Smoke control system testing

Special inspectors must know how to test and commission fire systems, sprinklers, dampers, and alarms. A discussion of relevant codes and standards is included.

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Learning objectives

• Learn about the roles and responsibilities of a special inspector as they relate to smoke control systems
• Understand the smoke control testing and inspection process used by special inspectors as it relates to smoke control testing systems.
• Know smoke control equipment listing requirements.

The role of a special inspector as it pertains to the International Building Code for the inspection and testing of fire/life safety systems shall be performed by a qualified person who demonstrates competence, to the authority having jurisdiction (AHJ)’s satisfaction, for the inspection of the particular type of construction or operation. This article will discuss the process special inspectors use for testing a new smoke control system.

Special inspectors wear two separate but equally important hats. One hat represents the owner who has retained the special inspector services per International Code Council Section 909.3 and Section 1704.16 to ensure that the system(s) installed within the building are installed and function per the record documents. The special inspector is a representation of the building official. The owner is responsible for the fees associated with the special inspector, but the special inspector is obligated to the AHJ by acting as an extension of the AHJ to ensure that the smoke control system(s) installed within the building are installed and function per the record documents.

The testing process does not begin until approved documentation has been provided to the special inspector. Documentation includes the rational analysis, fire alarm drawings, mechanical drawings, automatic fire suppression system drawings, electrical drawings, and architectural drawings. Included within these documents should be the control diagrams.

Per Section 909.15, control diagrams are to indicate all devices in the system and identify their location and function. These documents must be approved prior to starting the testing process. The typical documentation reviewed includes the fire alarm sequence of operations and smoke control mechanical matrices. The control diagrams should detail how the rational analysis is to be incorporated into the building design.

Per Section 909.4, the rational analysis supports the types of smoke control systems to be employed, their methods of operation, and the systems supporting the method of construction to be used by providing performance-based language. This document typically contains the pass/fail criteria of the smoke control systems. These systems include the pressurization method, airflow design method, and exhaust method.

If the special inspector discovers conflicts between the record documents and the applicable codes, he or she should alert the owner, design team, and construction teams by issuing a noncompliance report. The report should detail the documents used for the testing and/or inspection, and include a brief description of the discrepancy as well as its location.

During the review process of the automatic suppression system drawings, the special inspector should verify if the automatic fire suppression system is cross zoned. Cross zoning occurs when an automatic fire suppression system serving one smoke zone also provides sprinkler protection to a separate smoke zone.

Once the review of the approved documentation is completed and any issues or conflicts resolved, the special inspector or design team may prepare a smoke control test plan.
The smoke control test plan should detail the integrated procedures to check, inspect, and test every operational component of the smoke control system, from the function of a specific piece of equipment to the overall system performance. The test plan should be distributed to all parties involved with the project, including the building official. This will ensure that all parties involved understand the testing process.

Typically, the initial request for inspection and testing of the smoke control system is to inspect the ductwork that is associated with the smoke control system and to witness the associated duct leakage testing. The ductwork associated with a smoke control system is as critical as the equipment attached to the ductwork. It is important that this ductwork be capable of exhausting or supplying the air without contaminating adjacent smoke zones that the ductwork crosses.

Per Section 909.10.2, duct leakage testing is required for any smoke control exhaust or supply ductwork. Some jurisdictions may not require the special inspector to witness duct leakage testing of ductwork contained within the smoke zone(s). The theory is to verify that the supply or exhaust inlets are provided with the required design air to properly balance the smoke control system. The pass/fail criteria for the duct leakage test should be provided by the mechanical engineer of record and may be detailed in the rational analysis.

The ductwork should be pressure tested to 1.5 times the maximum design pressure, and leakage is not to exceed 5% of the design flow per Section 909.10.2. The special inspector also should inspect the installation of the ductwork. Per Section 909.10.2, the ductwork shall be supported directly from fire resistance rated structural elements of the building. During this inspection, ductwork joints should be checked for proper installation of joint compound materials. This joint compound material will help prevent smoke-contaminated air from leaking out of the ductwork.

It is essential that the construction team understand the special inspector's role schedule his or her inspection accordingly. There are critical inspections and tests that must occur at specific points of construction to ensure code compliance. Examples of these critical inspections and tests are the verification of smoke barriers, verification of cross sprinkler zoning, and damper installation inspections. If the contractor fails to schedule accordingly, the budget and schedule may impact the issuance of the certificate of occupancy.

Per Section 710, smoke barriers shall form an effective membrane continuous from outside wall to outside wall and from the top of the foundation or floor/ceiling assembly below to the underside of the floor or roof sheathing. The special inspector should visually inspect all smoke zone boundaries to confirm smoke barrier continuity. He or she should check that required opening protection is installed. Opening protection consists of doors, dampers, fire shutters, accordion folding doors, and so forth. All through penetrations shall be protected by an approved penetration firestop system. The inspector should review the through penetration firestop system data sheet to confirm the material used complies with and is installed in accordance with the UL listing requirements.

All doors located in smoke barriers should be visually inspected to confirm the proper fire protection rating and “S” rating is provided per the approved record documentation, and should be inspected for proper functionality. Doors 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 smoke zone activation. When a door coordinator is provided, he or she should test to ensure that the doors properly close and latch.

Dampers

There are two types of damper controls: electrically controlled dampers and pneumatically controlled dampers. The testing and inspection process for both are similar, with the exception of the inspection and testing required for the pneumatic control tubing.

Per Section 716, smoke dampers are installed in ducts and air transfer openings, and are designed to resist the passage of air and smoke. Two classifications of dampers are installed within or associated with a smoke control system: Class I and Class II.

Smoke dampers must be able to operate automatically via an approved fire alarm initiating device and manually through the firefighter’s smoke control panel. Smoke dampers can be used in HVAC systems where the fans are shut down in the event of a fire, and also can be used in smoke control systems designed to operate during a fire incident.

Combination fire/smoke and/or smoke dampers associated with a smoke zone should be visually inspected to confirm the equipment has been installed per the approved record documents noted above and verify the fail-safe position as required by the approved documentation. Dampers located at smoke zone boundaries should be confirmed to be minimum Class II, 250 F smoke dampers with a UL 555S listing. The leakage class determines the acceptable air leakage through the damper with a 0.0145 psi pressure difference.

The UL 555S rating is critical to the successful operation of the smoke control system. If the duct penetrates a fire-rated wall, the UL555S rated damper will maintain the fire rating of the wall and will provide the required smoke damper as well. The UL 555 listing indicates that the damper is a fire-rated damper and not rated for use in a smoke control system. If a damper penetrates a fire-rated wall, the damper should be installed within the center plane of the wall. It is critical that these dampers be placed in this position to maintain the integrity of the boundary within which the damper is installed. If the damper is not located within the plane of the wall, the integrity of the boundary may become compromised. If the duct does not penetrate a fire-rated wall and only a smoke damper is required, the smoke damper does not need to sit within the plane of the wall to meet...
the listing requirements. For combination fire/smoke dampers, the temperature rating of the fusible link will be confirmed to be not less than 160 °F or greater than 350 °F when located in a smoke control system.

Per Section 909.10.4, automatic control dampers and motorized control dampers associated with a smoke control system must meet the same requirements listed above, regardless of where they are installed within the smoke control system. Typically, we see these types of dampers installed on exterior walls and roofs to maintain the exterior building envelope as well as within the elevator hoistways as hoistway ventilation dampers.

Per Section 909.13, control tubing that supplies air to the pneumatically controlled dampers must be flushed clean and dry prior to the final connections. This is to prevent blockage and/or rust from forming within the control tubing, which would impair the system operation. The control tubing should be inspected for proper installation and connection to the control unit(s). Control tubing that passes through concrete or masonry must be properly sleeved. The purpose of the sleeve is to protect the control tubing from abrasion and electrolytic action. Pressure testing of the control tubing should be conducted to confirm that the control tubing is capable of maintaining the required pressure without pressure loss, destruction of the control tubing, or the uncoupling of the fittings and/or valves. This is accomplished by pressurizing the control tubing by three times the operating pressure. The control tubing must maintain this test for a minimum of 30 min.

When the special inspector witnesses this test, he or she should mark on the drawings the location and time where the pressure measurement was read, and then return 30 min later to confirm that the pressure did not drop. If there is a drop in pressure, notify the contractor responsible for the installation of the control tubing and issue a noncompliance report to the owner. Once repairs have been made, repeat the test. If the pressure test is successful, then the associated noncompliance report can be cleared. Inspect the air compressor supplying the air for the pneumatic controls. The air compressor should be provided with a secondary power supply in case of loss of the primary building power supply.

Controls, zoning, and testing

The control tubing associated with the smoke control system should be isolated from serving any other building system. If the control tubing serves other systems throughout the building, confirm that the control tubing used for smoke control is isolated by automatic isolation valves. If isolation valves are provided on the control tubing, close the isolation valves prior to the pressure test. If these isolation valves remain open, the pressure test will provide inaccurate test results, rendering the test invalid.

The installation and zoning of the fire suppression system should be inspected to confirm that the system has been installed in accordance with the approved sprinkler drawings and that sprinkler system cross zoning has not occurred. Once the interior finishes of an area are installed, it becomes very difficult to trace the sprinkler system installation. Fire sprinkler systems should be zoned to correspond with the smoke zones. Multiple fire sprinkler systems may serve one single smoke zone, but a single fire sprinkler system may not serve multiple smoke zones.

Once the contractors have completed the installation and pretesting of the smoke control system, the special inspector may begin the system testing process as detailed within the testing plan. There are typically three phases of testing:

1. The first phase consists of verification of the smoke control program. This includes confirming proper control and monitoring of the smoke control equipment.
2. The second phase consists of witnessing the fire alarm contractor testing the fire alarm system. During this phase the special inspector should confirm the smoke control system configures properly via automatic initiation.
3. The third phase is the performance verification. This includes, but is not limited to, witnessing of pressure differentials and door forces, verification of airflows, and verification of velocities. The final phase should only be conducted when the building construction is finished.

The firefighter’s smoke control panel is one of two panels that are essential for the operation of the smoke control system. The other is the fire alarm control panel. The fire alarm control panel receives input signals from the field devices and equipment, and sends output signals to the field devices and smoke control equipment. This panel sends and receives signals to and from the firefighter’s smoke control panel for specific zones to be controlled and to illuminate the correct status lights associated with the smoke control zones and smoke control equipment. The smoke control panel is required to be UUKL listed for the intended use.

Once notification is provided to the special inspector that the smoke control system installation is completed and pretested, the testing process may begin. The special inspector should 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.

To confirm correct control and monitoring of smoke control related dampers, the monitored dampers serving a smoke zone should be visually inspected for proper open, closed, and fault statuses. The damper position must be monitored for correct configuration in regard to the active alarm or upon manual activation from the firefighter’s smoke control panel. With the active smoke control properly configured, remove the power from dampers that open upon alarm and verify that the damper fails in the closed position. With the damper in the closed position, the fault indicator light should illuminate on the firefighter’s smoke control panel indicating that the system is not properly configured. Once the fault indicator light has illuminated, restore power to the damper, and confirm proper position of the damper for the active alarm, the fault indicator light has extinguished, and the system has properly reconfigured.

To test the monitoring of closed dampers, loosen the damper control linkage attached to the dampers that close upon alarm and force the damper to the open position. With the damper in the open position, the fault indicator light should illuminate on the firefighter’s smoke control panel indicating that the system is not properly configured. Once the fault indicator light has illuminated, reconnect the damper control linkage to the damper, and confirm proper position of the damper for the active alarm, the fault indicator light has extinguished, and the system has properly reconfigured.
Power supply

The secondary power supply to dampers, if electric, should be confirmed by performance of a shunt test of the property’s primary power supply system. This is to ensure that the damper is connected to the building’s secondary power supply system. If the dampers are pneumatically operated, the associated air compressor should be supplied with primary and secondary power. Loss of power to the associated air compressor will cause the pneumatically controlled dampers to fail closed due to lack of air pressure within the control tubing. The shunt test should be the last test conducted by the special inspector.

Dampers should also be tested for the removal of power during a non-smoke control condition. If loss of power has occurred prior to an event, the building engineer must provide the required maintenance for the equipment. The simplicity of the requirement is to provide a functional system at all times. If the system is nonfunctional and indication is provided only when an active alarm occurs, the system will not function as required.

All smoke control fans should be visually inspected to confirm that the correct fan has been installed, the correct number of belts has been installed, and belt tension is proper. Confirm that the smoke control fan motors have a minimum service factor of 1.15, and that the fan rotates in the correct direction when supplied with primary and secondary power. To confirm that the correct number of belts is installed, review the fan manufacturer’s data sheet. The data sheet should indicate the number of belts required for the fan if the fan is not used for smoke control. Multiply this number of belts by a factor of 1.5; this will provide the number of belts required for the fan to be used for smoke control. All smoke control related fans are required to have a minimum two belts.

If a variable frequency drive (VFD) is installed for the fan(s), the data sheet will state that the fan is compatible with a VFD. VFDs provided for fans used for smoke control purposes are required to be provided with secondary power supply. Due to the volatile memory of VFDs, an uninterruptable power supply (UPS) should be supplied providing for a 15-min power supply, if primary power is interrupted.

The special inspector should confirm proper monitoring of smoke control fans by the firefighter’s smoke control panel. Each fan should be provided with a monitoring device for supervising the fan on, off, and fault statuses. Monitoring of the smoke control fans should be via a current transducer switch, pressure differential switch, and so forth.

To conduct the belt on/off test, the smoke zone should be activated and proper system configuration confirmed. Then, engage the associated power disconnect switch serving the fan and confirm that the fault indicator light has illuminated at the firefighter’s smoke control panel. Remove all the belts associated with the fan, restore the power disconnect switch, and confirm that the fan starts and the fault indicator light remains illuminated. Engage the power disconnect switch, re-install the belts, restore the power disconnect switch, and confirm that the associated smoke control zone and/or smoke control equipment indicates proper system configuration and/or run status. Repeat these steps for each smoke control fan required to operate in smoke control mode. This includes stairway pressurization fans, vestibule pressurization fans, elevator machine room pressurization fans, makeup supply fans, exhaust fans, and so on.

Air balancing

Once the “belt on/off” testing is completed, the operating conditions (rpm, amps, operating voltage, cfm, supply, and exhaust rates) of the smoke control fans should be measured to confirm that the units are operating within design parameters.

These measurements are typically recorded by a certified air balance contractor. Measurement of the fan operating conditions should occur after confirmation of the proper performance of each zone. An “actual fan” curve should be obtained from the fan manufacturer at this time and supplied in the final report. Obtaining the new fan curve from the manufacturer will indicate that the fan is on the safe side of the fan curve and operating in a safe manner.

A current transducer switch is a device that detects electrical current and generates a signal proportional to the electrical current. Pressure differential switches are switches that operate by making or breaking electrical contact based on the pressure within the ductwork associated with the smoke control fan. To confirm that the on, off, and fault statuses are properly monitored by the firefighter’s smoke control panel, a “belt on/off” test should be performed. The presence of power downstream of all disconnects should be checked to confirm that when the disconnect switch is engaged, a fault signal is registered at the firefighter’s smoke control panel.

Automatic control of the smoke zone should be confirmed. Automatic initiation of the smoke zone occurs upon activation of a fire alarm initiation device such as area smoke detectors, heat detectors, beam detectors, or water flow switches associated with the fire sprinkler systems serving the smoke zone. Upon activation, the proper sequence of operations per the approved record documents should be confirmed visually in the field and at the firefighter’s smoke control panel. This testing is conducted to verify correct smoke zone configuration when the associated fire alarm initiating devices are activated. The firefighter’s smoke control panel should indicate correct configuration of the smoke zone as well as any fault conditions that result from equipment not configured correctly.

Functional testing of all duct detectors associated with the smoke control fans should be conducted. Duct detectors should be tested to confirm proper shutdown of the associated unit, with proper reporting to the fire alarm panel. If the associated duct detector is provided with sampling tubes, the velocity across the sampling tubes should be measured and recorded. Compare the recorded velocity readings to the duct detector manufacturer’s data sheets to confirm that the associated duct detector is rated for the measured velocity. If the fan is required to operate for smoke control purposes, the duct detector shutdown of the

http://www.csemag.com/single-article/smoke-control-system-testing/98fe82e9923373e17... 12/15/2014
associated fan should be overridden by the manual controls located on the firefighter’s smoke control panel. The firefighter’s smoke control panel shall have the highest priority over any other device in the smoke control system.

Confirm that the firefighter’s smoke control panel has priority over all possible control features of the smoke control system for each possible scenario. This is critical if the equipment is used for the building’s normal HVAC and controlled via a BAS. Also confirm that the smoke zone and applicable equipment (fans, dampers, doors, etc.) are capable of manual control from the firefighter’s smoke control panel (manual “on” and manual “off” after automatic initiation).

**Performance testing**

Once all of the smoke control related equipment and smoke zone boundaries have been inspected, tested, and found to operate per the approved record documents, performance testing of each smoke zone should be performed. Performance testing varies depending on the smoke control mode used. Different smoke control modes can be used within the same building. Below is a general description of the different smoke control modes and the associated performance testing required.

There are several options for the ventilation requirements of an enclosed pressurized exit stairway. This is the stair shaft air movement system detailed in Section 909.20.4.4. According to that section, a dampered relief is to be provided and the stairway shaft supplied with sufficient air to maintain a minimum positive pressure of 0.10 in. of water in the shaft relative to the vestibule with all doors closed.

Door opening forces should be measured to confirm the opening force is less than 30 lbs. The stairway shaft should be inspected to confirm that there are no utilities installed within the stairway that do not serve the stairway. All penetrations must be properly fire caulked with approved materials, and all doors must be provided with smoke gasket material and listed as a smoke-rated door, and meet the required fire rating for their installed location. 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.

The special inspector must inspect and test the ventilation system associated with the pressurized exit enclosures. The associated equipment serving the pressurized exit enclosures must be provided with a primary and secondary power supply as well.

The secondary power supply system serving equipment used for smoke control should 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**

Once the smoke control testing process detailed within the smoke control test testing plan has been completed, and per Section 909.18.8.3, the special inspector must prepare a complete report of testing. The report should include identification of all devices by manufacturer, nameplate data, design value, measured values, and identification tag or mark. The report should then be reviewed by the responsible registered design professional; when he or she is satisfied that the design intent has been achieved, the design professional should seal, sign, and date the report. This should be done before the report is submitted to the building official.

It is important to remember that the special inspector is not an enforcing agency and cannot mandate that the design or construction team remedy any deficiencies noted. In order for the special inspector to submit a final report to the building official, the smoke control system must be in compliance with the applicable codes and the approved documents. Some jurisdictions do not allow the special inspector to submit a final report with any outstanding deficiencies. The special inspector is obligated to provide such information to the AHJ and detail the deficiencies in the final report.

Each jurisdiction may have different requirements related to the testing of a smoke control system. This is why it is essential that the special inspector submit a detailed testing plan to and procures concurrence from the AHJ prior to commencing the testing process. In some jurisdictions, the AHJ may rely solely on the special inspector to ensure code and design compliance of the smoke control system.

At the completion of the project, the owner should be provided with a code-compliant smoke control system. Once the building’s certificate of occupancy is issued, it is the responsibility of the owner and its staff to maintain the smoke control system in working order through the implementation of a preventative maintenance program.

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Michael, TX, United States, 07/16/14 10:41 AM:

Informative article, however I would like to clarify your statements regarding UL Classification. A UL555S rated Smoke Damper does NOT maintain the fire rating of a wall, a UL 555S rating is only an indication of the damper's ability to restrict the spread of smoke or assist with the control of pressure differentials. A Fire/Smoke Damper with both a UL555 and UL555S rating will maintain the fire rating of a barrier and restrict the spread of smoke or assist with control of pressure differentials as part of an engineered smoke control system. Chapter 7 of the IBC (2012) permits exceptions to requiring fire dampers at penetrations of fire barriers when the duct is part of an approved smoke control system in accordance with Section 909 where the use of the fire damper would interfere with the operation of a smoke control system. In this instance, as a best practice a UL 555/UL 555S rated Combination Fire/Smoke Damper can be utilized.

MAHENDRAKUMAR, IA, India, 07/22/14 09:50 AM:

Excellent information.
Very useful for Safety personnel engaged in Maintenance of Big Offices, Shopping Malls, Public Cinema Halls.

Mike, FL, United States, 07/23/14 05:46 PM:

Thank you gentlemen, this was a great review of Special Inspectors duties and engagements in smoke control systems.