Evaluating Automist - assessing an innovative solution without an established product class

Abstract

The paper discusses the results of the fire performance testing of the Automist system at the Building Research Establishment (BRE Global) in Watford, UK. Kitchen oil fire and room furniture fire scenarios were set up in different room sizes and with different openings to evaluate the potential for life protection and possible limitations. Key findings from the testing were the improvement in tenability and survivability in several fire scenarios and observation of some critical boundary conditions on the application of watermist on domestic settings, such as number and distance of openings to the fire.

There are no established standards for the new class of products which Automist belongs to, a class which does not even have an established name: easy to retrofit, mobile, compact fire suppression devices, or appliances. Plumis sought the help of the BRE to define a set of tests to objectively verify the fire performance of Automist. The fire load setup was based on *DD 8458-1: Watermist fire suppression systems for residential and domestic occupancies (Part 1: Code of practice for design and installation*), the *"Easily installed automatic extinguishing systems"* (Swedish Rescue Services Authority, Räddnings Verket, and the Directorate for Civil Protection and Emergency Planning, DSB, Norway, 2007) and the *BS EN 1869:1997 Fire Blankets* documents. Performance criteria were focused on Fractional Effective Dosage (FED), a scientific method that predicts how long it would take a person to be incapacitated and ultimately die, due to oxygen deprivation, inhalation of toxic gases, and/or exposure to high temperatures.

Introduction

There are currently no published UK standards for the design and installation of domestic and residential land-based water mist systems (nor any water mist system components). British Standard Drafts for Development are in preparation for commercial and industrial applications and residential and domestic occupancies. These are:

1. DD 8489-1 Fixed fire protection systems – Commercial and industrial watermist systems – Part 1: Code of practice for design and installation (committee draft).
2. DD 8458-1 Watermist fire suppression systems for residential and domestic occupancies – Part 1: Code of practice for design and installation (committee draft).

In domestic scenarios, Approved Document B allows Building Control officers to authorise alternative fire protection solutions that don't fit established categories, as long as these products have been tested and shown to be fit for purpose. The growth of water mist technology in the UK to date has gone this route; over 1000 water mist systems have been installed in the UK and in each case the supplier has needed to show fitness for purpose.

Sprinkler standards typically specify such criteria as minimum water density and nozzle spacing as a function of fire risk, the aim being to match water density with the expected fire load and allow the specifier to add or remove nozzles and therefore customise the system to its location. The performance is verified using temperature measurements which correlate to validated tests and therefore pre-established suppression effectiveness.

BRE Global was commissioned by Plumis Ltd to provide assistance with a fire testing assessment of their 'Automist' fire suppression system. Plumis developed Automist with life protection in domestic kitchens, open plan kitchens and studios in mind. The system incorporates a manifold containing water mist nozzles integrated into the base of a standard kitchen tap. A ceiling mounted wireless heat detector, on alarm, is used to activate a high pressure pump stored under the sink which discharges mains water at high pressure into a kitchen as a water mist.

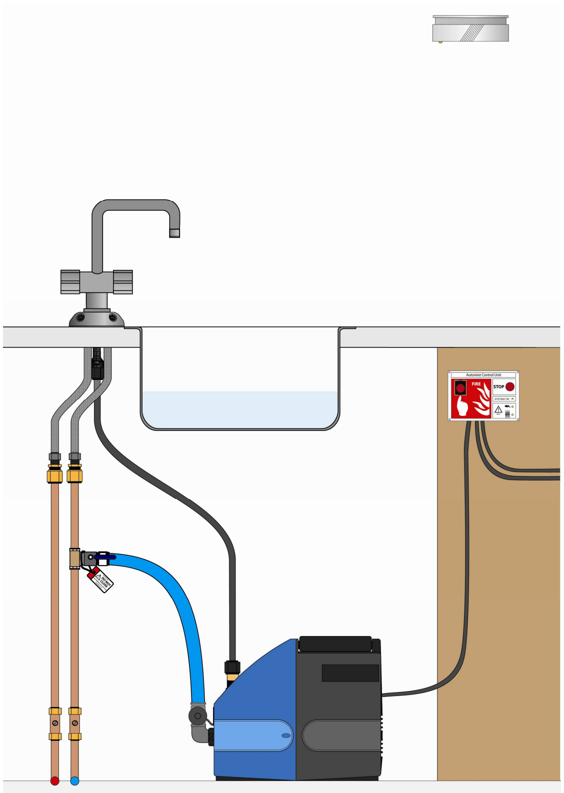


Fig.1.
A Diagram of the Automist

The Automist system is similar to a ‘conventional’ volume protection water mist system for domestic and residential occupancies but with some significant differences. Automist discharges from kitchen sink level and is therefore located typically about 1m above a floor and from the wall. A ‘conventional’ volume protection water mist system (i.e. not local application system) would typically have a ceiling mount nozzle usually positioned centrally within the protected room (assuming single nozzle protection). As a result the existing performance criteria and template for specification within current standards does not correlate well to Plumis’ system.

During the Automist product development, Plumis discussed testing with the Kensington and Chelsea Building Control team. They recommended BRE and proposed a specific methodology, Fractional Effective Dosage (FED) which evaluates occupant tenability and survivability and aligns with the life protection objectives of Building Regulations. Plumis wished to explore the limits of the systems suitability and applicability for actual installations.

Standards Benchmark

The following standards, drafts for development, proposals, and methodologies were benchmarked by Plumis with a view to identify the most adequate test setup to evaluate Automist:

- Fractional Effective Dosage - Purser, D.A. ‘Toxicity Assessment of Combustion Products.’
- BS DD 252 ‘Components for residential sprinkler systems – Specifications and test methods forresidential sprinklers’, British Standards Institution, 2002. / DD8458 ‘Code of Practice for design and installation of watermist fire suppression systems for residential and domestic occupancies’

- ‘Easily installed automatic extinguishing system’, a document developed by the Swedish RescueServices Authority (SRSA, RäddningsVerket) and the Directorate for Civil Protection andEmergency Planning (DSB, Norway), 2007
- BS EN1869 : 1997 Fire Blankets

FED

Fractional Effective Dosage (FED) is a calculation method used to predict impacts on fire victims as a result of the “doses” of toxic gases concentration and the temperature exposure during a fire. This is detailed by the method of Prof D.A. Purser and has been to British and European Standards (BS7899-2: 1999: Code of practice for assessment of hazard to life and health from fire. Guidance on methods for the quantification of hazards to life and health and estimation of time to incapacitation and death in fires and ISO TS 13571: Life-threatening components of fire – Guidelines for the estimation of time available for escape using fire data, respectively).

FED has a toxic gas component (FED-Asphyxia) and a temperature component (FED-Heat).

FED Asphyxia: Exposure to a sufficient inhaled dose of asphyxiant gases results in cerebral hypoxia (insufficient oxygen available to brain tissue), which leads to collapse with loss of consciousness followed by death if the exposure is prolonged. The inhaled dose of asphyxiant gases increases with fire duration and with the increased concentration of toxic gases with fire growth. Consequently, the main objective from a fire protection perspective is to minimize fire spread (reducing the concentration rate of increase) sufficiently to avoid loss of consciousness but most importantly death before rescue arrives. In the BRE tests, the toxic gases considered were carbon monoxide, carbon dioxide and low oxygen hypoxia. The dosage of toxic gases is also dependant on rate of air intake, for these tests, it has been assumed that an occupant was stationary but agitated while in the compartment during a fire, resulting in ventilation (VE) of 15 litres per minute. Using this method, loss of consciousness is expected when the FED of asphyxiant gases (FEDAG) reaches 1 while death is expected at an FEDAG of approximately 2-3.

FED Heat: The main hazards from a brief exposure to heat during a fire are skin pain and burns, followed by death in severe situations. This depends mainly on the duration of exposure and the temperature increase during a fire so suppression will not only reduce the temperature but also avoid it from increasing. When FED Heat reaches 1 it is assumed that an occupant will be incapacitated due to pain. Third degree burns are predicted at an FED of approximately 3. Additionally, for air saturated with water vapour (as in a water mist fought fire), the maximum temperature at which air can be breathed is 60℃.

DD252 & DD8458

Both DD252 and DD8458 stipulate similar fire test setups, layouts, fire loads and performance criteria. Fire performance is measured solely by temperature measurements at specific locations as summarised in the table below:

Thermocouple location	Maximum allowable temperature (^{o}C)
75 mm below underside of ceiling	320
1.6 m above floor	95
1.6 m above floor	55 (for not more than any 120 s interval)
Ceiling temperature - embedded 6.5 mm above the underside of the ceiling	260

Fig.2. Performance criteria

It was agreed with BRE that the furniture tests would use the fire loads and setups defined in these standards, as detailed below:

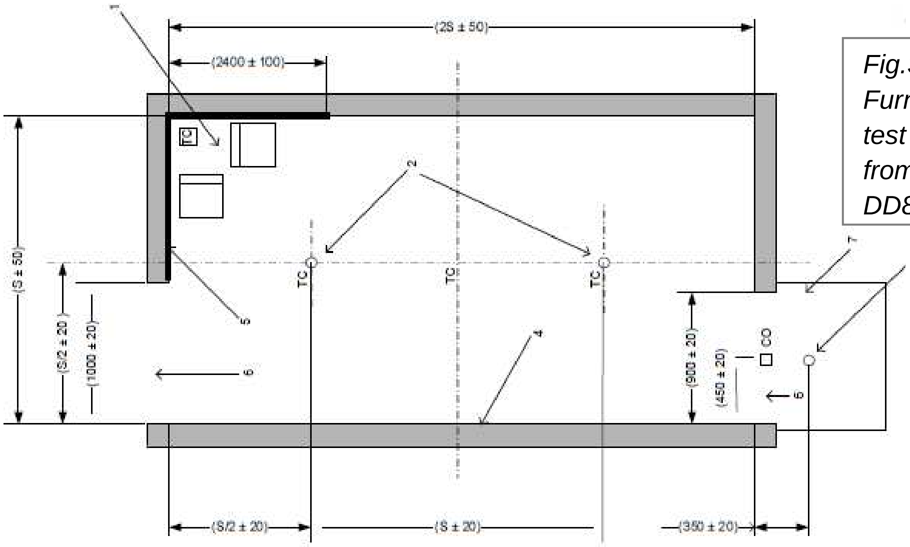


Fig.3. Furniture test setup from DD8458

The setup consists of two polyurethane foam sheets and a wood crib placed above a fuel tray containing water and heptane and positioned in the corner of the test room. Four marine grade untreated plywood panels, each measuring 1.2 x 2.4 m in size and 12 mm thick forms the walls in the corner of the test room. The foam sheets consist of two 100 mm thick pieces of polyurethane foam with a density of approximately 18 kg/m^3. The sheets are 810 mm wide, 760 mm high and were glued onto a 4 mm thick board of untreated plywood using contact adhesive. The distance from the edge of the board to the foam is 30 mm at the bottom edge and 15 mm along the edge of each side. The sheets of plywood were 840 mm wide and 790 mm high and are securely bolted to a supporting structure which holds them in an upright position.

Fig.4. Crib setup from

The fire is started by igniting the cotton wick beside the foam sheets and igniting the heptane at the base of the crib pile. Automist is activated automatically when the heat alarm sounds after reaching 57ºC in the centre of the room ceiling.

SRSA/DSB

The 'Easily installed automatic extinguishing system' test procedure developed by the Swedish Rescue Services Authority and the Directorate for Civil Protection and Emergency Planning consists of 3 fire test scenarios: a simulated furniture, very similar to the DD252 layout; a sofa and a kitchen scenario using a 200ml vegetable oil pan fire. All tests are run both in a closed and an open door setup. The layout of the fire tests is shown below, as is the setup for the kitchen test.

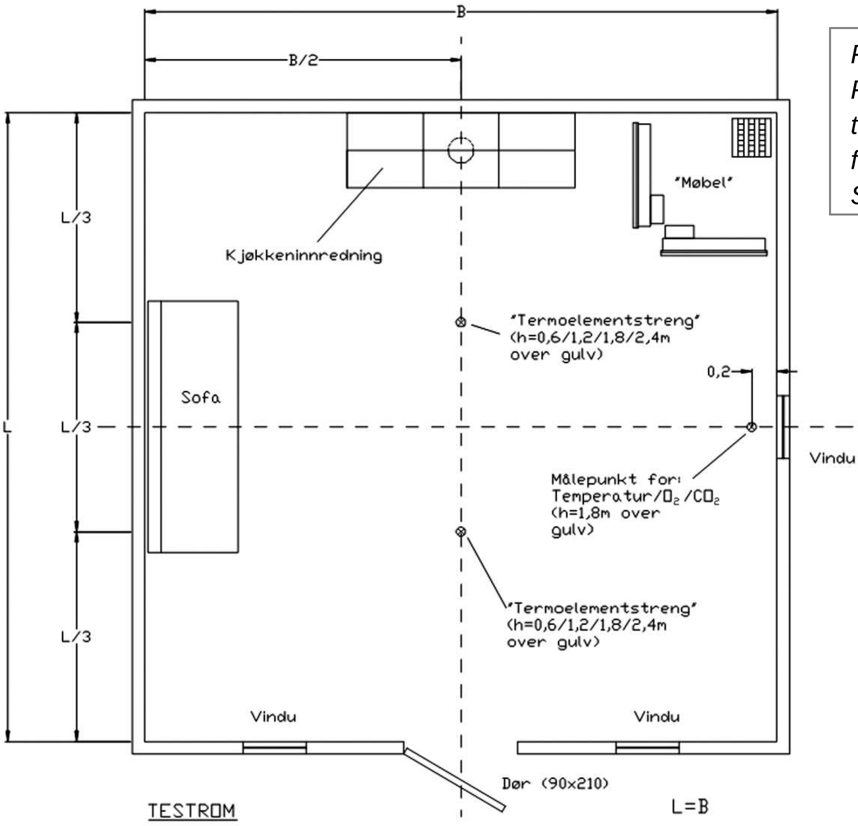


Fig.5. Furniture test setup from SRSA

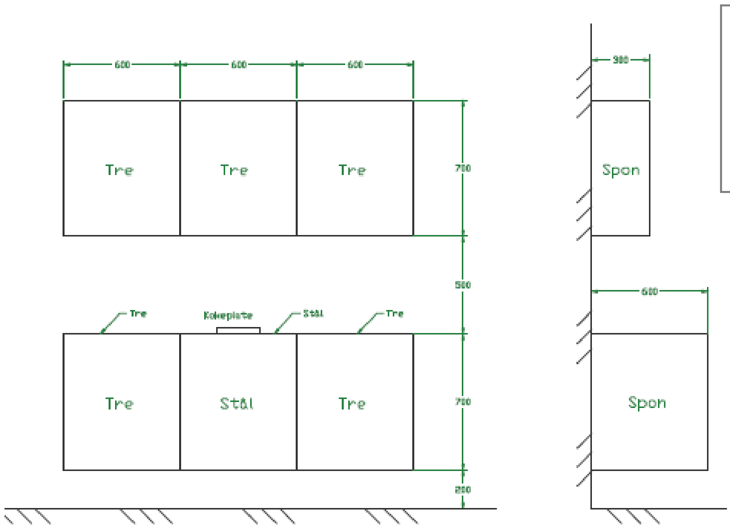


Fig.6. Kitchen test setup from SRSA

In internal fire tests carried out by Plumis, it was observed that an oil pan fire of 200ml did not produce a large enough fire to develop a dangerous fire scenario. As a result, a larger oil volume was used, based on BS EN 1869 (discussed below). The fire performance measure for this test procedure is used by evaluating the average temperature in a thermocouple tree (at 0.6m, 1.2m. 1.8m and 2.4m height), CO and O_2 concentrations at 1.8m height. The pass/fail criteria are:

• The average temperature for the two thermo-element trees in the room, over a period of one minute, ata time five minutes after the first activation of the extinguishing system, must not exceed 100℃.

• The CO dosage measured in the tests must not exceed 15,000 ppm/minute over a period of 20 minutesfollowing the first activation of the extinguishing system.

• The oxygen concentration in the room must not be less than 15% for longer than five minutes following the first activation of the extinguishing system.

The simulated kitchen fire setup represents a simple kitchen arrangement made of ‘standard’ materials commonly found in domestic kitchens. The cupboards consist of laminated chipboard panels and the worktop is made of solid wood. The empty kitchen units are 1800 mm wide and divided into three sections of 600 mm each. The upper cupboards were 700 mm high and 300 mm deep. The lower cupboards are 700 mm high and 600 mm deep. No shelves are installed in any of the cupboards. The worktop is 880 mm above the floor. The distance between the worktop and the underside of the upper cupboards is 580 mm. The kitchen fitted is typical of standard styles available at leading furniture outlets.

Fig.7. Kitchen test setup from SRSA

The pan was heated by a gas burned until it self-ignites (at approximately 350ºC), the gas is then put off and the pan left to burn. Automist is activated automatically when the heat alarm sounds after reaching 57ºC in the centre of the room ceiling.

BS EN 1869

BS EN 1869 outlines a test procedure to test the effectiveness of fire blankets on oil pan fires. The only parameter utilised from this procedure was the volume of 3 litres of oil in the pan fire.

Test Programme

All fires were run in either a 8m x 4m x 2.5m room or a 4m x 4m x 2.5m room with doors open or closed. The door openings were 1m wide and 2.1 m high. Temperature acquisitions were made at 1.8m and 0.6m heights at the centre of the two 4m x 4m quadrants. Gas concentrations where measured at a position 3m away from the fire and at heights of 0.6m and of 1.8m to determine FED Asphyxia. Temperatures were measured at a position 2m away from the fire and at heights of 0.6m and of 1.8m. Temperature measurements were also made around the crib and pan.

The test layout can be seen below:

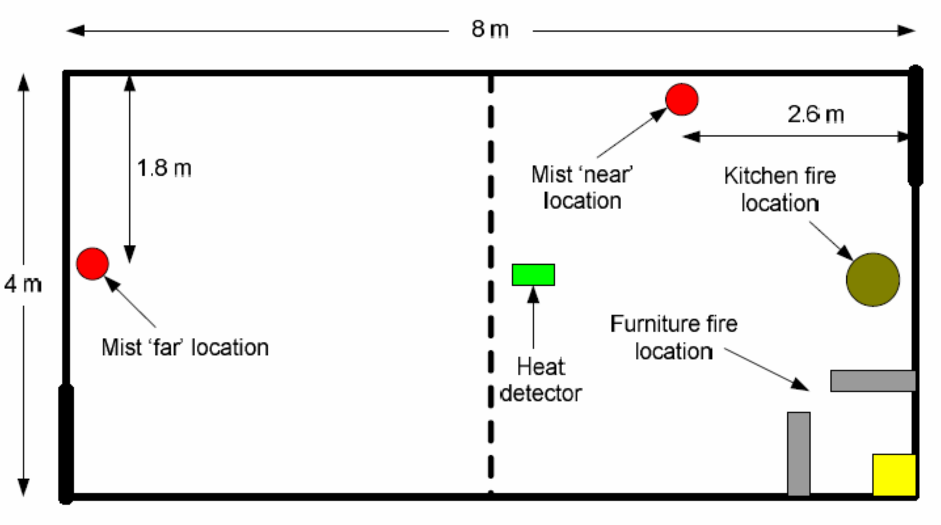


Fig.8. Test room layout

The experimental programme consisted of 11 fire tests:

Test number	Fire scenario	Test room size (m by m)	Number of doorways open or closed	Automist system present (Yes/No)	Location of automist system from fire
1	Furniture	8 by 4	2, closed	Yes	Distant
2	Furniture	8 by 4	2, open	Yes	Near
3	Kitchen, 2 litres of oil	8 by 4	2, open	Yes	Near
4	Kitchen, 3 litres of oil	4 by 4	2, open	Yes	Near
5	Kitchen, 3 litres of oil	4 by 4	2, open	No	Not applicable
6	Furniture	4 by 4	2, closed	Yes	Near
7	Furniture	4 by 4	2, closed	Yes	Near
8	Furniture	8 by 4	2, closed	Yes	Distant
9	Furniture	8 by 4	2, open	Yes	Distant
10	Furniture	8 by 4	2, closed	No	Not applicable
11	Furniture	8 by 4	2, open	No	Not applicable

Fig.9. Experimental matrix

Tests Results

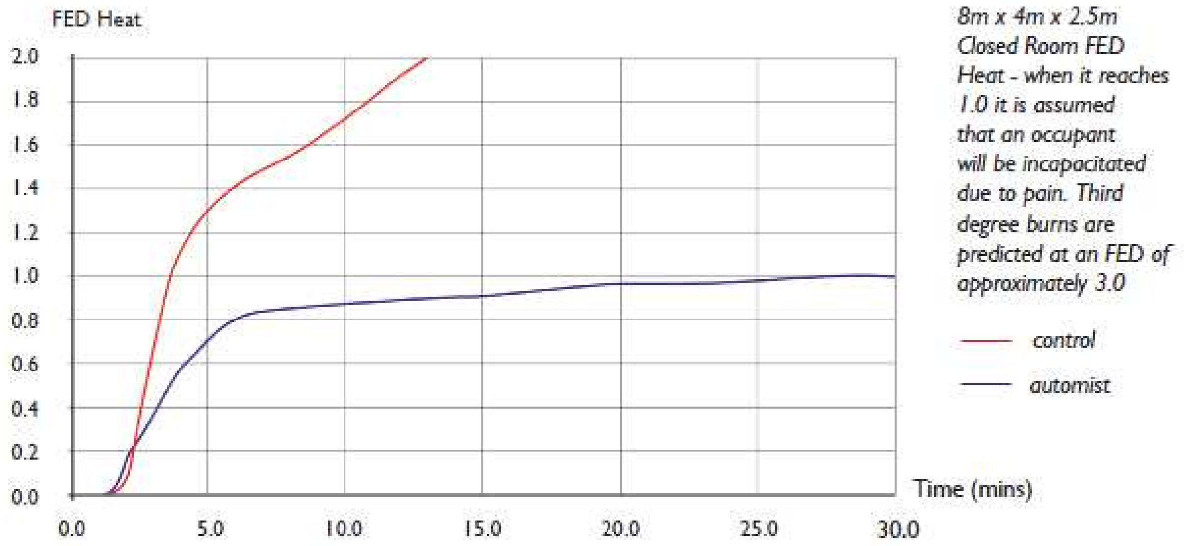
Below a summary of the FED results:

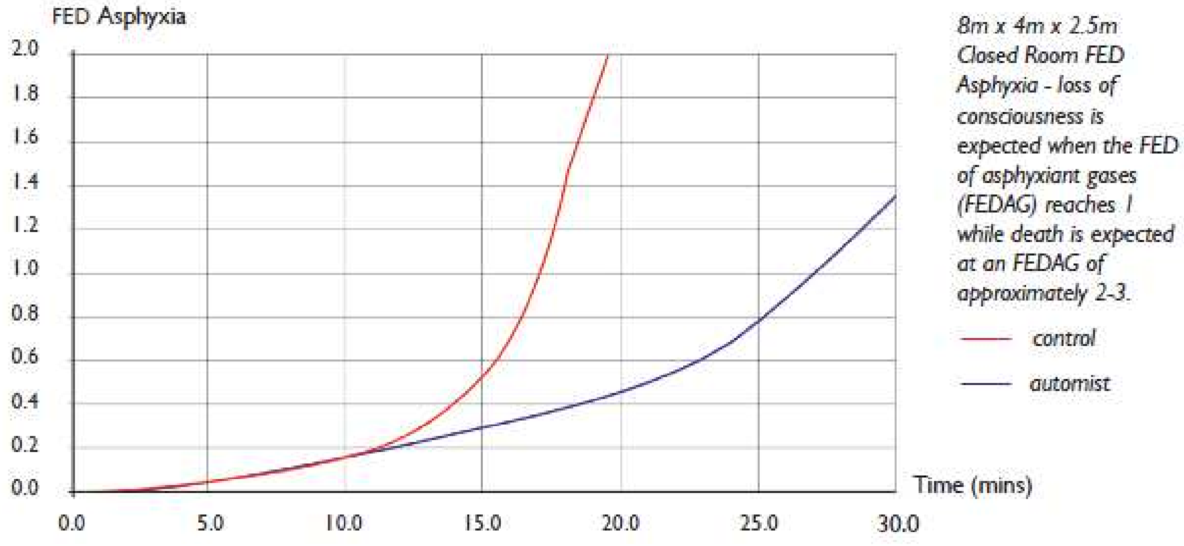
Test Description		**Test criteria reached (time in minutes, seconds)**			
		FED = 1 @ 1.8m	**FED = 2 @ 1.8m**	**FED = 1 @ 0.6m**	**FED = 2 @ 0.6m**
8m x 4m room with open doors	Automist @ 5m*	Not reached	Not reached	Not reached	Not reached
	Automist @ 8m	3 m 3 s (heat)	3 m 13 s (heat)	Not reached	Not reached
	Free Burn	2 m 19 s (heat)	2 m 27 s (heat)	Not reached	Not reached
8m x 4m room with closed doors	Automist @ 8m	23 m (heat)	Not reached	Not reached	Not reached
	Free Burn	3 m 40 s (heat)	12 m 53 s (heat)	7m 30s (heat)	21m 3 s (heat)
4m x 4m room with closed doors	Automist @ 3m	25 m (asphyxia)	Not reached	28m 17s (asphyxia)	Not reached

**Test was not run until completion, assumed conclusion on partial results*

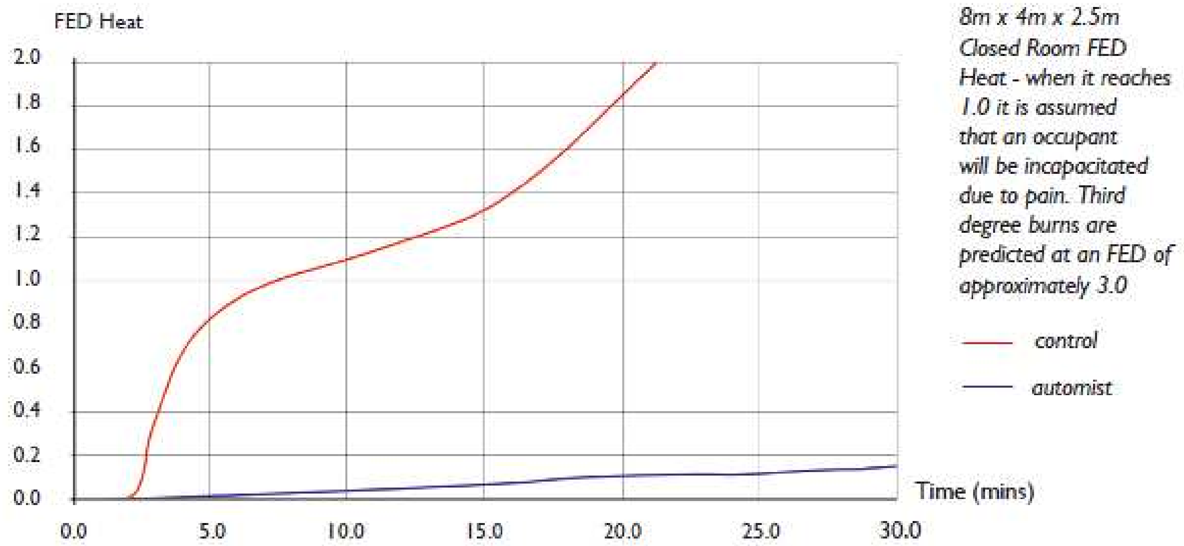
Closed room

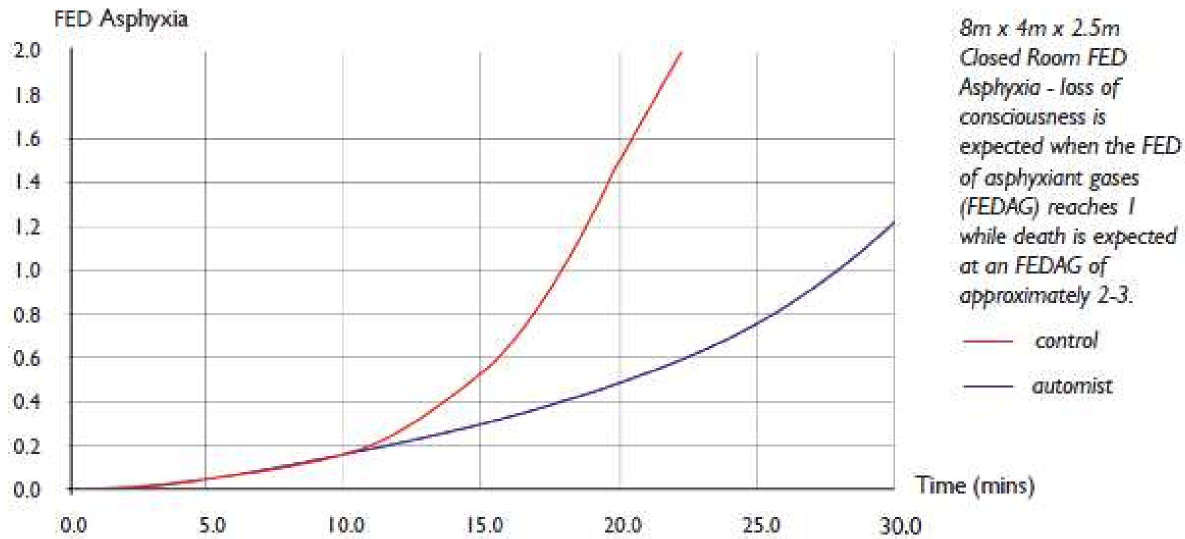
The graph below details the FED measurements at 1.8m high in the 8m x 4m closed room scenario. An unsuppressed fire would cause an occupant at 3m distance to the fire incapacitation due to pain in less than 4 minutes from ignition. In less than 13 minutes, death would probably occur due to excessive burns. However, with Automist at 8 metres away from the fire, pain and unconsciousness would only occur 23 minutes and 26 minutes after the fire started, respectively. Most importantly, life sustaining conditions are kept during the 30 minutes of test, providing vital time for rescue activities to take place with significantly improved conditions for the occupant and rescuer.



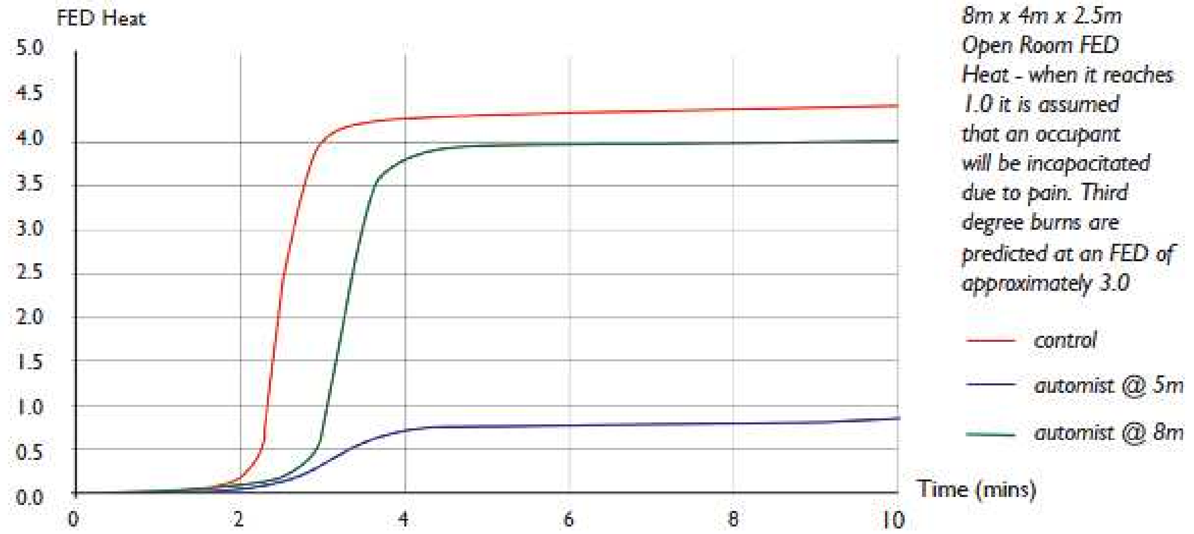


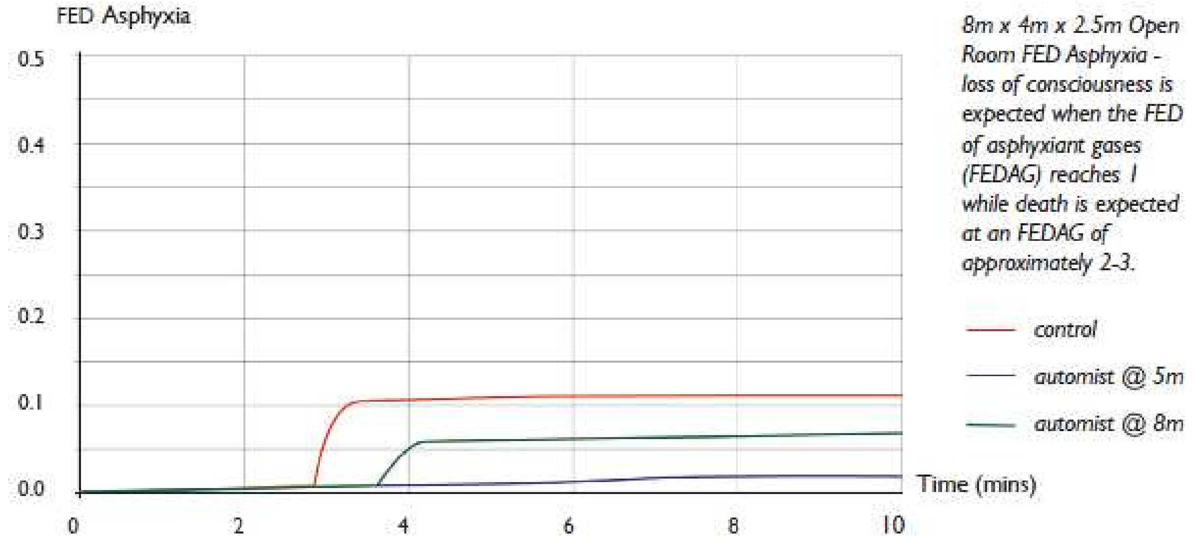
The graphs below show the results for the same test but at a lower height: 0.6m. By looking into this additional data, it is possible to observe the lower height effects to an occupant who is sleeping, sitting or has become unconscious once FED reached 1 at a higher level. At this height, survivability would be threatened by both heat and asphyxia since these reach a value of 2 at 21mins and 22.5mins respectively. With Automist operating, FED asphyxia had not gone beyond 1.2 for both tested scenarios large and small room while FED was below 0.2. These tests demonstrate the effective of Automist to suppress fire in a typical scenario with limited ventilation.





Open room





The graphs above details the FED measurements made in an open room scenario where 2 doors were kept open on either side of the room and Automist was located at 5m and 8m away from the fire. It is evident that a fire left unsuppressed with plenty of ventilation can develop very quickly into a fatal scenario. The control test reached FED of as quick as 2.5mins after ignition. This occurs because survivability decreases exponentially with the increase in temperature exposure. Effective fire suppression is able to choke the development of the fire to dangerous conditions, allowing for a controlled fuel load consumptions. This is observed on the graph above where despite being 5m away from the fire FED was stabilized at 0.8 within 5mins of fire ignition. It is also not surprising that FED asphyxia is kept close to 0.2 even for the unsuppressed scenario due to the significant ventilation inside the room. However, most importantly, the 8m distant test is as important. Despite there being suppression present, the air entering the fire was not entrained with mist droplets because of significant secondary air draft from a door out of range for Automist, as shown on the diagram on the following page.

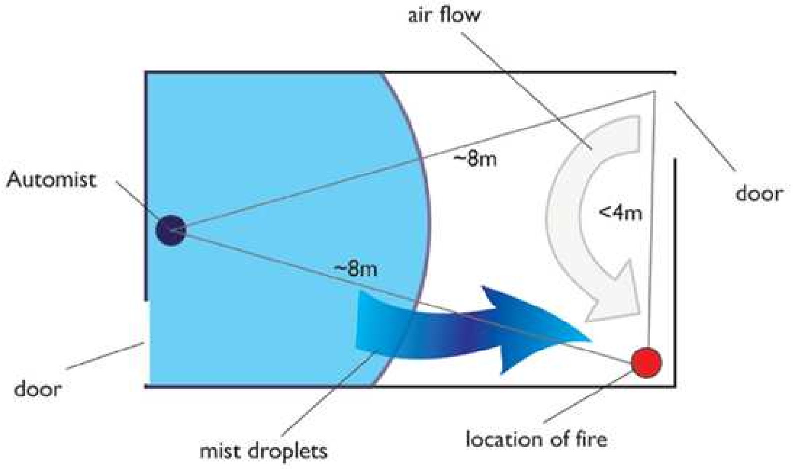
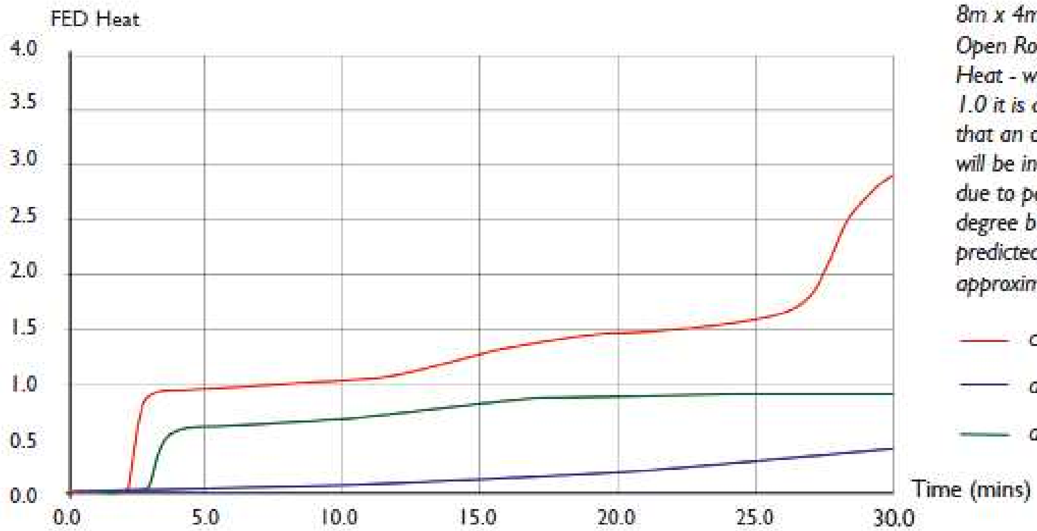


Fig.10. Ventilations effect on the fire

This shows that watermist can be a very effective fire suppressant as long as an assessment of potential secondary ventilation is carried out as detailed on the system requirements. Since the Automist radius of direct action is up to 5m, for Automist to be effective, any potential fires which are more distant than that cannot be susceptible to an air draft which does not go through the mist cloud.

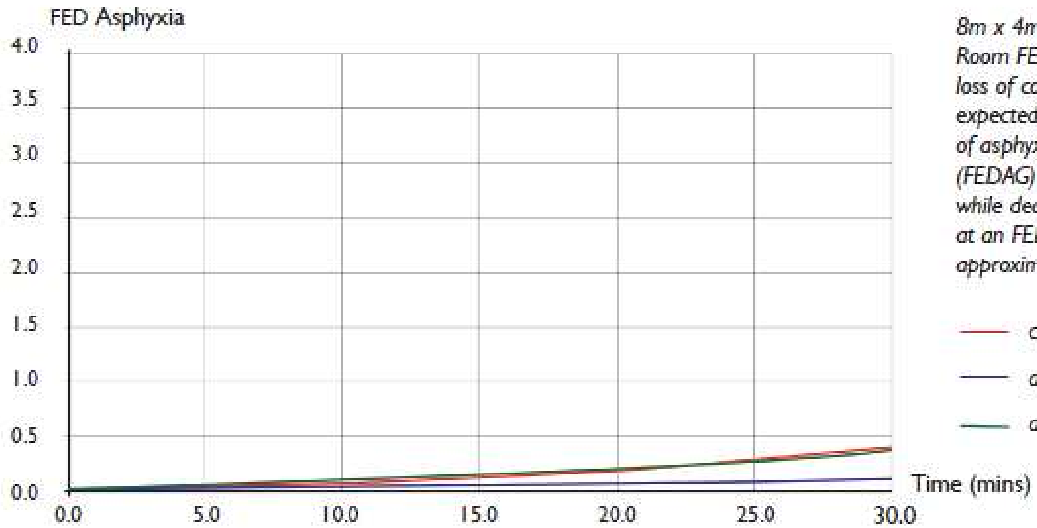


8m x 4m x 2.5m Open Room FED Heat - when it reaches 1.0 it is assumed that an occupant will be incapacitated due to pain. Third degree burns are predicted at an FED of approximately 3.0

control

automist @ 5m

automist @ 8m



8m x 4m x 2.5m Open Room FED Asphyxia - loss of consciousness is expected when the FED of asphyxiant gases (FEDAG) reaches 1 while death is expected at an FEDAG of approximately 2-3.

control

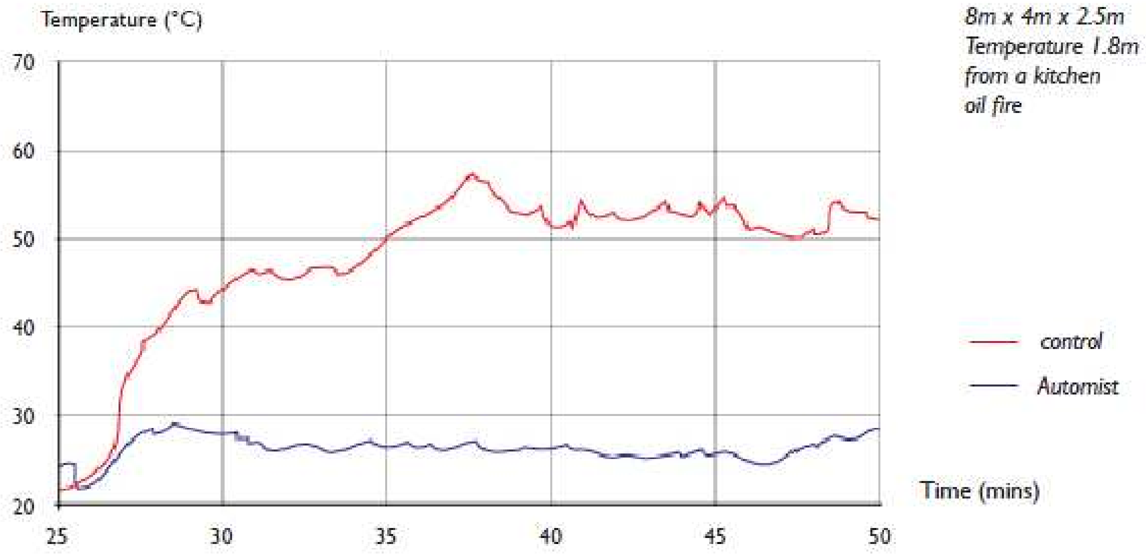
automist @ 5m

automist @ 8m

The graphs on the previous page detail the same open room tests but at a lower 0.6m height. These results show that FED does not go beyond 0.3 on heat even for the control test which burns freely. This test supports the statistics that it is smoke that most frequently kills, not heat. In this ventilated scenario, even if incapacitation and unconsciousness is reached, toxicity and heat exposure is diluted and “leaked” which does not happen in a closed room scenario. This test scenario does however have a limited fuel load and fire spread is limited to the room corner. In a realistic fire situation, fire spread due to available adjacent fuel load could increase heat exposure dangerously even at low levels. Nevertheless, Automist’s suppression effectiveness has been demonstrated when the air flow requirements are met.

Kitchen Oil Pan Fire

The graph below shows the difference in temperature at 1.8 m height in a suppressed and unsuppressed kitchen fire. There is a clear difference in temperature, demonstrating Automist’s ability to reduce the chance of the fire spreading beyond the kitchen. Kitchen fires are generally survivable even in a free burn scenario. The testing demonstrated that if an oil fire is left untouched and kept clear from other flammables it will eventually and often safely self-extinguish. Automist intervenes to stop people from either fighting the fire by throwing water (a frequent source of fire injuries in the home) or by limiting its abililty to spread to towels, appliances and other flammables placed close to the hob and reducing damage. Occupants would therefore be able to focus exclusively on leaving the premises.



The table below summarises the test results according to the DD252 performance criteria for comparison purposes. It is important to note that the position where the temperatures were measured was at 1.8m as opposed to 1.6m height as defined on DD252. It is possible to observe that Automist did not meet the performance criteria in all but one test and position despite having achieved some significant improvements in FED.

Test number and description	**Time test criteria exceeded, see section 4.7**			
	100 mm below the ceiling[1] (320 °C)	**1.8 m above the floor[2] (95 °C)**	**1.8 m above the floor, for any 2 minute period[2] (55 °C)**	**Ceiling temperature 6.5 mm above (260 °C)**
Test 1 – 8 x 4 m, furniture, 'distant' mist[3], sealed[4] room	11 m 38 s	2 m 14 s	3 m 35 s	n/m
Test 2 – 8 x 4 m, furniture, 'near' mist[3], open doors	2 m 30 s	1 m 49 s	3 m 21 s	n/m
Test 7 – 4 x 4 m, furniture, 'near' mist[3], sealed[4] room	Not reached	1 m 30 s	3 m 6 s	n/m
Test 8 – 8 x 4 m, furniture, 'distant' mist[3], sealed[4] room	19 m 50 s[5]	1 m 35 s	3 m 11 s	n/m
Test 9 – 8 x 4 m, furniture, 'distant' mist[3], open doors	2 m 13 s	1 m 47 s	3 m 15 s	n/m
Test 10 – 8 x 4 m, furniture, unsuppressed, sealed[4] room	1 m 41 s	1 m 32 s	3 m 15 s	n/m
Test 11 – 8 x 4 m, furniture, unsuppressed, open doors	1 m 45 s	1 m 22 s	3 m 3 s	n/m

[1] The measurement of temperature for the tests was 100 mm below the ceiling, the DD 8458-1 criteria relates to 75 mm below the ceiling.

[2] The measurement of temperature for the tests was 1.8 m above the floor, the DD 8458-1 criteria relates to 1.6 m above the floor.

[3] DD 8458-1 is specifically for ceiling mounted fixed water mist systems. The prototype Automist system was therefore not consistent with the specifications of the document.

[4] The DD 8458-1 fire test is conducted with open doors, therefore, the sealed test room was not directly applicable to the criteria.

[5] DD 8458-1 temperature criteria only applies for a 10 minute period.

n/m is not measured

The table below summarises the test results according to the SRSA pass criteria. Automist satisfies the performance criteria in all the tests, however, tests 5 and 11 which were unsuppressed control tests did not reach the criteria either. This is understandable for toxic gases items since these were open door tests but not breaching the temperature criteria on an unsuppressed open door fire indicates that it is not set at a challenging enough level.

Test number and description	**Test criteria reached, see section 4.7**				
	FED = 1	**FED = 2**	**Average temperature**	**Carbon monoxide**	**Oxygen**
Test 1 – 8 x 4 m, furniture, 'distant' mist, sealed room	17 m 50 s (heat)	23 m 4 s (asphyxia)	Not reached (61 °C)	Exceeded (20, 665)	Not reached[1]
Test 2[2] – 8 x 4 m, furniture, 'near' mist, open doors	Not reached	Not reached	Not reached (69 °C)	Not reached	Not reached
Test 3 – 8 x 4 m, kitchen, 'near' mist, open doors	4 m 1 s (heat)	4 m 35 s (heat)	Not reached	Not reached	Not reached
Test 4 – 4 x 4 m, kitchen, 'near' mist, open door	Not reached	Not reached	Not reached	Not reached	Not reached
Test 5 – 4 x 4 m, kitchen, unsuppressed, open door	Not reached	Not reached	Not reached	Not reached	Not reached
Test 6 – 4 x 4 m, furniture, 'near' mist, sealed room	Test abandoned	Test abandoned	Test abandoned	Test abandoned	Test abandoned
Test 7 – 4 x 4 m, furniture, 'near' mist, sealed room	27 m 20 s (asphyxia)	Not reached	Not reached (48 °C)	Not reached	Not reached
Test 8 – 8 x 4 m, furniture, 'distant' mist, sealed room	22 m 51 s (heat)	Not reached	Not reached (66 °C)	Not reached	Not reached
Test 9 – 8 x 4 m, furniture, 'distant' mist, open doors	3 m 3 s (heat)	3 m 13 s (heat)	Not reached (73 °C)	Not reached	Not reached
Test 10 – 8 x 4 m, furniture, unsuppressed, sealed room	2 m 48 s (heat)	3 m 40 s (heat)	Exceeded (111 °C)[3]	Exceeded (36,027)	Exceeded (12 m 21 s)
Test 11 – 8 x 4 m, furniture, unsuppressed, open doors	2 m 14 s (heat)	2 m 21 s (heat)	Not reached (89 °C)	Not reached	Not reached

[1] Oxygen reduced to below 15% after 17 minutes 30 seconds but did not breach the 5 minute criteria within the 20 minute evaluation after system operation.

[2] Test evaluation period 12 minutes only.

[3] Measured between 6 and 7 minutes after ignition.

Automist's performance level lies somewhere between the performance criteria stipulated in DD252 and the SRSA.

Conclusions

The tests demonstrated that Automist provided an improvement in the room heat and asphyxiant gas conditions and the extent of fire damage in all three test scenarios conducted which an unsuppressed equivalent scenario was compared. It extended the time taken to reach FED calculated human tenability threshold levels and in some cases, prevented levels being breached.

Additionally, the challenging test programme was able to expose the limitations of the system which can then be translated into installation requirements to ensure that the system will operate and provide the suppression effectiveness desired. The presence and location of automatic door closers to avoid secondary draughts is an example of such requirement being made.

Most importantly, the test suite demonstrated the need to develop a repeatable yet realistic test procedure and criteria for domestic furniture and domestic kitchens to be used to test adequately systems such as Automist. The procedure developed by SRSA/DBA is a significant step in that direction but requires some refinement of pass/fail criteria to more challenging levels. A repeatable yet realistic and challenging domestic kitchen test procedure would allow for an improved validation of products which seek to protect the kitchen, where over 60% of fires occur in the UK.

Biblography

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