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Tests with Flame Guard b.v. aerosol suppression system for prison cell fire protection

Prepared for: Flame Guard b.v.

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Protecting People, Property and the Planet

Prepared on behalf of BRE Fire and Security by

Name Kelvin Annable

Position Senior Consultant

Signature

Approved on behalf of BRE Fire and Security by

Name Steve Manchester

Position Business Group Manager, Fire Safety

Date 4th August 2008

Signature

BRE Fire and Security
BRE Global
Bucknalls Lane
Watford
Herts
WD25 9XX
T + 44 (0) 1923 664100
F + 44 (0) 1923 664994
E enquiries@breglobal.com
www.breglobal.com

Executive Summary

Flame Guard b.v. wished to investigate the effectiveness of their aerosol suppression technology for the fire safety protection of prison cells. Flame Guard supplied units of their Dry Sprinkler Powder Aerosol, type 5 (DSPA 5) to BRE for tests. The agent was contained as a solid in a metal unit and upon activation, self-propelled out of the unit as an aerosol. Combustion of the solid agent that is located in the generator body causes the formation of fire suppressing aerosols.

BRE have previously conducted a large programme of experimental work primarily investigating the effectiveness of water mist suppression systems for the fire safety protection of prison cells. BRE therefore had a test rig available, which was highly instrumented to enable measurements of temperatures and gas conditions in a fire. During the course of the previous work programme, BRE developed a ‘fire scenario’ suitable for water mist evaluation. The same fire scenario (but with differing ‘pre-burn’ times) and associated prison issue items (that is, bedside locker, mattresses, duvets etc) were used for tests with Flame Guard’s aerosol suppression technology.

The following tests were conducted:

- Test 1 – BRE developed ‘standard’ fire scenario with the suppression unit applied two minutes after ignition.
- Test 2 – BRE developed ‘standard’ fire scenario with the suppression unit applied 2 minutes after detection of the test fire (a domestic ionisation detector, centrally located on the ceiling of the test room, was used).

The quantity of agent in each generator unit is stated as 3.3 kg in Flame Guard literature. This equates to a concentration after discharge in the 36 m^3 test volume of 91.7 g/m^3. The discharge time of the aerosol unit is stated by Flame Guard as between 20 and 28 seconds.

Overall, the Flame Guard aerosol system demonstrated effective fire suppression and maintained tenable conditions for 20 minutes, for both of the tested fire scenarios.

Contents

1 Introduction

Flame Guard b.v. (Hulzenseweg 10-20, 6534 AN Nijmegen, Netherlands) wished to investigate the effectiveness of their aerosol suppression technology for the fire safety protection of prison cells. BRE Fire and Security were therefore commissioned by Flame Guard (part of the AFG Group) to conduct two fire tests with Flame Guard condensed aerosol extinguishing system units.

Flame Guard b.v. supplied units of their Dry Sprinkler Powder Aerosol, type 5 (DSPA 5) to BRE for tests. The agent was contained as a solid in a metal unit and upon activation, self-propelled out of the unit as an aerosol. Combustion of the solid agent that is located in the generator body causes the formation of fire suppressing aerosols.

This report details the work undertaken and the results of the two tests conducted.

1.1 Background

BRE have previously conducted a large programme of experimental work primarily investigating the effectiveness of water mist suppression systems for the fire safety protection of prison cells. BRE therefore had a test rig available, which is highly instrumented to enable measurements of temperatures and gas conditions in a fire. During the course of the previous work programme, BRE developed a 'fire scenario' suitable for water mist evaluation. The same fire scenario and associated prison issue items (that is, bedside locker, mattresses, duvets etc) were used for tests with Flame Guard's aerosol suppression technology.

The UK Ministry of Justice decided that it was necessary to investigate a different fire safety strategy than the one they currently employ for the suppression of fires in prison cells. Prisoners housed in cells are different from most other occupants of buildings in a fire as they are unable to evacuate themselves away from the heat and smoke generated. The Ministry of Justice therefore commissioned BRE Global, in the summer of 2007, to provide assistance in the development of fire safety strategies employed in the protection of prison cells, in particular with regard to the fuel loading of cells and the potential effectiveness of water mist suppression systems in tackling cell fires.

BRE Global conducted a programme of work including a series of 21 fire tests. The outcomes from this work programme have been detailed in BRE report number 242536[1]. An accompanying Suppression System Performance Specification fire test document, number 244357[2], was also produced by BRE Global. This document specifies requirements for fire testing of suppression systems for custodial premises and includes a number of 'pass/fail' criteria. The criteria are mainly based on Fractional Effective Dose (FED) methodology which is used to assess human survivability in fire atmospheres.

2 Description of the project

A fire test series was agreed by Flame Guard and BRE.

The following tests were conducted:

- Test 1 – BRE developed 'standard' fire scenario with the suppression unit applied two minutes after ignition.
- Test 2 – BRE developed 'standard' fire scenario with the suppression unit applied 2 minutes after detection of the test fire (a domestic ionisation detector, centrally located on the ceiling of the test room, was used).

2.1 Test room (cell)

The test room constructed for previous work was used, with the geometry and internal dimensions having been specified by the UK Ministry of Justice. The rig represented a double occupancy prison cell, measuring internally 3 m by 4 m and 3 m high; giving a volume of approximately 36 m^3. The room was of blockwork construction, internally clad with plasterboard, see Figure 1.

Figure 1 – Test room

The roof comprised timber joists with the ceiling being formed by two layers of plasterboards. A 'shower/toilet cubicle area' located in a corner was formed by plasterboard stud walls connected by two shower curtains. The stud walls were constructed to a height of 2.85 m, therefore leaving a gap of approximately 150 mm between the wall and the ceiling. The room was furnished with standard prison issue items, including two bunk beds (with metal frame), a chair and desk, see Figure 2. A standard prison issue door set was fitted to the test cell.

Figure 2 – Photograph showing shower/toilet cubicle area and prison issue bed, chair and desk

No mechanical ventilation to the test rig was provided although there was an opening to ductwork at ceiling level in the shower/toilet cubicle area. Additional openings were provided representative of the effective cross sectional area of a fully open prison window; approximately 0.04 m^2 (400 cm^2). These were in the form of two rows of 5 holes approximately 70 mm in diameter equally spaced vertically over 1 m, with the bottom holes 1.2 m from floor level. There was a further small area of opening around the cell door (crackage).

2.1.1 Instrumentation

The test room was instrumented to enable measurements of temperature and gas conditions. Room concentrations of oxygen, carbon monoxide and carbon dioxide were continuously monitored during tests.

The gas measuring locations were as follows:

- Low level – 250 mm from floor, 1600 mm from end wall and 850 mm from the wall opposite to bed.
- Mid level – 1600 mm from floor, 850 mm from door, 350 mm from long wall adjacent to bed.
- High level – 2750 mm from floor, 1600 mm from end wall and 850 mm from the wall opposite to bed.

The temperature measuring locations were as follows:

- Door location – thermocouples in contact with the floor and ceiling and spaced at 0.5 metre intervals of the entire height.
- Fire location – one thermocouple close to ignition location and thermocouples spaced at 0.5 metre intervals to the ceiling.
- Additional thermocouples were placed at mid and high level on the long wall opposite to the bed, at the gas measuring locations and in the extract ductwork.

2.1.2 Detection system

A household ionisation detector, centrally located on the ceiling, was used to detect the test fires. This is not representative of actual in-cell detection systems which need to be robust from malicious tampering. Aspirating systems are now increasingly being used to detect cell fires and due to the nature of the prison environment (dirty, dusty and with cell occupants allowed to smoke cigarettes) a level of de-sensitisation is required. Therefore, it is considered that the detection system used provided favourable fire detection for the testing.

2.2 Fire scenario

BRE Global had developed a test fire for the previous work that met the following criteria:

- It comprised prison issue items and representative ‘personal’ and food items that might be found in any cell (i.e. no “brought in” incendiary or particularly flammable material).
- It was (reasonably) repeatable and reproducible.
- It offered a challenging scenario for suppression systems.
- It was not so challenging that it might be expected to defeat all or most potential suppression systems.
- It was based on the scenarios used in previous related work.

The developed fire scenario consisted of a prison issue bedside locker placed on its side on the lower bunk of the bed at an angle of 45^{o} to the long wall of the room. The door of the locker was opened and resting on the top of the unit. This provided for four open compartments separated by shelving. The compartments were filled with the following items, as shown in Figure 3:

- 12 crisp packets and 4 boxes of cereal.
- A pair of jeans and vest.
- 2 toilet rolls and 2 plastic bottles.
- A paper and magazine.
- 10 single CD cases and a computer keyboard.
- Prison issue duvet cover, sheet and pillow slip.

The locker was placed on a duvet with prison issue duvet cover. The duvet was on prison issue mattress and mattress cover. The top bunk bed likewise was furnished with prison issue mattress, duvet and covers. The location of the locker was adjacent to a prison issue table and chair, see Figure 4.

This arrangement was used for both tests.

Figure 3 – Developed fire scenario

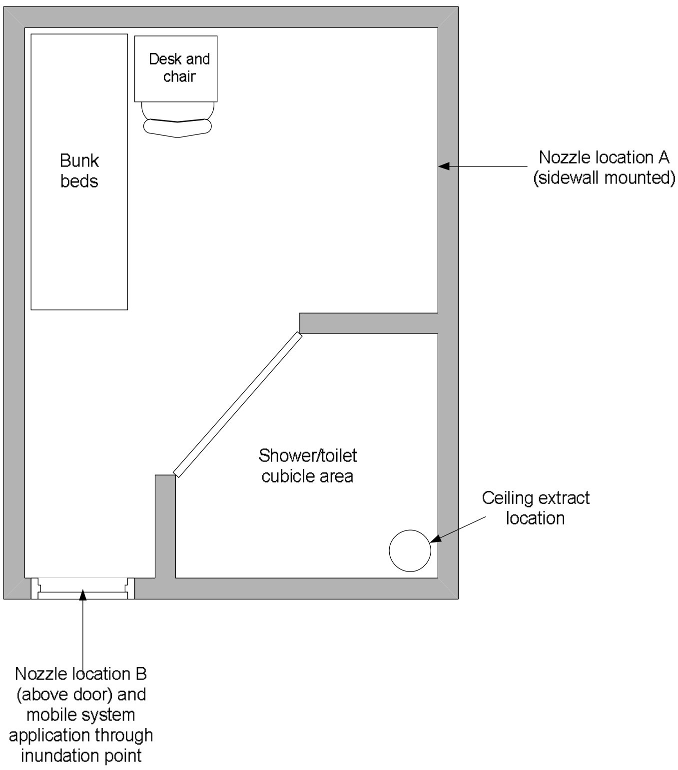

Figure 4 – Schematic of test room layout

2.2.1 Unsuppressed fire test scenario

The fire scenario was conducted with no suppression system as part of the previous work and is detailed in this section.

The fire scenario was checked for speed of development and repeatability (tests carried out external to the test room) with satisfactory results.

The scenario was also evaluated, with no suppression system fitted, inside the test room with measurements, as shown in Figure 5 to Figure 7.

The centrally located crisp packets were ignited using a cigarette lighter and test staff immediately left the room and closed the cell door. The fire was allowed to develop freely under closed room conditions until 10 minutes from ignition at which point the door was opened. The temperature readings at the door location for this test indicate a steady rise in temperature for a period of about 5 minutes at which point temperatures plateau for approximately 2 minutes. There is then a sharp rise in room temperature for a further 2 minutes before room conditions and oxygen concentrations force the vitiated fire to decrease in size with associated cooling of room temperatures. However, upon opening the door to the room on 10 minutes, the fire again began to increase in size due to the readily available supply of oxygen. The test was manually terminated with a water hose reel, deployed from the doorway, at about 11 minutes 30 seconds (from ignition).

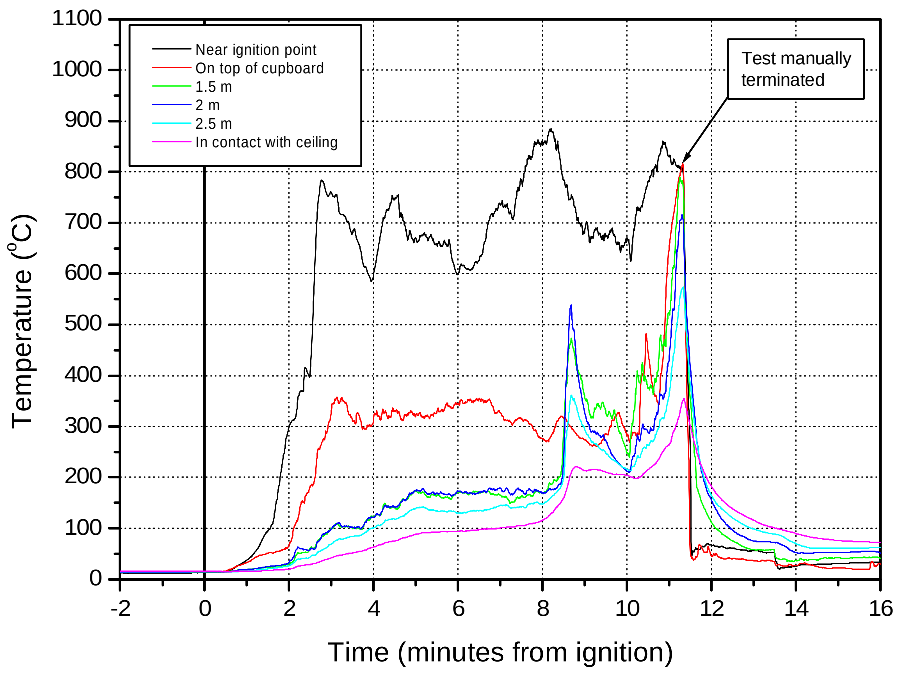

Figure 5 – Test 0 – Scenario development; temperatures above the fire location

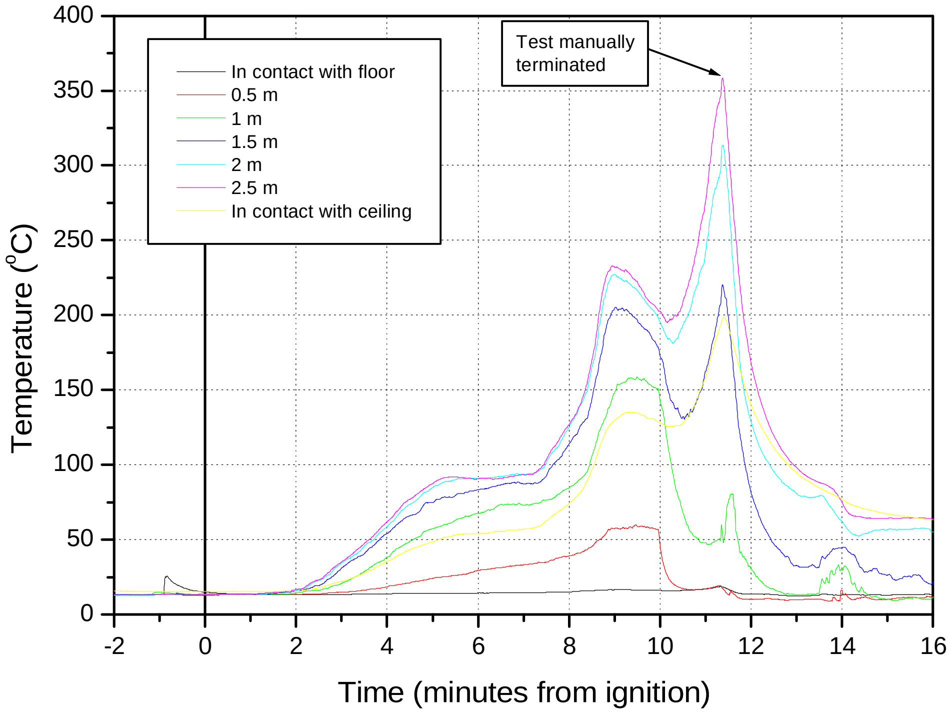

Figure 6 – Test 0 – Scenario development; temperatures close to the cell door

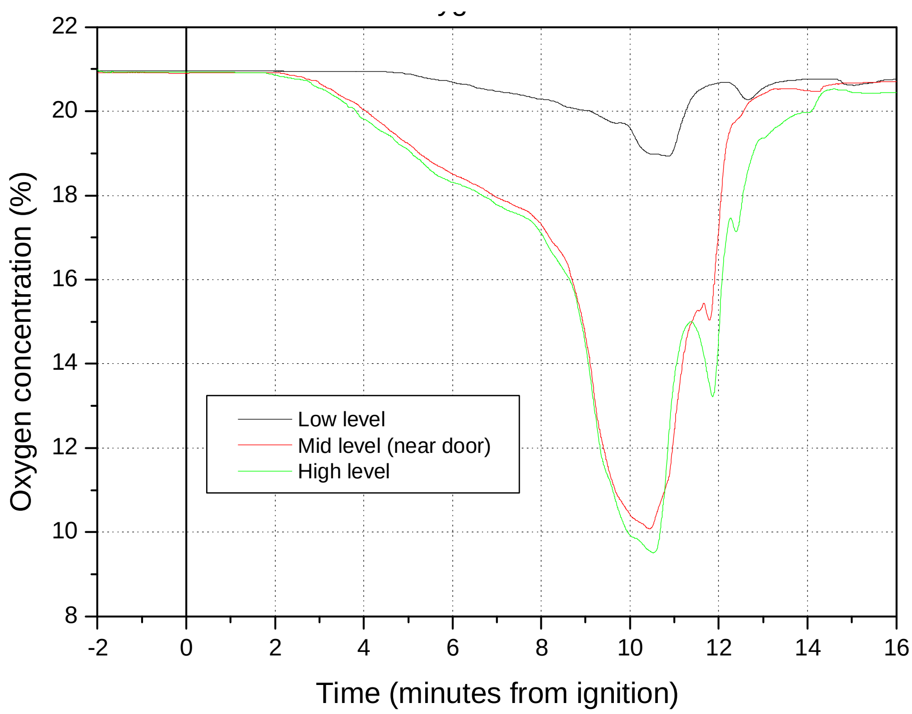

Figure 7 – Test 0 – Scenario development; room oxygen concentrations

Fractional Effective Dose calculations (see section 4) have indicated that conditions in the room became life threatening after approximately 10 minutes from ignition at mid height level. The developed test fire scenario was used for both Flame Guard tests.

2.3 Test procedures

The test fire was ignited and the cell door closed. For Test 1, after 2 minutes the door was opened and the DSPA generator thrown into the enclosure. The door was then quickly closed and remained closed for a period of 5 minutes. After this period the door was opened and then left open for the remainder of the test. For Test 2 the same procedure was adopted, however, the unit was applied two minutes after detection of the fire. Tenability conditions were monitored for a period of 20 minutes.

General test procedures are shown in Table 1.

Time	**Action**
Prior to test	Instrumentation and video recordings started.
0 min 0 sec	Ignition of fuel load by application of a cigarette lighter flame.
x min y sec	Detection of test fire
xx min yy sec	Generator unit applied (door quickly opened and then closed)
xx min yy sec plus 5 min	Door opened
20 min 0 sec	Tenability conditions monitoring end point
Post test	Test fire manually extinguished (if necessary), instrumentation and video recordings stopped.

Table 1 – Test procedure

Each test was recorded using both digital video and photography.

2.4 DSPA 5 suppression unit

The DSPA 5 suppression unit is shown in Figure 8 below.

Figure 8 – DSPA 5 generator unit

The aerosol-forming agent is encased in a metal housing. On one side of the metal housing there is a threaded bush which enables mounting of the activating assembly. There is also a handle on the body. Discharge of fire suppressing aerosol occurs via a slot situated on the side of the metal housing. DSPA 5 generators are activated by pulling the cord (away from the unit). There is an approximate delay of 8 seconds before the main compound is actuated. This delay allows time for the unit to be thrown into a room where a fire is located. After the main compound of the starting assembly has been actuated, ignition of the aerosol-forming agent occurs. The generator unit works by flooding the entire protected volume with aerosol to provide total volume fire protection (in a similar way to fixed gaseous systems).

3 Findings

3.1 Test 1 – Flame Guard aerosol suppression 2 minutes after ignition

A single Flame Guard DPSA 5 aerosol suppression generator unit was thrown into the test cell 2 minutes after ignition. Figure 9 below contains photographs taken during the test.

Figure 9 – Photographs showing test room, fire scenario and aerosol discharge shortly after activation

Details of the test result are shown in Table 2. The quantity of agent in each generator unit is stated as 3.3 kg. This equates to a concentration after discharge in the 36 m^3 test volume of 91.7 g/m^3. The discharge time of the aerosol unit is stated as between 20 and 28 seconds on the Flame Guard DPSA 5 information sheet (see Appendix A).

Generator unit	Generator weight	Detection (from ignition)	System operation	Max temperature near door	
				Pre-operation	Post-operation
	(kg)	(min:s)	(min:s)	(°C)	(°C)
DPSA 5	4.70	0m 52s	2m 0s	26	90

Table 2 – Test details for Test 1

Fire plume location temperatures are shown in Figure 10. After 2 minutes (when the generator unit was applied) the test fire was still small and had not become established beyond the lower compartment containing the crisp packets and cereal boxes. The temperatures at the fire location initially increased after operation but within approximately one minute declined rapidly. Temperatures did not increase when the door was opened 5 minutes after the unit had been applied and the fire was effectively suppressed (a small amount of smouldering was noted by test operators indicating that the fire was not completely extinguished). There was only a very limited amount of fire damage to the locker unit and the integrity of the hardboard back had not been breached. The aerosol system demonstrated effective fire suppression for the tested scenario.

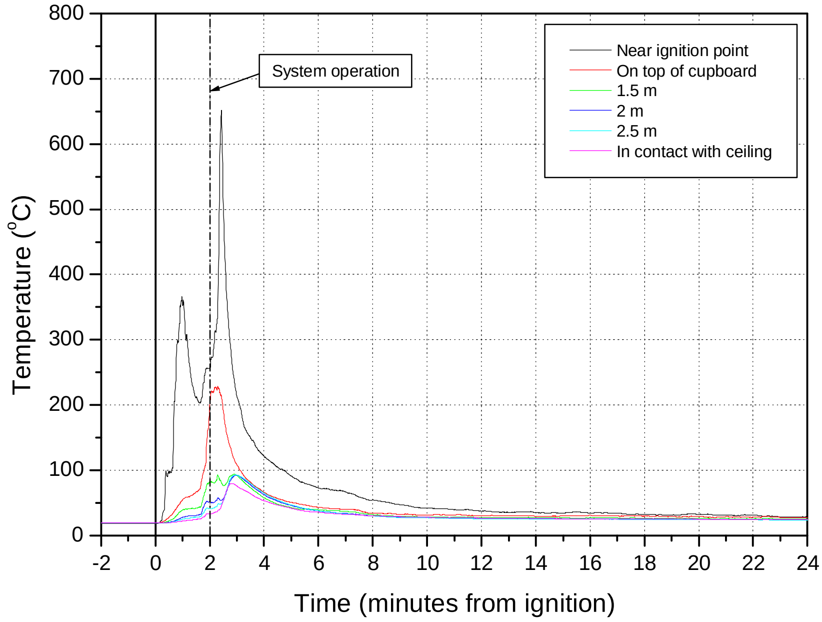

Figure 10 – Temperatures above the fire for Test 1

Temperatures near the door are shown in Figure 11. Temperatures near the door significantly increased after the unit was applied up to a peak of 90 °C. However, they began to fall after approximately one minute and were close to ambient levels after a further 5 minutes.

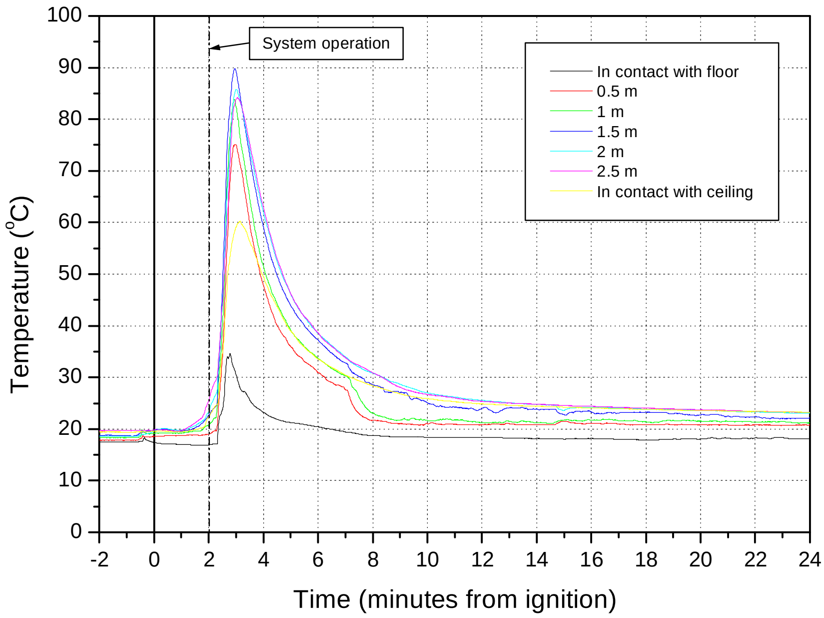

Figure 11 – Temperatures near the door for Test 1

Concentrations of oxygen measured during the test are shown in Figure 12. The oxygen concentration was not significantly depleted by the fire or operation of the aerosol suppression unit.

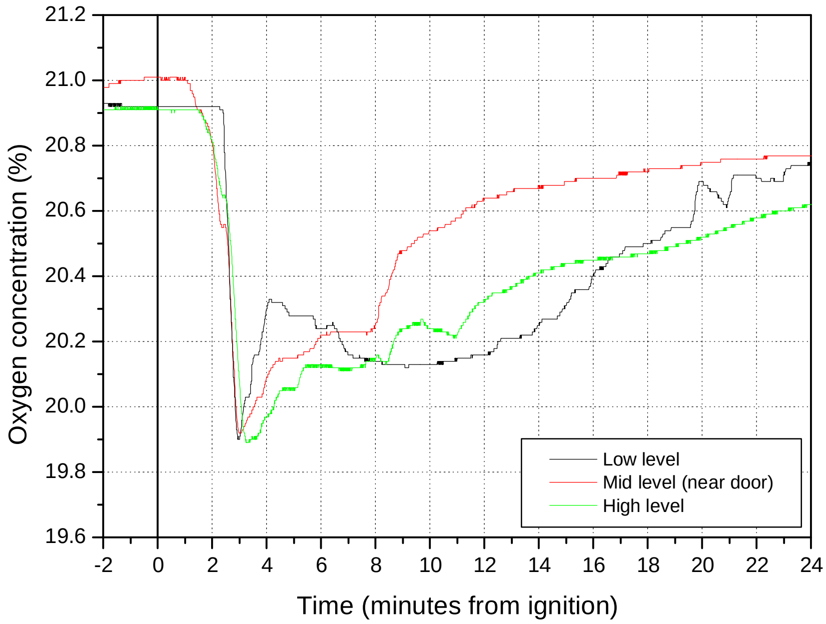

Figure 12 – Oxygen concentrations for Test 1

Concentrations of carbon dioxide measured during the test are shown in Figure 13. The peak concentration of carbon dioxide measured (at high level) was slightly in excess of 1.2 %.

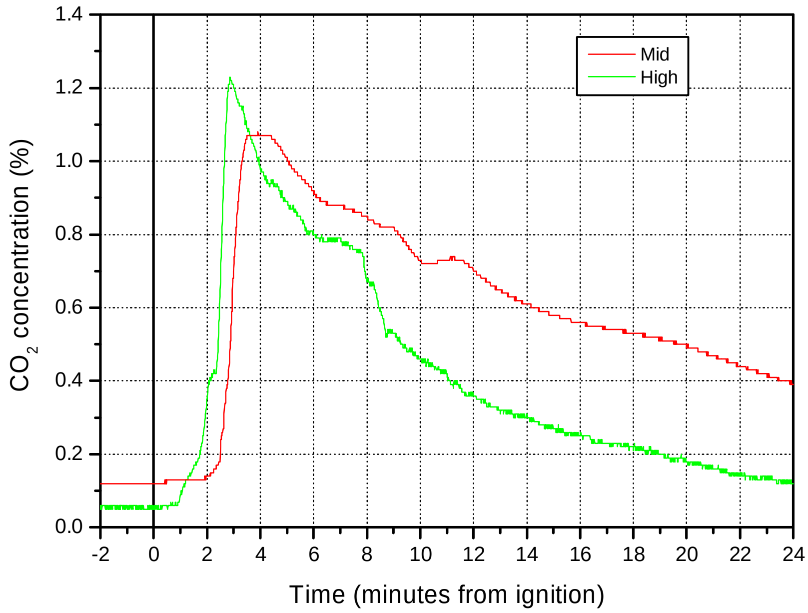

Figure 13 – Carbon dioxide concentrations for Test 1

Concentrations of carbon monoxide measured during the test are shown in Figure 14. The peak concentration of carbon monoxide measured (at high level) was slightly in excess of 3000 ppm.

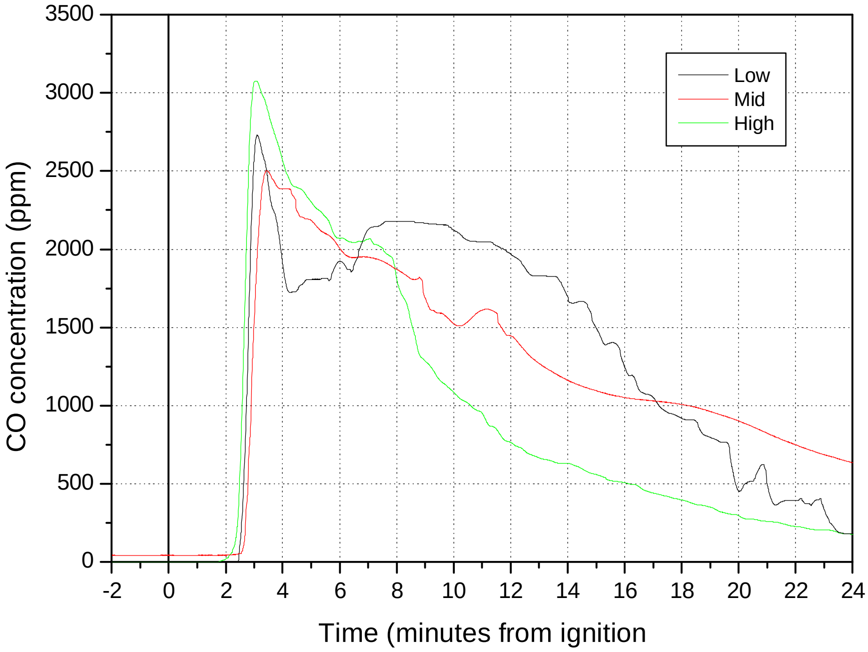

Figure 14 – Carbon monoxide concentrations for Test 1

The levels of both carbon dioxide and carbon monoxide prior to system operation were very low. Hence the combustion process of the aerosol forming agent has significantly contributed to the toxicity conditions within the cell. However, this must be balanced against the effective suppression of the fire by the aerosol system and the associated reduction in toxicity from the fire itself.

3.2 Test 2 – Flame Guard aerosol suppression 2 minutes after detection

A single Flame Guard DPSA 5 aerosol suppression generator unit (the same as for Test 1) was thrown into the test cell 2 minutes after smoke detection of the test fire. Figure 15 below contains photographs taken during the test.

Figure 15 – Photographs showing fire scenario and test room shortly after the door was opened (5 minutes after the generator unit had been applied)

Details of the test result are shown in Table 2. As for Test 1, the quantity of agent used equated to a concentration after discharge in the 36 m^3 test volume of 91.7 g/m^3.

Generator unit	Generator weight (kg)	Detection (from ignition) (min:s)	System operation (min:s)	Max temperature near door	
				Pre-operation (^oC)	Post-operation (^oC)
DPSA 5	4.84	1m 25s	3m 25s	55	107

Table 3 – Test details for Test 2

Fire plume location temperatures are shown in Figure 16. After 3 minutes 25 seconds (when the generator unit was applied) the test fire was larger than in Test 1 and had spread beyond the lower compartment to the upper compartments. The temperatures at the fire location declined rapidly soon after the unit had been applied. Temperatures did not increase when the door was opened 5 minutes later and the fire was effectively suppressed. There was only a limited amount of fire damage to the locker unit and it is likely the integrity of the hardboard back had not been breached on termination of the test. However, a small amount of smouldering was noted by test operators after the test (the fire had not been completely extinguished) which subsequently developed into flaming combustion and the integrity of the hardboard back of the locker unit was breached in the upper right hand side compartment (containing the newspaper, magazine, keyboard and toilet rolls). This demonstrated the potential for re-ignition. Overall, the aerosol system demonstrated effective fire suppression for the tested scenario.

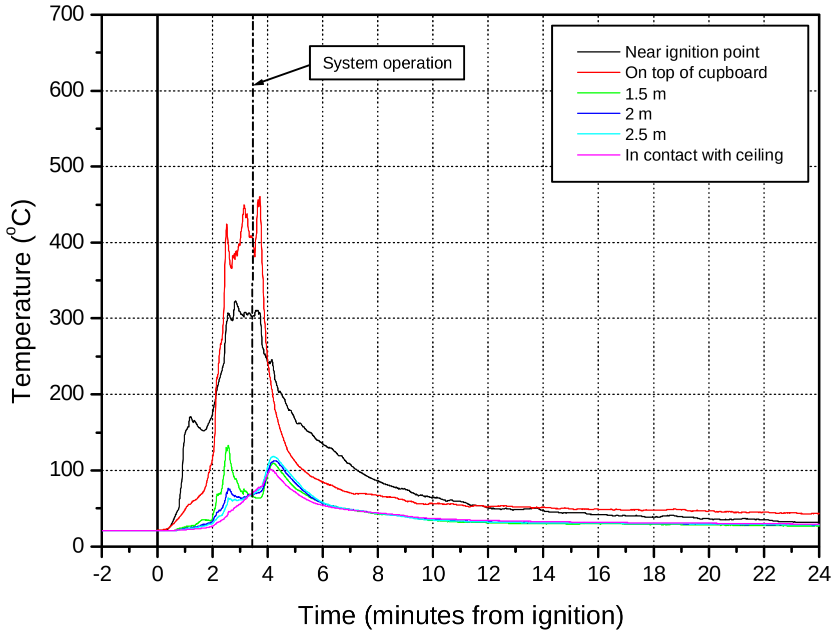

Figure 16 – Temperatures above the fire for Test 2

Temperatures near the door (see Figure 17) significantly increased after the unit was applied up to a peak of 106 ^{o}C. However, they began to fall shortly after and were close to ambient levels 5 minutes later.

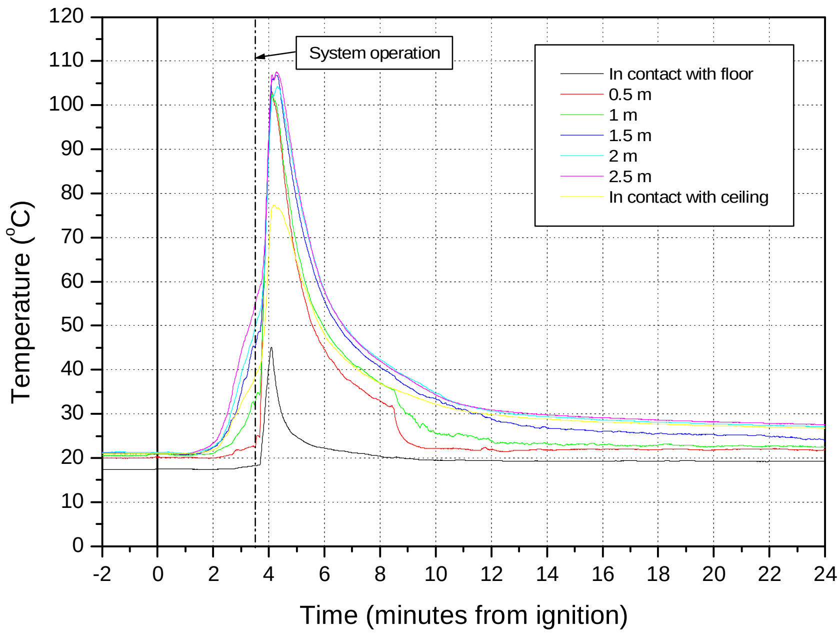

Figure 17 – Temperatures near the door for Test 2

Concentrations of oxygen measured during the test are shown in Figure 18. The oxygen in the room remained above 19 % despite the operation of the aerosol unit and the oxygen consumed by the fire.

A significantly reduced flow of gas through the pump drawing room gases at mid level was observed for this test. The influence of this can be seen in the concentrations of oxygen, carbon dioxide and carbon monoxide at mid level (red line) in Figure 18, Figure 19 and Figure 20 respectively. Peak concentrations (in actuality) are likely to have occurred in the room at a time consistent with the peaks noted at low and high level.

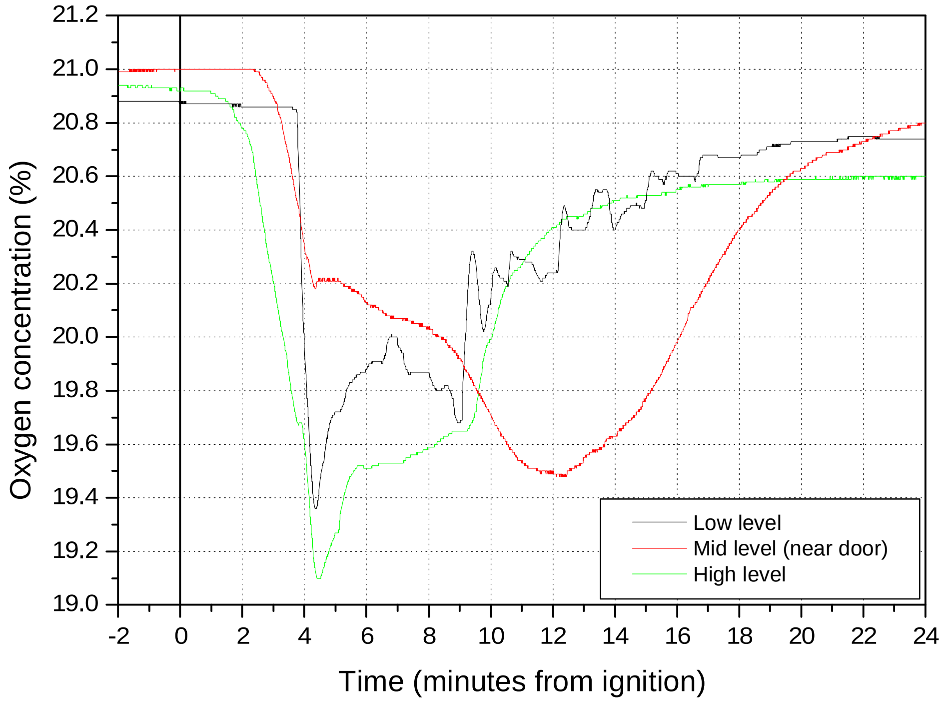

Figure 18 – Oxygen concentrations for Test 2

Concentrations of carbon dioxide measured during the test are shown in Figure 19. The peak concentration of carbon dioxide measured (at high level) was slightly in excess of 1.2 %.

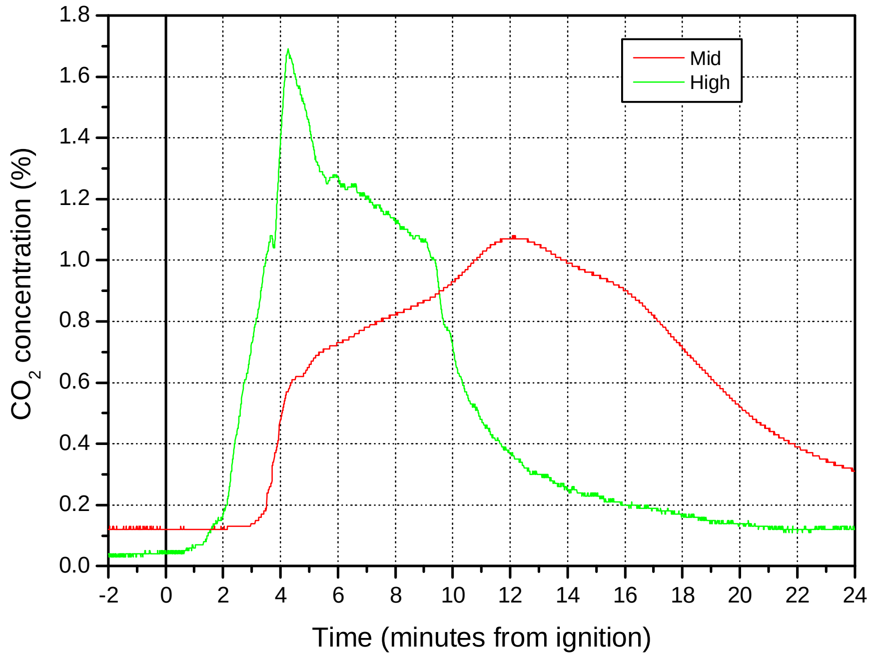

Figure 19 – Carbon dioxide concentrations for Test 2

Concentrations of carbon monoxide measured during the test are shown in Figure 20.

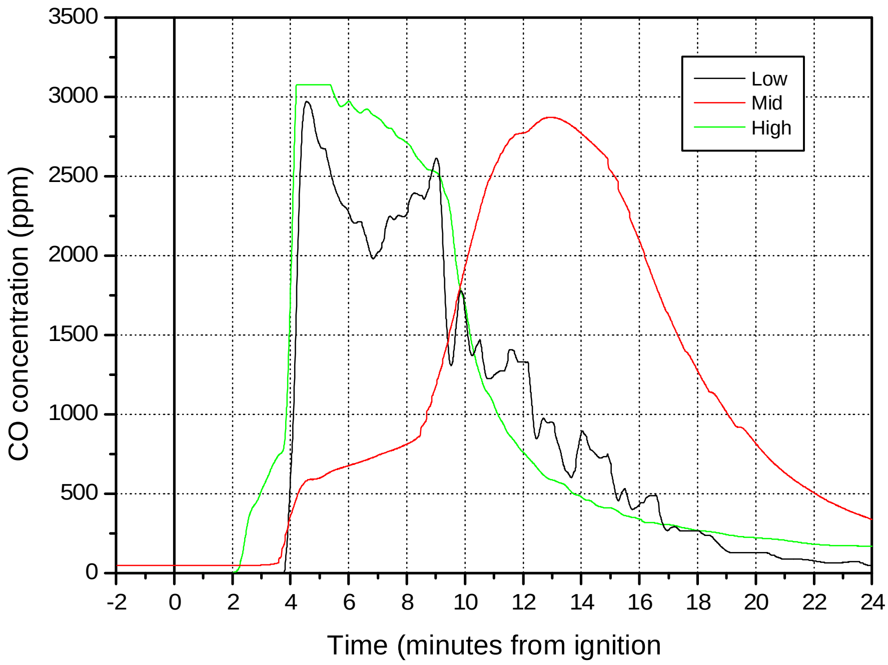

Figure 20 – Carbon monoxide concentrations for Test 2

The peak concentration of carbon monoxide measured (at high level) was in excess of 3000 ppm and was ‘off the scale’ of the measuring analyser for a period of over one minute. Peak concentrations at low and mid height level were approaching 3000 ppm.

The levels of both carbon dioxide and carbon monoxide prior to system operation were low. Hence the combustion process of the aerosol forming agent has significantly contributed to the toxicity conditions within the cell. Again, as for Test 1, this must be balanced against the effective fire suppression demonstrated by the aerosol system.

It was generally observed for both the tests that when the cell door was opened there was limited visibility in the cell. This would affect the ability of staff to carry out occupant rescue.

No measurements of room pressure were conducted, however, an initial overpressure could be observed upon activation of the aerosol generator unit as smoke and aerosol was emitted from the enclosure through the vents, door and ceiling of the test rig.

The aerosol generator suppression technology requires no water. It was observed subsequent to the tests that the room and room contents remained ‘dry’. This is considered a significant advantage for the prison environment as there is no possibility of consequential water damage. However, a thin ‘greasy’ residue was observed in the test room after each test.

4 Fractional Effective Dose (FED) calculations

4.1 Method for toxic hazard (FED) analysis

4.1.1 Fire hazard and tenability endpoints with respect to prisoners and staff

The main toxic hazards in fire effluent atmospheres consist of smoke irritants (particulates and gases) and asphyxiant gases.

Depending on their concentration, the irritant smoke particulates and gases such as hydrogen chloride can impede escape and rescue activities, and inhalation presents a potential health hazard through lung irritation and injury. It is almost inevitable that a cell inmate will suffer some degree of exposure to irritant smoke during any cell fire, but it is not inevitable that this will result in serious injury. The analysis conducted for this work is based on the assumption that no respiratory protection is used and therefore represents a worst case scenario.

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 time during a fire as the fire gases are inhaled and as the fire gas concentrations increase with a growing fire. The main consideration, with regard to cell inmates, is therefore as far as possible to minimize their exposure during the period before rescue during a cell fire, and in particular to prevent inhalation of a sufficient exposure dose to result in severe incapacitation (loss of consciousness) or death.

The main hazards from a brief exposure to heat during a cell fire are likely to be skin pain and burns, followed by death in severe situations. As with asphyxiant gases, the effects of heat exposure can be considered in terms of 'doses' of heat exposure required to cause different levels of injury. For exposure to hot fire gases this depends mainly on the duration of exposure and the increasing temperature during a fire. The main consideration is that, as far as possible, cell inmates should not suffer severe pain or burns during the period before rescue.

In order to assess tenability for this work, the hazards from exposure to asphyxiant toxic gases and heat (hazard from convection due to contact with hot fire gases) have been analysed using Fractional Effective Dose (FED) methodology.

The basis of the FED hazard assessment method is described in the next section.

4.1.2 Prediction of time to incapacitation and death from asphyxiant gases

Fire effluent contains a mixture of asphyxiant gases of which the most important are carbon monoxide (CO) and hydrogen cyanide (HCN). These have been shown to be additive in their combined effects. The presence of carbon dioxide (CO_2) in fires is also important since it causes hyperventilation (an increase in the volume of air inhaled each minute), which increases the rate of uptake of CO and HCN. Fire effluent is depleted in oxygen; so direct low oxygen hypoxia also contributes to the overall level of hypoxia, although this effect is usually minor.

Time to incapacitation (loss of consciousness) in a fire is considered to depend upon the overall effects of the mixed asphyxiant gases present in the fire effluent. The method described below has therefore been applied to the asphyxiant gases measured during the tests to calculate the proportion of an exposure dose likely to cause incapacitation (loss of consciousness) to which cell inmates and rescuers are exposed over the relevant periods of the fires.

After a person becomes unconscious due to the effects of these asphyxiant gases, they continue to breathe, and inhale the gases at a reduced rate, so that their condition gradually further deteriorates until death occurs (at approximately 2 - 3 times the dose of asphyxiant gases as that causing loss of consciousness).

The asphyxiant gases considered are carbon monoxide, hydrogen cyanide, carbon dioxide and low oxygen hypoxia. The combined effects of these gases have been estimated according to the method of Purser[3,4,5,6]. The method is a current British Standard (BS9899-2: 1999)[7] and an International Standard[8]. Details of the methodology are provided in the references cited.

Note, for this work, hydrogen cyanide was not measured. However, the previous work conducted by BRE had given an indication of the levels of hydrogen cyanide produced by the prison issue and miscellaneous items used for fuel in this test programme. The concentration of hydrogen cyanide in a fire will typically be roughly proportional to the concentration of carbon monoxide (which was continuously measured for all tests). A ratio of concentration (ppm) of CO:HCN of 80:1 was used for FED calculations. At this ratio the contribution of HCN to the overall toxic dose is limited to a minor effect.

Incapacitation (loss of consciousness) is predicted when the FED_{AG} summed with time reaches 1.

Death due to asphyxiation is predicted at an FED_{AG} of approximately 2-3.

4.1.3 Effects of level of physical activity on development of asphyxia

The volume of air inhaled each minute by a subject, and hence the rate of uptake of asphyxiant gases depends upon the level of physical activity and to some extent their mental state. For the cell inmates it has been assumed that they were basically ‘at rest’ physically but likely to be somewhat agitated while in the cell during the fire. On this basis, ventilation (VE) of 15 litres per minute has been assumed. This is then increased further according to the carbon dioxide concentration (using VCO_2).

4.1.4 Prediction of time to skin pain or hyperthermia due to convected heat

The time to incapacitation due to skin pain or hyperthermia (in minutes) by convected heat from contact with air (containing less than 10% by volume of water vapour) is given by:

$$t_{IHEAT} = 5 \times 10^{7} \times T^{-3.4}$$

where

T = temperature °C

The fractional dose of heat acquired per minute is the reciprocal of the time to incapacitation[5,6]. The fractional heat doses each unit of time are summed until the FED for heat reaches unity at which time incapacitation due to pain is predicted. Third degree burns are predicted at an FED for heat of approximately 3.

On the basis of the effects described the FED values for asphyxiant gases and heat have been calculated for each test as shown below.

4.2 FED results for tests conducted

The calculated FED results for the Flame Guard Tests are shown in Figure 21 and Figure 22. The graphs are derived from gas concentrations measured at mid height level (1.6 m from the floor) near the door. As previously stated a significantly reduced flow of gas through the pump drawing room gases at mid level was observed for Test 2. Peak concentrations (in actuality) are likely to have occurred in the room at a time consistent with the peaks noted at low and high level. However, it is considered that the fractional effective dose calculated after 20 minutes (0.69) is consistent actual toxicity conditions in the room.

The key reference point is the time at which an FED curve exceeds 1.0 on the FED scale – at which time incapacitation is predicted for a cell inmate (loss of consciousness for asphyxiant gases or severe pain to exposed skin for heat exposure). A curve remaining below an FED level of 0.33 is predicted to have minimal effects on even sensitive subjects.

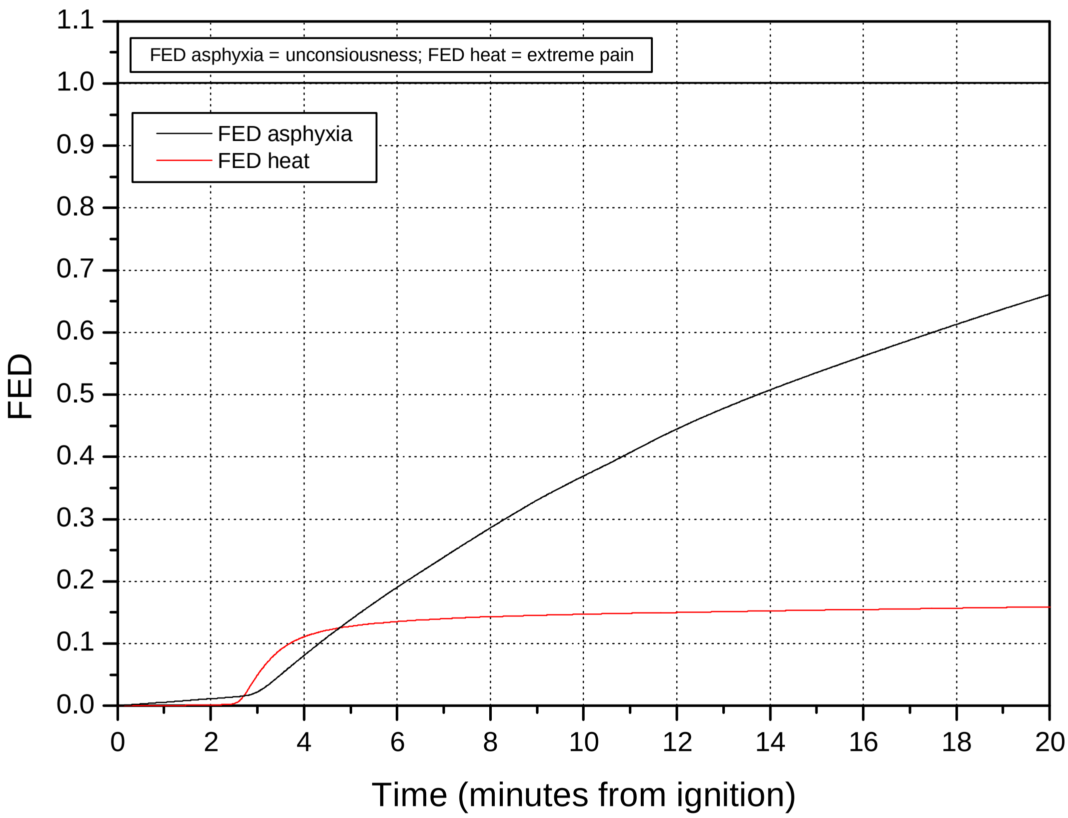

Figure 21 – FED at mid height for Test 1

The Flame Guard aerosol suppression system maintained tenable conditions (both for heat and asphyxiant gases) for a period of 20 minutes for Test 1. However, conditions were approaching an incapacitating dose for asphyxiant gases.

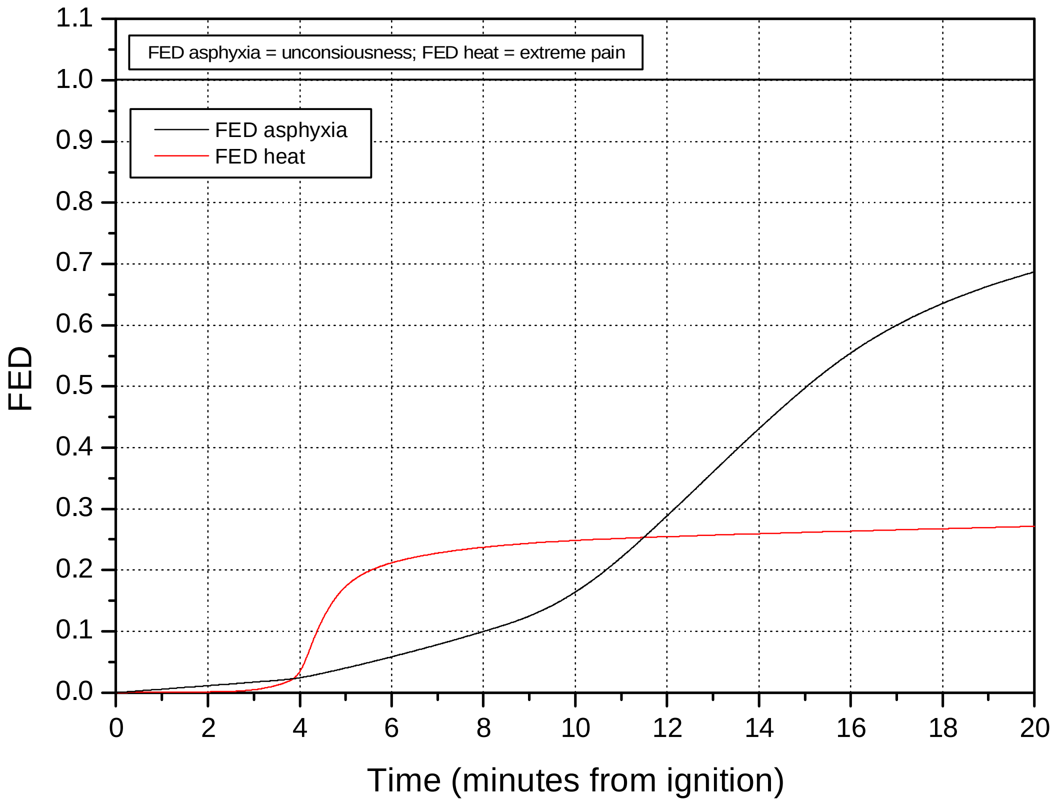

Figure 22 – FED at mid height for Test 2

The Flame Guard aerosol suppression system maintained tenable conditions (both for heat and asphyxiant gases) for a period of 20 minutes for Test 2. However, conditions were approaching an incapacitating dose for asphyxiant gases.

5 Conclusions

Flame Guard b.v. wished to investigate the effectiveness of their aerosol suppression technology for the fire safety protection of prison cells. Flame Guard supplied units of their Dry Sprinkler Powder Aerosol, type 5 (DSPA 5) to BRE for tests. The agent was contained as a solid in a metal unit and upon activation, self-propelled out of the unit as an aerosol. Combustion of the solid agent that is located in the generator body causes the formation of fire suppressing aerosols.

BRE have previously conducted a large programme of experimental work primarily investigating the effectiveness of water mist suppression systems for the fire safety protection of prison cells. BRE therefore had a test rig available, which was highly instrumented to enable measurements of temperatures and gas conditions in a fire. During the course of the previous work programme, BRE developed a ‘fire scenario’ suitable for water mist evaluation. The same fire scenario (but with differing ‘pre-burn’ times) and associated prison issue items (that is, bedside locker, mattresses, duvets etc) were used for tests with Flame Guard’s aerosol suppression technology.

The following tests were conducted:

- Test 1 – BRE developed ‘standard’ fire scenario with the suppression unit applied two minutes after ignition.
- Test 2 – BRE developed ‘standard’ fire scenario with the suppression unit applied 2 minutes after detection of the test fire (a domestic ionisation detector, centrally located on the ceiling of the test room, was used).

The quantity of agent in each generator unit is stated as 3.3 kg in Flame Guard literature. This equates to a concentration after discharge in the 36 m^3 test volume of 91.7 g/m^3. The discharge time of the aerosol unit is stated by Flame Guard as between 20 and 28 seconds.

The peak concentration of carbon monoxide measured was in excess of 3000 ppm for both tests. The levels of both carbon dioxide and carbon monoxide prior to system operation were low. Hence the combustion process of the aerosol forming agent has significantly contributed to the toxicity conditions within the cell. However, this must be balanced against the effective fire suppression demonstrated by the aerosol system.

It was generally observed for both the tests that when the cell door was opened there was limited visibility in the cell. This would affect the ability of staff to carry out occupant rescue.

No measurements of room pressure were conducted, however, an (ostensibly mild) initial overpressure could be observed upon activation of the aerosol generator unit as smoke and aerosol was emitted from the enclosure through the vents, door and ceiling of the test rig.

The aerosol generator suppression technology requires no water. It was observed subsequent to the tests that the room and room contents remained ‘dry’. However, a thin ‘greasy’ residue was observed in the test room after each test. Suppression systems not requiring any water are considered a significant advantage for the prison environment as there is no possibility of consequential water damage.

Fractional Effective Dose calculations have shown that the Flame Guard aerosol suppression system maintained tenable conditions, both for heat and asphyxiant gases, for a period of 20 minutes for both tests although conditions were approaching an incapacitating dose for asphyxiant gases.

When the generator unit was applied the temperatures in the room initially increased after operation (up to around 100 ^{o}C) but within approximately one minute declined rapidly. Temperatures did not increase when the door was opened 5 minutes after the unit had been applied and subsequently remained close to ambient levels. Both test fires were effectively suppressed (a small amount of smouldering was noted after each test by staff operators indicating that the fires were not completely extinguished). There was only a very limited amount of fire damage to the locker unit. However, a small amount of smouldering was noted by test operators after Test 2 which subsequently developed into flaming combustion and the integrity of the hardboard back of the locker unit was breached in the upper right hand side compartment (containing the newspaper, magazine, keyboard and toilet rolls). This demonstrated the potential for re-ignition.

Overall, the Flame Guard aerosol system demonstrated effective fire suppression and maintained tenable conditions for 20 minutes, for both of the tested fire scenarios.

6 References

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7. ‘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.’ BS 7899-2:1999, British Standards Institution.

8. ‘Life-threatening components of fire – Guidelines for the estimation of time available for escape using fire data.’ ISO 13571:2007, International Standards Organisation.

Appendix A – DPSA 5, Flame Guard product literature

DSPA.nl
Hulzenseweg 10-20 | 6534 AN Nijmegen | The Netherlands
P.O. Box 6572 | 6503 GB Nijmegen | The Netherlands
T +31 (0)24 35 22 573 | F +31 (0)24 37 87 583
info@dspa.nl | www.dspa.nl

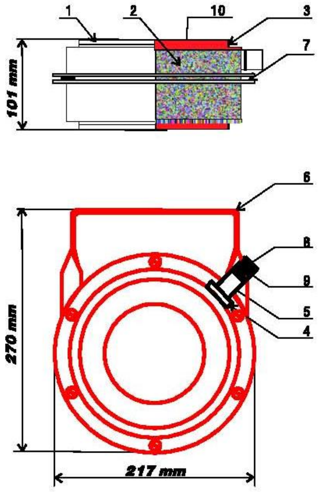
Fortis Bank 24.47.30.857
BTW nr. NL 007677443B01 Kvk 39060741

DSPA-5

The Dry Sprinkler Powder Aerosol 5 generator is intended for operational application during localization and extinction of fires of class A and B, and electrical fires, amongst others in industrial buildings, railroad, and vehicle transport.

PROPERTIES AND FUNCTIONING

The DSPA-5 generators (see figure below) consist of a body (1) where aerosol-forming agents are situated (2). The agents are separated from the inner surface of the body by a protective layer (3). The agents are separated from each other by an insulating element (10). The side surface of the body has a threaded bushing (4) for mounting of the starting assembly (5). There is a handle (6) on the body, which can be used for transportation and throwing of the generator into the area , where fire is located. Discharge of fire-extinguishing aerosol occurs via a slot nozzle (7), situated on the side surface of the body. The starting assembly consists of a metal housing, an activating device with a cord (8), a decelerator and a main compound. The upper part of the starting assembly is protected by a removable polyethylene cover (9), in order to prevent an accidental start of the generator.



1 body
2 aerosol forming agent
3 protective layer
4 threaded bushing
5 starting assembly
6 handle
7 slot nozzle
8 cord
9 protective cover
10 insulation element

The generator is started by abruptly pulling the cord (away from the generator in a straight line). The decelerator that has now been ignited ensures a delay of 7-10 sec before the main compound is actuated. This delay is required to throw the generator into the room where the fire is located. After the main compound of the starting assembly has been actuated, ignition of the aerosol-forming agent occurs. When the starting assembly is actuated, a specific sound is heard. A small jet of smoke and a flame tip will come from a drain port on the metal housing of the assembly.

Functioning of the generator is based on the inhibition of oxidation-reduction reactions of highly refined particles (aerosols) alkali and alkaline metals. These particles precipitate with the combustion of the aerosol-

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Hulzenseweg 10-20 | 6534 AN Nijmegen | The Netherlands
P.O. Box 6572 | 6503 GB Nijmegen | The Netherlands
T +31 (0)24 35 22 573 | F +31 (0)24 37 87 583
info@dspa.nl | www.dspa.nl

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forming agent and remain in suspension for a long time. The process of high-temperature combustion of the solid agent that is located in the generator body causes the formation of fire extinguishing aerosols.

PREPARATION AND ACTIVATION

To prepare the generator for operation it is necessary to remove the sealed packages of both generator and starting assembly. Then carefully twist the latter in the threaded bushing (4) without removing the protective cover (9) and without disturbing the fixation of the cord (8).

To activate the generator follow this sequence:
- Take the generator handle in one hand;
- Hold the generator vertically down;
- Remove the protective cover from the starting assembly (with the other hand);
- Release the cord loop and pull it curtly;
- Throw the generator into the area where the fire is located.

DSPAs that are not equipped with starting assemblies do not require specific safety measures. The temperature of self-ignition of aerosol-forming mixture is 270°C.

Please follow the instructions and advice under Paragraph 'Points to take into account' carefully.

APPLICATION

DSPA-5 generators are recommended for operational application by fire departments (defence), (railroad) transport and other persons, instructed about application and safety measures. The generators are used as a prime fire-fighting device to localize and extinguish fires in closed spaces, particularly in hardly accessible spaces.

It should be taken into consideration, that one generator can be applied to suppress a fire in a hermetically closed area **of up to 60 m^3, and up to 40m^3 provided there are** no significant openings **in the ceiling, floor or walls.**

To obtain the right concentration of fire-extinguishing aerosols for larger spaces, the number of DSPA-5 generators to be used can be calculated according to the following formula:
n = (V / 40) + 1, where n is the number of generators, and V is content of the space in m^3.
The results are always rounded off upwards.

In case there are openings in the protected space the number of generators should be increased and measures should be taken to reduce the air access by closing windows, doors, hatches, etc. When openings in the ceiling and the walls make more than 5% of the whole surface and there is natural or mechanical ventilation, the efficiency of the DSPA-5 reduces significantly.

The number of DSPA-5 generators needed to suppress a fire in a certain area has to be calculated in accordance with the above. For detailed information please contact our technical staff.

Areas where DSPAs cannot be applied:

- in escape routes;
- within automatic installations of aerosol fire-extinguishing in buildings that can not be abandoned before the start of these generators;
- to extinguish fires in the open air;
- under deck plating;
- for extinction of alkali and alkaline metals, nor for materials that can combust without oxygen.

POINTS TO TAKE INTO ACCOUNT

Please follow the advice and instructions below:

Before use:

- Only authorized and instructed staff is allowed to operate the generator. All operators must have clear knowledge of present information sheet.
- People younger than the age of 18 are not allowed to operate the generator.
- Before throwing the DSPA ventilation must be switched off.

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Hulzenseweg 10-20 | 6534 AN Nijmegen | The Netherlands
P.O. Box 6572 | 6503 GB Nijmegen | The Netherlands
T +31 (0)24 35 22 573 | F +31 (0)24 37 87 583
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- Do not remove sealed packages of the DSPA and the starting assembly until the decision on application of the generator has been made.
- The installation of the starting assembly in the body of the DSPA should be done carefully in order to prevent spontaneous activation of the generators.

During use:
- In case of fire and use of the generator, those present in the room should leave it, close the door tightly and not try to suppress the fire. Of course the fire-department must be warned.
- When the cord of the starting assembly has been pulled, the generator should be thrown immediately, even in case it is not sure if the starting assembly has been actuated.
- Do not use generators in areas where people are staying or in escape routes.
- Do not try to prevent actuation of the DSPA or discharge of aerosol after the start.
- In case the generator starts accidentally, it should be thrown into a safe place preferably in an area where no people are located. In case this is not possible, throw at a safe distance from public.
- In case quick abandoning of the space after actuation of the system is not possible, all people present should cover respiratory organs with a handkerchief and leave.
- It is strongly advised to always use a combination of two or more DSPAs in one room.
- The total number of generators needed for a certain area have to be thrown into this area without interruption.
- To ensure the safety of the person that activates the DSPA, the actuation of the main compound in the starting assembly has a delay of 6-10 seconds.
- The DSPA should be thrown flat on the floor to ensure smooth discharge of the aerosol.
- When activating the generator and or during actuation, the slot nozzle which releases the aerosols, must not point towards the operator or the people standing around.
- When the generator is activated a high-temperature zone up to 150°C is formed within the radius of 1,5 metre around the DSPA (See also paragraph 'Technical Details' below); please stand away at a safe distance.
- If required, other means of fire extinguishing can be used next to the DSPAs.
- Please be aware of the fact that when the aerosols are diffused, the visibility in the room will be significantly reduced.

After use:
- The gas-and aerosol mixture is non-toxic but irritates the mucous membranes of respiratory organs. Therefore it is advised to only enter the room after the DSPAs have been discharged completely.
- Before entering the area where DSPAS have been applied, it must be thoroughly checked that the space has been ventilated properly and respiratory organs must be protected by a particle respirator (dust mask)..
- Sediment of the aerosol can be easily removed from all surfaces with a damp cloth, by dusting or vacuum cleaning.

General: It is prohibited:
- to carry out welding and other fire activities within 2 m from the generator
- to use the generators with mechanical defects
- to dismantle the generators
- to subject the generator to impact

TECHNICAL DATA

Mass of equipped DSPA	No more than 5,4 kg
Protection capacity (hermetically closed area)	60m³
Recommended area	40m³
Mass of aerosol-forming agent	3,3 kg
Time of actuation delay	6 - 10 sec.
Time of fire extinguishing aerosol discharge	20 - 28 sec.
Time of suspended aerosol staying in an air-tight space	No less than 50 minutes
Activation system	Manual
Force of starting assembly activation	No more than 10 N

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P.O. Box 6572 | 6503 GB Nijmegen | The Netherlands
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Temperature zones during actuation of the DSPA:	
Up to 0,25m	>400°C
0,25m < distance < 0,6m	<400°C
0,6m < distance < 0,6m	<200°C
distance >1,6m	<75°C

Overall dimensions:	
Diameter	217 mm
Height	101 mm
Maximum overall dimension	280 mm

Operational conditions:	
Temperature	-70°C to +70°C
Relative humidity	Up to 98%at +25°C
Storage life after delivery	Up to 5 years

Storage

The DSPA-5 and starting assembly are delivered in separate sealed packages together with the information sheets, packed in cardboard boxes. The generators should be stored in original packaging in closed spaces at a temperature from +5°C to 40°C and a relative humidity up to 80% at 20°C. Starting assemblies should be stored separately in their original packaging, under the same circumstances. Storage of DSPAs and starting assemblies near harmful substances must be avoided. The DSPA-5 can be stacked no more than five high in original packaging. Starting assemblies should be protected from mechanical damage.

Transportation

The generators can be transported by all modes of transport in original packaging.

These guidelines are merely meant as an advice. All values are indications and are the result of technical research and experience. No liability can be derived from it. With current issue of this information leaflet all former issues are expired.

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