Motorised Fire & Smoke Protection in Ventilation Ducts

Mechanical Smoke Extraction

ASHRAE Seminar
College of the North Atlantic, Doha, Qatar
20th April 2013
Agenda

• Introduction
• Benefits of Motorising Fire & Smoke Dampers
• Mechanical Smoke Extraction (Smoke Control)
• Monitoring & Control Systems for F&S applications
• UL / EN Comparison
Introduction
Fire protection in buildings – The 3 pillars of fire protection

**Constructional**
- Fire compartments
- Smoke compartments
- Use of fire retardant materials
- Escape routes, emergency exits

**Technical**
- Fire dampers
- Fire alarm system
- Extinguishing systems (e.g. sprinkler)
- Smoke control systems
- Overpressure systems

**Organisational**
- Alarm and evacuation plans
- Emergency concepts
- Training of staff
- Periodical evacuation trainings
- Briefing of the fire brigade
Field of applications

Fire protection: Motorisation of fire and smoke dampers

Smoke control / smoke extraction: Motorisation of smoke control dampers
Benefits of Motorising
Fire & Smoke Dampers
Motorised Fire & Smoke Dampers

Impact of fires:

Loss and damage of…

- Lives
- Assets
- Environment
- Business operation
- Adjacent buildings
Motorised Fire & Smoke Dampers

Main protection target:

The spread of Fire and Smoke within the building through ventilation ducts must be prevented.
Motorised Fire & Smoke Dampers

Where are fire dampers required?

• Basic principle: The defined protection targets from the fire safety concept of a building must be reached.

→ The spread of fire and smoke through ventilation ducts must be prevented.

• Fire dampers have to be used when:
  • Ventilation ducts penetrate fire walls
  • Ventilation ducts penetrate fire rated ceilings

Note: Fire dampers must be installed in such a way, that cleaning and maintenance work is supported.
Motorised Fire & Smoke Dampers

Early sealing of compartment with motorised fire dampers

- Activation of fire dampers by fire alarm system
- Activation directly by a relevant smoke detector
- Activation by the building management system

→ Today's state of the art solution
Motorised Fire & Smoke Dampers

Early sealing of compartment with motorised fire dampers

- Example animation "Hotel room"
- Ventilation off situation
Motorised Fire & Smoke Dampers
Smoke Flow and Temperature Simulations

By AFC Air Flow Consulting AG, Zurich, Switzerland

• **Project objective**
  • To demonstrate possible advantages (time gain) of the activation of a fire damper installed in the outlet air duct by a smoke detector compared to the activation by a thermal fuse (fusible link)

• **Approach**
  • CFD simulations (Computational Fluid Dynamics) of a standardised office fire on the basis of various room types
Motorised Fire & Smoke Dampers
Smoke Flow and Temperature Simulations

**Basic definitions**

- Typical office building
- Room dimensions
  - Small: 600.0 m² (20 x 30 m)
  - Medium: 1,200.0 m² (30 x 40 m)
  - Large: 2,400.0 m² (40 x 60 m)
- Room height: 4.0 m
- Ventilation
  - Standard ventilation system
  - No smoke control system
- Sprinkler system: None
Smoke flow simulations

- **Fire definition**
  - Slowly developing fire
  - No sprinkler system
  - Power: max. 1 MW
Motorised Fire & Smoke Dampers
Smoke Flow and Temperature Simulations

- **Room layouts and location of the fire source**
  - Small room 20 x 30 m

- Measuring point
  - a) Thermal fuse
  - b) Smoke detector

- Fire source
Motorised Fire & Smoke Dampers
Smoke Flow and Temperature Simulations

- Room layout and location of the fire source
  - Medium room 30 x 40 m

- Measuring point
  a) Thermal fuse
  b) Smoke detector

- Fire source
Room layouts and location of fire source

- Large room 40 x 60 m

- Measuring point
  - a) Thermal fuse
  - b) Smoke detector

- Fire source
Motorised Fire & Smoke Dampers
Smoke Flow and Temperature Simulations

- Simulation results: Small room (600 m², 2’400 m³/h)
Motorised Fire & Smoke Dampers
Smoke Flow and Temperature Simulations

- Simulation results: Medium room (1'200 m², 4'800 m³/h)
Motorised Fire & Smoke Dampers
Smoke Flow and Temperature Simulations

• Simulation results: Large room (2'400 m², 9'600 m³/h)
Summary of the results / conclusions

- All results depend strongly on the fire scenario, the room layout and the location of detection.
- All conclusions are valid under consideration of the limits of the used model.
- Thanks to the use of a smoke detector fire dampers can close from 3:00 up to approx. 10:00 min earlier compared to temperature triggering.
- There are even fire scenarios where the operating temperature is never reached at the measuring point!
- Smoke detectors in combination with motorised fire dampers allow the most reliable and earliest activation in case of a fire.
Motorised Fire & Smoke Dampers
BRE Real Fire Test – Conclusions

Examination of the fire resistance requirements for ducts and dampers

The authors of this report are employed by BRE. The work reported herein was carried out under a Contract placed by the CCTB. Any views expressed are not necessarily those of the CCTB.

Public download:
http://www.bre.co.uk/filelibrary/pdf/rpts/partb/ducts_and_dampers.pdf
This report summarises the work carried out during this project. This includes a literature search and review of fire loss reports and data from actual fires relating to fires involving HVAC systems from UK and US sources which sought to identify relevant trends in performance during different fire situations. In addition, the results of the experimental programme are presented. The experimental work was carried out in two stages, one stage looked at the fire resistance of three different duct and damper installations built to current industry based codes. The second stage consisted of a detailed examination of the activation of dampers contained within the ductwork when exposed to developing fires.
The results of this work showed that dampers vary in terms of their activation characteristics. In the early stages of a developing fire, this project has indicated that dampers relying only on fusible links may not shut in a fan-off situation because the gas temperatures recorded at the fusible link at the damper position may be below the operating temperature of the fusible links (70°C).

In some cases, it has also been shown that dampers may not close in the fan-on situation and this is partly dependent on the position of the fusible link within the duct. If the fusible link is low down in the duct, it will be exposed to lower gas temperatures and may not reach its activation temperature. It is also to be noted that intumescent dampers in general, are designed to activate at higher temperatures than fusible links.

In some applications, it is therefore considered that fire and smoke combination dampers intended to prevent the spread of smoke and fire that are activated only by fusible links may not be suitable.

The multi-blade, circular single blade and intumescent fire dampers functioned extremely well in the fire resistance test which was designed to replicate three typical damper/duct/wall installations. All dampers closed/sealed and were able to provide the required fire resistance. Therefore, in a post-flashover fire situation, as represented by the fire resistance test, our work has shown that dampers can close and contribute to the maintenance of compartmentation.
## Motorised Fire & Smoke Dampers
BRE Real Fire Test – Conclusions

<table>
<thead>
<tr>
<th></th>
<th>FAN ON 500kW</th>
<th>FAN ON 300kW</th>
<th>FAN OFF after 2 Min.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average Closing Time</strong></td>
<td>406s</td>
<td>551s</td>
<td>-</td>
</tr>
<tr>
<td><strong>Did not Activate</strong></td>
<td>2 out of 7</td>
<td>1 out of 9</td>
<td>4 out of 4</td>
</tr>
</tbody>
</table>
Motorised Fire & Smoke Dampers

Sequence control of motorised fire dampers
  • Sealing of compartment and overpressure generation
# Motorised Fire & Smoke Dampers

## Summary Non-motorised vs. motorised fire dampers

<table>
<thead>
<tr>
<th>Conventional fire dampers</th>
<th>Motorised fire dampers</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Only activates when temperature reaches 72°C local to the damper – does not protect against the spread of cool smoke</td>
<td>• Fast activation via the fire detection system – therefore giving increased protection against the spread of cool smoke</td>
</tr>
<tr>
<td>• Maintenance is difficult, costly and complicated.</td>
<td>• Remote testing:</td>
</tr>
<tr>
<td>• Testing is seldom achieved.</td>
<td>- regular functional checks</td>
</tr>
<tr>
<td>• Restricted applications not suitable for:</td>
<td>- operating diagnostics</td>
</tr>
<tr>
<td>- fan on systems</td>
<td>• Provides compartmentation:</td>
</tr>
<tr>
<td>- means of escape</td>
<td>- early zone compartmentation in the event of fire</td>
</tr>
<tr>
<td>- sleeping risk dwelling</td>
<td>- night shutdown</td>
</tr>
<tr>
<td>• Fixed position – no control.</td>
<td>- non-occupancy</td>
</tr>
<tr>
<td></td>
<td>• Suitable for all applications.</td>
</tr>
</tbody>
</table>
Mechanical Smoke Extraction
(Smoke Control)
Some Facts

Where there is a fire, there also is smoke.

Example:
1 kg of burning PVC produces >500 m³ of smoke.

Smoke, usually toxic gases, is the most common cause of death in a fire.

90% of the people die due to the smoke.

Smoke is a killer!
Toxic Effects of Smoke

Composition of smoke:
- Toxic gases
- Irritant gases
- Pyrolysis products (VOC)
- Solid particles (carbon)

Symptoms:
- Headache, vertigo, shortage of breath, scraping in the throat, sickness
- Loss of consciousness, breakdown, edema of the lung, death

→ Five breaths are enough to die.
Psycological Effect of Smoke

Visibility in meters and (well-)beinging

20 +
Ease and orientation

10 - 20
Discomfort, insecurity

0 - 10
Fear, panic
Movement and Spread of Smoke

- Smoke gets a lift (buoyancy) from hot gases in the burning zone
- Smoke spreads within the burning zone
- With the stack effect smoke can spread in the entire building
- Wind pressures on the facade of a building have an influence on the movement of smoke, as well as ventilation and air conditioning systems and elevators
- Smoke is rather difficult to control, depending of what is burning, the size of the fire and how hot it is
Movement and Spread of Smoke

- Not only people are in danger of smoke, also assets values and the operability of businesses and organisations.

- Fire safety concepts for buildings should mandatorily also contain most effective measures for the protection against smoke (not only against heat).
Mechanical Smoke Extraction (Smoke Control)

Where are smoke control systems required?

- **Basic principle:** The defined protection targets from the fire safety concept of a building must be reached.

- **Depending on the construction and the use of a building, this can only be reached by using a powered smoke control system.**

- **Typically smoke control systems are used in buildings with "special utilisation", e. g.:**
  - Cinemas
  - High rise buildings
  - Hospitals
  - Hotels
  - Car parks, underground parking
  - Malls, shopping centers
  - Museums
Basic Principle of Smoke Control

Mechanical Smoke extraction

- Example animation "Cinema"
Influence of Extracting Smoke

With extraction of smoke

Without extraction of smoke
Benefits of Extracting Smoke

- Supports the evacuation of people and animals by creating a smoke free layer
- Cools the fire compartment and delays / prevents flash and the subsequent development of the fire
- Supports rescue and fire fighting work
- Protects assets and reduces the thermal effects on structural components during a fire
Definitions of Smoke Control Systems
As an example acc. to EN 12101-8 (Product Standard SC Dampers)
Definitions of Smoke Control Systems
As an example acc. to EN 12101-8 (Product Standard SC Dampers)
Key

1 Fire compartment
2 Smoke reservoir
4 Air inlet
5 Smoke barrier
6 Powered smoke and heat exhaust ventilator (fan)
7 Smoke control dampers for single compartments (EN12101-8 and EN1366-10)
8 Smoke control ducts for single compartments (EN12101-7 and EN1366-9)
9 Smoke control ducts for multi compartments (EN12101-7 and EN1366-8)
10 Smoke control dampers for multi compartments (EN12101-8 and EN1366-10) mounted inside or outside of wall or floor
11 Smoke control dampers for multi compartments (EN12101-8 and EN1366-10) mounted on the surface of the duct
12 Electrical equipment
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Cause & Effect

(Example)

Sensorik / Sensors

<table>
<thead>
<tr>
<th>Sensor No.</th>
<th>Damper No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
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<td>3</td>
<td>4</td>
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<td>5</td>
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<td>6</td>
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<td>6</td>
<td>7</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
</tr>
</tbody>
</table>

Sensor No. Damper No.

1 1

Scenario Matrix

Scenario

Damper OPEN
Damper CLOSED
Fire
Cause & Effect
(Example)
Cause & Effect
(Example)
Cause & Effect
(Example)
Special Topic:
Sprinkler Systems
Effects of Sprinkler Systems from a Smoke Control Point of View

Positive:
• Extinguishing the fire

Not positive:
• Production of low temperature smoke
• Production of moist and dense smoke
• Creates more smoke volume
If mechanical (non-motorised) fire dampers are installed and/or no smoke control system is available the following side-effects can be expected:

- **Low temperature smoke** passes through the ventilation system without triggering the fusible link. It also reduces the buoyancy of the smoke layer.

- **Moist smoke** produces sulphuric acid and smoke adhesion

- **Dense smoke** reduces visibility
  - Impedes the evacuation of people
  - Reduces the effectiveness of fire fighting

- **Increased smoke volume** generates overpressure
  - Increasing the speed of smoke travel through the system
  - Entering neighbouring zones
  - Contributes to the stack effect
How to avoid the side-effects of sprinkler systems:

- **Motorise all fire dampers (controlled by smoke detectors)**
  - Stops the spread of fire and smoke – gains time
  - Regular checking of safety systems – only as good as the last time it was tested
  - MTBF is increased
  - Closing the dampers during the night (most fires start at night)
  - Energy saving

- **Provide a smoke control system**
Monitoring & Control Systems for F&S Applications
• **Integration solutions**
  • Conventional control with position feedback

4- to 6-wire
(feedback open/closed provided by auxiliary switches)

2-wire (control open-close)
Monitoring & Control Systems

- **Integration solutions**
  - Zone solution with controller

* Optional: smoke detector with potential-free contact
Integration solutions

- Bus networks such as Modbus RTU or BACnet MS/TP

* Optional: smoke detector with potential-free contact

1...8 dampers

Modbus RTU

BACnet
Monitoring & Control Systems

• **Integration solutions**
  • Various protocols via DDC controller

* Optional: smoke detector with potential-free contact
Monitoring & Control Systems

- **Integration solutions**
  - LONWorks® via gateways

**Support for gateway is provided by third-party manufacturer**
Main advantages of monitoring & control systems for F&S dampers

- Reduced costs during the operation of the building
- Considerable reduction of wiring effort
- Considerable reduction of fire load within the building
- Full transparency throughout the building
  - Event logging
  - Failure protocols
  - Regular testing → Reduced risk level within the building
Regular Testing → Reduced Risk
Non-motorised Fire Damper

Risk level

- high
- medium
- low

Time (Months)

- 6 Months
- 12 Months
- 24 Months

Commissioning
On-site inspection
On-site inspection
On-site inspection
Regular Testing → Reduced Risk
Motorised Fire Damper (Conventional Actuator)

<table>
<thead>
<tr>
<th>Risk Level</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>medium</td>
<td>12, 24</td>
</tr>
</tbody>
</table>
Regular Testing $\rightarrow$ Reduced Risk
Motorised Fire Damper (Communicative Actuator)

Risk level
- high
- medium
- low

<table>
<thead>
<tr>
<th>Time (Months)</th>
<th>Risk Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 Months</td>
<td>medium</td>
</tr>
<tr>
<td>12</td>
<td>high</td>
</tr>
<tr>
<td>24</td>
<td>low</td>
</tr>
</tbody>
</table>

Commissioning  | Electr. function test  | On-site inspection |
----------------|------------------------|--------------------|
6 Months        | 12                     | 24                 |
UL / EN Comparison
UL / EN Standards Comparison

Underwriters Laboratories

Communauté Européenne
## UL / EN Standards Comparison

### Main Standards

<table>
<thead>
<tr>
<th></th>
<th>Fire Dampers</th>
<th>Smoke Dampers</th>
<th>Fire Dampers</th>
<th>Smoke Control Dampers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UL 555</strong></td>
<td>Test Standard</td>
<td><strong>UL 555S</strong></td>
<td>Test Standard</td>
<td></td>
</tr>
<tr>
<td><strong>EN 15650</strong></td>
<td>Product Standard</td>
<td><strong>EN 1366-2</strong></td>
<td>Test Standard</td>
<td></td>
</tr>
<tr>
<td><strong>EN 1366-10</strong></td>
<td>Test Standard</td>
<td><strong>EN 13501-3</strong></td>
<td>Classification Standard</td>
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<tr>
<td><strong>EN 13501-4</strong></td>
<td>Classification Standard</td>
<td></td>
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</tbody>
</table>

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**Addendum:**

- UL 555 Test Standard
- EN 15650 Product Standard
- EN 1366-2 Test Standard
- EN 13501-3 Classification Standard
- EN 12101-8 Product Standard
- EN 1366-10 Test Standard
- EN 13501-4 Classification Standard
UL / EN Standards Comparison
Additional Standards

- UL 33  Heat Responsive Links for Fire-Protection Service
- UL 873  Temperature-Indication and -Regulating Equipment

- ISO 10294-4  Test of thermal release mechanism
- EN 60730  Automatic electrical controls for household and similar use
UL / EN Standards Comparison
Main Differences – Typical Fire Dampers

Typical Fire Damper (Curtain Damper)
Typical Multi-Blade Fire Damper
Typical Combination Fire Smoke Damper
Single-Blade Round Fire Damper

Single-Blade Square Fire Damper
Single-Blade Round Fire Damper
Multi-Blade Fire Damper
### UL / EN Standards Comparison

#### Main Differences – Fire dampers (1/2)

<table>
<thead>
<tr>
<th></th>
<th>UL</th>
<th>EN</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Operational reliability</strong></td>
<td>Fire endurance Hose stream</td>
<td>50 cycles Fire test (Standard temp. curve)</td>
</tr>
<tr>
<td><strong>Response delay</strong></td>
<td>n.a.</td>
<td>2min. (3min.)</td>
</tr>
<tr>
<td><strong>Fire resistance</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- integrity (E)</td>
<td>Fire endurance Hose stream</td>
<td>360 m³/h·m² @ 300 Pa</td>
</tr>
<tr>
<td>- insulation (I)</td>
<td>not applicable</td>
<td>140°C / 180°C @ 300 Pa</td>
</tr>
<tr>
<td>- smoke leakage (S)</td>
<td>147, 367, 1469 m³/h·m² @ 100 Pa</td>
<td>200 m³/h·m² @ 300 Pa</td>
</tr>
<tr>
<td><strong>Durability</strong></td>
<td>250, 20'000, 100'000 cycles</td>
<td>300, 10'200, 20'000 cycles</td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td>Combination Fire Smoke Damper</td>
<td>Fire Damper</td>
</tr>
</tbody>
</table>
## UL / EN Standards Comparison

### Main Differences – Fire dampers (2/2)

<table>
<thead>
<tr>
<th>Actuator</th>
<th>UL</th>
<th>EN</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Design, Construction</td>
<td>diecast aluminium</td>
<td>steel, form-fit, manual operation</td>
</tr>
<tr>
<td>- Connection to BAE</td>
<td>n.a.</td>
<td>protected cable (shortcut)</td>
</tr>
<tr>
<td>- Test-Switch BAE</td>
<td>n.a.</td>
<td>yes</td>
</tr>
<tr>
<td>- Status indicator</td>
<td>n.a.</td>
<td>yes</td>
</tr>
<tr>
<td>- Aux. Switches</td>
<td>n.a.</td>
<td>integrated, fix position, form-fit</td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td>Combination Fire Smoke Damper</td>
<td>Fire Damper</td>
</tr>
<tr>
<td></td>
<td>UL</td>
<td>EN</td>
</tr>
<tr>
<td>------------------------</td>
<td>-----------------------------------------</td>
<td>-----------------------------------------</td>
</tr>
<tr>
<td><strong>Operational reliability</strong></td>
<td>20,000, 100,000 cycles</td>
<td>300, 10,200, 20,000 cycles</td>
</tr>
<tr>
<td><strong>Response delay</strong></td>
<td>75s</td>
<td>60s</td>
</tr>
<tr>
<td><strong>Nominal activation</strong></td>
<td>n.a.</td>
<td>man. / aut. activation (MI, AA)</td>
</tr>
<tr>
<td><strong>Fire resistance</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- integrity (E)</td>
<td>Fire endurance</td>
<td>360 m^3/h*m^2</td>
</tr>
<tr>
<td></td>
<td>Hose stream</td>
<td>@ 300 Pa</td>
</tr>
<tr>
<td>- insulation (I)</td>
<td>not applicable</td>
<td>140°C / 180°C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>@ 300 Pa</td>
</tr>
<tr>
<td>- smoke leakage (S)</td>
<td>147, 367, 1469 m^3/h*m^2</td>
<td>200 m^3/h*m^2</td>
</tr>
<tr>
<td></td>
<td>@ 100 Pa</td>
<td>@ 500, 1000, 1500 Pa</td>
</tr>
<tr>
<td>- cross section</td>
<td>n.a.</td>
<td>Maintenance of cross section</td>
</tr>
<tr>
<td>- compartmentation</td>
<td>n.a.</td>
<td>Single / Multi</td>
</tr>
<tr>
<td><strong>Mechanical stability</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>xy</td>
<td>Md vs. area</td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td>Combination Fire Smoke Damper</td>
<td>Smoke Control Damper</td>
</tr>
</tbody>
</table>
## UL / EN Standards Comparison

### Main Differences – Smoke Control Dampers

<table>
<thead>
<tr>
<th></th>
<th>UL</th>
<th>EN</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Actuator</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Design, Construction</td>
<td>diecast aluminium</td>
<td>steel, form-fit, manual operation</td>
</tr>
<tr>
<td>- Controls</td>
<td>ON / OFF</td>
<td>1-wire- / 2-wire- controls</td>
</tr>
<tr>
<td>- Torque running</td>
<td>pressure, air volume</td>
<td>min. 33Nm @ 45° (800x1'500mm2)</td>
</tr>
<tr>
<td>- Torque holding</td>
<td>n.a.</td>
<td>50Nm</td>
</tr>
<tr>
<td>- Aux. Switches</td>
<td>n.a.</td>
<td>integrated, fix position, form-fit</td>
</tr>
<tr>
<td><strong>Safety Positions</strong></td>
<td>1 (closed)</td>
<td>2 (open, closed)</td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td>Combination Fire Smoke Damper</td>
<td>Smoke Control Damper</td>
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</tbody>
</table>
Thank you for your attention!