

FAIRFAX COUNTY GUIDELINES FOR SMOKE CONTROL SYSTEMS

Virginia Construction Code 2015

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TABLE OF CONTENTS

Table of Contents	2
Smoke Control System (Smoke Containment and Smoke Management – VCC 2015)	3
General Requirements for Smoke Control Systems	5
Rational Analysis (VCC 909.4)	5
Fire and Smoke Barriers (VCC 404.6 & 909.5).....	6
Design Fire (VCC 909.9).....	6
Equipment (VCC 909.10).....	6
Power System (VCC 909.11).....	6
Detection and Control (VCC 909.12).....	7
Control Air Tubing (VCC 909.13)	7
Marking and Identification (VCC 909.14).....	7
Control Diagram (VCC 909.15)	7
Firefighter’s Smoke Control Panel (VCC 909.16).....	7
System Response (VCC 909.17)	7
Testing, Acceptance and Special Inspection (VCC 909.3 909.18, 909.19)	8
Smoke Containment (zoned smoke control, stairwell/elevator/vestibule/area of refuge pressurization)10	
Pressurization Method (VCC 909.6).....	10
Smoke Proof Enclosures (VCC 909.20).....	10
Stair Pressurization - Alternative to smoke proof enclosures (VCC 909.20.5).....	10
Elevator Hoistway Pressurization - Alternative to enclosed elevator lobbies (VCC 909.21)	12
Smoke Management System (smoke filling, opposed air flow, exhaust)	14
Exhaust Method (VCC 909.8)	14
Opposed Air Flow (VCC 909.7)	14
Smoke Filling/Natural Ventilation for Smoke Protected Seating (VCC 1028.6.2).....	15

SMOKE CONTROL SYSTEM (SMOKE CONTAINMENT AND SMOKE MANAGEMENT – VCC 2015)

The Authority Having Jurisdiction (AHJ) for smoke control systems is the Fairfax County Building Division and the Fire Marshal's Office.

The Architect or Engineer (A/E) is a Registered Design Professional (RDP), responsible in charge for the design of the system to meet compliance with Virginia Construction Code (VCC). The design of smoke control system must be completed by a RDP.

This document is divided into General and Specific sections. General applies to all smoke control systems while Specific is in addition to the different methods of smoke control: Smoke Containment and Smoke Management. In brief, Smoke Containment creates pressure differences to keep smoke outside of the protected area while Smoke Management interfaces with the smoke within the protected space. The RDP is responsible for compliance with all sections of the VCC.

This manual serves as an extension to **Special Inspections Program (SIP) 2015**, which provides guidelines on submission process, approvals and acceptance. See

<https://www.fairfaxcounty.gov/landdevelopment/special-inspections-program>

Smoke Control System:

VCC describes three methods of Smoke Control – Pressurization, Airflow and Exhaust. Note, Smoke and Heat Removal per VCC Section 910 are not considered Smoke Control Systems.

Large enclosed volumes, such as atriums, shall be permitted to utilize the Exhaust Methods as outlined in VCC section 909.8. Smoke control systems using the Exhaust Method shall be designed in accordance with one of the six design approaches defined in NFPA 92B 2009 edition (NFPA 92 2015 under VCC 2015) for VCC 2012. AHJ approval is required for the use of any of these methods within a project.

The A/E shall submit a preliminary Rational Analysis to AHJ for review and approval. A meeting may be required by AHJ to discuss this analysis with A/E and owner. The focus of the preliminary rational analysis will be on the design fire scenarios. The initial report should cover:

1. System performance goals and objectives
2. Performance criteria including tenability
3. Building characteristics
4. Design basis fire
5. Number of design fire scenarios to be analyzed
6. Fire location
7. Constraints
8. Design approach
9. Egress and tenability analysis
10. Conceptual floor plans, location of barriers, cross section that identifies the locations of the major components, pertinent calculations and sequence of operations.
11. Fire models to be utilized (zone fire models such as Consolidated Model of Fire and Smoke Transport (CFAST), Computational Fluid Dynamics (CFD), Fire Dynamics Simulator (FDS)).

Include as much information possible under the general and specific requirement sections of this document in the preliminary rational analysis.

The preliminary report shall be signed and sealed by the RDP. Once it is approved, the smoke control analysis can progress to minimize changes/rework of final design. Submit three copies of preliminary analysis to Fire Marshal's Office – Fire Plans Review Division located on the 3rd floor of the Public Safety Headquarter Building (PSHQ).

GENERAL REQUIREMENTS FOR SMOKE CONTROL SYSTEMS

This section discusses the general guidelines addressing all smoke control systems. It is not a complete list but the bare minimum that must be addressed in the design of smoke control. The final report must be signed, sealed and dated by the RDP and outline the following:

Rational Analysis (VCC 909.4)

Provide the following as a minimum to demonstrate compliance:

- A. Indicate the VCC edition.
- B. Locate and identify all of the walls, floors and ceilings that define the perimeter of the space(s) to be protected by the smoke control system.
- C. Locate and identify all means of egress and areas of refuge.
- D. Locate and identify the HVAC system components respective to the smoke control system.
- E. Locate and identify all smoke dampers respective to the smoke control system.
- F. Locate and identify all motorized dampers respective to the smoke control system.
- G. Locate and identify the interface requirements with the fire alarm system.
- H. Locate and identify the interface requirements for all devices whose operation is required by the smoke control system such as door hold open devices, smoke dampers, fire shutters, motorized ventilation dampers, fans, air handlers and smoke detectors.
- I. Identify the primary and secondary power supplies and their connections.

Show items B through I above on conceptual floor plan.

- J. Provide wording in the specifications that indicate that the components of and their locations which make up the smoke control system are not to be altered by the Contractor, without prior written approval by the A/E and the AHJ.
- K. Provide calculations as defined by the VCC (and NFPA 92B for Exhaust Method) that establish the performance requirements for the method of smoke control for this project.
- L. Define the calculated Required Safety Egress Time (RSET).
- M. Account for:
 - a. Conditions with doors closed and exterior door open.
 - b. Delay in detection and activation.
 - c. Location of detectors, type, access for testing/maintenance.
 - d. Effects on levels opening to design fire space (such as open floors, balconies, walkway).
 - e. Impact of egress door on pressure difference (opening force, undercut, listed door, operators, etc.).
- N. Define the maximum exhaust rate and effects on door opening forces.
- O. Define assumptions of stack effect, temperature of fire, wind effect, climate, impact of HVAC system. VCC 909.4
- P. Define the velocity of makeup air. At no point shall it exceed 200 feet per minute.
- Q. Provide the total cubic volume of each floor level accounted for in the design of the smoke control system.

Fire and Smoke Barriers (VCC 404.6 & 909.5)

- Define the construction of barriers. Provide UL details showing wall assemblies and details of through penetrations.
- Indicate location of automatic sprinklers if installed along barrier walls.
- Define the protected openings. Barriers must be maintained with no unprotected openings.
- Indicate all self-closing or automatic closing doors.
- Provide calculations for leakage area.
- Define any glass walls used to achieve equivalency of rated walls. Provide material data sheets that include framing gaskets.
- Indicate all glass-block assemblies complying with section. VCC 2110
- Ducts and air transfer penetrating barriers must be protected with listed dampers.
- Define any pressure differences applied across smoke barriers required to prevent smoke mitigation to adjacent spaces. Provide engineering calculations for such system.

Design Fire (VCC 909.9)

- Provide details of design fire, including location, size, fuel characteristics, types of plumes (axisymmetric, balcony spill, window), steady/unsteady fire, Heat Release Rate (HRR), separation distance from fuel packages, configuration of fuel, flashover, growth/decay, smoke production.
- Define impact of sprinkler activation.
- Define the temperatures generated.

Equipment (VCC 909.10)

- Duct work must comply with International Mechanical Code (IMC) and be able to withstand the experienced temperatures. VCC 909.10.2
- Define the source of makeup air and its location.
- Provide adequate noncombustible support for the duct work serving the exhaust system. The supporting structural construction shall be of fire resistance rating equal to that of the construction type of building floor assembly. VCC 909.10.2
- Define the location of exhaust and intakes with examination of wind effect. VCC 909.10.3
- Show location of dampers that are part of exhaust system. Damper must be listed ANSI/UL555S. VCC 909.10.4
- Provide cut sheet of fans serving system (curve, temperature rating, number of belts for belt-driven fans). Fans shall be supported and restrained by noncombustible construction. VCC 909.10.5

Power System (VCC 909.11)

- Standby system shall comply with VCC Chapter 27 and VCC 909.11.
- Verify smoke control system is on standby power including makeup air device.
- The separation requirement of room containing standby power shall meet VCC 909.11. Define UL details for the separation and all through penetration firestop system. Ventilation for room shall be directly to and from the exterior.
- Transfer to full standby power shall be automatic and within 60 seconds of primary power failure.

Detection and Control (VCC 909.12)

- Components of smoke control equipment shall be listed for use and/or approved by AHJ. VCC 909.12
- Control Panels must be UL 864-UUKL listed specifically for smoke control (Building Automation System (BAS) will only be accepted if listed as UUKL).
- System must be activated automatically and manually.
- Fire suppression and detection serving area of smoke control must be zoned separately from the remainder of the building fire protection system. Define boundary on plans.
- Define continuous raceway enclosures for all control wiring including fire detection. VCC 909.12.1
- A preprogram weekly test sequence shall operate all devices, equipment and component of the smoke control system. Any abnormal conditions shall be remediated. A printed report shall be kept for AHJ annual examination. See exception.

Control Air Tubing (VCC 909.13)

- Although VCC 909.13 allows for use of pneumatics operations, it is highly preferred that electronic systems be used. The A/E must indicate in the preliminary rational analysis if control air tubing is to be utilized for review and approval by AHJ.

Marking and Identification (VCC 909.14)

- All components of the smoke control system must be clearly identified and marked in field. This includes, but is not limited to, fire alarm initiating devices, junction boxes, panels, modules, relays, dampers, doors sensors and air movement sensors.

Control Diagram (VCC 909.15)

- Provide a detailed control diagram showing interface of all smoke control components and function.
- Provide a "Sequence of Operation" matrix that outlines the operation of components of all systems affected by the smoke control system.

Firefighter's Smoke Control Panel (VCC 909.16)

- Firefighter's smoke control panel or station (FSCS) shall meet the requirements of VCC 909.16.
- Manual override and control must be provided.
- Locate panel in fire command center adjacent to Fire Alarm Control Panel (FACP), if present. Panel location must be approved by the Fire Marshal's Office.
- Means shall be provided for verifying correct operation of components upon activation. This includes positive confirmation for the operation of fans, any fault conditions and manual overrides.
- Failure to receive or maintain positive confirmation must provide an off-normal indication within 200 seconds.

System Response (VCC 909.17)

- System duration of 20 minutes or 1.5 times RSET, whichever is greater, must be achieved after the detection of fire. VCC 909.4.6
- Activation of the smoke control system is required immediately upon detection.

- The smoke control system must be fully in operation prior to space exceeding the design smoke conditions. Define the parameters of time, time to detection, HVAC activation/shutdown, dampers opening and closing. VCC 909.17

Testing, Acceptance and Special Inspection (VCC 909.3 909.18, 909.19)

- The smoke control system is to be acceptance tested in accord with the requirements of the code and Special Inspections Program (SIP) 2015 Edition.
- The AHJ may choose to observe/audit the installed components of the smoke control system(s) and witness the smoke control system performance tests. The A/E and Contractor shall certify that the smoke control system is complete prior to acceptance test by the AHJ.
- Provide a description of the acceptance testing requirements. Indicate which of the acceptance tests are to be witnessed by the AHJ and special inspector. VCC 909.3
- Provide in construction documents specification for procedures related to commissioning, special inspections and testing.
- Once the smoke control system installation is completed and pretested by the contractor, notification shall be provided to the special inspector and the AHJ, five days in advance for final testing.
- Tests shall be conducted by a special inspector in conformance with VCC 909.18.8 and VCC 1704. Special inspector is hired by the owner and must adhere to all requirements in SIP.
- For acceptance testing, the special inspector shall first verify that the signals, statuses and controls of the smoke control equipment are provided and report the correct status to the firefighter's smoke control panel. This is to ensure that when the special inspector manually or automatically activates a smoke zone or smoke control-related piece of equipment, the correct status is reported to the firefighter's smoke control panel.
- There shall be component testing, acceptance testing and periodic testing. Periodic testing shall be performed twice a year for a dedicated smoke control system while annually for HVAC/smoke combination. Test reports shall be made available to AHJ when requested.
- System with makeup air supplied by fans shall be sequenced with exhaust fan activation.
- Smoke control testing sequence shall be demonstrated for the following (1) normal mode, (2) automatic smoke control mode for 1st alarm, (3) transfer to standby power, (4) return to normal.
- A visual inspection shall be done on all smoke zone boundaries to confirm barrier continuity and that required opening protection is installed. Opening protection consists of doors, dampers, fire shutters, accordion folding doors, etc.
- All doors located in smoke barriers shall be visually inspected to confirm that the proper fire protection rating and "S" rating is provided per the approved record documentation and shall be inspected for proper functionality. Doors that are provided with magnetic hold-open devices within the zone should be functionally tested to confirm proper release, closure, latching and re-latching upon local detection and overall zone activation. When a door coordinator is used, it shall be tested to ensure that the doors properly close and latch.
- A full review of the through penetration firestop system data sheet as to confirm the material used complies with and is installed in accordance with the UL listing requirements.
- Detectors, fans, duct, including joints of barriers, ceilings and controls shall be inspected and/or tested.
- Any glazing that encloses the space shall be thoroughly inspected.

- Combination fire/smoke and/or smoke dampers associated with a smoke zone shall be visually inspected to confirm the equipment has been installed per the approved record documents and verify the fail-safe position as required by the approved documentation. Dampers located at the smoke zone boundaries shall have a smoke damper with a UL 555S listing.
- No component shall be concealed until approved by the Building Official. Ducts shall not be concealed prior to leak testing and approval. Record location of all devices on duct system.
- Duct leakage testing is required for any smoke control exhaust and supply ductwork. Ducts shall be leak tested to 1.5 times the max design pressure. Leakage cannot exceed 5% of the design flow. VCC 909.10.2
- The secondary power supply system serving equipment used for smoke control shall be verified by performing a shunt test of the property's primary power supply system to the secondary power supply system. Prior to shunting the building's primary power supply, initiate the smoke control system with the largest amount of smoke control equipment. Confirm that the smoke control system has properly configured via the indicator lights located on the firefighter's smoke control panel, directing the responsible party to shunt the building's primary power supply.
- Once the building's power load has transferred to the secondary power supply system, confirm that the active smoke control system properly reconfigured on the secondary power supply. Reset this smoke control system and initiate each smoke control system and/or smoke control-related equipment to confirm that the secondary power supply has been provided. During this test, inspect each smoke control fan for proper rotation while on secondary power.
- Final reports shall be submitted to the AHJ for review and approval. The report shall be approved by RDP, dated, signed and sealed per VCC 909.18.8.3. The report shall include commissioning reports detailing the steps taken throughout construction to ensure design intent was achieved.
- Smoke or smoke bomb test shall not be used as a means for acceptance criteria unless approved by AHJ.
- Documents pertaining to the smoke control system must be kept on the building site for the life of the building in an accessible location for Fire Marshal's Office inspection.
- The owner is responsible for maintaining the system.

SMOKE CONTAINMENT (ZONED SMOKE CONTROL, STAIRWELL/ELEVATOR/VESTIBULE/AREA OF REFUGE PRESSURIZATION)

See also General Requirements Page 5.

Pressurization Method (VCC 909.6)

VCC 909.6 discusses the requirements for utilizing Pressurization Method for smoke control system. Minimum and maximum pressures must be achieved across the smoke barrier for compliance. The goal of such systems is to:

- Maintain tenable conditions in non-fire side
- Limit fire/smoke spread
- Use pressure difference across barrier
- Tenable conditions not required to be maintained in fire area origin

Smoke Proof Enclosures (VCC 909.20)

- VCC 403.5.4 requires all interior exit stair serving floors over 75 feet above lowest level of fire department access to have Smoke Proof Stair Enclosures.
- See section 909.20 for complete requirements.

Stair Pressurization - Alternative to smoke proof enclosures (VCC 909.20.5)

VCC Section 403.5.4 requires a smoke proof enclosure in every required exit stairway serving floors greater than 75 feet above fire department vehicle access to comply with VCC 909.20 and VCC 1023.11. VCC Section 909.19 requires the system be inspected and tested prior to issuance of a certificate of occupancy. The typical compliance path for VCC 909.20 is in the selection of VCC 909.20.5 Stair Pressurization Alternative. When applying the stair pressurization section of the building code, the A/E shall consider the design, construction and system acceptance testing as a complete package for the AHJ review and approval.

Design

- Maintain a positive pressure inside the stair between 0.10 and 0.35 inches of water column (w.c.) with all doors closed and not to exceed door opening force VCC 909.20.5, at max stack effect and wind conditions.
- This pressure differential is measured with all doors closed and latched. The stair pressurization system shall be an independent system and operate under normal and standby electrical power.
- The stair pressurization system is activated by smoke detectors installed at each floor level at the entrance to the stairs.
- The stair pressurization system is also to be activated during a loss of normal power; an approved standby power system is to be provided.
- Application of NFPA 70, The National Electrical Code Article 701.12 & VCC 909.20.6; the system is to operate at required performance levels within 60 seconds of power disruption. All power wiring, control wiring and equipment shall be protected within an enclosure with the same fire resistance rating as the stairway enclosure.

- Other factors to be taken into consideration when establishing the stair pressure set point is the operation of the fire doors entering the stairs.
- VCC 1008.1.3 requires the door latch to release when subjected to a maximum 15 pound force, the door set into motion when subjected to a maximum 30 pound force and the door to swing to full, open position when subjected to a maximum 15 pound force. 2010 ADA-ASAD 404.2.8 requires the door to close from a full, open position to a position of 12 degrees from the latch in a minimum of 5 seconds. Too high of a stair pressure set point negates the ability for the doors to perform in a compliant manner. Where exit stair doors discharge into a lobby or exit passageway, a door operator is typically required to achieve compliance with VCC 716.5.9 door closing and latching.
- Account for all leakage through floors and walls.

Construction

- A stair pressurization system requires the stairway to be complete and free of all construction materials.
- All doors shall operate, latch and open when the pressurization fans are running with the forces prescribed in the code.
- Smoke detectors required for the activation of the system shall be located outside each door to the stairway.
- The construction of the duct system shall not include fire dampers or smoke dampers. Backdraft dampers are permitted, but shall operate within the sequence of operation.
- All controls shall be connected to the standby power system.
- A separate control panel with a comprehensively labeled faceplate shall be located in the fire command center.
- The pressurization fans shall be tested, balanced and controlled as specified by the contract documents. Changing or revising the sequence of operation during the construction phase requires submission, review and approval by the AHJ.

Acceptance Testing

- Inspection of the stair pressurization system includes an inspection of the fire-rated enclosure, doors, door hardware, door latching and smoke detector locations.
- A timed sequence of the fan operation under normal and standby power is observed by the AHJ inspection team.
- The inspection will observe and report the following tests to confirm the stair pressurization system is operating in compliance with VCC 909.20:
 - Observation of door operation with stair pressurization system off.
 - Observation of stair pressurization system operation as initiated by smoke detector and immediate loss of normal power (standby power).
 - Observation of stair pressurization system operation as initiated by smoke detector and while under normal power.
 - Observation of stair pressurization system as initiated at the firefighter's stair pressurization control panel.
 - Observation of door operation with stair pressurization system on.
 - Test shall be conducted under both normal and standby mode.
- The Contractor should schedule the AHJ inspections to include A/E representative, fire alarm contractor, electrical contractor and the mechanical contractor. A certified air balancer with

pressure differential meter and pound-force gauge for the door forces and sufficient staff to prevent stairwell from being used during the test shall be present.

- Meters and gauges must have been calibrated within the past year.
- The door opening forces shall be measured as set forth under design.
- The stairway shaft shall be inspected to confirm that there are no utilities installed within the stairway that do not serve the stairway.
- All penetrations shall be inspected to ensure listed through penetration fire stop systems are utilized.
- All doors should be automatic or self-closing doors and be capable of re-latching with an active alarm after a building occupant exits through the door.

Elevator Hoistway Pressurization - Alternative to enclosed elevator lobbies (VCC 909.21)

Section 909.21 of VCC discusses an alternative method to achieving compliance utilizing pressurized elevator hoistway in lieu of enclosed elevator lobbies.

Design

- Maintain a positive pressure inside the elevator hoistway between 0.10 and 0.25 inches of water column (w.c.) with respect to adjacent occupied space on all floors.
- The elevator pressurization system is activated by smoke detectors installed at each elevator lobby and shaft as required by NFPA 72 and upon activation of the building fire alarm. The detectors and the fire alarm shall independently activate the pressurization system.
- The fan shall be equipped with a smoke detector which will shut off fan open smoke detection. A separate fan shall be used for each hoistway. Minimum capacity of each fan shall be at least 1000 cubic feet per minute.
- Account for all leakage through floors and walls.

Construction

- Supply air intake shall be accessed directly from outside, be uncontaminated and located a minimum of 20 feet from any air exhaust system or outlet.
- Ducts and fans supplying air for pressurization shall be protected with the same fire-resistant rating as the shaft enclosure for elevator. VCC 909.21.3 & 909.21.4
- Application of NFPA 70, The National Electrical Code Article 701.12 & VCC 909.20.6; the system is to operate at required performance levels within 60 seconds of power disruption. All power wiring, control wiring and equipment shall be protected within an enclosure with the same fire resistance rating as the stairway enclosure.

Acceptance Testing

- Inspection of the stair pressurization system includes an inspection of the fire-rated enclosure, doors, fans, duct and smoke detector locations.
- A timed sequence of the fan operation under normal and standby power is observed by the AHJ inspection team.
- The inspection will observe and report the following tests to confirm the elevator pressurization system is operating in compliance with VCC 909.21:
 - Observation of elevator pressurization system operation as initiated by lobby and shaft detectors.

- Observation of elevator pressurization system operation as initiated by building fire alarm system.
- Observation of elevator pressurization system as initiated at the firefighter's stair pressurization control panel.
- Test shall be conducted under both normal and standby mode.
- Locations of measurement of pressure differential to meet the design criteria shall be in accordance with 909.21.1.
- The Contractor should schedule the AHJ inspections to include A/E representative, elevator contractor, fire alarm contractor, electrical contractor and the mechanical contractor. A certified air balancer with pressure differential meter shall be present.
- Meters and gauges must have been calibrated within the past year.
- The shaft shall be inspected for proper construction in accordance with the UL design assemblies. All penetrations shall conform to VCC 713.8 and shall be visually inspected to ensure proper through-penetrations firestop systems are utilized to maintain integrity.

SMOKE MANAGEMENT SYSTEM (SMOKE FILLING, OPPOSED AIR FLOW, EXHAUST)

See also General Requirements Page 5.

Exhaust Method (VCC 909.8)

VCC 909.8 discusses the requirements for Exhaust Method. This method is most suitable for enclosed volume spaces such as large open spaces, atrium, malls, theaters and sports arena. The goal of this method is to maintain tenable conditions 6 feet above the highest walking egress surface within the smoke zone for 1.5 times the calculated Required Safety Egress Time (RSET) or 20 minutes, whichever is less.

The utilization of Computational Fluid Dynamic (CFD) modeling is an acceptable method for determining the basis of the exhaust rate to comply with VCC 909.8.

Design Consideration:

- Indicate the edition of NFPA 92 utilized for design of system.
- Define the threshold for tenable conditions - visibility distance, max thermal tolerance, product of combustion, asphyxiants.
- Define the height of the ceilings and cross-sectional area of the space of any communicating space.
- Define location(s) of walking surface that serves as part of the means of egress within the smoke zone.
- Define all Use and Occupancy Classification per VCC Chapter 3 of space and uses of communicating spaces including any off seasonal events.
- Define the steps taken to account for plugholding.
- Define any modification of exit signs (spacing and mounting height) and egress illumination impacted by the visibility tolerance during smoke conditions.
- Makeup air exhaust outlet(s) shall be located below the smoke layer interface. Furthermore, the mechanical makeup air shall be less than the mass flow rate of mechanical smoke exhaust.
- Indicate number of exhaust inlet.

Opposed Air Flow (VCC 909.7)

VCC 909.7 discusses the requirements for utilizing Airflow Design Method for smoke control systems. This method injects air to limit the migration of smoke from the fire zone.

Design Consideration:

- Demonstrate the impact of the opposed air flow on the smoke and fire.
- Airflow shall not exceed 200 feet per minute toward the fire zone.
- Achieve design in accordance with NFPA 92 2015.

Smoke Filling/Natural Ventilation for Smoke Protected Seating (VCC 1028.6.2)

VCC 1028.6.2 discusses capturing smoke in large assembly spaces with smoke protected seating.

Design Consideration:

- Define the construction of the ceiling, including the interior finish capturing the smoke.
- Define the roof height from the lowest portion of the roof deck above the highest aisle or aisle accessway.