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Smoke Detection in High Spaces using ASD

Section 1. Introduction

Reliable detection of smoke in high ceiling spaces has been considered a challenge for many years and most Design and Installation Codes (including BS5839-1) define limits on the ceiling height that may be protected by a particular technology. Most practitioners default to using detection technologies – such as Optical Beam Smoke Detectors (OBSD) or Aspirating Smoke Detectors (ASD) – which derive their smoke measurement over an area – not at a single location. Such “integrating” technologies are inherently more sensitive to smoke that is diluted or distributed as it rises to higher levels than point type detectors.

BRE Global has recently completed a research project jointly funded by the BRE Trust and the FIA to review the recommendations provided for using OBSD and ASD in high ceiling spaces. The results of this research are published in a BRE Information Paper but are summarized in this Fact File along with news of how the results have influenced changes to the FIA Code of Practice for ASD Systems.

Section 2. Background

To date, most European codes limit the ceiling height for both OBSD and ASD to less than 20m unless appropriate in-situ smoke performance tests are undertaken. BS5839-1:2002 is a notable exception in that it allows for OBSD up to 25m (or 40m for property protection if attendance within 5 minutes is provided by the Fire Rescue Services). However, the same standard only allows for Class C (normal sensitivity) ASD holes to a height of 10.5m. While this can be extended up to 21m (for property protection if attendance within 5 minutes is provided and Class A, very high sensitivity, ASD holes are used), the contrast to 40m allowed for the OBSD makes the recommendations for ASD appear *very* conservative.

The FIA Code of Practice (CoP) for ASD systems was revised in 2006 to accommodate the new product standard for ASDs, EN54-20:2006, which introduced three classes of sensitivity; Class A, B and C, being *very high*, *enhanced* and *normal* sensitivity respectively. This being a measure of the sensitivity of individual holes not of the whole system. At the same time the performance test defined in the CoP for testing ASD systems in high spaces (consisting of a smoke pellet burned on a 5.8kW gas heater) was simplified. However, despite positive experiences with this (and other field tests); proposals to increase the ceiling height limits given in the 1996 issue of the CoP were postponed pending more thorough research.

In 2008 the BRE Trust, in association with and sponsored by the FIA, commissioned a three-part research project; to review existing recommendations for the protection of spaces with high ceilings, investigate the value of computational methods for predicting performance in such spaces and, most importantly, to perform some full scale fire tests.

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Section 3. Summary of BRE Trust findings

Phase One – Review of available data

The objective of this first phase was to gather all available supporting data including; the recommendations given in EU installation codes; results of any relevant research work; methods used in computational predictions and the experiences and results from using ASD in high ceiling applications. Most notably during this phase, *no* evidence was forthcoming to support the use of OBSD at 40m other than verbal reports of testing at the Cardington facility nearly three decades ago. One key outcome of the testing in phase three is confirmation that OBSD and ASD systems are effective at 40m.

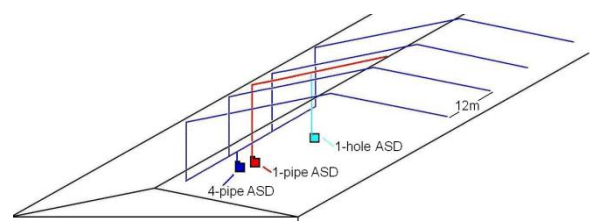
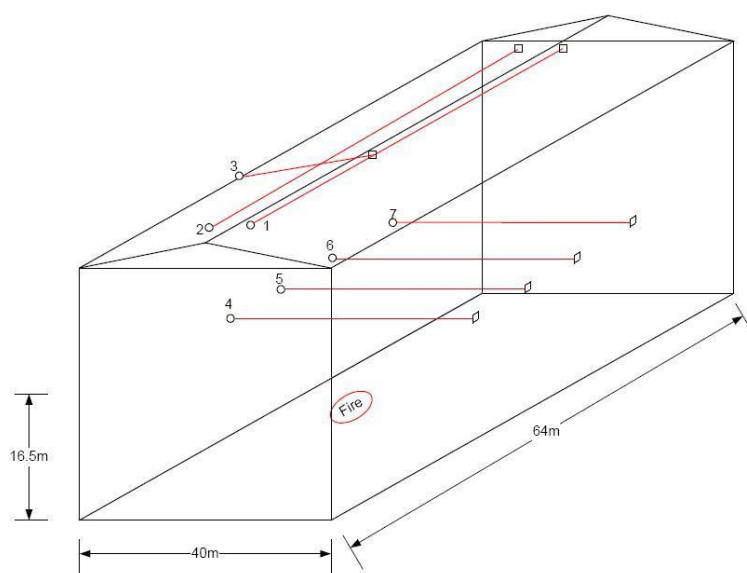
Phase Two– Using computational methods to predict performance

The objective of this phase was to generate and review prediction results using computational methods. Using a simplified model of a 40m high space, FDS¹ and Jasmine² predictions were generated for 14 fire scenarios ranging from 30kW to 250kW with various thermal gradients (up to 0.3°C/m) and cross flows (up to 0.3m/s). The clear conclusion from these computations is that the ambient conditions (including thermal gradients and cross flows) have a significant effect on the concentration of smoke rising to the ceiling and that the consistency (and by inference the accuracy) of results depends on the computational method used. However, the results presented using FDS show that a Class B ASD system at ceiling level would signal alarm in 9/14 of the scenarios modeled and a standard sensitivity OBSD (set at 35% obscuration) would signal alarm in 3/14 of the scenarios. It must be stressed that these results are only indicative but they predict that when sufficient smoke is present at the ceiling to trigger OBSD it is almost certainly sufficient to trigger a Class B ASD system.

Phase Three – Full scale fire tests

The objective of phase 3 was to perform a number of full scale fire tests to observe the reaction of an EN54-12 approved OBSD and EN54-20 approved ASD on a ceiling >40m above the floor. To maximize the value of the tests three ASD systems were installed to quantify the potential benefits of the integrating behaviour (or *cumulative effect*) and each ASD system was configured to provide Class A, B and C alarm signals. Three OBSD systems were installed at the ceiling and an additional layer of OBSD detection was provided at a height of 16.5m to demonstrate the benefit of intermediate detection (spaced in accordance with BS5839-1:2008 clause 22.5d). All OBSD systems were configured with an alarm threshold at 35% obscuration.

The arrangements of the OBSD and ASD detectors are illustrated below.



It can be observed from the figures that OBSD 1&2 were covering the same area as the 4-pipe ASD while OBSD 3 covered the same single line as the 1-pipe ASD. OBSD 4, 5, 6 & 7 provided intermediate detection while the 1-hole ASD provided a useful reference measurement of the smoke concentration at a single location directly above the fire.

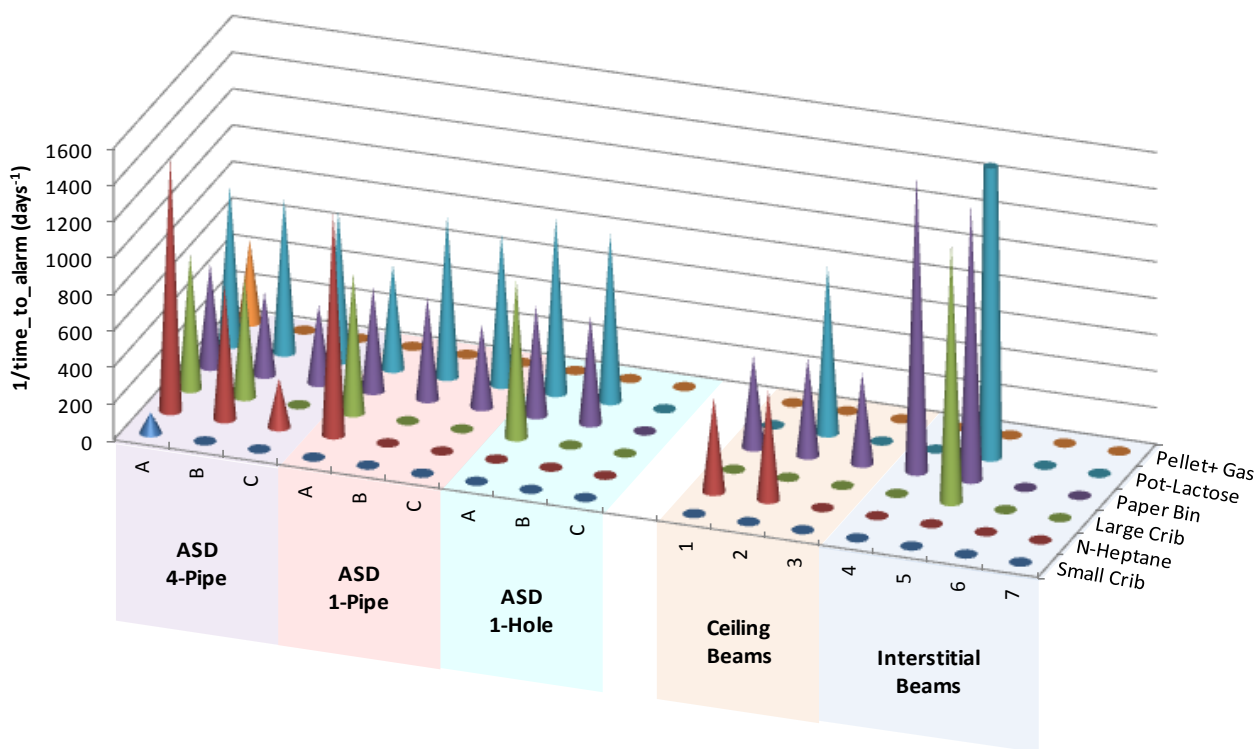
¹ NIST - FDS 5 – see <http://fire.nist.gov/fds/>

² BRE - Jasmine – see www.bre.co.uk/page.jsp?id=1856

The six test fires conducted spanned both flaming and smouldering fires and produced both black and white smoke with low and high energy. The following table provides a summary

Test	Description	Details	Heat	Duration	Smoke
1	Small wooden crib	49 beechwood sticks 40x40x500mm	~220kW	~16 mins	Very limited grey
2	N-Heptane	12 litres in 600x400mm tray	~400kW	~10 mins	Limited black
3	Large wooden crib	133 beechwood sticks 40x40x500mm	~560kW	~17 mins	Limited grey
4	Paper bin	53 sheets newspapers 570x370mm loosely packed into a ventilated bin	~30kW	~4 mins	Grey
5	Potassium chlorate & lactose	120g potassium chlorate & 180g lactose mixed & ignited in a small steel bucket	~45kW	~½ min	White
6	Smoke pellet & gas	13g smoke pellets burned on top of a gas burner – per FIA CoP Annex B	~5.8kW	~10 mins	White

The results were unsurprising and are most conveniently summarised by reproducing a chart from the BRE Information Paper (with some additional annotations for clarity). The chart (below) presents the response time of each detector to the six fires. The data is presented as “1/time_to_alarm (days⁻¹)” – thus those that responded quickly have a high value (e.g. 1440 = 1 minutes, 360 = 4 minutes) while those that did not respond are shown as zero.



The main observations from these results are:

- The 4-pipe Class A ASD responded to all the test fires including the small crib (very clean burn fire) and the Pellet and Gas test (very low thermal energy fire).
- The 4-pipe Class B ASD responded to 4/6 of the fires – only failing to detect two most challenging.
- The intermediate OBSD 5 responded quickest of all the detectors, because it was closest to and directly above the seat of the fire. However it only responded to three out of the six fires.
- The 1-pipe ASD responded to more test fires than the 1-hole ASD, and the 4-pipe ASD responded to more test fires than the 1-pipe ASD – thus demonstrating the increased reliability of detection with more sampling holes compared with detection at a single location (i.e. the *cumulative effect*).

In addition to these observations by BRE it is clear that:

- The 4-pipe Class C ASD shows similar performance to ceiling mounted OBSD 2 – thus indicating that a 35% OBSD installation and a Class C ASD system can be considered to have the same response to fire.
- The 1-hole Class C ASD system did not respond to any of the test fires – thus indicating that a standard EN54-7 point detector would be unlikely to respond.

The BRE report concludes:

The results confirm that the smoke from relatively small fires can extend 43m vertically into a high ceiling space with temperature differentials of 8°C and 12°C between floor and ceiling.

Furthermore the results indicate that both aspirator and beam systems are capable of detecting small amounts of smoke in high ceiling spaces although for both technologies suitable sensitivity levels are required to produce an acceptable response. The results also show the benefits of using integrative type smoke detection for detecting smoke in high ceiling spaces.

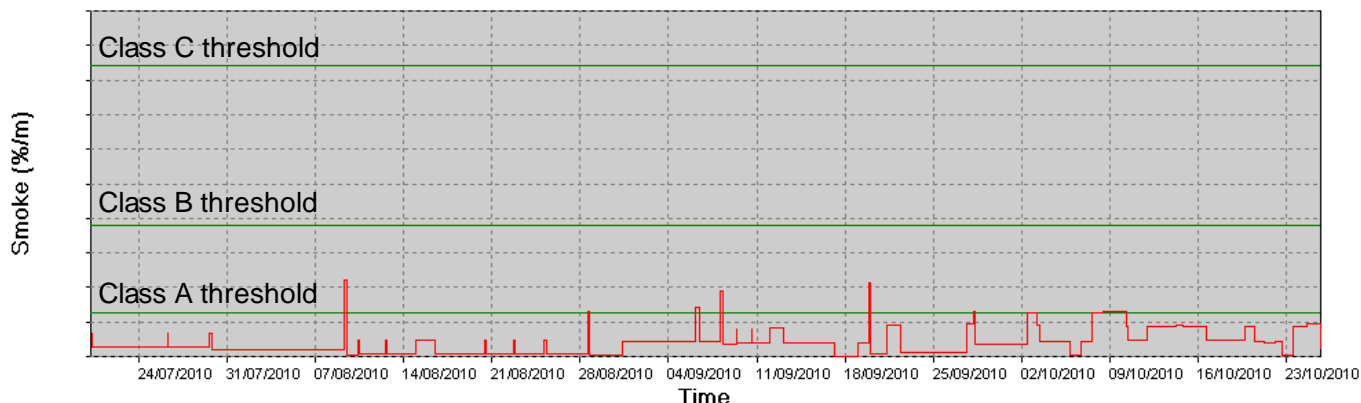
In addition to this general conclusion, the BRE report also recommends that the minimum sensitivity of OBSD at 40m should be 35% obscuration and that where practical 25% obscuration would be preferred. It specifically comments that the ceiling mounted OBSD, if set at 50% obscuration would not have responded to any of the fire tests.

In relation to ASD, the BRE report concludes that:

Generally a Class C aspirator with many sampling holes arranged over an area will reliably detect relatively small smoky fires but increased sensitivity to Class B would make them more dependable.

It also comments that high ambient levels may preclude practical use of Class A ASD systems in some applications and recommends that an assessment of the long term background levels is undertaken.

In fact, the 4-pipe ASD system was left operational at the test site and interrogation of the event logs since the BRE report was published has confirmed that, due to the industrial character of the environment (see photo)³, ambient levels were such that there were eight incidents of a Class A alarm on the 4-pipe system (see trend below). However, there were no Class B, alarms so a practical system could be realised with Class B thresholds present during the working hours and Class A during unoccupied periods. Alternatively, during periods of known activity the Class A threshold could be desensitised to Class B, either automatically, at certain times or manually by a simple switch – such is the versatility of many ASD systems.



Section 4. Discussion

This research, undertaken by BRE provides an excellent pool of data which, as concluded by BRE, “indicates that both aspirator and beam systems are capable of detecting small amounts of smoke in high ceiling spaces although for both technologies suitable sensitivity levels are required to produce an acceptable response.”

While it is then recommended that OBSD should be at least 35% sensitivity (and preferable 25%) and that ASD should be Class C with many holes (or preferably Class B) there is no direct comparison of the two technologies because this was not the purpose of the research. However, it is clear that that the predictions obtained in phase 2 – that a Class B ASD system is more effective than an OBSD system with an alarm threshold sensitivity of 35% obscuration – are supported by the test results obtained during phase 3 of the project. In fact, as noted in the

³ The site photo above was taken several months before the tests and illustrates the use of the area for welding and steel fabrication. Observe the haze around the lights >35m above the ground.

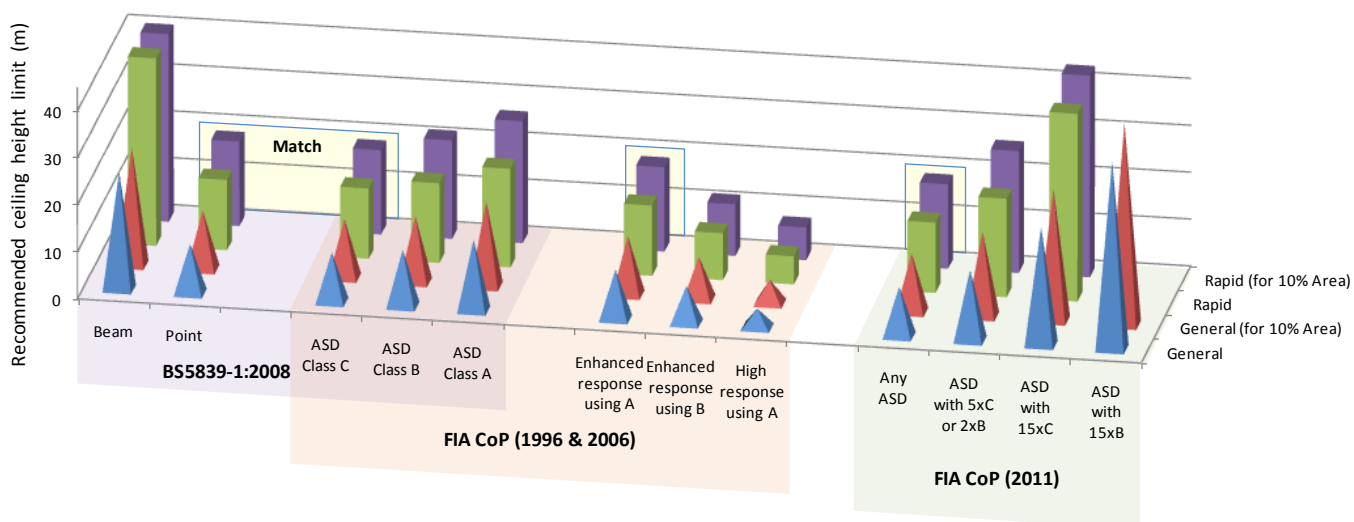
bullets above, it can be observed from the results that the 4-pipe Class C ASD shows similar performance to ceiling mounted OBSD set at 35%.

This research also provides evidence for the advantages of an integrating technology (known as the cumulative effect in ASD). In fact, the results indicate that there are advantages to integrating over an area (as is achieved with a multi-pipe ASD system) as opposed to integrating along a line (as with a single pipe ASD or beam detector).

To date, ceiling height limits have not considered this integrating advantage in that there are no requirements for the minimum lengths of a beam nor the minimum number of sampling holes for an ASD. However, as a result of the BRE research, the FIA Working Group responsible for the FIA CoP on ASD systems have revised the recommended limits for ASD taking into consideration the need for several holes. Furthermore it makes a recommendation that, where possible, a multi-pipe ASD system should be used in preference to a single run of holes to achieve integration over an area.

In previous editions of the FIA CoP (1996 & 2006), the ceiling height limits (table 3 p26) were obviously developed from the limits for point smoke detectors. In fact the requirements for a Class C ASD exactly match those for a standard point smoke detector in BS5839-1 (tables 3 & 4, p60). This is illustrated in the graph below.

If using “enhanced” (Class A) or “very high sensitivity” (Class B) ASD holes, then the maximum ceiling heights recommended in these previous editions increased marginally. These same limits are also reproduced in BS5839-1 and are summarised in the first two groups in the graph below.



Note: The third group in the table illustrates additional recommendations in the CoP (1996&2006) for systems where a “better than normal” response is desired. This level of complexity has been omitted in the latest edition of the CoP and is not discussed in detail in this Fact File

Section 5. Summary of changes to the FIA Code of Practice for ASD systems

The new BRE research summarized in this Fact File confirms that the ceiling height limits for ASD should be based on those for beam detectors (not point detectors), which have been used at heights of 25m (or 40m for property protection if attendance within 5 minutes is provided by the Fire Rescue Services) for many years.

After careful consideration of the facts, the height limits are to be revised as indicated in the graph above. Of particular note is that for increased ceiling height; it is required to have several sampling holes to ensure that the cumulative effect is exploited. For example, an EN54-20 ASD system with at least 15 Class C holes is now recommended for ceiling heights above 15m and up to 25m in general applications.

Additional to these core limits, the CoP provides recommendations on how enhanced performance can be achieved using a more sensitive detector and/or providing greater density of sampling holes. It also provides cautions with regard to stratification and cross flows and, to address such situations, recommends performance testing. In particular, a new standard performance test based on the paper bin test used during the BRE research is now included in the annex and other performance tests have been revised in the light of the research.

The new FIA CoP is due to be published in summer 2011 and will be available from the FIA website. To register for notification of publication please email: gsimons@fia.uk.com with subject “ASD CoP please”

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