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Integrating smoke control dampers and fans

Careful design considerations and proper interconnections are key.

Coordination between fans and dampers in smoke control systems requires consideration of the installation geometry, control sequence of operation, and sensor locations. There are both mechanical and electrical concerns. Among the basics are fan volume and pressures, damper tolerance to the pressures, and straight duct entrances to the equipment.

Smoke control system design and installation is multi-disciplined and complicated. Care with details is required in design, installation, and commissioning to ensure integration of components.

This article covers some of the smoke control basics of atria, air handling units (AHUs), shafts, vestibules, and stairwells. Figure 1 shows these typical smoke control systems. Each of the subsystems requires different control methods.

ATRIA

Atria and large spaces have large volumes, and exhaust is the best way to remove smoke from the occupied space. Unless natural ventilation is employed, make-up air dampers are installed in the lower side walls (see the lower left grey components in Figure 1).

If a fire occurs, the fire alarm system signals the atria exhaust system to start. As the exhaust fan starts, its discharge damper opens simultaneously (a barometric damper may be used instead of an actuated damper). In addition to the fan's discharge damper, a make-up damper in the space must open. Fresh air is pulled in to replace the smoke—typically via louvers located in the lower walls of the atria. There are several ways to wire fire alarms to fans and actuators; see Figure 2 for an example.

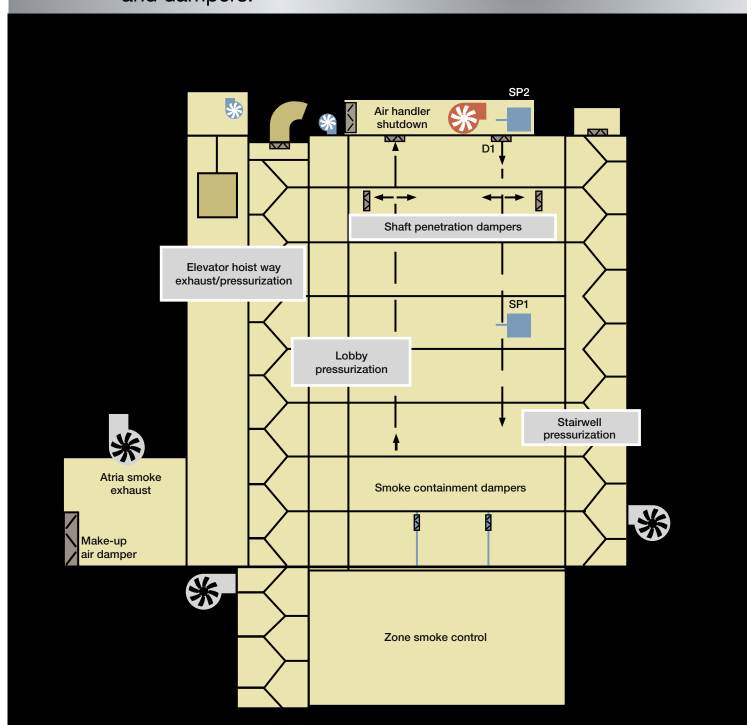
AHU SHUTDOWN

Regardless if AHUs are on or off, smoke will spread via the ducts and shafts (see Figure 3). As smoke cools, it drops and moves—both horizontally and vertically—down shafts and stairwells. If the AHUs are on, the smoke will spread even faster. In addition, open ducts allow passive airflow, supplying oxygen to the fire. For these reasons, smoke control dampers should be installed in all shaft penetrations. Dampers should close when the AHUs shut down to prevent the spread of smoke and feeding of oxygen to a fire.

ENGINEERED SMOKE CONTROL SYSTEMS

In an engineered smoke control system (such as a zoned smoke control system), the damper actuators are under automatic control

Figure 1: Primary smoke control systems showing fans and dampers.



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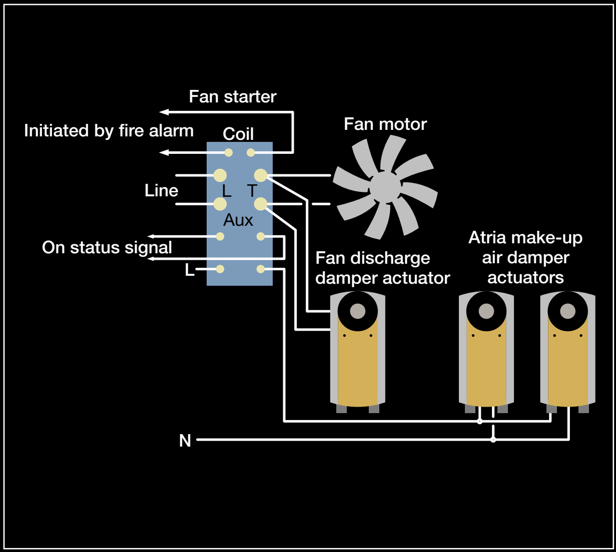


Figure 2: Fire alarm wiring to fan and actuator contactor or starter.

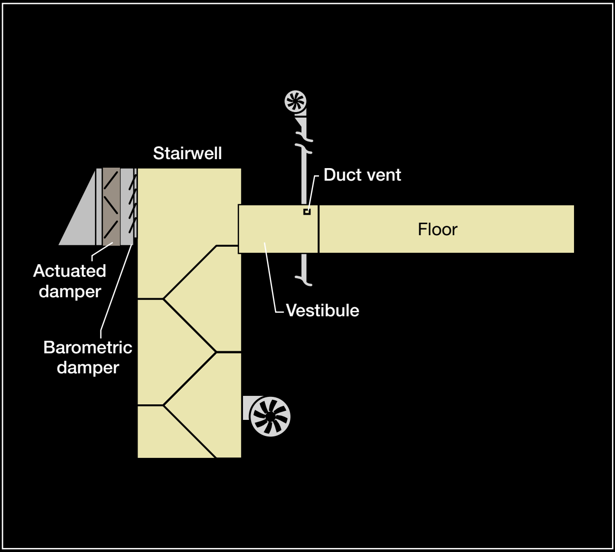
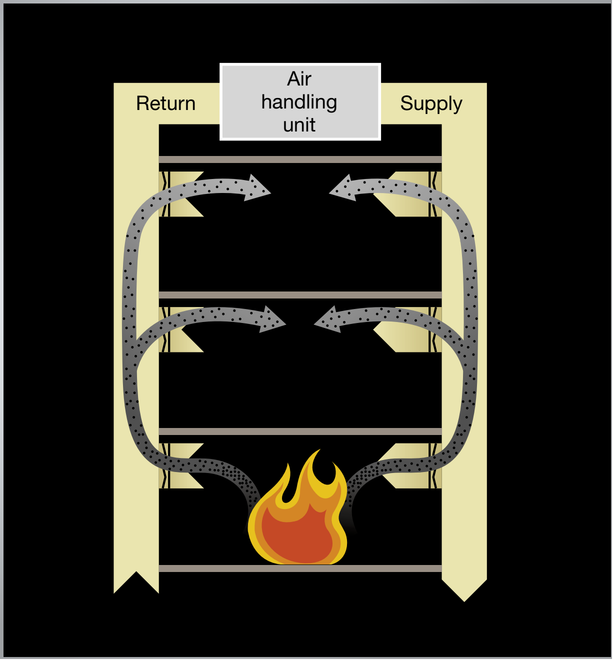


Figure 4: Vestibule between stairwell and occupied space.

of the smoke control panel. The dampers may open or close upon command from the automatic programming, or from command by the firefighters' smoke control system panel. Indication of open or closed status is achieved using actuator auxiliary switches, damper blade switches, or proximity switches.

Unless otherwise required by the International Building Code (IBC) 2006, Section 909, Smoke Control Systems, fans to spaces are typically shut down to (1) avoid fanning the fire with oxygen, and (2) prevent smoke from moving around the building.

Figure 3: Smoke movement through shafts without shaft dampers.



Wherever the ducts go through fire and smoke walls or barriers, combination fire and smoke dampers are installed.

It is common to find a static pressure (SP) sensor placed two-thirds of the way down the duct to control the inlet guide vanes or VFD to maintain pressure for the VAV boxes. In Figure 1, this is the blue sensor labeled SP1.

The same sensor can be used as a high-pressure limit for the fan. Take care to ensure that the controls contractor, concentrating on temperature control rather than smoke control, has not incorrectly programmed the system to use this sensor as a high limit for fan pressure.

If the main shaft smoke damper (D1 in Figure 1) closes, SP1 will not be able to sense the high static at the fan discharge. Alternately, if all the floor dampers close, then SP1 cannot sense the high pressure. As a result, the AHU walls and/or any ductwork between them and D1 can over-pressurize and blow out the seams of the duct. This is the number-one problem that contractors and commissioning agents report in fan-damper coordination. To help avoid this problem, install an additional sensor (e.g., SP2 in Figure 1) in the fan discharge, before any damper.

STAIRWELL PRESSURIZATION

It is critically important to prevent smoke in stairwells, as they are the primary means of egress in the event of a fire.

Barometric control. There are several different construction methods for stairwells. In high-rise buildings with vestibules (see Figure 4), the goal is to keep the stairwell air pressure positive with respect to the vestibules, and the vestibules positive with respect to the occupied floors. This keeps smoke from traveling toward the stairwell. There can be a single stairwell fan that pushes air toward the vestibule, or two fans: one for the stairwell and one for the vestibule. A duct runs from the vestibule fan with a takeoff to each vestibule. A simple blast gate can be used for balancing.

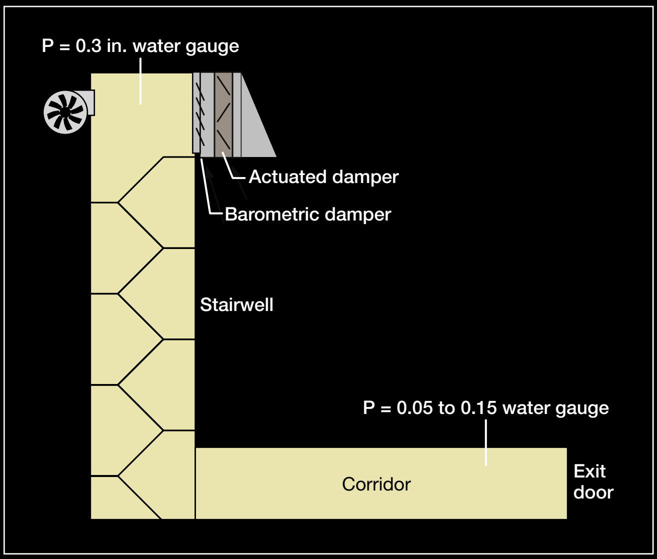


Figure 5: Fan discharge directly into damper prevents control at distant point.

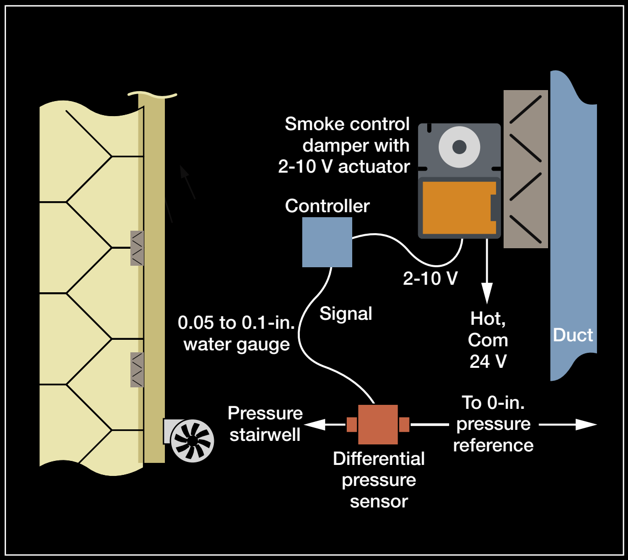


Figure 6: Ducted air distribution for stairwell pressure control.

When a fire alarm occurs, the stairwell fan starts and pressurizes the stairwell. A barometric damper relieves excess pressure. When doors open, the barometric damper closes and pressure is maintained.

Barometric dampers are lightweight and quite sensitive. Corrosion can occur over time without proper maintenance and can interfere with operation. One way to protect a barometric damper is to have an actuated damper in series on the exterior. The actuated damper opens fully, and the barometric damper relieves overpressure. The wiring is similar to that shown in Figure 2 for the motor and one actuator.

> "Buildings can be noncombustible or fire resistive. People are neither and they are not smoke resistive either."
>
> —*Francis Brannigan*

Figure 5 shows a geometric arrangement that does not allow correct coordination of pressures. The exit door end of the corridor must be maintained from 0.05-in. water gauge (IBC requirement) to 0.15-in. water gauge (some local requirements). There is pressure drop in the stairwell and corridor. The fan blows straight into the relief damper and the pressure at the top of the stairwell is too high. A duct must be installed to deliver the air, and outlets at appropriate locations would allow more even pressures.

Proportional damper control. A more common stairwell design features doors that connect directly to the occupied space or lobby. In this scenario, a fan must be large enough to push a volume of air against space pressure through at least one open floor door. The pressure required to do so varies with the occupied space pressure, which is often positive and could push smoke into the stairwell.

The fan may be constant volume or have a VFD. It is likely that air must be injected at various points up the stairwell via a duct. Two-stage motors or two fans may be used; for example, when the outside exit door opens, the high-speed windings or the second fan turns on to maintain the pressure in the stairwell.

In most cases, a duct is run the length of the stairwell and proportionally actuated dampers are used to control pressure (see Figure 6). Typically, there is one damper for every three to five floors.

In the event of a fire, the fan is on and the damper actuators are powered. When an exit door opens and air starts to flow into the floor, stairwell pressure drops and the dampers modulate open to maintain pressure. The damper nearest the open door will provide more air at the point it is needed.

The duct may be run within the stairwell or within a shaft in a wall adjacent to the stairwell shaft.

CODES AND STANDARDS

Smoke exhaust fans must be rated and certified by the manufacturer for the temperatures to which they are to be exposed.[1] In addition, fans must have smoke detectors in their inlets to stop them and prevent them from injecting smoke into a protected compartment. Smoke exhaust fans are UL793 listed for operation at 500 F (260 C) for 4 hr or 1,000 F (538 C) for 1 hr. Fan status and on-off-auto override switches are required at the firefighters' smoke control panel.

All dampers used in smoke control systems must be listed to UL555S.[2] However, exceptions are sometimes granted when the dampers will not be applied at high temperatures, or when they do not need to be low-leakage smoke rated (e.g., the barometric and outside air dampers used to relieve pressure at the top of a stairwell).

The connections to and from fans and dampers must take system effect into account. High pressure losses due to construction geometry can cause insufficient pressure. About three duct diameters upstream of a fan and one duct diameter per 1,000 fpm velocity downstream are required to avoid system effect.[3]

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REFERENCES

1. IBC 2006, 909.10.1.

2. IBC 2006, 716.3 in conjunction with 909.10.4.

3. Stevens, M. "Fan Specification System Effect." www.amca.org. Fall 2008. Also see AMCA Publication 201.

BIBLIOGRAPHY

ASHRAE 2007 Handbook, HVAC Applications. Chapter 52: Fire and Smoke Management.

ASHRAE Guideline 5 (1994 RA 2001), "Commissioning Smoke Management Systems."

Brannigan, F., and G. Corbett. "Building Construction for the Fire Service," Fourth Edition. National Fire Protection Association (NFPA). Sudbury, Mass.: Jones and Bartlett, 2008.

Klote, J. H., and J. A. Milke, "Principles of Smoke Management." American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc., 2002.

NFPA 72, National Fire Alarm Code, 2007.

NFPA 92A, Standard for Smoke-Control Systems Utilizing Barriers and Pressure Differences, 2009 Edition.

NFPA 92B, Standard for Smoke Management Systems in Malls, Atria, and Large Spaces, 2009 Edition.