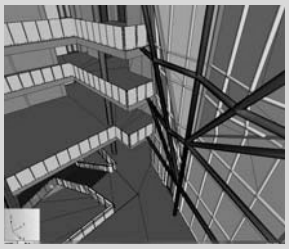
## Smoke Control - It's not Just for High-Rises



**ILLINOIS FIRE INSPECTORS ASSOCIATION**

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Presented by
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***JENSEN HUGHES, Inc.***

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## Overview

1. Intro to Smoke Control Requirements
2. Intro to Smoke Control Design
3. Pitfalls and Lessons Learned
4. After Certificate of Occupancy

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## 1. Smoke Control Requirements

Early Prescriptive Requirements (up to early 1990's)

- Air Changes
- Operable Windows

Current Prescriptive Requirements

- Passive or active smoke control
- Based on design fire and specific guidelines for feature being protected

Performance Requirements

- Establish Performance Goals
- Outline Design Method
  - Acceptance Testing Requirements

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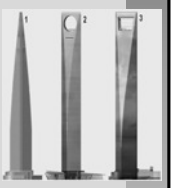
## 1. Where is Smoke Control Required?

- Atria / Covered Malls
- High Rise Buildings
  - Smokeproof Exit Enclosures-Section 403 (909)
  - Elevator hoistway pressurization alt – Section 707.14
- Underground Buildings
- Smoke Protected Assembly Seating (& Stages)
- Institutional Group 3 Windowless Compartments



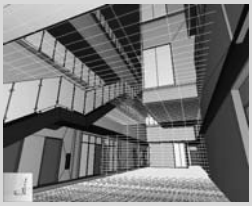


## 2. Methods of Smoke Control

Pressurization method 909.6

Airflow method 909.7

Exhaust method 909.8

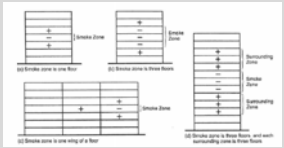




## 2. Methods of Smoke Control

Pressurization Method

- Maintain pressure difference across smoke barriers
  - Minimum 0.05 inch water gage
  - Maximum based on door opening/closing forces
- Pressure differentials are used to mitigate smoke spread





Images from the Handbook of Smoke Control Engineering, 2012

## 2. Methods of Smoke Control

Pressurization Method

- Problems
  - Building may be tighter than calculated
  - Oversizing fans means door opening problems
  - Balancing with stairs and other pressurization systems

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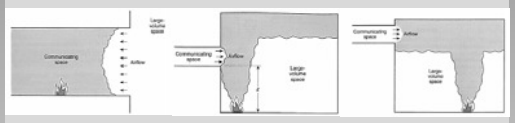
## 2. Methods of Smoke Control

Airflow Method

- Typically used in combination with other methods
  - Difficult to accomplish in large openings



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Images from NFPA 92B, 2009 Edition

## 2. Methods of Smoke Control

EXHAUST METHOD

- Used for large enclosed volumes
  - Maintain smoke 6-ft above highest walking surface used for egress
  - Require special approval

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## 2. Methods of Smoke Control

### Exhaust Method

- Make up air by natural or mechanical means is required
- Maximum make up air velocity – 200 fpm
- Exhaust high and supply low
- Plugholing
- Analyze balcony conditions



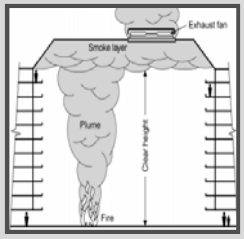
## 2. Methods of Smoke Control

### Axisymmetric Plume

Prototypical plume

Cone with tip at bottom

Air entrained on all sides






## 2. Methods of Smoke Control

Axisymmetric Plume

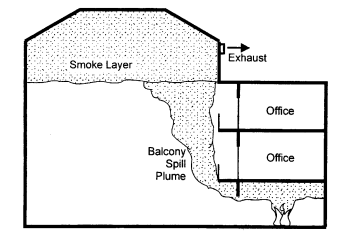
Result shows exhaust rate (fan size)

Problems:

- must know fire size
- very dependent on height
- does not address large area spaces (unique geometry)
- does not address dilution
- Conservative for tall, small spaces

## 2. Methods of Smoke Control

### Balcony Spill Plume






## 2. Smokeproof Enclosures

### Smokeproof Enclosures

- Three Options
  1. Open air vestibule or balcony
  2. Vestibule ventilation
  3. Stairwell pressurization



## 2. Smokeproof Enclosures

### Open air vestibule or balcony

- Provide rated vestibule
- Minimum dimensions (44-in X 72-in)
- Exterior opening 16 SQ. FT

## 2. Smokeproof Enclosures

Vestibule ventilation

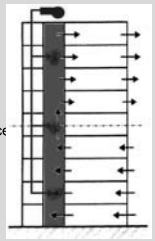
- Exhaust rate at 150% supply
- Stair pressurized to 0.10 in w.c.
- Smoke trap
- Location of vents



## 2. Smokeproof Enclosures

Stair Pressurization

- Pressures
  - Minimum 0.1 inch water gage
  - Maximum 0.35 inch water gage
  - Maximum based on door opening/closing force
- Injection points





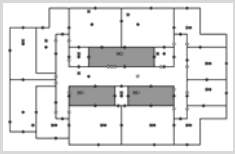
## 2. Smokeproof Enclosures

Elevator Pressurization

- Allowed as exception to elevator lobbies
- Elevator pressurized 0.1 to 0.25 in w.c.
- Challenges when balancing other systems

## 2. Performance Based Design Approach (Pressurization)

- Network Zone Model (ContamW)
  - Input flow paths, leakage, temperature differentials, weather
  - Simulate the impact of multiple systems on each other





## 2. Performance Based Design Approach

| CFD Models(Cons) | CFD Models(Pros) |
|---|---|
| • Simulations can be computationally extensive. | • Provides a more accurate assessment of the smoke control system (more efficient designs) |
| • Significant effort required to build and evaluate model | • Make-up air can often be introduced at velocities greater than 200 FPM |
| | • More design flexibility |



## 3. Pitfalls

| | |
|---|---|
| Smoke control systems are forever | Fans |
| Smoke control system required | Power systems |
| Special Inspector | Detection and control systems (positive confirmation) |
| Rational Analysis/Report | Control diagrams |
| Smoke barrier construction | Firefighters' Smoke Control Panel |
| Opening protection | Acceptance testing |
| Ventilated Vestibule | Smoke Control Inspection Report |
| Pressurized stairs | Final system acceptance |
| Elevator Hoistways | After acceptance |
| Leak testing of smoke control ducts | |

## 3. Smoke Control Systems are Forever

Smoke control systems require attention from project concept to past the C of O

Get involved at the beginning

Have a written procedure

Understand and come to agreement of smoke control system configuration.

Get help



## 3. In the Beginning

Smoke control system concept prior to submission for permit (exhaust and airflow).

ID of special inspector.

Verify concept on permit drawings

- Fan Schedules
- Matrix (Sequence of Operation)



## 3. Smoke Control System Required

Responsibility of the design team

Don't assume

Should be obvious (atriums)

But not always (stair and elevator pressurization)

## 3. Special Inspector

Sections 909.3 and 909.18.8

Qualifications (Section 1704.2.1)

- Fire Protection Engineering
- Mechanical Engineering
- Certified Air Balancer



## 3. Special Inspector

Typically retained by the Owner

Always responsible to the AHJ

Prepares Test Plan

Should work early and closely with the construction team



## 3. Special Inspector

Review design drawings

Review contractor drawings/data sheets

- Mechanical
- Electrical
- Sprinkler



## 3. Special Inspector

Inspects systems as they are being installed.

Tests completed systems

Files inspection and test report with AHJ

Assists AHJ during final acceptance



## 3. Rational Analysis/Report

Section 909.4

- Stack effect
- Temperature effect of fire
- Wind effect
- HVAC systems
- Climate
- Duration of operation

Must be approved by AHJ (exhaust & airflow)



## 3. Smoke Barrier Construction

Section 909.5

Minimum leakage

Door fan testing – passive systems

Door components

Penetrations

Get it done early!!!

## 3. Opening Protection

Section 909.5.2

Self-closing

Automatic closing/opening devices

Latching or re-latching

Fire/smoke dampers



## 3. Automatic Closing/Opening

Automatic closing doors or shutters activated by local smoke detector

- Sometimes, any alarm

Automatic opening doors

- Usually make-up air
- Security bypass
- Weekly test



## 3. Latching/Relatching

Need to check after door is released and latched.

Pressure conditions can vary



## 3. Fire/Smoke Dampers

Must have access door.

Verify free movement.

Verify class

Visually verify position during smoke control operation

No fire sealant

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## 3. Ventilated Vestibule

909.20.4.2

Verify air flow requirements

Verify exhaust & supply grille location

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## 3. Pressurized Stairs

Section 909.20.5

0.10 to 0.35 inches water column

15-pound door force (1008.1.3)

- Door sweeps
- Door guy

Penetrations

Elimination of barometric relief damper

- Still required by NFPA 101

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## 3. Elevator Hoistway Pressurization

909.21

In lieu of elevator lobbies

0.10 to 0.25 inches water column

Measured at midpoint each door

Verify door operation



## 3. Leak Testing of Smoke Control Ducts

Section 909.10.2

Tested at 1.5 times maximum design pressure

Leakage shall not exceed 5% of design flow

Need documentation

Certified Test & Balance Contractor

Perform prior to installing dampers



## 3. Fans

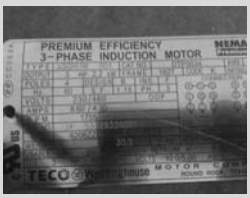
Section 909.10.5

1.15 service factor for fan motor

1.5 times the required belts

Minimum two belts

Letter from fan manufacturer



## 3. Power Systems

Section 909.11

Normal and Emergency

Separate room

Ventilation directly to outside



## 3. Detection & Control Systems (Positive Confirmation)

Section 909.12

Controls input/output signals

UL 864, UUKL

Actuation

Manual override

Power downstream of all disconnects

Testing of equipment



## 3. Positive Confirmation

Power downstream of all disconnects

- Current Sensor
- Switch position

## 3. Positive Confirmation

Power downstream of all disconnects

- H-O-A switches
- VFDs
- MCC
- Normal and smoke control modes



## 3. Positive Confirmation

Fans

- Belts off
- Current sensor
- Pressure switch
- Sail switch

Dampers, Doors and windows

- End switches
- Damper disconnects



## 3. Control Diagrams

Section 909.15

Indicates all devices

- Sequencing
- Identification numbers

## 3. Firefighters' Smoke Control Panel

Section 909.16

Fans, ducts, dampers and other equipment

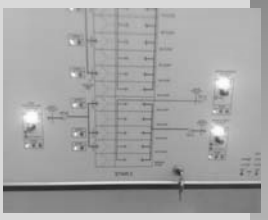
- "Complex System" exemption

Individual status and control

Red, Green, Yellow AND White indicators



## 3. FF Smoke Control Panel





## 3. FF Smoke Control Panel

"On", "Off", "Open", "Close" and "Automatic" Control

Highest priority

Lock out

First Smoke Control Sequence Locks in

## 3. FF Smoke Control Panel

Initiation

- SC Panel switch in manual position
- SC fan/system switch in off position
- Cause alarm – no smoke control
- Turn system on

Overrides

- Duct detectors
- Freezestats
- Smoke control sequence






## 3. Acceptance Testing

Section 909.18

Fire alarm devices

Dampers, fans and ducts

Smoke barriers

Controls

Weekly self-test



## 3. Acceptance Testing

Should be based on 909 performance requirements

Smoke bombs not realistic, but can show air flow



## 3. Smoke Control Inspection Report

Section 909.18.8.3

Devices and equipment

Design/measured values

Signature, stamp and date from the Engineer of Record

Maintain in building/fire command room

## 3. Final System Acceptance

Section 909.19

Certificate of Occupancy, or lack thereof

Phased openings

Fully completed and operational



## 4. Are We Done?

System maintenance and testing

Semi-annual required (NFPA 92A/B)

Case histories

- 1 year installation
- 3 year installation
- 25 year installation



## 1 Year Installation

Passenger and freight elevator lobby doors did not close and latch.

Smoke seals were missing.

New penetrations were discovered that were not sealed.

Three fans and three dampers were in fault on the smoke control panel.

Some dampers were not closing on alarm.

Several damper power junction boxes were missing covers and had wires hanging out.



## 3 Year Installation

We could not find a supposedly existing dedicated smoke exhaust fan. When we questioned the building engineer, he said the fan never operated, so they took it out.

Elevator lobby doors did not close and latch.

Stair vestibule doors did not close and latch. Some stair or vestibule doors couldn't close because the concrete floor had "heaved" and created a door stop.

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## 25 Year Installation

The 12 story guest tower had 3 dampers per floor and a supply unit to provide make-up corridor air. On a floor alarm, the fan was supposed to shut down and dampers close. Fan did not shut down, only 9 of 30 dampers were operable (the rest stayed open). This deficiency created a condition similar to MGM Las Vegas fire over 20 years ago and killed many people from smoke migration far from the fire's origin.

None of the stair pressurization systems worked on alarm. Power wiring was disconnected on one system and fuses blown on another.

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## 25 Year Installation

The hotel's three story "atrium" (basement, first and second floor) had a smoke control system based on 6 air changes per hour. Current actual performance was poor because one required exhaust system was enclosed within wall construction on some previous renovation project. Also, several fans that were supposed to shut down and dampers close didn't and were inoperable.

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## 25 Year Installation

System was “tested” annually and passed each time, according to test certificates. You need more than just a fire alarm contractor to test these systems. Individual contractors are not familiar with how all portions of an integrated system work.

A controls contractor was modernizing the VAV box motor operators without acknowledging the smoke control system requirements (you guessed it, they arranged the fail-safe position opposite to the existing requirements).



## Thank You For Your Time!

Questions?

Jensen Hughes, Inc.

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