampers	Prepare zones for pressurization and limit smoke spread
8	Open fully adjacent zone supply air dampers	Prepare zones for pressurization and limit smoke spread

	Smoke control sequence commands	Objective
9	Close supply air dampers to remote zones on central system	Limit smoke spread
10	Close exhaust air dampers to remote zones on central system	Limit smoke spread
11	Start central system supply fan (if not currently on)	Pressurize adjacent zones
12	Start central system return fan (if not currently on)	Create negative pressure in smoke zone by exhausting smoke
13	Reset the static pressure control (if present) to maximum allowable value for all systems under active FSCS control	Monitoring and control
14	Monitor air flow and damper position at panel	Confirms system operation

Note: Multiple central systems serving portions of a fire floor will require sequencing for each central system command consistent with smoke control application

Dual duct smoke control system

Table 16 lists the sequence for a dual duct smoke control system.

Table 16: Dual duct smoke control

	Smoke control sequence commands	Objective
1	AUTO OFF	Overrides HVAC system
2	Open central outside exhaust damper	Reduce pressure development in smoke zone
3	Open central outside supply damper	Limit smoke spread
4	Close central return damper	Limit smoke spread
5	Reset duct static pressure controls to maximum design levels	Maximize air flow and prevent duct collapse or failure
6	Close smoke zone hot duct damper	Isolate smoke development
7	Close smoke zone cold duct damper	Isolate smoke development
8	Open smoke zone exhaust damper	Reduce pressure development
9	Close adjacent zone exhaust dampers	Prepare zones for pressurization and limit smoke spread
10	Open fully adjacent zone hot duct dampers	Prepare zones for pressurization and limit smoke spread
11	Open fully adjacent zone cold duct dampers	Prepare zones for pressurization and limit smoke spread
12	Configure adjacent zone mixing boxes for maximum air flow	Prepare zones for pressurization and limit smoke spread
13	Close hot dampers to remote zones on dual duct system	Limit smoke spread
14	Close cold dampers to remote zones on dual duct system	Limit smoke spread
15	Close exhaust air dampers to remote zones on dual duct system	Limit smoke spread
16	Start central system supply fan (if not currently on)	Pressurize adjacent zones
17	Start central system return fan (if not currently on)	Create negative pressure in smoke zone by exhausting smoke
18	Monitor air flow and damper position at panel	Confirms system operation

Note: Multiple dual duct systems serving portions of a fire floor will require sequencing for each dual duct system consistent with smoke control application.

Multi-zone smoke control

Table 17 lists the sequence for a multi-zone smoke control system.

Table 17: Multi-zone smoke control

	Smoke control sequence commands	Objective
1	AUTO OFF	Overrides HVAC controls
2	Open central multi-zone outside exhaust outside dampers	Reduce pressure development in smoke zone
3	Close central multi-zone return damper	Limit smoke spread
4	Reset duct static pressure controls to maximum design levels	Maximize air flow and prevent duct collapse or failure
5	Close smoke zone air supply damper	Isolate smoke development
6	Open smoke zone air exhaust damper	Reduce pressure development

	Smoke control sequence commands	Objective
7	Close adjacent zone exhaust dampers	Prepare zones for pressurization and limit smoke spread
8	Open fully adjacent zone supply air dampers	Prepare zones for pressurization and limit smoke spread
9	Close supply air dampers to remote zones on multi zone system	Limit smoke spread
10	Close exhaust air dampers to remote zones on multi zone system	Limit smoke spread
11	Start multi-zone system supply fan (if not currently on)	Pressurize adjacent zones
12	Start multi-zone system return fan (if not currently on)	Create negative pressure in smoke zone by exhausting smoke
13	Monitor air flow and damper position at panel	Confirms system operation

Note: Multiple dual duct systems serving portions of a fire floor will require sequencing for each dual duct system consistent with smoke control application.

Variable air volume (VAV) smoke control

Table 18 lists the sequence for a variable air volume (VAV) smoke control system.

Table 18: Variable air volume (VAV) smoke control

	Smoke control sequence commands	Objective
1	AUTO OFF	Overrides HVAC System
2	Open central VAV outside exhaust outside dampers	Reduce pressure development in smoke zone
3	Close central VAV return damper	Limit smoke spread
4	Reset duct static pressure controls to maximum design levels	Maximize air flow and prevent duct collapse or failure
5	Close smoke zone air supply damper	Isolate smoke development
6	Open smoke zone air exhaust damper	Reduce pressure development
7	Close adjacent zone exhaust dampers	Prepare zones for pressurization and limit smoke spread
8	Open fully adjacent zone supply air dampers	Prepare zones for pressurization and limit smoke spread
9	Close supply air dampers to remote zones on VAV system	Limit smoke spread
10	Close exhaust air dampers to remote zones on VAV system	Limit smoke spread
11	Start VAV system supply fan (if not currently on) and set for maximum allowable volume	Pressurize adjacent zones
12	Start VAV system return fan (if not currently on) and set for maximum allowable volume	Create negative pressure in smoke zone by exhausting smoke
13	Monitor air flow and damper position at panel	Confirms system operation

Note: Multiple VAV systems serving portions of a fire floor will require sequencing for each VAV system consistent with smoke control application.

Chapter 4
Smoke control acceptance and testing

Summary

Initial smoke control system turn on procedures and information concerning acceptance testing is provided in this chapter.

Content

Testing

Absence of a consensus agreement for a testing procedure and acceptance criteria for smoke control has historically created numerous problems at time of system acceptance, including delays in obtaining a certificate of occupancy.

The building owner, smoke control system designer, and VM-1 SCS designer/installer must agree upon the objective and design criteria for smoke control with the authority having jurisdiction (AHJ)at the planning stage of the project to help ensure testing requirements are consistent with the systems original design. VM-1 SCS design submittals for AHJ approval should include a procedure for acceptance testing in order that any programming or operational requirements set by the AHJ may be incorporated.

VM-1 SCS contract documents should include operational and acceptance testing procedures so that system and smoke control systems designers, installers, and the owner have an understanding of the system objectives and the testing procedure. The system designer, responsible for defining air flow rates, zones, and tenability will rely heavily upon the VM-SLC to provide detection of fire and control of components which compartmentalize or vent smoke.

Testing documentation

Upon completion of acceptance testing, a copy of all operational testing documentation should be provided to the owner and the AHJ. This documentation should be available for reference in periodic testing and maintenance. For integrated systems, installed in compliance with NFPA 72, records of all testing and maintenance shall be kept on the protected premises for a period of at least 5 years.

Smoke control panel acceptance test procedure

Once the system has been wired, programmed, and the circuit faults corrected, all installed components should be tested *as a system*, to ensure proper operation. Since most VM-1 SCSs will be integrated into an VM-1 fire alarm network, testing and acceptance may also need to comply with the requirements of NFPA 72. The FSCS, where installed, may also be integrated into the VM-1 fire alarm network and tested under NFPA 72.

The initial system check is designed to verify that all components of the system are installed and operating as designed. Verifying that the system was designed and installed according to specifications requires all aspects of the system to be exercised and the results verified. Where test results differ from those expected, corrective action must be taken.

Before commencing testing, notify all areas where the alarm sounds and off premise locations that receive alarm and trouble transmissions, if any, that testing is in progress.

Testing of the smoke control system will logically be performed as a part of the smoke control air flow and compartmentation testing. While flow rates of fans may be the responsibility of others, their operation is contingent upon proper installation and programming of the VM-1 SCS and FSCS. The test procedures reflect smoke control building component testing and smoke control system and FSCS testing divided into three categories based upon NFPA 92A and NFPA 92B test procedures:

- Component testing
- Acceptance testing
- Periodic testing and maintenance

Building component testing: The intent of building component testing is to establish that the final smoke control installation complies with the specified design, is functioning properly, and is ready for acceptance testing.

Prior to testing, the party responsible for this testing, normally the system designer, should verify completeness of building construction or compartmenting components including the following architectural features:

- Shaft integrity
- Firestopping or glazing which may enclose a large space
- Doors and closers related to smoke control
- Partitions and ceilings

The operational testing of each individual building system component is performed to determine if smoke zones or areas are complete exclusive of VM-1 SCS programmed commands. These operational tests normally will be performed by various trades before interconnection to the VM-1 SCS is made.

It should be certified in writing by the responsible trades that each system component's installation is complete and the component is functional including relays installed by others for interconnection to the VM-1 SCS. Each component test should be individually documented, including such items as speed, voltage, and amperage.

Because smoke control systems are usually an integral part of building operating systems, testing of the building system should include the following subsystems to the extent that they affect the operation of the smoke control system:

- Energy management system
- Building management and security system
- HVAC equipment
- Electrical equipment
- Temperature control system
- Power sources and standby power for fans and damper
- Automatic suppression systems
- Automatic operating doors and closures
- Emergency elevator operation

In most applications building control components to the smoke control system are required to operate from the building's emergency power system as a backup to primary power. The electrical load required for motors in fan control circuits and status indicators from the emergency power must be provided for in emergency power design.

VM-1 SCS/FSCS component testing: Components activated by the smoke control system to be tested include:

- Dedicated smoke control systems
- Nondedicated smoke control systems
- Fire alarm systems installed under NFPA 72

The FSCS series graphic annunciator must receive power from other sources. The cabinet does not contain batteries for emergency power.

Acceptance testing

The intent of acceptance testing is to demonstrate that the final integrated system installation complies with the specified design and is functioning properly. One or more of the following should be present to grant acceptance:

- Building system designer
- VM-1 SCS designer/installer
- AHJ

All documentation from component testing should be available for inspection.

Building test equipment

The following equipment may be needed to determine air flows and compartmentation as a part of smoke control acceptance testing:

- Differential pressure gauges, inclined water or electronic manometer
- Scale suitable for measuring door-opening force
- Anemometer, including traversing equipment
- Ammeter
- Flow-measuring hood (optional)
- Door wedges
- Tissue paper roll (for indicating direction of airflow)
- Signs indicating a test of the smoke control system is in progress
- Walkie-talkie radios for coordinating equipment

VM-1 SCS test equipment

Required Tools:

- Slotted screwdriver, insulated
- Digital multimeter
- 12 in. (30.5 cm) jumper lead with alligator clips
- Panel door key

Building test parameters

The following parameters need to be measured during acceptance testing:

- Total volumetric flow rate
- Airflow velocities and direction
- Door-opening forces
- Pressure differentials and ambient temperature

Smoke control test parameters

The following parameters need to be confirmed during acceptance testing:

- VM-1 SCS component control
- VM-1 SCS detection
- FSCS override and component control

Building component testing procedures

Prior to beginning acceptance testing, all building equipment should be placed in the normal operating mode, including equipment that is not used to implement smoke control, such as toilet exhaust, elevator shaft vents, elevator machine room fans, and similar systems.

Wind speed, direction, and outside temperature should be recorded on each test day.

If standby power has been provided for the operation of the smoke control system fans, louvers, or dampers, the acceptance testing should be conducted while on both normal and standby power. Disconnect the normal building power at the main service disconnect to simulate true operating conditions in this mode.

VM-1 SCS/FSCS test procedures

Smoke control acceptance testing should include demonstrating that the correct outputs are produced for each input of a control sequence specified. Consideration should be given to the following control sequences, so that the complete smoke control sequence is demonstrated:

- Normal mode
- Automatic smoke control mode for first alarm
- Second alarm annunciation without automatic override of first alarm
- Manual override of normal and automatic smoke control modes
- FSCS controls (where installed) override of all other system controls
- Return to normal

It is acceptable and desirable to perform acceptance tests for the fire alarm system in conjunction with the smoke control system. One or more device circuits on the fire alarm system could initiate a single input signal to the smoke control system.

A prepared smoke control system testing procedure should be developed to establish the appropriate number of initiating devices and initiating device circuits to be operated to demonstrate the smoke control system operation for the AHJ's approval. The section titled "Other test methods" in this chapter contains additional information on test methods which may come under AHJ consideration for acceptance testing.

Initial acceptance testing for primary power supplies

The following steps are required for a VM-1 SCS.

1. Verify that all components are installed in workman like manner.
2. Verify adequate separation between power-limited and nonpower-limited wiring.
3. Verify that the installed batteries are the proper capacity for the application including the FSCS series graphic annunciators, where installed.
4. With the batteries disconnected, verify that the supply's full alarm load can be sustained by the power supply without the batteries connected. (Temporarily jumper the positive battery terminal to the positive auxiliary output to remove the battery trouble.)
5. With the batteries connected, disconnect the AC source and verify that a power supply trouble is annunciated, and that the supply's full alarm load can be sustained by the batteries. The full alarm load may include the FSCS.
6. Verify that the battery charger properly charges the batteries to 80% capacity within 24 hours.

Initial acceptance testing for CPU panel controller module with LCD display module

1. Verify the CPU is properly installed on the chassis and its mounting plungers securely in place, and that the LCD is properly installed on the CPU and its mounting screws tightened. Verify that removable terminal strips TB1 and TB2 are firmly seated.
2. Verify that all components are installed in workmanlike manner.
3. Verify that the correct date and time are displayed on the LCD display, and the Power LED is on.
4. Activate the lamp test function: Main Menu > Test > Lamp Test. Verify that all LEDs on the graphic panel light.
5. Initiate an alarm. Verify that the Alarm LED flashes, the alarm relay transfers, the correct device message appears at the top of the LCD window, the active point counter increments, the event sequence indicates a 1, the active Alarm events counter at the bottom of the display indicates 0001, the event type indicates Alarm, and the local panel buzzer sounds. The graphic annunciator panel alarm LED and zone LED will light, also.

   Access Main Menu > Test > VM Device Test > Alarm, and enter a panel, card, and device address. Verify that the Alarm LED flashes.

   Press the ACK/Panel Silence button. Verify that the panel buzzer silences, the ACK/Panel Silence LED lights, and the Alarm LED lights steady.

   Press the Alarm Silence button. Verify that the required notification appliances are silenced.

   Press the Details button. Verify that the alarm device's details message, if any, displays.

   If a printer is connected to the CPU, verify that all specified information appears on the printer.
6. Initiate a second alarm in another smoke control zone. Verify that it appears at the bottom of the LCD window, the active point counter changes, the event sequence indicates a 2, the active Alarm events counter at the bottom of the display indicates 0002, the event type indicates alarm, the Alarm LED flashes, the local panel buzzer sounds, and the *first* alarm message remains at the top of the LCD window.

   Press the ACK/Panel Silence button. Verify that the Alarm LED lights steady.
7. Initiate a third alarm in a remaining area. Verify that its message appears at the bottom of the LCD window, the active point counter changes, the event sequence indicates a 3, the active Alarm events counter at the bottom of the display indicates 0003, the event type indicates Alarm, the local panel buzzer sounds, and the alarm message remains at the top of the LCD window.
8. Use the up and down buttons to verify that you can scroll through all three messages in the Alarm queue, as indicated by the event sequence window.
9. Press the Reset button. Verify that all initiating devices reset and that all panel indicators clear except the green power LED on the panel or remote annunciator CPU, and the graphic annunciator panel.
10. Initiate an active monitor condition. Verify that the Monitor LED flashes, the correct active monitor device message appears in the top and bottom of the LCD window, the active point counter changes, the event sequence indicates a 1, the active Monitor events counter at the bottom of the display indicates M001, and the event type indicates Monitor.

    Press the ACK/Panel Silence button. Verify that the Monitor LED lights steady.
11. Initiate a second active monitor condition. Verify that the first monitor message remains at the top of the LCD window, the second monitor message appears at the bottom of the window, the active point counter changes, the event sequence indicates a 2, and the active Monitor events counter at the bottom of the window indicates 0002.
12. Initiate an active trouble condition. Verify that the Trouble LED flashes, the correct active trouble device message appears in the top and bottom of the LCD window, the trouble relay transfers, the active point counter changes, the event sequence indicates a 1, the active Trouble events counter at the bottom of the window indicates 0001, the event type indicates Trouble, and the local panel buzzer sounds. The graphic annunciator panel general trouble LED will light, also.

Press the ACK/Panel Silence button. Verify that the panel buzzer silences, the ACK/Panel Silence LED lights, and the Trouble LED lights steady.

On the graphic annunciator panel the Panel Silence and Reset button should be activated, also.

13. Initiate a second active trouble condition. Verify that the first trouble message remains at the top of the LCD window, the second trouble message appears at the bottom of the window, the active point counter changes, the event sequence indicates a 2, and the active Trouble events counter at the bottom of the display indicates 0002.
14. Initiate an active supervisory condition. Verify that the Supervisory LED flashes, the correct active supervisory device message appears in the top and bottom of the LCD window, the local panel buzzer sounds , the supervisory relay transfers, the active point counter changes, the event sequence indicates a 1, the active Supervisory events counter at the bottom of the window indicates 0001, and the event type indicates Supervisory.

    Press the ACK/Panel Silence button. Verify that the Supervisory LED lights steady.
15. Initiate a second active supervisory condition. Verify that the first supervisory message remains at the top of the LCD window, the second supervisory message appears at the bottom of the window, the active point counter changes, the event sequence indicates a 2, and the active Supervisory events counter at the bottom of the window indicates 0002.
16. Initiate an active alarm. Verify that the Alarm LED flashes, the correct fire alarm/smoke control message appears in the top and bottom of the LCD window, the active point counter changes, the event sequence indicates a 1, the active alarm events counter at the bottom of the window indicates 0001, and the event type indicates Alarm.

    Press the ACK/Panel Silence button. Verify that the Alarm LED lights steady.
17. Initiate a second alarm condition, Verify that the first alarm message remains at the top of the LCD window, the second alarm message appears at the bottom of the window, the active point counter changes, the event sequence indicates a 2, and the active alarm events counter at the bottom of the display indicates 0002.
18. LEDs for operation of smoke control components in 1 through 11 above are also contained on the graphic annunciator panel and must be confirmed for each device.
19. Press the Reset button on the LCD and graphic annunciator panel. Verify that all devices reset and the panel returns to the normal condition.

Initial acceptance testing for a VM-NOC card, class B configuration

1. Verify that the card is properly installed on the CPU and secured with the nylon screw.
2. For smoke control panels that are networked, start with the network in the normal condition and use the status command to verify all connected cabinets are communicating over the network.
3. Disconnect the network data communications wiring from the cabinet with the primary LCD module. Verify that all the other system cabinets connected to the network appear in the trouble queue.

Initial acceptance testing for a VM-NOC card, class A configuration

1. Verify that the card is properly installed on the CPU and secured with the nylon screw.
2. For smoke control panels that are networked, start with the network in the normal condition and use the status command to verify all connected cabinets are communicating over the network.
3. Disconnect the network data communications wiring from the cabinet with the primary LCD module. Verify that a Class A network data communications fault is annunciated. Repeat step 2 to verify that all connected cabinets are still communicating over the network.

Initial acceptance testing for a VM-SLCXB card

1. Verify that the card is properly installed on the chassis and its mounting standoffs securely in place. Verify that the loop controller removable terminal strips are firmly seated.
2. Verify the wiring to all V-Series and Signature devices.
3. Map the signaling line circuit by reading the device data; adjusting, modifying, and accepting devices as

required; writing the information back to the devices; and re-reading the device data.

4. With no map errors displayed, put an input device on the circuit in the active mode. Verify the appropriate message is displayed on the LCD module and graphic annunciator, where installed. Put the input device in the trouble mode and verify that the correct trouble message is displayed.

Initial acceptance testing for LED displays, VM-1 SCS panels, and FSCS series graphic annunciators

1. Verify that the displays are properly installed on the SCS panel module and in the graphic annunciator panel. Verify that the ribbon cable between the display and its host module is firmly seated on both ends.
2. For the SCS panel perform a lamp test: Main Menu > Test > Lamp Test.

   For the graphic annunciator panel press the momentary button.

Initial acceptance testing for control/LED displays, VM-1 SCS panels, and FSCS series graphic annunciators

1. Verify that the displays are properly installed on the SCS panel module or graphic annunciator panel. Verify that the ribbon cable between the display and its host module is firmly seated on both ends.
2. For the SCS panel perform a lamp test: Main Menu > Test > Lamp Test.

   For the graphic annunciator panel press the Lamp Test button.
3. Perform a functional button test.

VM-1 SCS detection acceptance testing

The procedures listed in this section should be performed on the detectors, input modules, output modules, and related accessories connected to each cabinet. Additional procedures for manual initiating devices may be found in “Smoke control input modules” on page 58. These procedures are presented to test the devices and smoke control system programming.

Note: The network configuration, control module information must be downloaded into the network and the audio controller, using the software configuration utility, before testing begins.

Every detector connected to the smoke control system should be visited, and manually activated during the installation process to verify that:

- The location meets design parameters for spacing and air flow.
- The location annunciated by the smoke control system agrees with the physical location of the device.
- That the activated device initiates the correct smoke control system response.

Initial acceptance testing for V-Series and Signature Series detectors and bases

1. Verify that all components are installed in a workman like manner.
2. Individually activate each detector. Verify that the appropriate alarm and location message is displayed on the LCD module. Verify that the detector initiates the appropriate system responses. If the detector is installed in a relay base, verify that the base’s relay function operates correctly. If the detector is installed in an isolator base, verify that the base isolates the required circuit segments.
3. Duct mounted detectors should be tested to verify that minimum and maximum airflow requirements are met and that smoke control actions or overrides are functioning.
4. Remove the detector from its base. Verify that the appropriate trouble and location message is displayed on the LCD module.
5. After all detectors have been individually inspected, run a Sensitivity report, using the Reports command.

Initial acceptance testing for conventional smoke detectors on a GSA-UM(-MAB)

1. Verify that all components are installed in a workmanlike manner.
2. Verify that jumper JP1 on each UM or MAB module is installed across pins 1 and 2.

3. Individually activate each detector. Verify that the appropriate alarm and location message is displayed on the LCD module. Verify the UM or MAB initiates the appropriate system responses.
4. Duct mounted detectors should be tested to verify that minimum and maximum airflow requirements are met and that smoke control actions or overrides are functioning.
5. Remove the detector from its base. Verify that the appropriate trouble and location message is displayed on the LCD module.

Initial acceptance testing for beam detectors

1. Test the detector at the receiver.
2. Use test cards and obscuration filters supplied with the unit's installation kit.
3. Follow installation instructions for testing for total obscuration and then use filters to verify sensitivity.

Smoke control input modules

Every input module connected to the smoke control system should be visited, and manually activated during the installation process to verify that:

- The installed location of the initiating device connected to the module meets proper engineering practices.
- The location annunciated by the system agrees with the physical location and function of the initiating device.
- The initiating device/module activates the correct smoke control system response.

Initial acceptance testing for Signature Series input modules

1. Verify that all components are installed in a workmanlike manner.
2. Individually activate each initiation device. Verify that the appropriate circuit type and location message is displayed on the LCD and graphic annunciator. Verify that the circuit initiates the appropriate system responses.
3. Open the circuit. Verify that the appropriate circuit trouble and location message is displayed on the LCD module.

Initial acceptance testing for manual stations (for stairwell pressurization only)

1. Verify that all components are installed in a workmanlike manner.
2. Activate the mechanism.
3. Verify that the appropriate circuit type and location message is displayed on the LCD module. The graphic annunciator panel, tailored to each installation may use only a single alarm LED to indicate multiple device conditions. Verify that the device initiates the appropriate smoke control system zone and design response.
4. Open the circuit. Verify that the appropriate trouble and location message is displayed on the LCD.

Smoke control output modules

Every output module connected to the system should be visited, and manually activated during the installation process to verify that:

- The installed location of the controlled device meets proper engineering practices.
- The location of the controlled device annunciated by the system agrees with the physical location of the device.
- The device is activated by the correct system inputs.

Initial acceptance testing for Signature series output modules

1. Verify that all components are installed in a workman like manner.
2. Using the Activate Output command, individually activate each output. Verify that the device responds appropriately and the LED and graphic annunciator LEDs light.
3. For supervised output circuits, open up the circuit. Verify that the appropriate circuit trouble and location message is displayed on the LCD module.

4. If the output is activated by one or more system inputs, activate these inputs and verify that the output priority function operates appropriately.
5. Confirm sequential operation for output modules connected to fans, dampers, and doors.

Weekly testing of dedicated smoke control systems

1. Programming for the SCS must include a weekly test of dedicated systems and their components.
2. Results of automatic testing should verify that all components operate in the programmed sequence.
3. The program, at the designated time, must automatically activate the output command for each of the system inputs, verifying were necessary that dampers (and other compartmenting components) have opened or closed and fans have started or stopped.
4. A record of the automatic test sequences and results must be maintained at the location of the VM-1 SCS.

Dedicated systems

Zoned smoke control and atrium systems

Verify the exact location of each smoke control zone and the door or other openings in the perimeter of each zone. If the building plans do not specifically identify them, the smoke control system may have to be activated in zones so that any magnetically held doors will close and identify smoke zone boundaries.

For the building components verification, the component designer should measure and record the pressure difference across all smoke control zones that divide a floor. The measurements should be made while the HVAC systems serving the floor's smoke zones are operating in their normal (i.e. non-smoke control) mode. The measurements should be made while all smoke barrier doors that divide a floor into zones are closed. A measurement should be made across each smoke barrier door or set of doors, and the resulting data should clearly indicate the higher and lower pressure sides of the doors.

Using smoke control input devices, verify the proper activation of each zoned smoke control system in response to all means of activation, both automatic and manual, as specified in the contract documents. Where automatic activation is required in response to alarm signals received from the building's smoke control system, each separate alarm signal should be initiated to ensure that proper automatic activation of the correctly zoned smoke control system occurs. Automatic weekly testing of dedicated systems should be conducted to verify all components operate as installed and programmed and that the test time is agreeable to the building owners. Verify confirming indications, documenting the proper operation of all fans, dampers, and related equipment for each separate smoke control system zone.

Activate the zoned smoke control system that is appropriate for each separate smoke control zone. Measure and record the pressure difference across all smoke barrier doors that separate the smoke zone from adjacent zones. The measurements should be made while all smoke barrier doors that separate the smoke zone from the other zones are fully closed. One measurement should be made across each smoke barrier door or set of doors, and the data should clearly indicate the higher and lower pressure sides of the doors. Doors that have a tendency to open slightly due to the pressure difference should have one pressure measurement made while held closed and another made when unrestrained.

Continue to activate each separate smoke control zone and make pressure difference measurements. Ensure that after testing a smoke zone it is properly deactivated and the HVAC systems involved return to their normal operating mode prior to activating another zone's smoke control system. Also ensure that control verifying damper and fan operation necessary to prevent excessive pressure differences are functioning to prevent damage to ducts and related building equipment. Component testing should have previously verified operation of fans, dampers, doors, and other smoke control equipment.

Stair tower pressurization systems

The building system designer, with all building HVAC systems in normal operation, should measure and record the pressure difference across each stair tower door while the door is closed. After recording the pressure difference across the door, measure the force necessary to open each door, using a spring-type scale. The building system designer should establish a consistent procedure for recording data throughout the entire test . The stair tower side of the doors will always be considered as the reference point and the floor side of the doors will always have the pressure difference value (positive if higher than the stair tower and negative when less than the stair tower). Since the stair tower pressurization system is intended to produce a positive pressure within the stair tower, all negative pressure values recorded on the floor side of the doors indicate a potential airflow into the floor.

The VM-1 system designer, working with the building system designer, should verify the proper activation of the stair tower pressurization systems in response to all means of activation, both automatic and manual, as specified in the contract documents. Where automatic activation is required in response to alarm signals received from the building's smoke control system, each separate alarm signal should be initiated to ensure that proper automatic activation occurs. Automatic weekly testing of dedicated systems should be conducted to verify all components operate as installed and programmed and that the test time is agreeable to the building owners. Verify and document the proper operation of all fans, dampers, indicators, and related equipment for each separate smoke control system zone.

With the stair tower pressurization system activated, the building system designer should measure and record the pressure difference at points similar to those evaluated in zoned smoke control and atrium systems.

After recording the pressure difference across each closed door, measure the force necessary to open each door. Use the established procedure to record data throughout the test. The local code and contract documents should be followed regarding the door to be opened for this test.

With the stair tower pressurization system activated, open the doors required by the system design, one at a time, and measure and record the pressure difference across each remaining closed stair tower doors after the opening of each additional door. After recording the pressure difference across each closed door, measure the force necessary to open each door. Use the established procedure to record data throughout the test. The local code and contract document requirements should be followed regarding the number and location of doors that need to be opened for this test.

With the stair tower system activated, and all required doors open, determine and record the direction of airflow through each of the open doors. This can be done by using a small amount of smoke at the open doorway. If velocity measurements are required, a door opening traverse needs to be performed with the door fully open.

Stairwell pressurization systems typically have a smoke detector at the stair intake to stop fans should smoke begin to enter from the outside. There must be a manual override on the system to keep fans operating should a qualified emergency person determine that the smoke infiltration is minor. Testing of the override feature should be in the acceptance procedure.

Elevator shaft pressurization systems

Shaft systems may incorporate exhausting of air from the fire floor, pressurization of elevator lobbies, pressurization of the elevator hoistway or by construction of smoke tight elevator lobbies with pressurization. The type or combination of designs will dictate system operation and testing. Elevator recall and the use of elevators while the shaft or lobby is pressurized will be an integral part of the test procedure developed.

The piston effect due to car movement on elevator shaft pressurization has been researched and is discussed in several of the texts referenced in Chapter 1. There are no recommended tests to determine how shaft pressurization might be impacted with car movement. Elevator door testing currently assumes a median value for pressures developed against a door independent of car movement. No dynamic testing of the shaft pressurization system with car movement is therefore dictated.

The building system designer must define smoke control sequences for design and testing and measure and record pressure differences in a manner similar to those described for stairwells.

Using smoke control input devices, verify the proper activation of the shaft pressurization system in response to all means of activation, both automatic and manual, as specified in the contract documents. Where automatic activation is required in response to alarm signals received from the building smoke control system, each separate alarm signal should be initiated to ensure that proper automatic activation occurs.

With the elevator shaft pressurization system activated, measure and record the pressure difference across each shaft or lobby door with all doors closed.

If an elevator door is held open due to recall, measure and record the pressure difference across each remaining closed door. Use an established procedure to record data throughout the entire test. The local code and contract documents should be followed regarding the elevator recall door to be opened or closed for this test.

With the elevator shaft system activated, determine and record the direction of airflow through each of the shaft or elevator lobby doors. This can be done by using a small amount of smoke at the doors.

Additional considerations

Other test methods

The test methods presented in this chapter provide an adequate means to evaluate a smoke management system's performance. Historically, other test methods have been used in instances where the authority having jurisdiction requires additional testing. These test methods have limited value in evaluating certain system performance, and their validity as a method of testing a smoke management system is questionable.

As covered in the Chapter 1 of this manual, the dynamics of the fire plume, buoyancy forces, and stratification are all major critical elements in the design of the smoke management system. Therefore, to test the system properly, a real fire condition would be the most appropriate and meaningful test. There are many valid reasons why such a fire is usually not practical in a completed building. Open flame or actual fire testing might be dangerous and should not normally be attempted. Any other test is a compromise. If a test of the smoke control system for building acceptance is mandated by the authority having jurisdiction, such a test condition would become the basis of design and might not in any way simulate any real fire condition. More importantly, it could be a deception and provide a false sense of security that the smoke control system would perform adequately in a real fire emergency.

Smoke tests do *not* provide the heat, buoyancy, and entrainment of a real fire and are *not* useful in evaluating the real performance of the system. A system designed in accordance with this manual and capable of providing the intended smoke control might not pass smoke tests. Conversely, it is possible for a system that is incapable of providing the intended smoke control to pass smoke tests. Because of the impracticality of conducting real fire tests, the acceptance tests described in this manual are directed to those aspects of smoke control systems that can be verified and are consistent with current research and testing in the fire protection field.

Examples of other test methods that have been used with limited effectiveness are chemical smoke tests, tracer gas tests, and real fire tests.

VM-1 SCS owner's manual and instructions

Information should be provided to the owner that defines the operation and maintenance of the smoke control system. Basic instruction on the operation of the smoke control system should be provided to the owner's representatives. Since the owner may assume beneficial use of the smoke control system upon completion of acceptance testing, this basic instruction should be completed prior to acceptance testing and the owner's representative who will have a maintenance responsibility should also be present.

Partial occupancy

Acceptance testing should be performed as a single step when obtaining a certificate of occupancy. However, if the building is to be completed or occupied in stages, multiple acceptance tests may have to be conducted in order to obtain temporary certificates of occupancy.

Modifications

All operational and acceptance tests should be performed on the applicable part of the system upon system changes and modifications. Documentation should be updated to reflect changes or modifications.

Periodic testing

During the life of the building, maintenance is essential to ensure that the smoke control system will perform its intended function under fire conditions. Proper maintenance of the system should, as a minimum, include the periodic testing of all smoke control equipment including VM-1 SCS controls, initiating devices, fans, dampers, controls, doors, and windows. The equipment should be maintained in accordance with the manufacturer's recommendations. Refer to NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*, for suggested maintenance practices for nondedicated HVAC and damper requirements. NFPA 92A, NFPA 92B, and NFPA 72 should be consulted for smoke control panel testing.

These tests should be performed on a periodic basis to determine that the installed system continues to operate in accordance with the approved design.

The smoke control system should be tested in accordance with the following schedule by persons who are thoroughly knowledgeable in the operation, testing, and maintenance of the systems. The results of the tests should be documented in the operations and maintenance log and made available for inspection upon request.

Dedicated Systems

Weekly: Automatic testing every seven days of dedicated systems will operate all components. Automatic tests must be recorded, with failure of any monitored components noted.

Semiannually: Operate the smoke control system for each control sequence in the original design and observe the operation of the correct outputs for each given input. Tests should be conducted under standby power, if applicable.

Nondedicated Systems

Annually: Operate the smoke control system for each control sequence in the approved configuration and observe the operation of the correct output for each given input. Tests should be conducted under standby power, if applicable.

Special arrangements might have to be made for the introduction of large quantities of outside air into occupied areas or computer centers when outside temperature and humidity conditions are extreme. Since smoke control systems override limit controls, such as freezestats, tests should be conducted when outside air conditions will not cause damage to equipment and systems.

Glossary

AHJ: Acronym for authority having jurisdiction.

ASHRAE: Acronym for the American Society of Heating, Refrigerating, and Air-conditioning Engineers.

automatic control: A system operating in this mode will initiate smoke control measures without personnel intervention due to a fire detection system actuation.

atrium: A large-volume space created by a floor opening or series of floor openings connecting two or more stories that is covered at the top of the series of openings and is used for purposes other than an enclosed stairway, elevator hoistway, escalator opening, or utility shaft used for plumbing, electrical, air-conditioning, or communications facilities.

buoyancy: The ability or tendency of smoke to rise in air.

communicating space: Spaces within a building that have an open pathway to a large-volume space such that smoke from a fire in the communicating space can move unimpeded into the large-volume space. Communicating spaces can open directly into the large-volume space or can connect through open passageways.

compensated system: A smoke control system where the air injected into a stairwell is modulated or excess pressure is vented depending upon the number of doors opened or closed in the stairwell. This keeps the pressure barrier relatively constant.

covered mall: A large-volume space created by a roofed-over common pedestrian area in a building enclosing a number of tenants and occupancies. Covered malls may include retail stores, drinking establishments, entertainment and amusement facilities, offices, or other similar uses where tenant spaces open onto or directly communicate with the pedestrian area.

dedicated system: A smoke control system designed for the sole purpose of controlling smoke within a building. Equipment is not linked to the building HVAC system. This is accomplished by installing a system for air movement that is separate and distinct from the building's HVAC system and only operates to control smoke.

FSCS: Acronym for firefighter's smoke control station. See also, *firefighter's smoke control station.*

firefighter's smoke control station (FSCS): Includes monitoring and over-riding capability over smoke control systems and equipment provided at designated locations within the building for the use of the fire department. Other firefighter's systems not required for smoke control (voice alarm, public address, fire department communication, and elevator control and status) may be at the same location.

HVAC: Acronym for heating, ventilation, and air-conditioning.

large-volume space: A space, generally two or more stories in height, within which smoke from a fire either in the space or in a communicating space can move or accumulate without restriction. Atriums and covered malls are examples of large-volume spaces.

manual control: A smoke control system operates in this state when controls for the station are changed manually to override automatic control functions.

noncompensated system: A smoke control system in which a single speed fan provides pressurization in a stairwell. Pressure will vary depending upon the number of doors opened in the stairwell.

nondedicated system: A smoke control system that shares components with other air moving equipment. When the smoke control mode is activated, the operating of the building's air moving equipment changes in order to accomplish the objectives of the smoke control design.

pressurized stairwell: A type of smoke control system in which stair shafts are mechanically pressurized with outdoor air to keep smoke from contaminating them during a fire event.

SCS: Acronym for smoke control system. See also *smoke control system.*

separated spaces: Spaces within a building that are isolated from large-volume spaces by smoke barriers that do not rely on airflow to restrict the movement of smoke.

smoke: The airborne solid and liquid particulates and gases evolved when a material undergoes pyrolysis or combustion, together with the quantity of air that is entrained or otherwise mixed into the mass.

smoke barrier: A membrane, either vertical or horizontal, such as a wall, floor, or ceiling assembly, that is designed and constructed to restrict the movement of smoke. A smoke barrier might or might not have a fire resistance rating.

smoke control mode: A predefined operational configuration of a system, zone, or device for the purpose of smoke control.

smoke control system: An engineered system that uses mechanical fans to produce airflow and pressure differences across smoke barriers to limit and direct smoke movement.

smoke damper: A UL Listed device designed to resist the passage of air or smoke. Smoke dampers are installed in ducts or smoke barriers separating floor or smoke zones. A fire barrier constructed to limit smoke may also serve as a smoke barrier and may use a combination fire and smoke damper that is also UL Listed. Systems serving more than one floor with a capacity greater than 15,000 cfm are required by NFPA 90A to have smoke dampers installed to isolate the air handling equipment, including filters, to restrict the circulation of smoke.

smoke exhaust system: A mechanical or gravity system intended to move smoke from a smoke zone to the exterior of a building, including smoke removal, purging, and venting systems, as well as the function of exhaust fans utilized to reduce the pressure in a smoke zone.

smoke proof enclosure: A continuous stairway which is enclosed from top to bottom by a 2-hour firewall and exits to the exterior of a building. Entry into the stairway must be through vestibules or outside balconies on each floor. The design must limit smoke entry and include ventilation which is natural or mechanical.

smoke zone: The smoke control zone in which the fire is located.

stack effect: The vertical airflow within buildings caused by the temperature-created density differences between the building interior and exterior or between two interior spaces.

tenable environment: An environment in which smoke and heat is limited or otherwise restricted in order to maintain the impact on occupants to a level that is not life threatening. In a zoned smoke control system, pressure differences are used to maintain a tenable environment in an area intended to protect building occupants while evacuation is taking place.

UBC: Acronym for uniform building code.

UUKL: The Underwriters Laboratories (UL) complementary product category designation for smoke control system equipment.

VAV: Acronym for variable air volume.

zoned smoke control: A smoke control system that includes smoke exhaust for the smoke zone and pressurization for all contiguous smoke control zones. The remaining smoke control zones in the building also may be pressurized.