New Approaches to Design for Fire Safety
- Residential sprinklers, open plan flat layouts and water mist

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About BRE Group

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BRE Group structure

- BRE
- bretrust
  - BRE Privatised 1997
- breglobal
- breeam
- breventures

Protecting People, Property and the Planet
BRE services

- Commissioned research
- BRE Innovation Park - “Green” housing
- Construction - methods, materials etc.
- Acoustics, thermal properties, durability
- Weather tightness
- Wind-loading
- Structural performance and integrity
- Publications, education and training

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Topic

• Residential sprinklers
Historical context

• Automatic fire sprinkler systems are a well established technology and have demonstrated their effectiveness in protecting life and property in industrial and commercial applications over many years.

• Sprinklers have been introduced relatively recently into domestic and residential buildings in UK primarily to reduce risk to life and also reduce risk to property damage caused by fire.

• Residential sprinklers have been installed in new, existing, refurbished, historic in individual buildings and whole estates.
Residential sprinklers

- Typically consists of water supply connected to main control valve, backflow prevention check valve, priority demand valve (where appropriate), and an array of pipework fitted with individual sprinkler heads, also internal and external alarm system.

- Heads fitted at specific locations normally at ceiling level.

- Main purpose:
  - to detect fire
  - to provide water to control and/or extinguish fire

- In a fire, operate by the release of seal when fusible link melts or glass bulb containing liquid shatters.

- Water spray is produced.
Residential sprinklers and other fire safety measures

- Installed as part of overall package of fire safety measures in building
- Generally smoke alarm systems, or fire detection and alarm systems and passive fire protection measures installed
- Combustion modified foam furniture, fire safety management and community fire safety education also important
Reasons for installing residential sprinklers

- Life safety recommendations intended to meet the Building Regulations or the Regulatory Reform (Fire safety) Order
- Life safety, additional to the Building Regulations
- Life safety, as an alternative solution to satisfy recommendations intended to meet the Building Regulations
- Property protection to meet insurer’s requirements
- Fire service recommendation
- Decision of the owner or developer
- As a cost beneficial solution to a range of options
- Installed following a real fire incident
- To meet planning requirements
- District council policy
- Protection of people who are vulnerable or at high risk
- As a trial pilot scheme
- (Examples of alternative solutions: to compensate for inadequate fire service access, extend travel distances, replace external protected staircases and/or internal doors, allow for open plan design)
Residential sprinklers - issues

- Important that
  - Sprinkler systems for residential or domestic premises are correctly designed, installed and maintained in accordance with recognised standards
  - Key stakeholders are involved at an early stage including relevant authorities
  - Water supplies are reliable and provide sufficient flow and pressure for design requirements
  - A suitably qualified and experienced specialist sprinkler contractor is appointed to carry out the design, installation and commissioning of the system (Third party residential sprinkler installers schemes available (e.g. LPCB LPS 1301 scheme))
  - Regular maintenance is carried out by suitable specialist sprinkler contractor
  - Sprinkler components are fit for purpose and approved
Cost benefit analysis

COSTS
• Components and installation
• Provision of water supplies
• Ongoing maintenance

BENEFITS
• Lives saved
• Injuries prevented
• Reduced property damage
• Potential reduced environmental impact
• Possible reduced insurance premium
• Reduced fire service costs
• Indirect cost savings due to reductions in requirements for other aspect of building design
Recent BRE experimental studies for CLG

- Effectiveness of sprinklers in residential premises, BRE project report 204505, 2004
  Available from [www.bre.co.uk/page.jsp?id=422](http://www.bre.co.uk/page.jsp?id=422)

- Effectiveness of sprinklers in residential premises – the evaluation of concealed and recessed pattern sprinkler products, BRE project report 218113, 2006
  Available from [www.bre.co.uk/page.jsp?id=723](http://www.bre.co.uk/page.jsp?id=723)

- Sprinkler Effectiveness in Care Homes, BRE Output no. 228138pv, 2006

- Residential sprinkler installation practice to maximise functionality and to prevent possible fire penetration, BD 2551, 2009
Effectiveness of sprinklers in residential premises

- Industry Steering group
- Pilot study
- Cost benefit analysis
- Benchmark fire tests (18)

- Experimental programme using 5 realistic scenarios (lounge, kitchen, bedroom) to assess effectiveness in controlling toxicity, heat, visibility
  - House fires (8)
  - Compartment fires (29)
  - Calorimetry tests (4)

Dissemination
Selected main findings

• For majority of scenarios experimentally studied, addition of residential sprinkler protection proved effective in potentially reducing casualties in room of fire origin and connected spaces

• Sprinkler protection was not found to be complete answer, slow growing and shielded fires can be problems

• Closing the door to room of fire origin, found to be effective in keeping tenable conditions in connecting spaces

• Residential sprinklers are probably cost effective for
  – residential care homes (for old people, children and disabled people)
  – tall blocks of flats (eleven storeys and above)

• Residential sprinklers are not cost effective for other dwellings

• To become cost-effective in a broader range of buildings, high risk buildings may be targeted, and justified on case-by-case basis and/or installation and maintenance costs must be minimal, and/or alternative solutions may be provided to reduce costs by indirect means
Approved Document B recommendations – residential sprinklers

- 2006 edition volumes 1 and 2
- Use of residential sprinklers to BS 9251 recognised
- Option of providing residential sprinklers throughout dwelling instead of alternative escape routes included for dwelling houses with a floor >7.5m above ground level
- Loft conversions and open plan ground floor arrangement one option includes provision of sprinkler protection to open plan area in conjunction with other measures
- Residential care homes, if sprinklers fitted, bedroom doors do not need self closing devices and increase in number of beds
- Blocks of flats >30 m high, individual flats should be fitted with residential sprinkler system
- Flats with more than one storey, options of providing residential sprinklers and/or protected stairway instead of alternative escape routes
Approved Document B recommendations

- Alternative ways of achieving compliance, alternative solutions:

- “The Approved Documents are intended to provide guidance for some of the more common building situations. However, there may well be alternative ways of achieving compliance with the requirements.

- Thus there is no obligation to adopt any particular solution contained in an Approved Document if you prefer to meet the relevant requirement in some other way”

- need to understand the provision that the residential sprinkler system will compensate and how that system will perform compared to that provision
British standards (1)

- **BS 9251:2005**
- British Standard
- Recommendations for design, installation, components, water supplies, commissioning, maintenance, testing
- Designed to protect the whole building
- Minimum design densities (mm/min) can be applied
- **BS DD 252: 2002 (under revision)**
- British Standard Draft for Development
- For residential sprinkler heads
- Recommendations for construction and performance of sprinklers including fire tests
British standards (2)

- BS EN 12845: 2004
- Fixed firefighting systems – Automatic sprinkler systems – Design, installation and maintenance
- In conjunction with LPC Sprinkler Rules for automatic sprinkler installations, covering insurer’s requirements
- BS EN 12259 (Series): various dates
- Companion components standards
Project

- Assessing Life Safety of Open Plan Flat Layouts in Event of Fire
Assessing Life Safety of Open Plan Flat Layouts in Event of Fire

- One-year study, published September 2009
- Commissioned by the NHBC Foundation
- Aim to assess the life safety of open plan flats in the event of a fire
- Specific objectives to
  - Review the potential methods of meeting the Building Regulations requirements
  - Develop knowledge base and concise guidance to assist designers and house builders
- Work involved
  - Industry Steering Group
  - Literature review and questionnaire
  - Assessment of open plan flat layouts with different fire protection systems using computer modelling evaluation of risks
  - Main analysis and sensitivity analysis
Background

- Recent increase in popularity of open plan flat designs in UK
  - Bedrooms in particular being designed as “inner rooms”
- These designs may conflict with existing UK Building Regulations and guidance (e.g. Approved Document B)
- Pressure on Building Control Officers to approve designs (with or without compensating features)
- Various arguments used for open plan flats
Inner room

- One in which the only escape route passes through another room
Existing guidance: Approved Document B

- Restrictions on “inner rooms”
- Bedrooms need alternative means of escape – not feasible above first floor.
- No explicit mention of compensatory features such as sprinklers
Approach

- Evidence from fire models used to justify open plan flats needs to consider all aspects of the whole system, including human behaviour.

- BRE CRISP computer model used to determine and compare the risk to life for selected open plan flat layouts and equivalent AD B compliant designs.
The CRISP computer model

- Computation of Risk Indices by Simulation Procedures
- BRE evacuation and fire spread computer model
- Simulation of the entire fire scenario (fire, smoke, sprinklers, detection, human behaviour, interactions between them)
- Monte-Carlo method based on random numbers
- Agreement between CRISP predictions of fire and smoke behaviour and relevant available experimental data (including sprinklers), real fire incident data for human behaviour, other computer model predictions
Flat layouts, detection and sprinklers

• Three different sizes of flat
  – 1, 2 or 3 bedrooms

• For each size of flat
  a) baseline case compliant with AD B (smoke alarm in the circulation space)
  b) open plan/inner room variant plus enhanced detection (smoke alarm in each room)
  c) same as b) enhanced detection plus sprinklers*

*In accordance with BS 9251 or BS EN 12845, as appropriate.
Case 3a as example
Case 3c
Objects in the CRISP simulation

- Sprinkler
- Hot smoke layer
- Plume
- Item on fire
- Window
- Door
- Floor
- Person
- Alarm
From simulation to Monte Carlo

- **Random variables**
  - fire type and location
  - occupant population
  - door and window status

- **Random processes**
  - glass breakage
  - human decisions
  - time delays for actions and events

- **Typical output**
  - number of people
  - each person’s fractional effective dose (FED) of toxic products

- **Risk calculation**
  - risk of death
    \( = \Pr(\text{FED} > 1.0) \)
Modelling – physical features

- Internal geometry
- Smoke zone model
- Heat loss to walls
- Fire type and location
- Probability of fire spread
- Flashover
- Probability of doors closed
- Window breakage
- Smoke detectors
- Heat detectors
- Alarm audibility
- Sprinklers

Modelling – people behaviour

- Building population (adults, elderly and children)
- Family size and composition
- Location of people at time of fire
- Awake or asleep
- Mobility
- Tenability perception
- Behavioural roles (leader, led, dependent)
- Behavioural rules
- Time required for different actions
- Effect of toxic smoke
Results

Risk of death or injury for different flats & protection strategies

Average number of people per fire

- Case 1a
- Case 1b
- Case 1c
- Case 2a
- Case 2b
- Case 2c
- Case 3a
- Case 3b
- Case 3c

Legend:
- FED1
- FED10
- FED30
- FED100
Conclusions (1)

- Open plan flats with a sprinkler system (in accordance with BS 9251 or BS EN 12845, as appropriate) and an enhanced detection (LD1 system in accordance with BS 5839-1) can provide a level of fire safety for occupants that is at least as good as that of a similar AD B compliant design.

- NB caveats apply (see report)
Conclusions (2)

• Flat size/travel distance has not been shown to be a significant factor.
• It is not possible to state with sufficient confidence that enhanced detection alone could satisfy the requirements of the Building Regulations.
• Fire engineered solutions should consider all aspects of the entire fire “system”, including fire growth, smoke movement, detection, suppression, human behaviour, and interactions between these aspects.
• Those that do not might not give an adequate measure of the risk.
• NB caveats apply (see report)
Caveats

• Conclusions apply to specific layouts examined and simulations carried out using CRISP model, with input parameter values as specified in report.
• Important that any practitioner using guidance within report for design of open plan flats satisfies themselves that scenarios and parameter values are appropriate to their design.
• Modelling assumed that active fire protection systems would be maintained in accordance with appropriate standards.
• NB other specific caveats also apply (see report)
Full report

- Published, available from NHBC Foundation
- Open Plan flat Layouts NF19
- Report plus CD-Rom containing supplementary results
• Water mist systems for domestic and residential premises
Water mist systems - background

- Currently subject of debate
- Demonstrated to be suitable and effective for protection of spaces on board ships
- Emerging technology for building applications including residential
- Information about the overall effectiveness of these systems for land-based life safety applications is not well established
- Number of myths and misunderstandings
“There are many alternative (to sprinklers) or innovative fire suppression systems available.

Where these are used it is necessary to ensure that such systems have been designed and tested for use in domestic buildings and are fit for purpose.”
Water mist system - description

• Fixed fire protection system
• Uses water to control, suppress or extinguish a fire
• Comprises automatic nozzles attached to a piping system containing water and connected to a water supply.
• At operation, discharges a cone of spray containing small water droplets that fills the protected zone with water mist.
• Some additionally discharge other gases or include additives.
• Should generate, distribute, and maintain a concentration of small droplets sufficient for the protection of the fire risk for sufficient time to achieve protection objective
• Three generic types of system:
  – Low pressure (0 – 12 bar)
  – Medium pressure (12 – 35 bar)
  – High pressure (above 35 bar)
Water mist systems - key components

• All distinctly different. Key components:
  – Fire fighting medium
    • potable water, water & antifreeze, water & additive, water & inert gas
  – Detection
    • automatic quick response glass bulb nozzles, smoke detectors & actuators, with/without cover plates, alarms & control panel
  – Atomisation
    • nozzle & orifice, filters, strainers, single/twin fluid system
  – Delivery
    • wet/dry pipe/pre-action/deluge system, pipe & supports
  – Supply
    • storage vessel (e.g. tanks, cylinders), towns mains, propellant (e.g. nitrogen), pumps.
• For domestic and residential: low pressure, wet pipe systems, with automatic, quick response glass bulb nozzles, supplied by cylinders or tanks containing potable water
Water mist – protection strategies

• Two types:
  – **Local application** – Systems are designed to protect a specific object or hazard and the system water discharge is specifically directed for that purpose
  – **Total compartment volume** – Systems are designed to discharge water mist to protect all hazards within an enclosure, usually a room
Water mist systems

- Cannot be treated in the same way as sprinklers
- Bespoke and distinctly different from each other
- Fire control mechanisms are different
- Effectiveness largely unproven for buildings
- Very few reported fire events
- Reliability and long term maintenance largely unknown/unproven
- No general design rules
- Not simply mm/min, also properties of water sprays (droplet size and momentum distribution) critical to system effectiveness
- Performance sensitive to e.g. fire type, ventilation, fire size, ceiling height, obstructions, blockages
- Danger of inappropriate application
Independent guide for residential buildings

• An independent guide on water mist systems for residential buildings
• Funded by Communities and Local Government
• For approving authorities, e.g. building control bodies and fire safety officers
• Assessing water mist systems in residential buildings
• Includes checklist and pro-forma for a water mist system assessment
• Published in 2006
• www.bre.co.uk
Guide recommendations - evidence of suitability

- Approving authority needs to satisfy itself whether there are relevant adequate published standards or equivalent for design, installation and maintenance and for components to ensure effective performance of system in fire

- British standards for domestic and residential premises, when available, should be used to assess water mist systems for these applications

- Currently, other standards should not be used

- Essential that fire performance tests are carried out for proposed water mist system in the residential premises
  - either generic fire tests (specified in appropriate standard) or
  - project specific adhoc fire performance tests

- General fire demonstrations not acceptable
- Consultation with relevant authority
- Independent laboratory test reports should be supplied to authority
- Approval listing and test reports should be checked for appropriateness to particular project
Water mist - current status of standards (1)

- BS DD 8458 Part 1 (draft)
- Code of practice for design and installation of water mist fire suppression systems specifically for residential and domestic occupancies and associated hazards
- Recommendations for design, installation, components, water supplies, commissioning, maintenance, testing and fire test protocols
- British Standard Draft for Development
  - Based on best technical information available
  - Gaps in knowledge and a lack of research and development in some areas
  - Needs further development before it can become a full British Standard resulting from
    - experience in using in the field
    - addition of new text
    - underpinning research
Water mist - current status of standards (2)

- BS DD 8458 Part 1 (draft)
- Primarily for life safety purposes
- Volume protection
- Wet pipe systems
- Actuated by glass bulb or fusible link, quick response
- Alternative to residential sprinkler systems (BS 9251 and BS DD 252)
- Design parameters established by the prescribed fire tests
- BS DD 8458 Part 2 Components (not started)
System design and room fire test

- Room fire test based on fire test for residential sprinklers
- Fire tests used to establish for each manufacturer’s equipment:
  - necessary number of nozzles
  - locations
  - flows
  - operating pressures
  - spacing
  - other required design characteristics
- Consideration of fire load positions, ventilation conditions, ceiling heights, additives
Water mist solutions for prison cells

- Fire safety in prison cells - **effectiveness of water mist systems**
- Funded by Ministry of Justice (England and Wales)
- August 2007 to January 2009
- Aim to provide assistance in development of fire safety strategies employed in the protection of prison cells, in particular the fuel loading of cells and potential effectiveness of water mist suppression systems in tackling cell fires
- Client report and performance specification document for manual systems, not in the public domain
Water mist experimental research for offices

- Understanding the mechanisms for successful water mist systems
- 2007 to 2010
- Funded by the BRE Trust supported by industry partners
- Objectives to
  - Identify **one specific commercial application** for which water mist systems would be beneficial
  - Characterise **mechanisms and factors** that govern performance of water mist systems in selected application
  - Produce specification for evaluating water mist systems for application
- BRE Trust research report, to be published and Draft specification of office fire scenario for British Standards
Conclusion

Thank you.....

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