THE CITY OF SAN DIEGO

Design and Testing Requirements for Smoke Control Systems

TECHNICAL BULLETIN

BLDG-9-1

CITY OF SAN DIEGO DEVELOPMENT SERVICES
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The purpose of this Technical Bulletin is to provide the smoke control guidelines and requirements to the building permit applicant. This bulletin also describes the minimum requirements for smoke control design and special inspection.

Documents Referenced in this Technical Bulletin

- **2013 California Building Code, (CBC)**
- **2013 California Electrical Code, (CEC)**
- **2013 California Mechanical Code, (CMC)**
- **ASHRAE Handbook of Smoke Control Engineering**
- **CONTAM**
- **NFPA 92, Standard for Smoke Control Systems**

I. SMOKE CONTROL SYSTEMS

A. ATRIA AND OTHER LARGE VOLUME SPACES

Atria connecting more than two stories and other large volume spaces requiring smoke control shall use the exhaust method specified in California Building Code (CBC) Section 909.8 and Section III, Part A below.

B. HIGH-RISE BUILDINGS

Buildings determined by the City of San Diego to be high-rises (defined in the CBC as having an occupied floor more than 75 feet above the lowest level of fire department access) are required to have all stairwells designed as smokeproof enclosures per CBC Section 909.20 and Section III, Part C below.

In addition, high-rise buildings shall be provided with an active or passive smoke control system or combination thereof. Active systems shall be designed in accordance with the pressurization method specified in CBC Section 909.6 and Section III, Part B below. Passive systems must be verified via a tenability analysis at the time of building permit submittal and must be testing by the special inspector at the time of final acceptance of the smoke control system as required in Section VIII, Part D, #4 below.

C. ELEVATOR HOISTWAY PRESSURIZATION

In lieu of providing elevator lobbies, elevator hoistway pressurization shall be provided in accordance with CBC Section 909.21 and Section III, Part D below.

D. WINDOWLESS BUILDINGS

Group I-3 occupancies that are windowless buildings or have portions considered windowless must be provided with an engineered smoke control system in accordance with CBC Section 909, windows or doors, smoke vents or an equivalent means per CBC Section 408.9.1. If a system in accordance with Section 909 is proposed, it must meet the requirements of the pressurization method in CBC Section 909.6 and Section III, Part B below.

E. UNDERGROUND BUILDINGS

Underground buildings per CBC Section 405 shall be provided with a smoke control system in accordance with the pressurization method in CBC Section 909.6 and Section III, Part B below.

F. SMOKE-PROTECTED ASSEMBLY SEATING

Group A occupancy smoke-protected seating must be designed in accordance with CBC Section 1028.6.2.

G. OTHER BUILDINGS WITH SMOKE CONTROL SYSTEMS

When a smoke control system is proposed for a building or use other than Items A-F above, contact the City of San Diego to discuss the proposed designs.

II. SUBMITTING A SMOKE CONTROL SYSTEM

A. RATIONAL ANALYSIS REPORT

A rational analysis report per CBC Section 909.4 must be provided with the building permit drawings for all smoke control systems. At a minimum, the rational analysis shall include the following:

1. Stack Effect

Stack effect shall be analyzed for all probable weather scenarios and interior temperatures. Also, include any open vents (such as elevator vents), garage doors, and other sources of airflow in the design. At least a high temperature summer and low temperature winter shall be used.

For the summer high temperature, use the 0.4% cooling dry bulb summer temperature in the ASHRAE Handbook of Smoke Control Engineering. For the winter low temperature, use the 99.6% heating dry bulb winter temperature in the ASHRAE Handbook of Smoke

Control Engineering.

2. **Temperature Effect of Fire**
   Verify that buoyancy and expansion due to the design fire will not adversely affect the smoke control system.
3. **Wind Effect**
   The adverse effects of wind must be included in the analysis. At least two different wind directions shall be used and these wind directions shall be the worst-case scenarios (i.e. long side of the building, most openings on a wall). For the wind speed used in the analysis, use the extreme 1% annual wind speed in the ASHRAE Handbook of Smoke Control Engineering.
4. **HVAC Systems**
   The design must include the effects of the building's HVAC systems on the smoke control system. Where systems are required to remain operational during a fire scenario, these systems must be included in the analysis. When systems are required to shut down in a fire event, the system must be designed as such and the sequence of operation shall specify which HVAC systems are proposed to shut down.
5. **Climate**
   The design must include the effects of low temperature on the systems, the property and occupants.
6. **Duration of Operation**
   All portions of the smoke control systems must operate for at least 20 minutes or 1.5 times the calculated egress time whichever is less.
7. **Sequence of Operations**
   A detailed sequence of operations must be provided for all active and passive systems. Activation methods (such as smoke detectors, Waterflow switches) and required response(s) must be included. This should be as detailed as possible. If fans need to turn on/off or dampers need to open/close for proper smoke control operation, this must be reflected in the sequence of operation.

B. BUILDING PERMIT DRAWINGS

When a smoke control system is required, the entire design must be incorporated into the building permit submittal.

1. Structural, Architectural, Electrical, Mechanical and Plumbing Drawings shall be coordinated with the smoke control design. All fans, dampers, operable doors/windows, etc. must be included in the drawings and must be indicated as smoke control components. Each item needing operation to open, close, start or stop needs to be provided with a unique label (i.e. Fan SF-2, SFD-3-1) which must correspond with the sequence of operations.
2. Smoke control plans must be included in the building permit drawings. At a minimum, drawings must include the following from the rational analysis report:
   a. Smoke control zones clearly identified on architectural backgrounds (hatched or shaded).
   b. Smoke barrier construction requirements.
   c. Detailed sequence of operations for the smoke control system(s).
   d. Special inspection and testing requirements.
   e. Special Inspector for the project must be named.
   f. Any other details pertinent to the smoke control system proposed.

C. FIRE ALARM DRAWINGS

The City of San Diego allows fire alarm drawings to be a deferred submittal to the building permit drawings. When fire alarm drawings are submitted for review and there is a smoke control system, a detailed fire-fighter's smoke control panel drawing must be submitted for approval. The fire alarm contractor must obtain a stamp from the designer of the smoke control system (author of the rational analysis report) prior to approval from the City of San Diego.

D. FIRE SPRINKLER DRAWINGS

The City of San Diego allows fire sprinkler drawings to be a deferred submittal to the building permit drawings. When fire alarm drawings are submitted for review and there is a smoke control system, the fire sprinkler zones must correspond to the smoke control zones. The sprinkler contractor must obtain a stamp from the designer of the smoke control system (author of the rational analysis report) prior to approval from the City of San Diego.

III. SMOKE CONTROL METHODS

A. EXHAUST METHOD

1. **Methods of Modeling.** When using the exhaust method, use the calculations contained within NFPA 92 or use a computational fluid dynamics (CFD) program. For atria with non-uniform cross-sections or complex geometries, CFD program must be used.
2. **Other Smoke Control Systems.** When a building contains an exhaust method system along with another smoke control system, the exhaust system shall be designed as stated above. Then, the exhaust system shall be considered for the modeling for the remainder of the building systems.

B. PRESSURIZATION METHOD

1. **Methods of Modeling.** When using the pressurization method for smoke control, either use the calculations contained within NFPA 92 or use a multi-zone airflow model such as CONTAM.
2. **Smoke Barriers.** To model smoke barrier leakage rates, use the leakage area ratios in CBC Section 909.5 or the values contained within the ASHRAE Handbook of Smoke Control Engineering. Provide references for

all leakage areas ratios used in the modeling effort within the rational analysis report.

3. **Minimum Pressure Differentials.** All pressurization method systems must achieve at least a 0.05 inch water gauge pressure differential across smoke barriers. The pressurization method can be designed using either via exhaust or supply to achieve the minimum pressure differentials.
4. **Door Opening Forces.** The design of pressurization methods must allow for a maximum door opening force of 15 pounds for all side-hinged, swinging doors used for exiting. CBC, Equation 9-1 shall be used to calculate opening force. When doors are used that are different heights or widths, the allowable pressure difference across each door type shall be calculated. If the modeling cannot be designed to achieve less than 15 pounds of opening force, door-assist devices must be provided on the building permit drawings. Power to these doors shall be provided in the electrical design.

C. SMOKEPROOF ENCLOSURES

1. **When Required.** All exit enclosures in high-rise buildings, except those that serve three or less adjacent floors where one of the levels is the level of exit discharge, must be designed as smokeproof enclosures.
2. **Access to Smokeproof Enclosures.** The only openings permitted into a smokeproof enclosure are for vestibules or open exterior balconies.
   - **a.** Vestibules must be at least 44 inches wide and no less than 72 inches measured in the direction of egress travel. Where standpipes and valves are located in the vestibule, they must be located so that they do not obstruct egress when the hose lines are connected and charged.

     Vestibules must be separated from all adjacent spaces by 2-hour rated fire barriers or horizontal assemblies however the door from the vestibule to the stair can be a 20-minute rated assembly. In addition, a transfer grill to allow air movement from the stair into the vestibule is permitted. This transfer grill must be fixed at the time of occupancy and this opening does not require a smoke or fire damper.
   - **b.** Open Exterior Balconies must be at least 44 inches wide and no less than 72 inches measured in the direction of egress travel. Open exterior balconies must be constructed as required for the fire resistance rating of the floor assemblies for the building. The door leading to the smokeproof enclosure must be a fire door in accordance with CBC Section 716.5.
3. **Design Requirements.** See Section III, Part B for using the Pressurization Method for modeling smoke barriers, pressure differentials and door opening forces for smokeproof enclosures. In addition, the following shall be designed:
   - **a.** A relief vent shall be installed at the top portion of the smokeproof enclosure. This relief vent must discharge at least 2,500 cfm at the pressure that the smokeproof enclosure is designed. The modeling must include this relief vent and, in all scenarios modeled, must exhaust 2,500 cfm. The relief vent shall not be fixed and shall be weighted so that the relief vent closes when the pressure is reduced in the smokeproof enclosure.
   - **b.** Multiple injections points are recommended for all smokeproof enclosures. For smokeproof enclosures extending greater than 100 feet in height, single injection is not permitted.
4. **Equipment.** Ventilation systems used for smokeproof enclosures must be independent of all other building ventilation systems. The equipment, control wiring, power wiring, and ductwork must be located in accordance with one of the following:
   - **a.** Exterior to the building and directly connected to the smokeproof enclosure or connected to the smokeproof enclosure by ductwork enclosed by 2-hour fire barriers or horizontal assemblies.
   - **b.** Located in the smokeproof enclosure with the intake or exhaust directly from and to the exterior or through ductwork enclosed in 2-hour fire barriers or horizontal assemblies.
   - **c.** Located within the building, separated from the remainder of the building (including other mechanical equipment) by 2-hour fire barriers or horizontal assemblies.

     Control and power wiring is permitted to utilize a 2-hour rated cabling or cable system or be encased in not less than 2 inches of concrete.

D. ELEVATOR HOISTWAY PRESSURIZATION

Where elevator hoistway pressurization is used in lieu of providing an elevator lobby, the elevator hoistway pressurization system must comply with the following.

1. **Minimum Pressure Differentials.** Elevator hoistways must be pressurized to a minimum of 0.10 inches of water and a maximum of 0.25 inches of water with regards to the adjacent occupied space. This must be measured for each floor of the building that the elevator(s) serve. The pressure must be measured at the midpoint of the elevator doors, with all of the elevator cars at the floor of recall and the elevator doors open. When the system is balanced, all elevator doors must be able to opened and closed.

2. Equipment. Fans and ducts must be designed as follows.
- **a.** A separate fan must be provided for each hoistway.
- **b.** If the fans are located in the building, the fan system must also be protected with the same fire-resistance rating as required for the elevator shaft.
- **c.** The supply fan must be specified by a registered design professional or the fans should be adjustable with a capacity of at least 1,000 cfm per door in the hoistway.
- **d.** The supply air intake must be from outside, uncontaminated source located at least 20 feet from any air exhaust or outlet.
- **e.** Any ducts that are a part of the pressurization system must be protected with the same fire-resistance rating as required for the elevator shaft.

IV. HIGH-RISE BUILDINGS

A. MODELING

Due to the complexity of high-rise building smoke control systems, it is highly recommended that a multi-zone airflow modeling program such as CONTAM be used for design. If other methods are proposed, calculations must include complex flow networks as described in ASHRAE Handbook of Smoke Control Engineering. Such flow network calculations must address all leakage paths, stack effect, all means of air movement (i.e. elevator shaft pressurization, floor smoke control, exterior openings, HVAC systems, wind, temperature, etc.)

B. FLOOR SMOKE CONTROL SYSTEMS

The CBC permits active, passive or a combination of the both for the smoke control systems in high-rise buildings. The smoke control designer must determine what the best means of protecting the high-rise building.

1. Active Smoke Control Systems shall be modeled with all scenarios, including smokeproof enclosures and elevator hoistway pressurization systems, active. Only the fire zone needs to meet the minimum pressure differentials specified in Section III.

2. Passive Smoke Control Systems are permitted for high-rise buildings provided that a tenability analysis is prepared as a part of the Smoke Control rational analysis report for the various uses/spaces in a variety of locations in the building. The tenability analysis shall include the effect of wind and temperature on the tenability along with all anticipated worst-case scenarios. The following areas should be evaluated for the tenability of the occupants:
- **a.** Heat exposure
- **b.** Thermal radiation
- **c.** Reduced visibility
- **d.** Toxic gas exposure

Door fan testing shall be performed per Section VIII, Part D, Item #4 below to verify that the smoke barriers were installed and constructed per the modeling.

3. Combination Smoke Control Systems shall comply with both passive and active smoke control systems as stated above.

C. OTHER SMOKE CONTROL SYSTEMS

The following systems also need to be included in the smoke control system for the building.

1. Where enclosed parking garages are within the high-rise building (subterranean and above grade), the Carbon Monoxide (CO) supply and exhaust fans are permitted to be used for smoke removal in lieu of an active smoke control system. Sizing of these systems shall be in accordance with the requirements of the CMC for CO systems.

The CO parking garage fans do not need to meet the requirements in Section 909 for fans and do not need to activate upon building alarm. The fans do need to be provided with manual control only via the Fire-Fighter's smoke control panel. Where CO fans have variable frequency drives (VFDs), the fans shall go into 100% exhaust upon manual activation.

2. Fans used in lieu of providing dampers such as kitchen, dryer and bathroom exhaust systems that are required to be continuously running shall be modeled in the smoke control design. They also are required to be designed with a secondary power source in accordance with CBC Section 909.11.

V. SECONDARY POWER SYSTEMS

A. GENERAL

All portions of a smoke control system must be provided with two sources of power except for those items that do not require power to operate (i.e. dampers that fail-safe in the smoke control position). Primary power for the system must be from the normal building power. The secondary power source must comply with CBC Chapter 27 for approved standby power sources.

B. LOCATION

The standby power source and its transfer switches must be located in a room separate from the normal power transformers and switchgears. The room shall meet the following requirements:

1. Enclosed in 1-hour fire barriers and horizontal assemblies. When generator is used as a high-rise building standby power source, the room housing the generator must be enclosed in 2-hour fire barriers and horizontal assemblies

2. Ventilation directly to and from the exterior of the building. The ventilation cannot combine with any other building ventilation systems. Where the generator is located separate from the transfer switch(es), the transfer switches

may not be provided with ventilation provided that the mechanical and electrical design engineers determine that ventilation is not required for proper operation of the transfer switch.

C. TRANSFER

The transfer to full standby power must be automatic and must occur within 60 seconds of failure of the primary power supply.

D. UPS AND POWER SURGES

All elements of the smoke control system that rely on volatile memories or similar means must be provided with uninterruptable power source (UPS) to span 15-minutes of primary power interruption. Also, the elements of the smoke control system that are susceptible to power surges must be suitably protected.

VI. DETECTION AND CONTROLS

A. WIRING

All wiring used for smoke control must meet the requirements in the California Electrical Code (CEC). In addition, the wiring must be enclosed in continuous raceways, regardless of the voltage. Raceways are defined in the CEC which provides examples of acceptable raceways. Note that manufactured cable assemblies such as metal-clad cable (Type MC) or armored cable (Type AC) are not included in the definition of a raceway and are therefore not permitted to be used for smoke control purposes.

B. MONITORING STATUS

Controls for mechanical smoke control systems must include provisions for verification. Verification must include positive confirmation of, testing, manual override, the presence of power downstream of all disconnects, and testing. Abnormal conditions must be reported audibly, visually and by printed report. In addition, the status of dampers actuation and fans must be as required below.

1. Damper status must be determined using limit or proximity switches installed at the damper or they shall be incorporated into the damper actuator. Where multiple dampers are grouped together in an assembly that requires one or more actuators, each damper requires independent control by a separate actuator and provided with an individual limit or proximity switch or the dampers must be linked together by a reliable mechanical permanent means into one or more groups, with each group provided with a common limit or proximity switch.
2. Fan status must be determined by sensing the air flow downstream of the fans by using pressure differential switches/transmitters or current sensors.

C. ACTIVATION

Activation shall be per the requirements below.

1. Active smoke control systems such as exhaust method or pressurization systems must be activated by automatic control. Active activation shall be accomplished by a properly zoned automatic sprinkler system and smoke detectors (where required by the engineering analysis). Manual control is also required for use by the fire department.
2. Passive smoke control systems actuated by approved spot-type detectors listed for releasing service are permitted.

D. DUCT SMOKE DETECTION

Supply air systems used for smoke control with a total airflow of 2,000 cfm or more shall be provided with smoke detectors approved and listed by the California State Fire Marshal for air duct installation per the CMC. These smoke detectors shall report to the Fire Alarm Control Panel (FACP) as a supervisory signal but shall not automatically shut-off the supply air system.

VII. FIRE-FIGHTER'S SMOKE CONTROL PANEL

A. GENERAL

A fire-fighter's smoke control panel must be provided for all smoke control systems. The panel must be for fire department emergency response purposes only. A separate annunciator panel is required to be provided for all high-rise structures per CFC Section 907.6.3.1. The annunciator panel cannot be combined with the fire-fighter's smoke control panel.

B. LOCATION

The panel must be located in the Fire Command Center for smoke control systems in high-rise buildings and buildings with smoke-protected assembly seating. Otherwise, the panel must be in a location approved by the City of San Diego.

C. PANEL DETAILS

Fans that are a part of the smoke control system must be shown on the panel along with the direction of airflow. Shafts shall be shown and the panel shall show all floor levels identified with the proper floor designations.

1. **Status Lights.** All fans, dampers, and other operating equipment such as doors must be provided with four lights – White, Red, Green, and Yellow/Amber in accordance with:
   - **a.** White light indicates that item is in its normal status. This means that there is no automatic smoke control function and the manual switch is in the Auto position.
   - **b.** Red light indicates that the item is in the Off or Closed position. For fans that are on in normal conditions (dual-use fans), the light must still be Red even if the fan is running. Only activation of the smoke control system or manually putting the fan switch to the On position would change the light to Green.
   - **c.** Green light indicates that the item is On or Open status. When the Green light is On,

that indicates that the item is running in smoke control mode or the damper/door is open.

d. Yellow Light indicates that the item is in a Fault status. If the fan/damper/door needs to turn on or off (or open/close) in smoke control mode and it does not perform correctly, then the Yellow light shall go on. In that scenario, the Yellow light should turn on along with the associated Red or Green light (the actual status of the device). In addition, if a fan does not have power to it, the Yellow light should be on.

2. Control Capability. The fire-fighter's control panel must provide control capability over the entire smoke control system and all associated equipment. Controls shall be as follows:

a. Fans shall have a switch with ON-AUTO-OFF control.

b. Dampers and doors shall have a switch with ON-AUTO-CLOSE control.

c. Items with no Auto function may have a switch with ON-OFF or OPEN-CLOSE position. These items will have the highest priority of any other control points.

d. Where the system is complex in nature, damper and fan controls may be combined to a single control. For example, one control could be provided for all functions of an atrium exhaust system or one control to configure each story's pressurization system for high-rises with active smoke control. The failure of any one component to operate must show a fault light on the firefighter's smoke control panel for that system.

VIII. SPECIAL INSPECTION TESTING

A. SCOPE OF TESTING

Special inspections are required during the erection of ductwork and prior to concealment so that leakage testing and device locations can be performed/reviewed.

B. QUALIFICATIONS OF INSPECTOR

The special inspector must have expertise in the areas of fire protection engineering, mechanical engineering and certification as air balancers. If the special inspector does not have certification as an air balancer, a certified air balancer must be provided.

C. TESTING PLAN

A detailed testing plan must be submitted to the City of San Diego by the Special Inspector for approval prior to final acceptance. The testing plan shall include the different smoke control scenarios that are possible.

D. PASSIVE BARRIERS VERIFICATION

All passive barriers must be inspected for the following:

1. Inspections. All passive barriers must be inspected throughout the building's construction progress at various times. The passive barrier item inspections to be performed include ductwork, floor/exterior wall joints, passive dampers, penetration fire stopping assemblies, and door assemblies (rating, closer device, "S-rating), etc).

2. Ductwork. Ducts and drywall shafts must be leak tested to 1.5 times the maximum design pressure in accordance with nationally accepted practices, such as Association of Air Balance Council. The measured leakage shall not exceed 5 percent of the design flow. Long runs of ductwork that exceeds the capability of available leakage testing apparatus may be tested in shorter segments, with allowable leakage is based upon the maximum airflow in the section of ductwork being tested.

3. Dampers. Dampers must be installed and listed to conform with the building permit drawings and the CBC. Verify full range of movement of dampers.

4. Door Fan Testing. For smoke control designs incorporating passive smoke control systems, door fan testing must be performed. A minimum of 10% of all spaces passively protected shall be tested. A variety of spaces and locations within the building shall be selected in order to verify that the passive barriers were constructed properly. The results must be documented in the final Special Inspection report and shall be compared to the leakage values that were used in the modeling for the rational analysis.

E. SYSTEM VERIFICATION

1. Fans. All smoke control fans must be verified having the following:

a. Belt-driven fans must have at least 1.5 times the number of belts required for the design duty with the minimum number of belts being two.

b. Fan motors must not operate beyond their nameplate horsepower as determined from the measurement of the actual current draw or kW meter.

c. Fans must be examined for correct rotation. Measurements of voltage, amperage, revolutions per minute, and belt tension must be made.

d. Verify that the airflow sensors (current or pressure differential) are installed properly.

e. Verify that the fans are monitored downstream of all disconnects. If the fan has a Hand-Auto-Off switch at the fan, the switch shall either be removed or locked with a chain and padlock.

f. Verify that when fan belts are removed, the fire-fighter's smoke control panel indicates a fault light (Yellow) for the fan when the fan is set into smoke control mode.

2. Inlets and Outlets. The airflow from the inlet/outlet points for the smoke control system

must be measured using generally accepted practices.

3. **Pressures and Door Opening Forces.** Pressure differentials and maximum opening forces described in Section III must be measured for all scenarios. All potential smoke control scenarios must be tested and documented such as activation of just the smokeproof enclosures, activation of the smokeproof enclosures and an atrium exhaust system, and activation of the smokeproof enclosures, floor exhaust and an atrium exhaust system.

   The system shall be tested under normal power and emergency power. For buildings with smokeproof enclosures, the relief damper at the top of the smokeproof enclosure must be verified as exhausting 2,500 cfm once the entire system has been balanced and testing is complete.
4. **Control Verification.** Controls must be tested for all scenarios including the following:
   - **a.** All detection devices (smoke detectors, beam detectors) that are specified by the Sequence of Operations to activate a smoke control system must be tested by the special inspector. Proper configuration of the smoke control system must be confirmed for all detection devices.
   - **b.** Verify that there is positive confirmation of actuation, testing and manual override at the Fire-fighter's smoke control panel for all monitored fans, dampers, doors, etc.
   - **c.** Verify that there is presence of power downstream of all disconnects.
   - **d.** Verify that all panels that rely on volatile memories have uninterruptible power supplies that will span up to fifteen minutes of primary power interruption.

F. FINAL SMOKE CONTROL SPECIAL INSPECTION REPORT

A copy of the final Smoke Control Special Inspection report must be provided to Development Service and an identical copy must be provided in the Fire Command Center of the building. At a minimum, the final Smoke Control Special Inspection report must contain the following.

1. A copy of the approved smoke control and rational analysis report.
2. Documentation of each specific item inspected and tested including dampers, doors, detection devices, etc. (i.e. SFD Level 4 Men's Restroom).
3. Final Air Balance reports documenting all fans tested and each inlet/outlet.
4. Duct leakage testing reports.
5. Narrative detailing any modifications to the original smoke control design made during testing.
6. The entire report must be reviewed by the responsible registered design professional. Once the report is acceptable, the responsible registered design professional must seal, sign and date the report.