ODPM Building Regulations Division
Project Report :

The production of smoke and burning droplets from
products used to form wall and ceiling linings

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Executive Summary

Project

The overall aim of this project was to evaluate, for the purpose of the Building Regulations, the need to include in Approved Document B (AD B), provisions for greater control of smoke production and burning droplets from construction products that are used to form walls and ceilings.

The project originated from issues that were raised at the time of AD B of the Building Regulations 2000 to incorporate the new European fire test methods and classifications. Amongst the new European fire test methods for assessing the reaction to fire performance of products was the Single Burning Item (SBI) test method (BS EN 13823: 2002).

This completely new test method includes measurements of the rate of heat release, rate of smoke production and observations of the production of falling flaming debris and/ or droplets. From the measurements taken during the test, it is then possible to derive a classification based upon a fire growth rate index (FIGRA) and "additional classifications" for smoke production (s1, s2 or s3) and falling flaming droplets and/or particles (d0, d1 or d2), with s1 being the highest requirement and lowest level of smoke production and d0 being the highest requirement and corresponding to the occurrence of no falling flaming debris and/or droplets.

The current consolidated version of AD B provides for the use of the European reaction to fire classes for wall and ceiling linings (Table 10). However, it sets no limits for smoke production and falling flaming droplets and /or particles i.e. the additional classification requirements are: s3, d2 in all cases. The fundamental question that this project has sought to address is whether introducing a requirement for stricter additional classes for smoke and falling flaming droplets and/or particles into AD B on life safety grounds can be justified from both technical and cost beneficial perspectives.

Results

A review of regulations in other Member States relating to the production of smoke and falling flaming droplets and/or particles has revealed that there is no consistent pattern between Member States in relation to the regulatory requirements and the progression from National to European testing and classification. Very few Member States have introduced new requirements where none previously existed. The differences in approach to the control of the production of smoke and burning droplets are mainly due to different regulatory frameworks and philosophies between Member States.

The results obtained from the SBI test programme produced good repeatability and reproducibility (limited study), therefore confidence in data from this work is high.

The results from this work and from the data obtained from the literature review suggest that falling flaming droplets and/or particles either occur or not, so the existing refinement

of classes that exists within the European classification system is probably unnecessary. The production of falling flaming droplets and/or particles tends to be a material based property. This is currently recognised within the context of thermoplastic materials in AD B through the limitations in terms of area of permitted thermoplastic product in ceilings. It would seem most appropriate to continue to deal with this issue in a similar way alongside the introduction of the new European fire tests and appropriate European classifications. The detail of such a proposal is outside the scope of this project. However, the results from this work have suggested that the introduction of more stringent general requirements in Table 10 of AD B for the control of materials that produce falling flaming droplets and/or particles is probably unnecessary at this time.

Comparison of the results obtained from the toxicity assessments based upon the data of the specific extinction area or yield of smoke versus the equivalence ratio in the flaming combustion mode indicate that products which produce the highest smoke yields in well ventilated conditions do the same in less well ventilated. However, the yield of smoke or specific extinction area is related to the mass of product consumed and it is this that makes the issue of smoke production in larger scale experiments difficult to interpret or predict.

The smoke classes associated with the SBI test are based upon the rate at which smoke is produced from the product and has a limitation on the total amount of smoke produced. However, the total amount of smoke produced is rarely the criterion that determines the smoke class. Typically, the rate of smoke production through the Smoke Growth Rate Index (SMOGRA) is the determining factor.

In seeking to establish the meaning of additional smoke and droplet classes from the SBI test, it was necessary to try to relate the data to some appropriate real scale hazard scenario that is relevant to AD B, is repeatable and reproducible as a test method and can be used to study product performance under different ventilation conditions. The ISO 9705 test was selected as appropriate in satisfying these criteria. Whilst the direct correlation between the SMOGRA values obtained from the SBI test and the ISO 9705 room corner test is poor, it is possible to further consider the effect of ventilation on the production of smoke by comparison of the data from the ISO 9705 room corner tests at 100% and 12.5% ventilation. These generally showed that reducing the ventilation tended to result in a reduction in the SMOGRA index for those products for which a significant change was observed. However, the data clearly showed that the reduction in ventilation conditions produced an increase in the total smoke produced and for some products, resulted in different burning behaviour. The potential conversion of product into smoke during a fire in a real scenario is something that would need careful consideration if smoke classes were to be introduced into Approved Document B as the SBI test smoke classification does not appear to adequately characterise this process which is directly related to the mass of the product consumed and the ventilation available to the fire. This is further supported by the analysis of results from previous work [4] which tend to show that the performance of a product in terms of smoke production rate will vary depending upon its application within a building.

It should be noted that the results of this work, as contained within this report, should not be used as a means of challenging current regulatory provisions in buildings in relation to the construction products that are used to form walls and ceilings. This is specifically relevant to licensed premises including night clubs.

Cost Benefit Analysis

A survey of manufacturers of construction products used to form wall and ceiling linings has been undertaken to establish whether a requirement in AD B to control smoke and burning droplets from these materials would reduce the risk of death and injury in fires and what the cost implications of this would be. This cost benefit assessment was not a Regulatory Impact Assessment as it did not include additional considerations such as a small firms' impact test and a competition assessment. Further, there was no review by CORIU (Cabinet Office Regulatory Impact Unit) or the DTI's SBS (Small Business Service). The value of the assessment carried out as part of this project is limited by the number and quality of responses received to the questionnaire.

Two possible alternatives of a requirement were proposed compared to a "do nothing" option and these were:

All ceiling and wall lining products achieving Euroclasses A2, B, C or D will need to achieve an additional classification of s1, d0, or,

All ceiling and wall lining products achieving Euroclasses A2, B, C or D will need to achieve an additional classification of s2, d1.

In the survey, the respondents were asked to quantify the impact of these two alternatives (compared to the 'do nothing' option) as far as possible in terms of loss (or gain) of sales as well as highlighting any other impacts.

The outcome was that both alternatives of the proposed requirement would, if adopted, have a significant impact on product sales. The most demanding option could potentially affect sales with an annual value of upwards of £249M, and for the least onerous, the value of sales affected could be more than £160M. Sales would not change to this extent overnight as manufacturers would re-engineer their products to meet the new requirements and sales adjust accordingly, but the costs to re-engineer are considerable, ranging from tens of thousands to several million pounds. Re-engineering would also involve extensive testing and certification of products which could also incur costs of many millions of pounds and would take between 2 and 5 years to complete.

The UK fire statistics for 2002 suggest that wall and ceiling linings are likely to be responsible for only a very small number of deaths and injuries (if any), but that limitations with the data make it difficult to be precise. A number of the respondees to the questionnaire commonly shared the view that fires typically start in the contents in a building, which are not currently regulated within AD B, and that building occupants are exposed to the smoke and gases from these objects from the time of ignition. The benefits in terms of lives saved or reduced injuries by the introduction of a requirement for stricter additional classes for smoke and falling flaming droplets and/or debris are considered to be low. Using accepted valuation techniques for deaths and injuries the annual benefit is estimated to be £174k per year.

Overall, it is suggested that neither of the proposals are workable and could not be justified on cost-benefit grounds in the context of a Regulatory Impact Assessment (RIA). The additional risk posed by the production of smoke and falling flaming droplets and/or particles from wall and ceiling linings alone is impossible to quantify and appears to be small. Certainly, given that a requirement would only apply to new and refurbished buildings the reduction in deaths and injury would be extremely small as most of the existing stock would be unaffected by the proposal. The costs of the requirement would run into many millions of pounds which vastly exceeds any potential benefit.

Summary

In summary, the overall results from this project indicate that, at this time, there would be no significant benefit in the introduction of stricter additional classifications for smoke and falling flaming droplets and/or particles for wall and ceiling linings.

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Introduction

This project was developed in response to a request from ODPM Building Regulations Division to submit a project proposal against their specification for a project titled "The production of smoke and burning droplets from products used to form wall and ceiling linings" ODPM Contract reference CI 71/5/3, BD 2412. This project is commissioned under the ODPM Fire Safety Framework Agreement with the BRE led consortium with Buro Happold and University of Ulster as Partners.

The project originated from issues that were raised at the time of updating Approved Document B (AD B) of the Building Regulations 2000 to incorporate the new European fire test methods and classifications. That is, amongst the new European fire test methods for assessing the reaction to fire performance of products was the Single Burning Item (SBI) test method (BS EN 13823: 2002). This completely new test method includes measurements of the rate of heat release, rate of smoke production and observations of the production of falling flaming debris and/ or droplets. From the measurements taken during the test, it is then possible to derive a classification based upon a fire growth rate index (FIGRA) and additional classifications for smoke production (s1, s2 or s3) and falling flaming debris and/or droplets (d0, d1 or d2), with s1 being the lowest level of smoke production and thus highest requirement and d0 being the highest requirement and corresponding to the occurrence of no falling flaming debris and/or droplets. The classifications are required to clearly declare how the product was tested and how it relates to “end use” application. This requires detailed attention to methods of mounting, fixing and jointing of the product in the test. The current consolidated version of AD B enables the use of the European reaction to fire classes, but places no limits on the additional classes for smoke and falling flaming debris and /or droplets. That is, the additional requirements are – s3, d2 in all cases.

To fully appreciate the context of this issue, consideration should also be given to the existing National system for reaction to fire testing and classification which is based upon the BS 476 series of test methods. Using the guidance provided in AD B, the existing National fire testing and classification system offers an alternative route to the European system for compliance with the requirements of the Building Regulations. There are no requirements within the Building Regulations that require the control of smoke production from wall and ceiling linings because the underlying philosophy is that buildings should be designed to separate people escaping from a building from the products of combustion, such as smoke. As such, there is no generally accepted test method for measuring and providing a smoke classification. The same is also true in relation to falling flaming debris and/or droplets. As a consequence, there is no historical test data within the UK to enable any comparisons of existing product performance with performance in the new European tests. Therefore, the fundamental question that the UK must seek to address is how do the s1, s2 and s3 smoke and d0, d1 and d2 falling flaming debris and/or droplets classes relate to real life safety hazards that are of concern to the Building Regulations.

Description of the project

The overall aim of this project was to evaluate, for the purpose of the Building Regulations, the need to include in AD B, provisions for greater control of smoke production and burning droplets from construction products that are used to form walls and ceilings.

The project was divided into three different phases. The first phase of the work was predominantly desk-based and involved reviews of regulations in different Member States, available data from the SBI test, products in current use, and the results of a Workshop with Key Stakeholders (see Appendix A) to determine the basic strategy and timing for an experimental programme of fire tests. The second phase was to carry out an experimental test programme using the SBI test apparatus (BS EN 13823: 2002)[1], the ISO 9705 room corner test [2] and the bench-scale BRE tube furnace (BS 7990: 2003)[3]. Six products were selected for the experimental programme of work on consultation with ODPM and the Key Stakeholders Group as follows:

- Rock fibre acoustic ceiling tiles
- Plasterboard-faced polyisocyanurate (PIR) foam
- Medium density fibreboard (MDF) to BS 476 part 7 class 1
- Glass reinforced polyester (GRP) rooflight material
- Expanded polystyrene (EPS) ceiling tiles
- Prismatic polystyrene lighting diffuser material

The third and final phase of the work was to carry out a cost benefit assessment of the potential options for implementation within Approved Document B. This phase of work in particular was dependent upon the contributions and input from the Key Stakeholders Group. We would like to record our sincere thanks to all of those who contributed to what was such an essential part of the project and those who actively participated within the Group.

Methodology and Findings

Phase 1

Review of the regulations relating to the production of smoke and burning droplets

A review of the current regulations relating to the control of the production of smoke and burning droplets within different Member States was undertaken. This information is summarised in table 1 below.

Table 1. A summary table showing the original National position compared with the European position in relation to the issues of production of smoke and burning droplets.

Member State	National smoke classes	National regulation of droplets	European smoke classes	European droplet classes
Austria	Yes	Yes	Yes	Yes
Belgium	No information	No information	No information	No information
Denmark	Yes	Yes (large-scale)	Yes	Yes
Finland	Yes	Yes (large-scale)	Yes	Yes
France	No	Yes	Yes	Yes
Germany	Yes	Yes	Yes	Yes
Ireland	No	Indirect	No	No
Italy	No	Yes	Undecided	Undecided
Netherlands	Yes	No	Yes	No
Portugal	No information	No information	No information	No information
Spain	No	Yes	No information	No information
Sweden	Yes	Yes (large-scale)	Yes	Yes
UK	No	Indirect	No	No

It should be noted that at the time of the review, the position of Italy in relation to the implementation of the European classification system for reaction to fire was undecided. With reference to table 1, it can be seen that no Member State has introduced requirements for burning droplets classes during the implementation of the European system where there were no previous National requirements, although France appear to have introduced some additional requirements in relation to smoke. In addition, most of the Member States appear to have introduced the European classes in the absence of comparative data between their National and European systems. It would seem that decisions were largely based upon commercial and political considerations, as well as the issue of safety levels. The differences in approach to the control of the production of smoke and burning droplets are mainly due to the different regulatory frameworks and philosophies between Member States.

Review of available data relating to product performance in the SBI test

A review was carried out of all sources of available information from the public domain and as provided by the members of the Key Stakeholders Group for the project relating to the performance of wall and ceiling linings in the Single Burning Item (SBI) test (BS EN 13823: 2002) [1] and the room corner test (ISO 9705: 1993)[2].

Table 2: Summary of smoke and flaming droplet data from all identified sources

		Droplet classification		
		d0	d1	d2
Smoke classification	s1	Wallpaper, starch adhesive High density unfaced glass wool slab Acoustic mineral fibre tiles Ordinary gypsum board Calcium silicate board Cement particle board Steel-faced mineral wool Fire retarded particleboard Fire retarded high pressure decorative laminate Steel-faced phenolic Clear polycarbonate Plasterboard-faced extruded polystyrene Wood and wood based panels, ρ>400kg/m^3	No data	Low density fibreboard
	s2	Fire retarded high pressure decorative laminate faced composite panel Fire retarded MDF Class 0 Fire retarded MDF Class 1 Unfaced phenolic foam Steel-faced polyisocyanurate Flexible melamine foam Aluminium foil-faced polyisocyanurate foam Printed paper backed vinyl, PVA adhesive Wood and wood based panels, ρ >400kg/m3	No data	No data
	s3	Steel-faced polyurethane Steel-faced polyurethane Expanded polystyrene, Type A Clear, prismatic polyvinylchloride sheet Class 0 GRP Fire retarded polystyrene Steel-faced polystyrene Clear GRP - roofing Aluminium foil-faced polyurethane foam Class 3 GRP Polyurethane spray foam	Extruded polystyrene	Clear, prismatic Polystyrene Clear, cast PMMA Fire retarded polyvinylchloride Co-extruded cellular PVC-u cladding system Expanded polystyrene, Type N

Table 2 provides a summary of the additional smoke and droplet class data from all the reviewed sources of information. It can be seen that some of the additional class combinations are heavily populated, while others are very sparsely populated or empty. That is, there appear to be very few generic product types that achieve s1, d1 or s1, d2 or s2, d1 or s2, d2 or s3, d1 class combinations in the SBI test. They tend to be polymeric-based types of products, but it is not possible to simply generalise in this way as polymeric-based products also appear in the left hand column. Additionally, some of these products have clearly not been tested in a manner representative of “end use”.

Overall, this tends to suggest that the d1 class is probably unnecessary and that products either produce falling flaming debris and/or droplets which persist for more than 10 seconds or they don't produce any. The refinement of the d1 class which relates to falling flaming debris and/or droplets that persist for less than 10 seconds appears to be too precise and a poor representation of what actually occurs in the SBI test.

In terms of smoke, a number of products were found for each of the defined classes. This tends to suggest that the number of defined classes are reasonably appropriate for the ranges of products that have been tested and results reported. However, in order to consider the relationship between the defined limits for the smoke classes and the realistic hazard scenarios that are of primary concern within the context of the Building Regulations, the potential for correlating and understanding the physical meaning of the smoke data from the SBI test, with other hazard scenarios must be considered.

A primary source of useful data for comparing the smoke data from the SBI test with other large-scale scenarios can be found in reference [4] in which five large-scale scenarios were studied as summarised in table 3. For each of the large-scale scenarios and a range of six products, the smoke production rates were measured and the data calculated in terms of the smoke growth rate index, SMOGRA (m2/s2) using the room-corner test method [2] and total smoke produced (m2) to the end of the test. Each of the products were also tested in the SBI test method and calculations were made for SMOGRA and total smoke produced in accordance with the methods defined in BS EN 13823: 2002 [1]. The correlation between the SMOGRA and total smoke produced data from the SBI test with each of the large-scale scenarios are summarised in table 3.

Table 3. Correlations of smoke data between the SBI test and some large-scale scenarios

Scenario	**Dimension (m)**	**Correlation coefficient, R^2**	
		SMOGRA (m^2/s^2)*	**TSP (m^2)****
Corner wall	7.2m-high, wings 3.6m-wide and 4.2m-wide	0.896	0.818
Duct	1.2m wide by 0.3m-high by 7.2m-long	0.016	0.401
Corridor	1.2m-wide by 2.4m-high by 7.7m-long	0.061	0.007
Shaft	2.2m-wide by 4.9m-high by 3.5m-long	0.793	0.953
Room	2.4m width x 2.4m height x 3.6m length	0.151	0.352

* Calculated for SBI data as in BS EN 13823 [1]. Calculated for large-scale scenario using room-corner-method [2] .

** Calculated for SBI data as in BS EN 13823 [1]. Calculated for large-scale scenario as total smoke production to end of test.

From the results in table 3, it can be seen that the correlations between the SBI test and the large-scale corner wall and shaft scenarios are good. However, the correlations with the duct, corridor and room scenarios are very poor. The primary reason for these differences is believed to be due to the differences in the ventilation conditions during the test. In both the large-scale corner wall and shaft scenarios, the fires were almost fully ventilated throughout which is a good approximation to the conditions within the SBI test. The same was not true for the other three large-scale scenarios, all of which reached ventilation controlled conditions at some point during the tests. These results tend to show that the performance of a product in terms of smoke production rate will vary depending upon its application within a building and as such, the relevance of the SBI test in determining meaningful smoke production data and classes appropriate to all possible applications is questionable.

Review of product types in current use

A review of the specific types of products commonly used in buildings as wall and ceiling linings was carried out and for which test data was available in the public domain. These products were then categorised in terms of broad generic types to provide some assistance in determining a representative set of products that span a range of classes in terms of smoke and falling flaming particles and/or droplets. These broad generic product types are listed below;

- Wood-based panels
- Wall/ceiling coverings (e.g. paper, vinyl, EPS)
- Paints
- Thermoplastic lighting diffusers, rooflights
- Thermoset plastic lighting diffusers, rooflights, panels
- Faced cellular plastics
- Rock fibre based boards
- Gypsum wall boards
- Calcium silicate boards
- Decorative laminates
- Textile coverings

From these generic product types and following discussions with ODPM and the Key Stakeholders Group which took account of the way in which products are regulated within AD B, the following six products were selected for inclusion in the experimental test programme;

a) Rock fibre acoustic ceiling tile

The product was described as a 20mm-thick, stone wool (resin bonded mineral wool), acoustic ceiling tile. The interior facing consisted of a 1.2 mm-thick composite mineral fleece. The exterior of the product was faced with a 0.54 mm-thick mineral fleece. The interior face and edges of the product were coated with a water-based acrylic paint. The product dimensions were nominally 600 mm wide by 1200 mm-long. The density of the product was 90 kg/m^3 (nominal).

b) Plasterboard-faced PIR foam

The product was insulated dry-lining plasterboard. It was described as CFC/HCFC-free rigid urethane foam, faced with 12.5mm-thick gypsum-based plasterboard. The underside of the product was faced with a wet lay coated glass fibre tissue. The density of the product was 32 kg/m^3 (nominal).

c) “Class 1” MDF board

The product was 12mm “class 1” fire rated medium density fibreboard and was supplied as sheet material in 1220mm x 2440mm panels. The product had a density of 740 kg/m^3 (nominal).

d) GRP roof-light material

The product was a nominal 1-mm thick “Class 1” GRP roof-light material. The product was a translucent flat sheet formed from glass reinforced polyester. The resin used to manufacture the product was formulated to achieve a Class 1 rating to BS 476 Part 7: 1997. The mass per unit area was stated to be 1.8 kg/m^2 (nominal).

e) EPS ceiling tiles

The product was described as an expanded polystyrene (EPS) ceiling tile. The product was white in colour and the internal face of the product was textured (stippled). The product dimensions were nominally 300 mm-wide by 300 mm-long by 8 mm-thick. The density was 18 kg/m^3 (nominal).

f) Prismatic polystyrene lighting diffuser material

The product was as described polystyrene thermo- set prismatic sheet, which was clear with one smooth side and one side with a prismatic finish. The product was supplied as 1220mm x 2420mm with a nominal thickness of 1.5mm.

Phase 2

Experimental Test Programme

The experimental test programme consists of three parts;
- SBI tests
- Toxicity assessments
- ISO 9705 room corner tests

Each of the six products was tested in each of the above test methods to obtain some comparable data.

The SBI test

BS EN 13823: 2002 [1], the Single Burning Item (SBI) test simulates the conditions experienced by a building product in the corner of a room, when exposed to the thermal attack of a single burning item positioned in that corner. The test specifies a method of test for determining the reaction to fire performance of construction products excluding flooring, as defined in Commission Decision 2000/147/EC [5].

The SBI tests were carried out in accordance with the EN 13823: 2002 - "Reaction to fire tests for building products - Building products excluding floorings exposed to the thermal attack by a single burning item".

The test specimen consists of two vertical wings, which form a right-angled corner. The dimensions of the specimen wings are:

- (495 ± 5) mm-wide by (1500 ± 5) mm-high.
- (1000 ± 5) mm-wide by (1500 ± 5) mm-high.

The maximum product thickness, including air gaps that can be accommodated in the SBI test is 200 mm.

Specimen mounting and fixing details

Details of the specific mounting arrangements for the six products tested in this project are provided in Appendix B.

Product assessment

The results of the BS EN 13823: 2002 [1] are expressed in terms of:

a. Heat production parameters.

- $FIGRA_{0.2MJ}$
- $FIGRA_{0.4MJ}$
- THR_{600s}

b. Smoke production parameters.

- SMOGRA
- TSP_{600s}

c. Lateral flame spread. Flame spread reaching the edge of the 1.0m-wide wing, between (500 ± 3) mm and (1000 ± 3) mm above the bottom edge of the specimen.

d. Flaming droplets and particles.

It should be noted that the scope of this project was to focus on the additional classifications for smoke and falling flaming droplets and/or particles, therefore only the information relevant to this scope will be presented and discussed.

Smoke production parameters

SMOGRA (m^2/s^2) is the smoke growth rate and is defined as the maximum of the quotient SPRav(t)/(t-300), multiplied by 10000. The SMOGRA index is only calculated for that part of the exposure period in which the threshold values for the 60 s averaged smoke production rate (SPRav) and the total smoke production (TSP) have been exceeded ($0.1m^2/s$ and $6m^2$ respectively). Specimens with an average rate of smoke production value, RSPav, of not more than 0.1 m^2/s during the total test period or a total smoke production value of not more than 6 m^2 over the total test period are assigned a SMOGRA index of zero. The total smoke production at 600 s, TSP_{600s}, is measured; this value refers to a time of 600 s after the flame has been applied to the specimen. This therefore represents a time period of between 300 s of 900 s from the start of the test.

In addition to the data required by the test standard, the total smoke production for the whole test duration, TSP_{1200s} was also measured.

The following classification limits are used in the SBI test.

s1: SMOGRA ≤ $30m^2/s^2$, TSP600s≤ $50m^2$.

s2: SMOGRA ≤ $180m^2/s^2$, TSP600s≤ $200m^2$.

s3: Not s1 or s2.

Flaming droplets or particles

Flaming droplets or particles are observed for ten minutes after ignition of the main burner, i.e. (300 ± 5) s to (900 ± 5) s. Flaming droplets or particles are recorded when they reach the floor of the SBI trolley, i.e. the level of the bottom edge of the specimen, outside the burner zone. The burner zone is defined as the trolley area at the front of the specimen wings, less than 300 mm from the corner line between the specimen wings. A quarter circle drawn on the floor of the trolley marks the boundary of the zone, see Figure 1.

Two occurrences are recorded during the 600s observation period:

- The fall of a flaming droplet or particle that remains flaming for less than 10 s (d1 classification), and,
- the fall of a flaming droplet or particle that remains flaming for more than 10 s (d2 classification).

If flaming droplets or particles are not recorded during this period a classification of d0 is achieved.

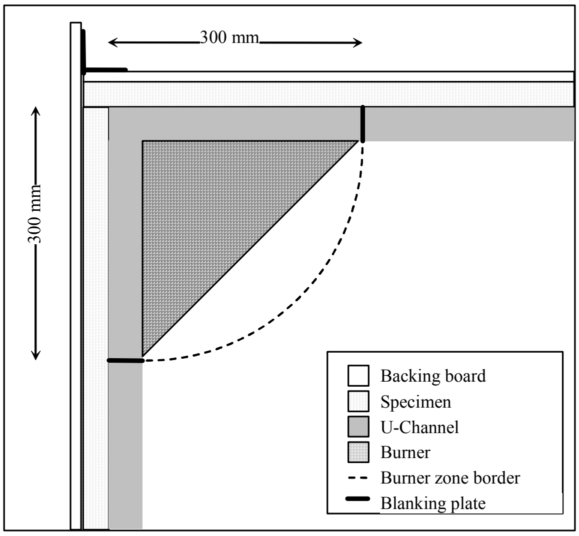

Figure 1. Quarter circle demarcating the burner zone

Summary of classes related to smoke and burning droplets based upon the SBI test results (FRS and University of Ulster)

Using the results from those obtained at FRS and the University of Ulster, it is possible to derive classes, for the smoke production and production of burning droplets/falling debris, in accordance with the Commission Decision 2000/147/EC [5] and EN 13501-1 [6]. It was found that for every product, with the exception of the smoke class for the expanded polystyrene ceiling tiles, the same class was obtained by both laboratories. This indicates that there is good reproducibility between the laboratories and that there is a high level of confidence in relation to the classes. In the case of the expanded polystyrene ceiling tiles, the results for the smoke class were very close to the s1 and s2 class division i.e. the product was borderline. The results suggest that the plasterboard substrate used in these tests may have made a contribution to the smoke class. However, for this product, the class has been decided using the results from all of the SBI tests carried out. These are summarised in table 4 below.

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Table 4. Summary of additional classes for the six products tested.

Product	Smoke and droplets classes
Rock fibre acoustic ceiling tiles	- s1, d0
Plasterboard-faced PIR foam	- s1, d0
Medium density fibreboard	- s2, d0
Glass reinforced polyester rooflight material	- s3, d0
Expanded polystyrene ceiling tiles	- s2, d0
Prismatic polystyrene lighting diffuser material	- s2, d2

Toxicity assessments

The SBI test basically represents a well ventilated case for a pre-flashover flaming fire. In practise, real scale fires cover a range of decomposition conditions from well ventilated to vitiated. In practice, the smoke yields may vary considerably under different conditions and the well ventilated case is likely to produce the lowest yields. In the SBI test, the smoke is representing the entire effluent. If toxic gas yields vary considerably between different fire conditions and especially if they vary more than smoke yields, this impacts upon the validity of using simple smoke production data as a basis for hazard classification. The small-scale tube furnace method BS 7990:2003 [3] which provides a simple method for measuring the yields of smoke and a set of important toxic gases under a range of fire conditions for a material was used in this project to investigate these issues.

The six products were tested to determine their yields of smoke and toxic products following the protocol described in the small-scale tube furnace method BS 7990: 2003 [3]. The apparatus is shown schematically in figure 2. The method uses a sample of material in the form of a solid or segmented strip introduced into a tube furnace at a constant rate. A current of primary air is passed through the furnace over the specimen, flowing in the same direction as the specimen, to support combustion. The effluent is expelled from the tube furnace into a mixing and measurement chamber, where it is diluted with secondary air. The decomposition conditions in the furnace are set using different combinations of temperature and primary air flow in separate runs, to model the decomposition condition in a range of stages and types of fires as required, including those characterised in BS 7899-2 [7].

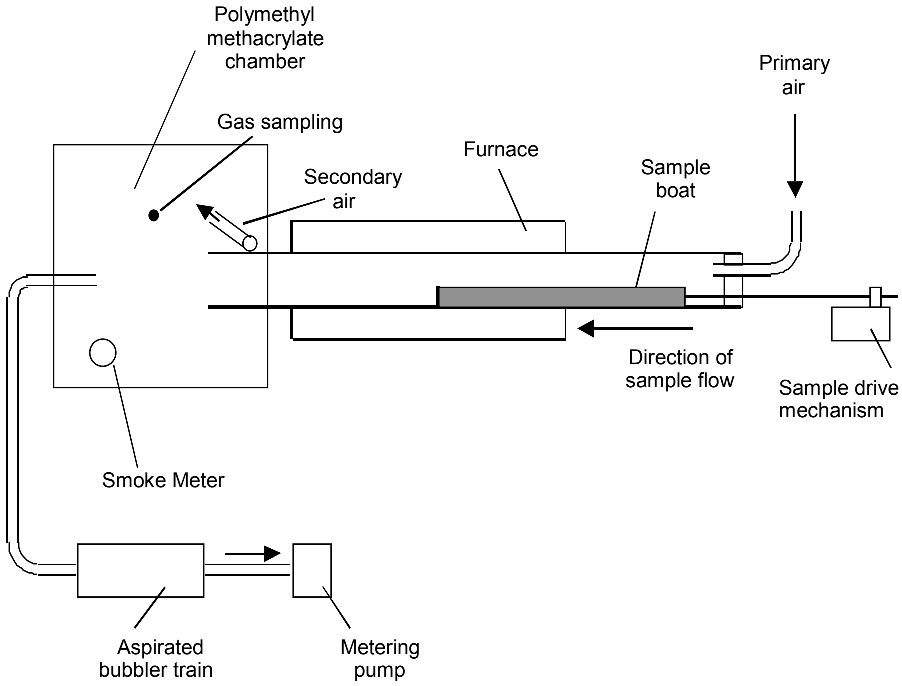

Figure 2. A schematic diagram of the apparatus used for the small-scale tube furnace experiments.

The fire conditions studied in this project were:

Stage 1b	-	oxidative pyrolysis (non-flaming decomposition)
Stage 2	-	well ventilated flaming
Stage 3a	-	small vitiated or reduced oxygen fires in closed or poorly ventilated compartments (two levels of vitiation)
Stage 3b	-	post-flashover fires in large or open compartments (vitiated)

Table 5 provides the details of the specimen preparation from the product for toxicity assessment and table 6 provides a summary of the test programme.

Table 5. Test specimen preparation for tube furnace experiments

Table 5 Test specimen format for tube furnace experiments	
Product/material	**Specimen preparation**
Mineral fibre acoustic ceiling tiles	Full thickness of composite cut into 2 strips (10 and 30mm), plus representative strip of latex edging (4mm).
GRP roof-light material	Strips of material, segmented (10mm x 40 mm), pairs of segments laid uniformly in specimen boat
Polystyrene prismatic lighting diffuser material	Granules (3-5mm) prepared from material, and then laid uniformly in specimen boat.
Polystyrene ceiling tiles	Full thickness of material cut into 3strips (22-30mm) segmented randomly and laid uniformly in specimen boat.
PIR faced with plasterboard	Split into two components and tested separately: (i) Plasterboard encased in paper, full thickness of composite, cut into single strip (28mm) (ii) PIR foam plus facings both on faces, full thickness of composite, and cut into single strip (11mm), and divided down the middle. Segmented (50mm) and laid uniformly in specimen boat.
MDF board	Full thickness of material, cut into thin strips (12 x 1.5mm) segmented (40mm) and laid uniformly in specimen boat.

Table 6. Summary of test programme

Table 6	Fire conditions set up in tube furnace, BS7990:2003					
Material	**Furnace temp**	**Fire stage**[a]	**Flaming/ non-flaming,**	**Equivalence ratio ± 0.2** (<1 = well ventilated, >1 = vitiated)		
	(°C)		**ventilation**	**0.5**	**1.0**	**1.5**
Acoustic tile	400	1b	Non-flaming	√	√	
	650	1b	Non-flaming	√		
	650	1b	Non-flaming		√	
	850	3b	Flaming, vitiated			√
	850	High temp[b]	Flaming, well ventilated	√		
GRP	400	1b	Non-flaming	√		
	700	2	Flaming, well ventilated	√		
	700	3a	Flaming, vitiated		√	√
	850	3b	Flaming, vitiated			√
	850	High temp[b]	Flaming, well ventilated	√		
Prismatic polystyrene sheet	400	1b	Non-flaming	√		
	650	2	Flaming, well ventilated	√		
	650	3a	Flaming, vitiated		√	√
	850	3b	Flaming, vitiated			√
	900	High temp[b]	Flaming, well ventilated	√		
Polystyrene ceiling tiles (EPS)	400	1b	Non-flaming	√		
	650	2	Flaming, well ventilated	√		
	650	3a	Flaming, vitiated		√	√
	850	3b	Flaming, vitiated			√
Plasterboard / (paper casing)	400	1b	Non-flaming	√		
	650	2	Flaming, well ventilated	√		
	650	3a	Flaming, vitiated		√	
	900	High temp[b]	Flaming, well ventilated	√		
Rigid urethane foam	400	1b	Non-flaming	√		
	700	2	Flaming, well ventilated	√		
	700	3a	Flaming, vitiated			√
	900	High temp[b]	Flaming, well ventilated	√		
MDF board Class 1	400	1b	Non-flaming	√		
	700	2	Flaming, well ventilated	√		
	700	3a	Flaming, vitiated		√	√
	850	3b	Flaming, vitiated			√
	900	High temp[b]	Flaming, well ventilated	√		

a - Fire stages: Stage 1b - oxidative pyrolysis (non-flaming decomposition)
Stage 2 - well ventilated flaming
Stage 3a - small vitiated fires in closed or poorly ventilated compartments
Stage 3b - post-flashover (vitiated) fires in large or open compartments

b - High temperature run (850-900ºC) to establish material properties (stoichiometric oxygen demand, carbon content)

The degree of vitiation is expressed in terms of equivalence ratio - ϕ (phi), where:

Equivalence ratio ϕ: mass fuel/oxygen ratio in a fire divided by the stoichiometric mass fuel/oxygen ratio. This can also be expressed as fuel/oxygen ratio x stoichiometric oxygen demand)

For fuel lean mixtures (small or well-ventilated fires) $\phi < 1$

For stoichiometric mixtures $\phi = 1$

For fuel rich mixtures (ventilation-controlled fires) $\phi > 1$

The concentrations of CO_2, CO, O_2, NOx and smoke optical density were measured continuously using on-line analysers. The acid gases (HCl, HBr etc) and smoke particulates were measured by passing the combustion gases through a liquid (trapping media) in a glass vessel (bubbler) during the steady state combustion period of the test run. The trapping media was then subsequently analysed to determine the concentrations of the acid gases etc. The unburnt organic content of the fire effluent was measured continuously by oxidising a sample of the effluent from the mixing chamber, passing through a high temperature oxidising furnace and measuring the resulting CO_2 concentration.

The results from the tube furnace work have demonstrated that the combustion behaviour and the yields of smoke and toxic products for these products and materials vary considerably with the fire conditions. This will be further discussed in the context of the comparisons with the SBI and ISO 9705 test data.

ISO 9705 Room corner tests

The six products were each tested in the ISO 9705 room corner test [2], some with different ventilation conditions. Figure 3 is a schematic diagram of the test apparatus. The interior dimensions of the ISO room were (2.4 ± 0.05) m-wide by (3.6 ± 0.05) m-long by (2.4 ± 0.05) m-high. A 2.0m-high by 0.8m-wide door opening was situated in the short wall that adjoined the hood. The outside surface next to the door opening was marked at intervals from the floor to the top of the door opening to allow an estimate of smoke heights in the room during the fires.

The combustion products released by the burning specimen accumulated below the ceiling of the ISO room, forming a hot gas layer. The combustion products were then collected in a fan-driven hood and duct system, centrally located above an open burning area.

Measurements of gas temperature and velocity, smoke density, oxygen concentration, carbon monoxide concentration and carbon dioxide concentration were made in the calorimeter duct.

Products for test were fixed to walls and ceiling by proprietary fixing systems (see Appendix C), as required by the ISO 9705 standard and the standard propane diffusion flame burner was used. The propane flame was applied to a rear corner at low level and provided 100 kW for 10 minutes followed by 300 kW for a further 10 minutes.

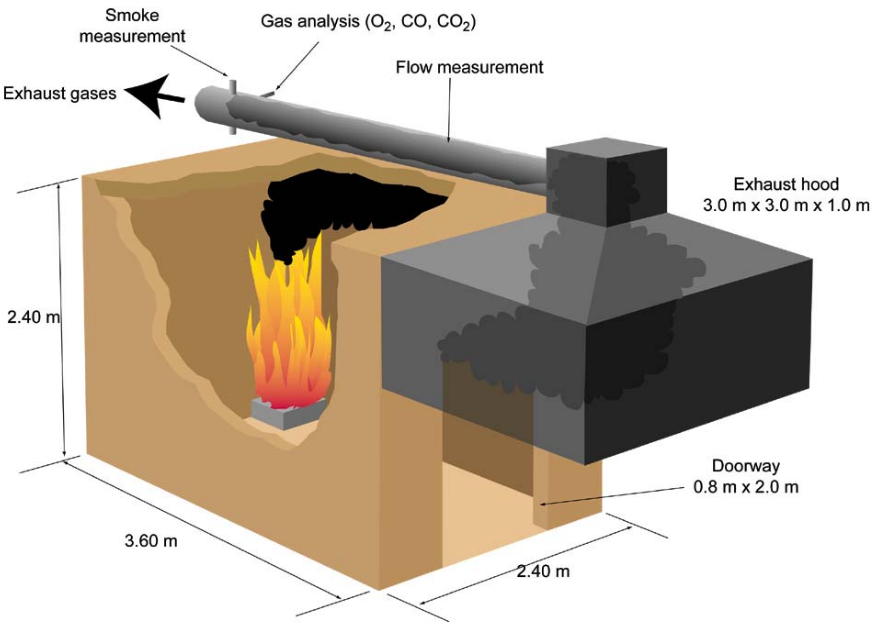

Figure 3. Schematic of the ISO 9705 room and calorimeter apparatus

Ventilation conditions

The ventilation conditions of the room were varied by reducing the door area, thus restricting the inflow of air and the out flow of the fire gases. This was achieved by means of a pair of appropriately-sized door reducers, constructed from 12 mm-thick calcium silicate board with an average density of 900 kg/m^3. The door reducers were bolted onto the outside wall of the room, one on either side of the door opening, to produce a central vertical opening. The ventilation openings used in this study are summarised in table 7 below.

Table 7. Summary of ventilation openings used in this study.

Ventilation Condition	Door Width	Door Height
100 %	0.8 m	2.0 m
25 %	0.2 m	2.0 m
12.5 %	0.1 m	2.0 m

The duration of the ISO 9705 test is dependent upon the behaviour of the product. The end of the test using the 100% ventilation, and therefore in full accordance with the ISO 9705 test, corresponds to either 20 minutes from ignition or the onset of flashover (flames through the doorway of the room or a heat release rate in excess of 1000kW). The tests at reduced ventilation were allowed to proceed until any of the above criteria were satisfied or conditions were considered to be unsafe due to factors such as the product slumping over the burner or the view of the burner restricted by smoke.

The table 8 below provides a summary of the tests that were carried out on the different products at the different ventilation openings.

Table 8. A summary of the tests that were carried out in the ISO 9705 room corner test.

Product	100% vent opening	25% vent opening	12.5% vent opening
Rock fibre acoustic ceiling tiles	Tested	Not tested	Tested
Plasterboard-faced PIR foam	Tested	Tested	Tested
Medium density fibreboard	Tested	Not tested	Tested
Glass reinforced polyester rooflight material	Tested	Not tested	Not tested
Expanded polystyrene ceiling tiles	Tested	Tested	Tested
Prismatic polystyrene lighting diffuser material	Tested	Not tested	Tested

Observations were taken during each test to determine if the products produced any flaming droplets. The criteria for determining droplets were flaming items falling 1.2 m from the burner with continued burning for 3 seconds after reaching the floor.

It was observed that only two products – EPS and Prismatic polystyrene - produced any flaming droplets/burning debris. In the case of the EPS ceiling tiles, one drop was produced once during one of the tests. In the case of the prismatic polystyrene, the product tended to slump and melt onto the floor and then continue to burn in molten patches or pools.

In the ISO 9705 room corner tests, in general, the reduction in ventilation resulted in an increase in the production of smoke and degree of vitiation. However, for some products, the reduction in ventilation resulted in an observed modification to the fire behaviour which was probably as a consequence of the equivalent reduction in heat loss from the room.

Comparison of tube furnace data with SBI test and ISO room corner test data

The tube furnace data include heats of combustion, yields of toxic species and of smoke. They have been obtained for the six test specimens under the following decomposition conditions:

Non-flaming 400°C

Well ventilated flaming 650 or 700 °C

Stoichiometric flaming 650 or 700 °C

Vitiated flaming 650 or 700°C

Vitiated flaming 850°C (post flashover)

The conditions in the SBI test were anticipated to represent well-ventilated flaming conditions. The tube furnace data for this case in terms of carbon dioxide and smoke yields have been compared with the SBI test data.

In addition a number of comparisons have been made between the tube furnace data and the ISO room corner calorimeter data. The ISO room corner tests were conducted under a range of ventilation conditions for which the results can be compared with the tube-furnace results.

The tables of comparative data for each of the six products tested and used in the analysis are provided in Appendix D. The basis of the calculation methods used is also provided in Appendix D.

Results of comparisons between the SBI test – tube furnace data

Using the calculated mass loss rates in the SBI test, it was possible to make comparisons of CO_2 and smoke yields between the tube furnace and SBI test for each product. The results showed good agreement between CO_2 yields obtained under well-ventilated conditions in the two methods, but the absolute smoke yields tended to be somewhat lower in the tube furnace results. The possible reasons are discussed in the following sections.

A “smoke yield ratio” was calculated for each product from the smoke yield under vitiated conditions relative to the smoke yield under well ventilated conditions. This ratio was then applied as a multiplier to the individual values of SMOGRA and total smoke produced from the SBI tests to provide an indication of the possible smoke yield that would be obtained under vitiated conditions in the SBI test (if it were possible). The results indicate that for the products included within this project, vitiation increased the smoke yields. However, due to the values of SMOGRA and total smoke produced for the products tested and their resultant position in relation to the smoke class limits, the results suggest that none of the products changed smoke class due to vitiation except for the Medium density fibreboard where the total smoke produced exceeded the s2 class limit of 200m^2. Further, it should be realised that this analysis has assumed that the only variable is the degree of vitiation. That is, other possible physical changes that may occur in a real scale fire scenario, such as modifications to the heat transfer between the fire and the product have not been considered.

In addition to the changes in smoke yield with vitiation, there were changes in the yields of toxic gases. In general these were as follows:

- Vitiation resulted in an increased CO yield for all materials
- The CO yields were observed to have increased by factors of between 1.13 and 9.97.

For some materials the relative increase in yield for CO was more than three times greater than it was for smoke. The yields between well-ventilated and vitiated conditions resulted in an increase by a factor of ten for CO compared with a factor of three for smoke, for the six products tested.

Results of ISO room corner test – tube furnace comparison for Medium Density Fibreboard

Although not included in the scope of work for this project ,it is useful to make a comparison between the tube furnace yield data and the yield data from the ISO room corner tests. The example material chosen for this purpose was Class I MDF.

The best method for evaluating the ISO 9705 calorimeter data is not to use the overall test summary data but to treat the two phases (100kW burner output and 300kW burner output) of the test independently as the conditions are obviously so different. Calculated this way, the first 600 seconds of the test are shown to be operating under more well ventilated combustion conditions, because the CO_2 yield is higher and the CO yield lower. The CO yield is still relatively high and the CO_2/CO ratio relatively low, due to the fire-retardant treatment.

For the second phase of the test, the combustion conditions are shown to be extremely vitiated with a very low CO_2 yield, a high CO yield and a very low CO_2/CO ratio.

The calorimeter test with the 12.5 % door opening was stopped at the end of the 100 kW burner period. The conditions can be seen to be very vitiated throughout the test.

Overall the results show that combustion of this material over the conditions used in this test is never highly efficient due to the fire-retardant treatment. The smoke yields are relatively high and similar over a range of decomposition conditions, but generally somewhat higher under vitiated combustion conditions than under well-ventilated combustion conditions. The CO yields are also relatively high, but increase considerably with the degree of vitiation.

The tube furnace data also show relatively high smoke yields, but somewhat lower than those obtained in the ISO room calorimeter. As with the SBI tests this may partly reflect the mixed decomposition conditions of the specimen in different locations in the ISO room. It is probable that some parts of the specimen were decomposed under non-flaming conditions while other parts were flaming. The smoke yield in the tube furnace under non-flaming conditions is considerably higher than under flaming conditions. This may be due to the sample form and heat exposure conditions which differ markedly. The CO yields obtained in the tube furnace under stoichiometric combustion conditions are very similar to those obtained in the ISO room. The yields under vitiated combustion conditions at 850°C are also quite similar. As with the ISO room the CO yields are generally higher under more vitiated conditions.

The smoke yields, derived as explained above, were generally higher in the SBI test than those obtained in the ISO room test at different ventilation openings, for MDF.

Overall

Comparison of the results obtained from the toxicity assessments based upon the data of the specific extinction area or yield of smoke versus the equivalence ratio in the flaming combustion mode indicate that products that generate the highest smoke yields in well ventilated conditions do the same in less well ventilated conditions. However, the yield of smoke or specific extinction area is related to the mass of product consumed and it is this that makes the issue of smoke production in larger scale experiments difficult to interpret and predict.

The smoke classes associated with the SBI test are based upon the rate at which smoke is produced from the product and has a limitation on the total amount of smoke produced. However, this upper limit on the total amount of smoke produced is rarely the criteria that determines the smoke class. Typically, the rate of smoke production through the SMOGRA index is the determining factor.

Whilst the direct correlation between the SMOGRA values obtained from the SBI test and the ISO 9705 room corner test is poor, it is possible to further consider the effect of ventilation on the production of smoke by comparison of the data from the ISO 9705 room corner tests at 100% and 12.5% ventilation. These generally showed that reducing the ventilation tended to result in a reduction in the SMOGRA index for those products for which a significant change was observed (Medium density fibre board and prismatic polystyrene lighting diffuser material). This is probably because the early stages of the fire are most dominant in determining SMOGRA and it is during this phase of the fire that the ventilation conditions will have least effect. However, the data clearly showed that the reduction in ventilation conditions produced an increase in the total smoke produced. This information was only available for 3 of the products, plasterboard faced PIR foam, rock fibre acoustic ceiling tiles and expanded polystyrene ceiling tiles, since the tests on the remaining products were stopped before 20 minutes. In the cases of the plasterboard faced PIR foam and rock fibre acoustic ceiling tiles, this increase in total smoke produced was substantial in relative terms. However, the increase observed for the expanded polystyrene ceiling tiles was smaller because in both tests, a substantial proportion of the product was consumed. Therefore, the potential conversion of product into smoke during a fire in a real scenario is an important factor that would need further careful consideration if smoke classes were to be introduced into Approved Document B as the SBI test smoke classification does not appear to adequately characterise this particular process which is directly related to the mass of the product consumed and therefore appears to be strongly dependent on the ventilation conditions.

If a smoke classification were to be applied to the ISO 9705 room corner test results based upon SMOGRA as the determining factor, the products could be broadly grouped as follows;

- Smoke class 1 - Plasterboard faced PIR foam wall board, expanded polystyrene ceiling tiles and rock fibre acoustic ceiling tiles
- Smoke class 2 - Prismatic polystyrene lighting diffuser material and medium density fibreboard
- Smoke class 3 - GRP rooflight material

These classes map onto the smoke classes obtained in the SBI test reasonably well. The main discrepancy is the class associated with the expanded polystyrene ceiling tiles which achieved an s2 class in the SBI test, although it was borderline s1, s2. It is also worth noting that the prismatic polystyrene lighting diffuser material achieved an s2 class in the SBI test because of the total smoke produced. Based upon SMOGRA alone, the class requirement for s1 was satisfied.

Phase 3 - Cost benefit assessment

Introduction

The development of the new European fire test standards has meant that it is now possible to assess the production of smoke and burning droplets from construction products. In the light of this it has been suggested that this now provides a vehicle to include a requirement in AD B to control the production of smoke and burning droplets from products used to form wall and ceiling linings. Currently, there are no such provisions in AD B, the rationale being that building occupants should generally have early warning of a fire to enable them to escape along protected routes which are free from the products of combustion, such as smoke and burning droplets. However, ODPM is always keen to explore all reasonable ways to reduce the number of deaths and injuries attributable to fire, and this includes fire fighters who may be required to enter a building to rescue occupants.

A key issue to explore whenever there are proposed changes to Building Regulations is that they are reasonable and proportionate, in other words any burdens they impose on the industry (in terms of additional costs) can be justified in respect of the benefits (e.g. lives saved and injuries prevented) that would be realised. A new requirement in AD B to control smoke and burning droplets from construction products would impose a burden on manufacturers in terms of the need to test existing products to see if they complied with any proposed new requirement and, if necessary, re-engineer these products to ensure that they did comply. Ultimately, any proposed changes to AD B will need to be justified by means of a Regulatory Impact Assessment (RIA), which would require additional considerations such as a small firms' impact test and a competition assessment (neither of which were carried out as part of this project).

Statistics

Reference to the Fire Statistics United Kingdom for 2002 [8] clearly show that in relation to smoke it is not possible to discriminate between smoke produced by burning linings and that produced by building contents. This is an important factor in the subsequent cost benefit analysis as it makes it very difficult to quantify possible benefits. However, analysis of the fire statistics does provide some insight in terms of the main contributory factors to fire development.

Of the 439 fire related deaths in buildings on 2002, the vast majority (410, i.e. over 90%), occurred in dwellings. There were 29 fire related deaths in other buildings which include private garages and sheds, retail distribution premises, industrial premises, restaurants, cafes, public houses and hospitals. (These figures for 2002 are fairly representative of the statistics recorded over the last 5 years.) Many of these types of other buildings are the subject of ongoing control in a way that most dwellings are not.

Further examination of the fire statistics for 2002 for other buildings show that for only one fatality was the structure and fittings within the building identified as the first item ignited. The structure and fittings within the building were identified as mainly responsible for the development of the fire in relation to two fatalities, with the floor/stairs being the main factor in one case and the roof/roof members being the main contributor in the other case. If these categories are considered to be indicative of the main factors contributing to specific fatalities, it could be concluded that none of the 29 fire deaths in non-domestic buildings are attributable to wall and ceiling linings, but are attributable to other factors which include building contents.

In dwellings there were four fatalities attributed to fires in which the material mainly responsible for the development of the fire was wall,/partition/wall tiles and one fatality attributed to fires in which the material mainly responsible for the development of the fire was ceiling/ceiling linings. Further examination of these cases showed that these five deaths occurred in three separate fire incidents, one of which was a caravan and therefore outside the scope of this project. In the other two incidents there was no way of knowing whether the wall and ceiling linings involved satisfied the current requirements within Approved Document B.

The reduction in non fatal casualties that could result from the introduction of proposed controls of smoke and burning droplets from wall and ceiling lining products may result in some potential cost benefit. An assessment has been made of this possible contribution based upon the Fire Statistics United Kingdom 2002 [8], but it should be treated with some caution due to the assumptions as outlined below.

Any cost benefits from the reduction of non fatal casualties would be derived from the refurbishment of existing building stock and new build and are based upon a weighted average per injury of £58k [9]. In the fire statistics, 56 non fatal casualties were attributed to fires in which the material mainly responsible for the development of the fire was wall/partition/wall tiles, ceiling and ceiling linings. If we optimistically assume that the buildings are refurbished at a rate of 10% per year and that the introduction of the proposed controls would be effective in 50% of cases, then the associated benefit would be £174k per year. However, it should be noted that not all refurbishment work is governed by the Building Regulations in that Requirement B2 (Internal fire spread) is not a relevant requirement under the Building Regulations material alteration definition. Therefore, the cost benefit of £174k derived from the reduction of non fatal casualties only is considered to be an overestimate and must be considered along with any other benefits and costs identified in the subsequent paragraphs below.

Methodology

The scope of the cost benefit assessment was to investigate the likely impact of a requirement to control the production of smoke and burning droplets from wall and ceiling linings within the context of Approved Document B. This specifically means that environmental and energy saving issues were outside the scope of this project. The primary focus has been in relation to life safety of building occupants and fire and rescue service personnel. The baseline for the analysis is the current situation as it relates to the available statistical information on fire related death and injury in the UK. The report only addresses issues related to long term health effects in so far as they are included in the fire related death and injury statistics in the UK.

A short questionnaire was circulated to those who manufacture and sell construction products used to form wall and ceiling linings, many of whom were members of the Key Stakeholder group of the project. It was also circulated to other interested stakeholders, many of whom were also members of the Key Stakeholder group. At the request of the Key Stakeholder group, respondents were given six weeks to reply to the survey. The questionnaire was issued on 15th June 2004, and members were reminded at the steering group meeting on 12th July 2004.

The questionnaire was divided into a number of sections:

- Background information (e.g. name of respondent, sector turnover).
- Table summarising generic products produced, their classification (as established using the existing BS476 series as well as the new European test methods), extent of UK sales and size of EU and non-EU export markets.
- General section to establish respondents' views on smoke and burning droplets produced by wall and ceiling linings, whether clients and specifiers were concerned about this, whether respondents supported such a requirement in AD B and what the likely impacts would be.
- More specific section which was concerned with determining the impact of two possible forms of a requirement:

Option (a)

All ceiling and wall lining products achieving Euroclasses A2, B, C or D will need to achieve an additional classification of s1, d0, or, *Option (b)*

All ceiling and wall lining products achieving Euroclasses A2, B, C or D will need to achieve an additional classification of s2, d1.

Respondents were asked to quantify the impact of these two alternatives (compared to the ‘do nothing’ option) as far as possible in terms of loss (or gain) of sales as well as highlighting any other impacts.

Finally, respondents were asked to quantify what product testing costs they might incur in order to establish what European classification their products would achieve, and whether costs would be incurred to re-engineer products to meet the required classification. There are a number of benefits arising from testing products to the new European standards including reducing the need for multiple testing (a cost saving) and this can increase opportunities for export. Respondents were also asked whether there was any scope for this. These were the same set of questions that were asked of a wider group of UK construction product manufacturers as part of another BRE project for ODPM which is looking at the impact of proposed changes to the Construction Products Directive (CPD).

A copy of the questionnaire is included at Appendix E.

Results

Amongst manufacturers the intention was to try to obtain data from their trade associations in order to obtain as comprehensive picture as possible but, practically, many trade associations do not hold information about their members to the level required in the survey. The questionnaire was therefore forwarded to specific manufacturers to complete as well. In these cases, care was required to ensure that double counting did not occur. A number of manufacturers found it difficult to quantify impacts, and others were reluctant to provide detailed information because of concerns about commercial confidentiality. Clearly, the value of any such survey is limited by the number and quality of responses received to the questionnaire.

In total, 18 questionnaires were circulated originally by BRE to members of a Key Stakeholder Group - some of which appear to have been subsequently forwarded to specific manufacturers - and 14 responses were received. The responses received were based on a sectoral cross-section as follows;

- Insulation
- Lighting
- Wall coverings
- Rooflights
- Enforcers
- Organisations representing a range of sectoral interests.

In analysing the data provided and its sources, the possibility for double counting has been considered and taken into account wherever possible. Further, whilst it is recognised that the responses and figures were provided by stakeholders in good faith, it should be noted that there does seem to be some inconsistency in relation to the market share within the insulation sector. However, this inconsistency is not regarded as a major factor in the assessment since it would not alter the overall outcome.

Between them, these respondents are responsible for UK sales of at least £603 million – a number of respondents were unable to supply this data or it was not relevant to this survey. Data from the Construction Products Association (CPA) indicates that across all construction product manufacturers in the UK the total turnover is some £37,400 million, and analysis of product mandates suggest about 80% (i.e. £30,100 million) of this is subject to harmonised European Standards.

In addition, the respondents are responsible for just over £70m in exports the vast majority of which is to the EU. (DTI data shows that exports of all UK construction products to the EU amounts to £2,300 million per year.) In practice, the sales and export figures for wall and ceiling linings will be much higher since a number of manufacturers did not or were unable to respond to the survey.

Detailed responses

Views on smoke and burning droplets

Respondents were first asked for their views on the risks posed by the production of smoke and burning droplets from wall and ceiling linings in general. This was to supplement the analysis of the 2002 fire statistics described above which, as discussed, suggested that wall and ceiling linings are likely to be responsible for only a very small number of deaths and injuries (if any), but that limitations with the data make it difficult to be precise.

Many respondents noted that fires typically start in the contents of the building and that building occupants are exposed to the smoke and gases from these once ignited until their evacuation. It was felt that wall and ceiling linings are generally involved at a later stage of the fire when it is fully developed which is after the time that people have been evacuated from the building; they are therefore considered to pose little additional risk. However, two respondents felt that there was a risk: burning droplets can initiate fires in new locations - although information is mostly anecdotal - and that smoke from some sandwich panel fires was so copious that it restricted use of escape routes. One of these felt that although the additional risk was small anything that is done will be of benefit. A further respondent suggested that smoke should not be considered a risk for general construction with the exception of specific applications where escape considerations require a detailed fire engineering approach, e.g. hospitals and airport terminal buildings.

A key difficulty – as raised by some respondents – is that building occupiers will put much more hazardous items in the building (e.g. soft furnishings) and on the walls than was in the original construction, and this cannot easily be controlled. This is particularly the case in domestic situations where most deaths occur. Several respondents referred to the *Furniture and Furnishings (Fire) (Safety) Regulations 1988* which has been successful in reducing the number of deaths and injuries. One respondent commented that linings are currently controlled in licensed premises and where it is known linings produce high levels of smoke and/or droplets they are normally rejected.

The safety of fire fighters was touched upon by a number of respondents because they may be required to enter a building once a fire is fully developed so that may be more affected by smoke and burning droplets. It was noted that fire fighters automatically wear breathing apparatus in order to protect themselves from smoke and toxic substances regardless of the fire's origin. Information from the Fire and Rescue Services highlighted the fact that when materials that produce falling flaming droplets and/or particles were first introduced into buildings, burn injuries to the hands and necks of fire fighters were relatively commonplace. However, modern personal protective fire fighting apparel and protective fire fighting tactics have served to reduce this risk.

Attitude of clients and specifiers

Respondents were asked whether clients and specifiers had expressed concern about smoke and burning droplets from products used to form wall and ceiling linings.

Most respondents stated awareness of the issue amongst such bodies was generally low and that they did not appear to be concerned. However, this is not always the case, and that awareness is increasing. One respondent stated that clients and specifiers need to be more aware of their responsibilities through COSHH requirements as well as their risk assessment duties under the *Fire Precautions (Workplace) Regulations 1997* as amended. The proposed *Regulatory Reform (Fire Safety) Order* may make these duties more specific. Another respondent said that aesthetics are usually the main concern and that additives to improve flame spread often vary the appearance of materials to the dissatisfaction of architects. A further respondent said that clients and specifies believed that Building Regulations took into consideration all risks and so, in their opinion, it was incumbent upon ODPM to raise awareness of smoke and burning droplets.

The potential requirement to control smoke and burning droplets

Respondents were asked directly whether they supported a requirement in AD B to control smoke and burning droplets. They were asked to give reasons, and also whether they thought such a proposal would reduce the risk of death or injury.

Eleven of the fourteen respondents said 'no', they did not support such a proposal. These included respondents from the rooflight sector, wall coverings sector, lighting sector and some of the trade associations with broad sector interests. The insulation sector was divided in its support for such a proposal. The respondents that said "no" reiterated or referred back to the arguments presented above, i.e. wall and ceiling lining products only contribute smoke and droplets once a fire is fully developed which occurs after people are evacuated, and there is no additional risk compared to that posed by the products of combustion originating from furnishings etc. over which there is little or no control. Two respondents referred to additional smoke detectors and active suppression systems – perhaps as a compensatory feature – as a means to reduce risk. Insurance companies look to sprinklers as a means to reduce property losses due to fire.

One respondent voiced very strong support for adopting the proposal though. They referred to an in-balance between other EU countries where there were requirements and the UK, and that smoke from such products is important and should be considered in tandem with legislation aimed at furnishings and furniture. A second respondent supported the proposal saying that the contribution from smoke and burning droplets from lining materials has become important following efforts to limit emissions from building contents and that the fabric of a building is likely to alter frequently during its lifetime. Finally, one respondent gave a cautious welcome to the proposal since although the additional risk was small, doing something would be of benefit. Further, in the case of licensed premises such a requirement would remove two tier control. However, the respondent went onto say that the need for a requirement in protected escape routes requires careful consideration since the assumption is that fire will not originate in them and should not penetrate such areas. Also, although control would be possible at the new-build stage in residential premises (where most deaths take place), maintenance of control would be impossible.

Respondents were then asked to highlight in general terms the impacts of such a requirement on their business. Nearly all respondents referred to major negative impacts in terms of increased testing costs because of the need to move to the Euroclassification system immediately since the BS 476 procedures do not measure smoke, and restricting the use of certain products which could severely affect sales ultimately leading to job losses. No positive impacts were identified. The one trade association that supported the proposal stated that its members had already invested considerably to meet their environmental duties and that such a requirement would be part of the continual process to improve their products. These impacts are expanded upon and quantified in the next two sections.

Impact of proposals on product sales

As mentioned above, respondents were asked about the impacts of two proposals compared to ‘do nothing’ (i.e. maintain the current situation where there is no requirement) and these were that: (a) all ceiling and wall lining products with a Euroclass would need to achieve an additional smoke and droplet classification of s1,d0; or, (b) the less onerous additional classification of s2,d1. Respondents were asked to assess impacts (both positive and negative) - primarily in terms of sales - for each of the two options and also to identify any other impacts. Impacts in terms of product testing are discussed in the next section.

Many respondents felt that they would be adversely affected by both proposals, although option (b) would have less severe consequences. Focussing on those respondents on whom the proposals would have a direct impact there are three who felt that product sales would not be affected or the effect would be small, and this would be the case for either option. The remaining respondents would be affected, in many instances significantly. All but three of these were able to quantify the impact in terms of the value of sales that would potentially be affected.

With regard to the more demanding option (a) the individual values of sales that would be affected ranged from 25% to 95% of total sales. This equates to an annual sales value of nearly £249M which represents nearly 60% of UK sales for all the relevant survey respondents. In reality the actual sales value will be greater because not all respondents could quantify the impact and not all industries affected by the proposals have responded to the survey.

With respect to option (b) the individual values of sales that would be affected ranged from 5% to 90% of total sales. This equates to an annual sales value of about £160M which represents 40% of UK sales for all the relevant survey respondents. Again, for the reasons mentioned above, the actual sales value is likely to be greater than this.

These figures do not mean that sales would slump dramatically overnight to this extent because firms would re-engineer existing products to meet any new requirement in AD B and sales would adjust accordingly. This transition would take several years, but industry would also incur costs which would include testing of the new products. This is discussed further in the next section. Nevertheless, the value of sales affected by these proposals is very considerable and many firms are likely to be hit hard (a number of respondents mentioned job losses) during the transition period.

Respondents identified several other impacts:

- Increased cost of constructing lightweight framed buildings
- Additional costs of sourcing products and assessing compliance
- Confusion amongst specifiers
- Impact on insulation values for panels making government targets for reducing CO_2 emissions harder to achieve.

None of these impacts were quantified.

Finally, one respondent stated that there would be an increase in sales for some of their insulation products which met the required smoke and droplet classification. This would amount to about 10-15% and be equivalent to about £1M for option (a) and £0.2M for option (b).

Impact of proposals on product testing

Adopting either of the two options would require manufacturers to test wall and ceiling lining products to the European fire test standards to obtain the relevant classifications. This would give rise to additional costs in terms of certification and product testing, re-tooling and re-engineering, revisions to product literature and staff training. Such costs could be a one-off or be incurred continuously. Survey respondents were asked to identify these costs where possible.

Testing and certification costs for individual products ranged from £1.2k to 3.4k which amounted to £30-50k per year for some firms, and to one-off costs of £4M and even £9M for others in order to cover the whole product range. Given the wide variety in products and required testing it is not possible to give a single figure. Respondents were also asked the time it would take to enable the testing of their full product range to the European standards. This timescale ranged from 2 to 5 years with most suggesting that it would take 5 years.

There was little information given on re-tooling and re-engineering but some respondents said that costs would be significant. Figures ranged from £45k to several millions. Revisions to literature and promotional information and staff training were generally felt to lie in the region £10-60k per respondent.

The only costs that some respondents felt could be absorbed into the normal review cycle for product development and marketing was that for product literature and promotional information.

A benefit of testing products to the harmonised European standards is that it reduces the need for multiple product testing, multiple product variations and costs of quality management, packaging etc. Where relevant virtually all respondents said that they would not see any cost savings in this respect; only one said this would occur but it would be minimal. Following on from this respondents were asked if this would increase EU exports; all but one said that there would be no increase, but one felt there would be a doubling in EU sales over 10 years.

Conclusion and recommendations

The review of regulations in other Member States relating to the production of smoke and falling flaming droplets and/or debris has revealed that there is no consistent pattern between Member States in relation to regulatory requirements.

The results obtained from the SBI test programme produced good repeatability and reproducibility (limited study), therefore confidence in data from this work is high.

The results from this work and from the data obtained from the literature review suggest that flaming droplets/burning debris either occur or not, so the existing refinement of classes that exists within the European classification system is probably unnecessary. The production of flaming droplets/burning debris tends to be a material based property. This is currently recognised within the context of thermoplastic materials in AD B through the limitations in terms of area of permitted thermoplastic product in ceilings. It would seem most appropriate to continue to deal with this issue in a similar way alongside the introduction of the new European fire tests and appropriate European classifications. The detail of such a proposal is outside the scope of this project. However, the results from this work have suggested that the introduction of more stringent general requirements in Table 10 of AD B for the control of materials that produce flaming droplets/burning debris is probably unnecessary at this time.

Comparison of the results obtained from the toxicity assessments based upon the data of the specific extinction area or yield of smoke versus the equivalence ratio in the flaming combustion mode indicate that products that generate the highest smoke yields in well ventilated conditions do the same in less well ventilated conditions. However, the yield of smoke or specific extinction area is related to the mass of product consumed and it is this that makes the issue of smoke production in larger scale experiments difficult to interpret or predict.

The smoke classes associated with the SBI test are based upon the rate at which smoke is generated from the product and has a limitation on the total amount of smoke produced. However, this upper limit is rarely the criteria that determines the smoke class. Typically, the rate of smoke production through the SMOGRA index is the determining factor.

Whilst the direct correlation between the SMOGRA values obtained from the SBI test and the ISO 9705 room corner test is poor, it is possible to further consider the effect of ventilation on the production of smoke by comparison of the data from the ISO 9705 room corner tests at 100% and 12.5% ventilation. These generally showed that reducing the ventilation tended to result in a reduction in the SMOGRA index for those products for which a significant change was observed. However, the data clearly showed that the reduction in ventilation conditions produced an increase in the total smoke produced and for some products, resulted in different burning behaviour. The potential conversion of product into smoke during a fire in a real scenario is a factor that would need careful consideration if smoke classes were to be introduced into Approved Document B as the SBI test smoke classification does not appear to adequately characterise this process which is directly related to the mass of the product consumed and appears to be strongly dependent on the ventilation conditions.

A survey of manufacturers of construction products used to form wall and ceiling linings has been undertaken to establish whether a requirement in AD B to control smoke and burning droplets from these materials would reduce the risk of death and injury in fires and what the cost implications of this would be.

Both alternatives of the proposed requirement would have a significant impact in terms of the value of product sales they would potentially affect. The most demanding option could affect annual sales of upwards of £249M, and for the least onerous, the value of affected sales could be more than £160M. Sales would not reduce to this extent overnight as manufacturers would re-engineer their products to meet the new requirements and sales would adjust accordingly, but the costs to re-engineer are considerable, ranging from tens of thousands to several million pounds. Re-engineering would also involve extensive testing and certification of products which could also cost millions of pounds and would take between 2 and 5 years to complete.

Analysis of UK fire statistics for 2002 suggests that wall and ceiling linings are likely to be responsible for only a very small number of deaths and injuries (if any), but that limitations with the data make it difficult to be precise. The respondees to the questionnaire commonly shared the view that fires typically start in the contents in a building, which are not currently regulated within AD B, and that building occupants are exposed to the smoke and gases from these objects from the time of ignition. The benefits in terms of lives saved or reduced injuries by the introduction of a requirement for stricter additional classes for smoke and falling flaming droplets and/or debris are considered to be low. Using accepted valuation techniques for deaths and injuries the annual benefit is estimated to be £174k per year.

Overall, it is suggested that neither of the proposals are workable and could not be justified on cost-benefit grounds in the context of an RIA. The additional risk posed by the production of smoke and falling flaming droplets and /or particles from wall and ceiling linings alone is impossible to quantify but appears to be small. Certainly, given that a requirement would only apply to new and refurbished buildings the reduction in deaths and injury would be extremely small as most of the existing stock would be unaffected by the proposal. The costs of the requirement would run into many millions of pounds which vastly exceeds any potential benefit.

In summary, the overall results from this project indicate that, at this time, there would be no significant benefit in the introduction of stricter additional classifications for smoke and falling flaming droplets and/or debris for wall and ceiling linings.

References

[1] BS EN 13823: 2002. Reaction to fire tests for building products - Building products excluding floorings exposed to the thermal attack by a single burning item.

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[3] British Standards Institute (BSI) BS 7990:2003. Tube furnace method for the determination of toxic product yields in fire effluents.

[4] D A Smith, N Marshall, K Shaw and S Colwell. Correlating large-scale fire performance with the Single Burning Item test. Proceedings of the 9th International Fire Science and Engineering Conference, Interflam 2001, published by Interscience Communications, London, 2001, p 531

[5] EC Decision 2000/147/EC. Commission Decision of 8th February 2000 implementing Council Directive 89/106/EEC as regards classification of the reaction to fire performance of construction products (OJ L 50, 23.02.2000, p.14).

[6] BS EN 13501-1: Fire classification of construction products and building elements, Part 1 – Classification using test data from reaction to fire tests.

[7] British Standards Institute (BSI) BS 7899-2:1999. Code of practise 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.

[8] Fire statistics United Kingdom 2002. Published April 2004, Office of the Deputy Prime Minister.

[9] Effectiveness of sprinklers in residential premises. BRE report 204505. 2004.

Appendix A – Key Stakeholder Group Membership

FRS, BRE	Debbie Smith
	Carol Rock
	Peter Fardell
	Dave Purser
	Jenny Purser
	Phil Clark
ODPM	Anthony Burd
AEAT representing ODPM	Mike Payne
ABE	Beryl Menzies
ASFP	Larry Cody
BPF	Chris Lukas
BRUFMA	Wilf Ball
CPA	John Tebbit
EPIC	Mark Harris
FBU	Graham Jones
FSDG	Bob Moore
IACSC	Jimmy Bittles
IFE	David Smith
LIF	Brock Hoaran
MCRMA	Nick Selves
NARM	Ian McKane
PFPF	David Sugden
University of Ulster	Michael Delichatsios
Buro Happold	Adam Monaghan

Appendix B - Mounting and fixing arrangements used in the SBI tests

Rock fibre acoustic ceiling tile

The ceiling tiles were through-fixed into a lightweight steel framework using wafer head drywall screws. The head track, floor track and side tracks were constructed from 0.5mm-thick lightweight steel ‘U’ channels; 0.55mm-thick vertical ‘C’ wall studs were positioned behind the vertical joints. A calcium silicate backing board was loose laid against the back of the framework to give an air gap of 52mm between the rear surface of the product and the front face of the calcium silicate backing board. The tiles were mounted such that the cut edges were positioned along the outside edge of the specimen wings.

Horizontal joints were introduced in both the 1.0m-wide wing and 0.5 m-wide wings at a height of 0.5m from the trolley floor. Vertical joints were introduced in the 1.0m-wide wing, 200 mm and 800 mm from the finished surface of the 0.5 m-wide wing. The mounting details are shown in Figure B1 below (front view).

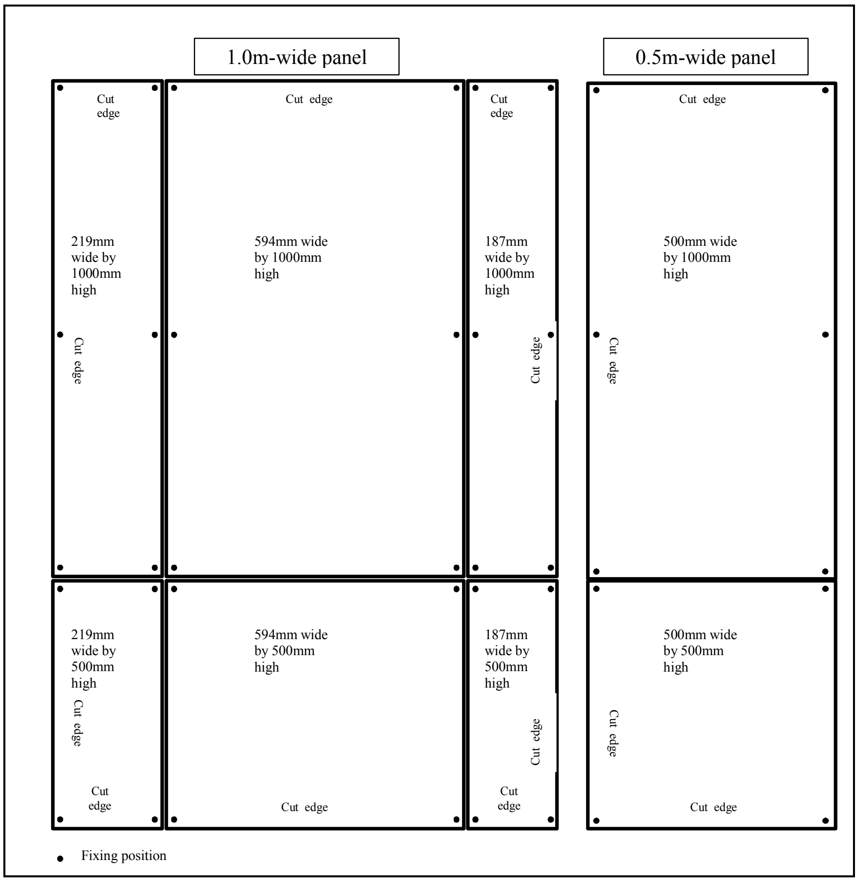

Figure B1: Mounting arrangement for rock fibre acoustic ceiling tiles

Plasterboard-faced PIR foam

The product was fixed to 38 mm-wide by 25 mm-thick timber battens. Battens were placed along the vertical edges of each specimen wing and an additional vertical batten was positioned 600 mm from the left-hand edge of the 1.0 m-wide wing. The product was screwed to the battens at 150 mm centres, the fixings were positioned approximately 19 mm from the edges of the board.

“Class 1” MDF board

The wings of the specimen were mounted directly against the U-channel of the SBI trolley (without mechanical fixings). A calcium silicate backing board was loose laid against the back of the product.

GRP rooflight material

The SBI equipment was placed in the arrangement used for testing products that are free-standing in their end-use application or that have a ventilated cavity in their end-use application, according to Clauses 5.2.2a) and 4.4.11 of EN 13823: 2002 (alternative configuration). This necessitated replacing the two side panels by half panels, covering only the upper half of the opening. The two wings were mounted in a right-angled test frame made from 25 mm-wide, 5mm-thick steel strip as shown in Figure B2 below. The test frame was positioned immediately behind the U-profile of the SBI test apparatus. A spacer frame and a 12 mm thick calcium silicate backing board were positioned behind each wing of the specimen to give an air gap of 100 mm between the rear surface of the specimen and the front face of the backing board. The angled support was held in position with rear clamps. The mounting arrangement is shown in Figure B2.

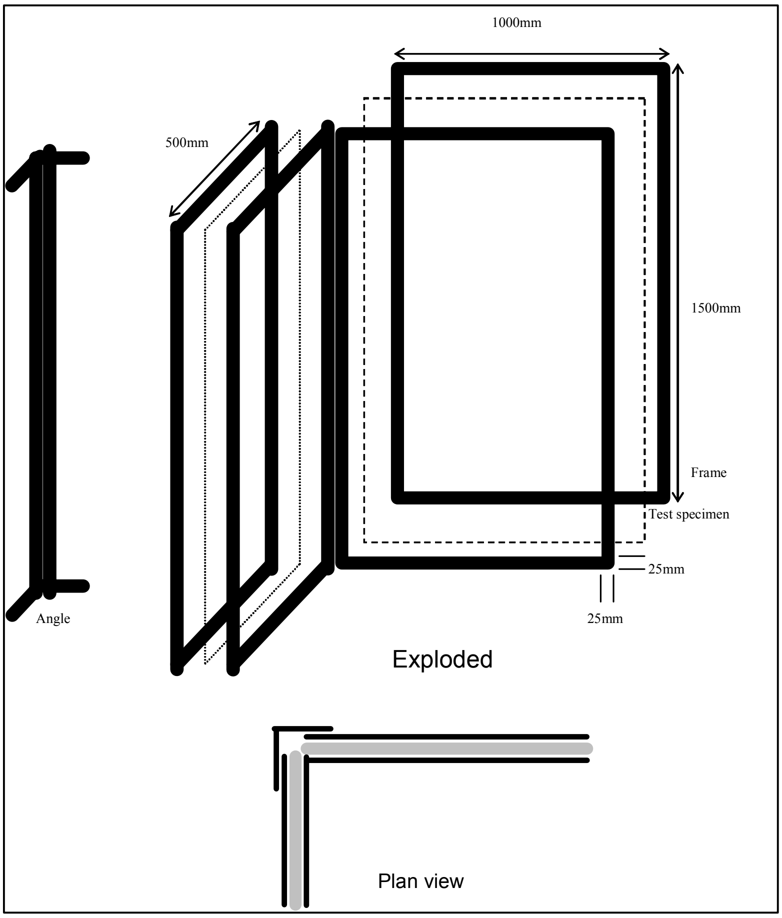

Figure B2: Mounting arrangement for GRP rooflight material and polystyrene prismatic lighting diffuser material

EPS ceiling tiles

The ceiling tiles were adhered to a plasterboard substrate meeting the requirements of Clause 5.2 of EN 13238:2001 [1]. The product was adhered to the substrate using a high performance ready mixed wallpaper adhesive suitable for the mounting of ceiling tiles.

The first tile was adhered to the bottom of the substrate along the edge nearest to the burner. Subsequent tiles were placed above and to the side of this tile until the substrate was completely covered. The cut edges of the product were therefore situated along the edge furthest away from the burner. No additional joints, other than those present between tiles, were introduced. A calcium silicate backing board was loose laid against the back of the substrate.

Prismatic polystyrene lighting diffuser material

The product was mounted in an identical manner to that utilised for the “Class 1” GRP rooflight material.

Appendix C – Mounting and fixing arrangements used in the ISO 9705 room corner tests

The products were mounted and fixed within the ISO 9705 room using a method typical of what would be found in practise and where possible, were agreed with manufacturers in advance of the testing programme. In all of the tests, the product was fixed to 38 mm x 50 mm timber battens, giving a 38 mm air gap or fixed to lightweight steel stud wall framing, giving a 50 mm air gap.

Product	**Fixing**
Rock fibre acoustic ceiling tiles	Steel Stud wall framing
Plasterboard-faced polyisocyanurate (PIR) foam	Timber Battens
Medium density fibreboard (MDF) (class 1)	Timber Battens
Glass reinforced polyester (GRP) roof-light material	Steel Stud wall framing
Expanded polystyrene (EPS) ceiling tiles	Timber Battens
Prismatic polystyrene lighting diffuser material	Steel Stud wall framing

Rock Fibre acoustic ceiling tiles

The tiles were standard size tiles of 1200 mm x 600 mm with a thickness of 20 mm. The sample was mechanically fixed using screw fixings at 300 mm centres onto a lightweight steel stud wall. The tiles were butt jointed with no other fixing used.

Plasterboard-faced polyisocyanurate (PIR) foam

The product was a manufactured board of 50 mm PIR foam insulation material, with a 12.5 mm plasterboard facing. The product was supplied as standard 1200 mm x 2400 mm panels. The sample was mechanically fixed in the room on timber battens at 600 mm centres as specified in the manufacturer's installation instructions. The material was butt jointed with only the joints on the rear wall skimmed with filler and scrim tape.

Medium density fibreboard (MDF) (Class 1)

The MDF board was 1200 mm x 2400 mm x 12.5 mm in size. The sample was mechanically fixed in the room onto timber battens.

Glass reinforced polyester (GRP) roof-light material

The material was supplied as flat sheet material of 1000 mm x 1200 mm x 1.0 mm. The material was mechanically fixed into the room onto lightweight steel stud wall framing using screw fixings.

Expanded polystyrene (EPS) ceiling tiles

Prior to fixing the ceiling tiles, the room was lined throughout with 12.5 mm plasterboard screw fixed onto timber battens at 600 mm centres. This formed the substrate for the tiles, which were glued to the plasterboard using high strength wallpaper adhesive. The tiles were 300 mm x 300 mm with a thickness of approximately 4 mm.

Prismatic polystyrene lighting diffuser material

The material was supplied as a sheet of 2400 mm x 1200 mm x 2 mm and was mechanically fixed within the room by screw fixing into lightweight steel stud wall framing.

Appendix D - Comparison of tube furnace data with SBI test and ISO room corner test data

Calculations

SBI test derived parameters

Total heat release and total CO_2 generated in the test were corrected for burner output in order to obtain the total heat release and CO_2 emissions for the test material (assuming that the heat and carbon dioxide yield from the burner is the same under test conditions as under calibration conditions).

All derived parameters for the SBI test data given in the following tables are calculated from the mean of three results for each material.

The mass of material consumed in the SBI tests was calculated from the heat released during the period specified divided by the effective heat of combustion for that material as measured in the tube furnace experiments under well ventilated conditions at 650-700 °C. For example, for MDF, mass burned in SBI test after 600 s = THR_{600s} / 14.93 MJ/kg (except for the Rock fibre acoustic tile – for which well ventilated flaming did not occur).

Yields of CO_2 (g/g) were calculated from the volume of CO_2 released during the period specified, converted to mass CO_2 and the mass fraction ratio calculated from the mass burned.

Yields of smoke (m^2/kg), were calculated from the smoke production during the period specified, and the area/mass ratio calculated from the mass burned.

Yields are calculated for the first 600 and the full 1200 seconds burn time.

ISO 9705 room corner derived parameters

For the room corner test data, the total heat release and total carbon dioxide have also been corrected by subtracting the total heat and carbon dioxide produced by the propane burner (assuming that the carbon dioxide yield from the burner is the same under test conditions as under calibration conditions).

The mass loss from the specimen has been calculated from the total heat release, divided by the effective heat of combustion measured in the tube furnace under conditions considered to be appropriate to the specific room-corner test. The CO_2/CO ratios in the calorimeter and tube furnace tests were used to make judgements of fire conditions in the calorimeter test. Appropriate effective heats of combustion were then selected from the tube-furnace data in order to calculate the mass of material consumed in the room corner test.

A complication of the calorimeter tests was that two burner outputs were used. For the first 600 seconds the burner was run at 100 kW. The output was then increased to 300 kW for a further period, the duration of which depended on the performance of the product being tested. This change in burner heat output tended to change the combustion conditions, which presented complexities when interpreting the overall test data. For this reason the calorimeter summary data have been presented in several different ways, as follows:

Evaluation A. Total period. The calorimeter data summarized over the entire test duration are expressed in relation to a heat of combustion figure from the tube furnace selected on the basis of the calorimeter CO_2/CO ratio.

Evaluation B. The overall mass burned in the test was calculated using two individual effective heat of combustion variables for the two phases of the test. The calculated mass consumed in each phase of the test were then summed

Evaluation C. The overall mass burned was calculated using the well ventilated value for heat of combustion obtained in the tube furnace.

The initial period and final period of the ISO room corner test were treated separately.

SBI test - tube furnace comparisons for: Rock fibre acoustic tile						
SBI test data						
Time from ignition (s)		THR (MJ)	Effective heat of combustion (MJ/kg) [a]	Mass burned (kg) [b]	Yield CO_2 (g/g)	Yield smoke (m^2/kg)
600s		0.839	16.04	0.0523	0.9911	778.1
			22.20	0.0378	1.3713	1076.6
1200s		1.301	16.04	0.0811	1.4336	856.9
			22.20	0.0586	1.9840	1185.9
Tube furnace data						
Test code	Temp (ºC)	Combustion mode [c]	Effective heat of combustion (MJ/kg)	Equivalence ratio (phi)	Yield CO_2 (g/g)	Yield smoke (m^2/kg)
t326	400	nf	8.92	0.49	0.5789	418.6
t324	400	nf	10.60	1.02	0.6279	427.3
t327	650	nf	12.60	0.60	0.8148	102.5
t328	650	nf	13.93	1.12	0.9625	77.1
t325	850	fl,vit	16.04	1.09	1.2757	57.1
t329	850	fl, ht	22.20	0.62	1.8478	38.5

SBI - tube furnace comparisons for: Plasterboard-faced PIR

SBI data

Time from ignition (s)	THR (MJ)	Effective heat of combustion (MJ/kg) [a]	Mass burned (kg) [b]	Yield CO_2 (g/g)	Yield smoke (m^2/kg)
600s	0.594	14.35	0.0414	1.3089	780.3
1200s	1.435	14.35	0.1000	1.5228	673.0

Tube furnace data

Test code	Temp (ºC)	Combustion mode [c]	Effective heat of combustion (MJ/kg)	Equivalence ratio (phi)	Yield CO_2 (g/g)	Yield smoke (m^2/kg)
1. Paper casing from plasterboard component						
t344	400	nf	0.92	0.14	0.3087	789.7
t345	650	fl, wv	14.35	0.56	1.4232	2.9
t346	650	fl,vit	11.06	1.23	0.9797	4.1
t343	900	fl, ht	13.24	0.42	1.5748	4.5
1. PIR foam component						
t348	400	nf	11.35	0.42	0.8119	1231.1
t349	700	fl, wv	24.13	0.54	2.2807	94.2
t350	700	fl,vit	18.43	1.43	1.4530	196
t347	900	fl, ht	24.69	0.50	2.4367	43.9

SBI - tube furnace comparisons for: Class 1 MDF

SBI data

Time from ignition (s)	THR (MJ)	Effective heat of combustion (MJ/kg) [a]	Mass burned (kg) [b]	Yield CO_2 (g/g)	Yield smoke (m^2/kg)
600s	4.215	14.93	0.2823	1.5327	390.0
1200s	8.931	14.93	0.5982	1.4853	394.0

Tube furnace data

Test code	Temp (ºC)	Combustion mode [c]	Effective heat of combustion (MJ/kg)	Equivalence ratio (phi)	Yield CO_2 (g/g)	Yield smoke (m^2/kg)
t356	400	nf	5.71	0.50	0.4459	551.8
t359	700	fl, wv	14.93	0.53	1.3321	56.7
t358	700	fl, stoich	9.02	1.17	0.7781	104.1
t360	700	fl, vit	7.60	1.46	0.6281	126.9
t361	850	fl, vit	8.66	1.67	0.7005	139.7
t357	900	fl, ht	16.39	0.54	1.6141	8.1

SBI - tube furnace comparisons for: GRP roof light material						
SBI data						
Time from ignition (s)		THR (MJ)	Effective heat of combustion (MJ/kg) [a]	Mass burned (kg) [b]	Yield CO_2 (g/g)	Yield smoke (m^2/kg)
600s		1.692	13.36	0.1266	0.9338	1963.7
1200s		2.161	13.36	0.1618	1.2931	1864
Tube furnace data						
Test code	Temp (ºC)	Combustion mode [c]	Effective heat of combustion (MJ/kg)	Equivalence ratio (phi)	Yield CO_2 (g/g)	Yield smoke (m^2/kg)
t330	400	nf	0.94	0.67	0.0589	880.5
t333	700	fl*, wv	13.36	0.53	0.8608	428.6
t334	700	fl*,stoich	14.09	1.09	0.865	597.6
t335	700	fl*, vit	12.61	1.64	0.7775	741.2
t332	850	fl*, vit	14.67	1.45	0.9092	572.9
t336	850	fl*, ht	19.38	0.56	1.5074	301.1

SBI - tube furnace comparisons for: EPS Ceiling tiles						
SBI data						
Time from ignition (s)		THR (MJ)	Effective heat of combustion (MJ/kg) [a]	Mass burned (kg) [b]	Yield CO_2 (g/g)	Yield smoke (m^2/kg)
600s		2.187	32.50	0.0673	2.6749	795.0
1200s		2.677	32.50	0.0827	2.8299	1146.1
Tube furnace data						
Test code	Temp (ºC)	Combustion mode [c]	Effective heat of combustion (MJ/kg)	Equivalence ratio (phi)	Yield CO_2 (g/g)	Yield smoke (m^2/kg)
t351	400	nf	0.68	0.69	0.0081	1556.1
t352	650	fl, wv	32.50	0.51	2.5893	359.4
t353	650	fl, stoich	29.48	0.94	2.3240	645.5
t354	650	fl, vit	23.46	1.42	1.7603	981.0
t355	850	fl, vit	25.88	1.34	2.0165	1005.8

SBI - tube furnace comparisons for: Prismatic polystyrene lighting diffuser material					
SBI data					
Time from ignition (s)	THR (MJ)	Effective heat of combustion (MJ/kg) [a]	Mass burned (kg) [b]	Yield CO_2 (g/g)	Yield smoke (m^2/kg)
600s	20.530	31.02	0.6618	2.4222	1323.3
1200s	58.713	31.02	1.8927	2.4293	1501.9

Tube furnace data

Test code	Temp (ºC)	Combustion mode [c]	Effective heat of combustion (MJ/kg)	Equivalence ratio (phi)	Yield CO_2 (g/g)	Yield smoke (m^2/kg)
t337	400	nf	0.71	1.16	0.0096	1393.3
t338	650	fl, wv	31.02	0.47	2.4354	539.1
t339	650	fl, stoich	32.27	1.04	2.5785	431.7
t340	650	fl, vit	25.43	1.36	1.9277	736.9
t341	850	fl, vit	27.08	1.36	2.0368	781.1
t342	900	fl, ht	36.42	0.52	3.0008	643.4

Footnotes to SBI-tube furnace comparisons

a Value for effective heat of combustion for the material derived from tube furnace data under well ventilated conditions

a Mass burned calculated from heat release for specified period divided by the effective heat of combustion for the material under well ventilated conditions.

b Combustion mode: nf = nonflaming; fl,wv = steady flaming, well ventilated; fl* = mainly flaming with short periods of non-flaming; fl,stoich = flaming under stoichiometric conditions; fl,vit = vitiated flaming; fl,ht = flaming at high temperature, well ventilated

ISO 9705 Room corner test/Tube furnace comparisons: Class 1 MDF

ISO 9705 room corner data

Venti-lation (%)	Time period and method of evaluation	THR (MJ)	Eff heat combust (MJ/kg)	Mass burned (kg) [a]	CO2/CO (Ratio)	Yield CO_2 (g/g)	Yield CO (g/g)	Yield smoke (m^2/kg)
100	Total period, ign - 681s Evaluation A [b]	113.97	10.05	11.340	2.29	0.8648	0.2406	260
	Evaluation B [b]	49.623 64.348	14.93) 7.60)	11.791	2.29	0.8317	0.2315	202
	Evaluation C [b]	113.97	14.93	7.634	2.29	1.2846	0.3575	312
100	Initial period at 100kW [c], ign -600s	49.623	14.93	3.324	6.38	0.9619	0.0973	209
	Final period at 300kW [d], 600-681s	64.348	7.60	8.467	1.74	0.7756	0.2841	267
12.5	Total period [e], ign -603s	41.940	7.60	5.518	2.99	0.6016	0.1282	248

Tube furnace data

Run code	Temp ºC	Combustion mode	Eff heat Combust (MJ/kg)	Phi	CO2/CO ratio	Yield CO_2 (g/g)	Yield CO (g/g)	Yield smoke (m^2/kg)
t356	400	nf	5.71	0.50	2.73	0.4459	0.1041	552
t359	700	fl, wv	14.93	0.53	13.36	1.3321	0.1307	57
t358	700	fl,stoich	9.02	1.17	4.57	0.7781	0.1084	104
t360	700	fl,vit	7.60	1.46	2.78	0.6281	0.1440	127
t361	850	fl,vit	8.66	1.67	2.00	0.7005	0.2225	140
t357	900	fl, wv, ht	16.39	0.54	131.4	1.6141	0.0078	8

a Mass burned calculated from heat release for specified period divided by the effective heat of combustion for the material derived from tube furnace data under appropriate combustion conditions.

b Evaluation A - the overall mass burned in the test was calculated using an average "effective heat of combustion" value (i.e. mass burned =THR/10.05 mJ/kg = 11.340 kg).
Evaluation B - the overall mass burned in the test was calculated using 2 individual "effective heat of combustion" values. For the first 600s of the test, 14.93 mJ/kg was used, and for the residual 81s of the test, 7.60 mJ/kg was used. The two masses then were summed (11.791kg) to calculate yields.
Evaluation C - the overall mass burned in the test was calculated using the well ventilated value for "effective heat of combustion". (i.e. mass burned =THR/14.93 mJ/kg = 7.634 kg)

c Material exposed to 100 kW for this period under well ventilated conditions. Mass burned calculated using THR/14.93 mJ/kg

d Material exposed 300 kW for this period under vitiated conditions, test terminated. Mass burned calculated using THR/7.60 mJ/kg

e Material exposed to 100 kW for this period under vitiated conditions. Mass burned calculated using THR/7.60 mJ/kg

Appendix E – Cost benefit assessment questionnaire

Part B to the Building Regulations: Control of the production of smoke and burning droplets: Cost benefit assessment of construction product manufacturers

The Office of the Deputy Prime Minister (ODPM) has recently begun the process of revising Approved Document B (Fire Safety) (AD B) to the Building Regulations and is considering a wide range of proposals and issues that have been raised. As such, the ODPM has contracted BRE to undertake a project to evaluate, for the purposes of the Building Regulations, the need, or otherwise, to include in AD B, provisions for greater control of smoke production and burning droplets from construction products that are used to form walls and ceilings.

Part of the work undertaken was to carry out a review to see:

- what regulations exist in other Member States relating to the control of smoke and burning droplets,
- what data is available regarding product performance in the Single Burning Item (SBI) test, and,
- what products are in current use.

BRE, on ODPM's behalf, is working closely with key stakeholders and has already canvassed views and input to this project through a workshop in December 2003.

Ultimately, ODPM intends to produce a Regulatory Impact Assessment (RIA) which sets out the costs and benefits of the proposals that result from the current ongoing revision of AD B. To better understand the impact that the possible options relating to the production of smoke and burning droplets will have on industry, BRE is undertaking a cost benefit type assessment through the key stakeholders steering group which includes a range of Trade Associations, professional institutions and other bodies. Therefore, we would be very grateful if you could complete the attached questionnaire and return it by 23rd July 2004 to;

Mr Richard Hartless
BRE
Bucknalls Lane
Garston
Watford
Herts WD25 9XX

Or by email ; hartlessr@bre.co.uk

Many thanks for your time.

1. Background information

Please could you provide some background information and indicate whether you are prepared for this information to be used generically in the final project report.

Name of person completing questionnaire	
Job title	
Company name	
Contact details	
Phone	
E-mail	
Trade Association	
Size of company (Micro <10 employees, Small 10-49, Medium 50-250, Large>250)	
Annual turnover (£m)	

2. Wall and ceiling lining products

Please could you provide details of products that you sell. How much is sold in the UK, and how much is exported (if any) to EU and non-EU countries? Add extra rows if required.

Generic class[1]	BS classification	European classification (smoke, droplet)	Annual sales in UK			Value of exports (£ million)	Export breakdown (%)		Comments
			Quantity	Unit (m^2, tonnes etc.)	Value (£ million)		EU	Non-EU	

[1] e.g. Wood-based, Paper, Plastic (cellular), Plastic (Thermoplastic), Plastic (Thermoset), Mineral wool etc.

3. Impact of possible options

3.1 Introduction

Please could you answer these general questions regarding the impact of the possible options.

Q1. What are your views on the risks posed by smoke and droplets produced by wall and ceiling lining products?

Wall and ceiling lining products in general
Wall and ceiling lining products produced by your company

Q2. Are clients and specifiers concerned about smoke and droplets produced by wall and ceiling lining products?

Q3. Would you support the possible option to introduce a requirement into Part B to control smoke and droplets? YES/NO

Please provide details, for example: Do you think such a proposal would reduce the risks (i.e. lead to lives being saved and injuries prevented)?

Q4. In <u>general terms</u> what would be the impact of such a requirement on your business? Such impacts could be both positive (benefits through increased sales) and negative (increased costs).

3.2 Specific impact

There are basically three options under consideration;
(i) Do nothing, or,
(ii) All ceiling and wall lining products achieving Euroclasses A2, B, C or D will need to achieve an additional classification of s1, d0, or,
(iii) All ceiling and wall lining products achieving Euroclasses A2, B, C or D will need to achieve an additional classification of s2, d1.

The latter two however, represent a change to the current regulatory system, for which information is being sought. Please could you answer these questions regarding the impact these possible options would have on your business. Product testing costs etc. are covered in section 3.3 below.

Q5. Do you anticipate to **<u>lose</u>** sales as a result of these possible options? Can you specify which products would be affected, and, if possible, quantify (in % terms) what this loss could be?

Option (ii)	*Option (iii)*

Q6. Do you anticipate to **<u>gain</u>** sales as a result of these possible options? Can you specify which products would be affected, and, if possible, quantify (in % terms) what this gain could be?

Option (ii)	*Option (iii)*

Q7. Do you foresee any other impacts (either positive or negative) as a result of these possible options (product testing is covered in Section 3.3. below)?

Option (ii)	*Option (iii)*

3.3 Product testing

Adopting either or a combination of the above possible options will require that wall and ceiling lining products will need to be tested to the European fire test standards to obtain a relevant classification, since there is no means of attaining equivalent smoke and droplets classes using the current BS 476 fire test methods. This could have an impact on your business.

Please could you answer the following questions regarding this.

Q8. Could you specify and quantify the cost impact of product testing on your business? Are they continuous (i.e. incurred each year) or one-off (tick which one applies)?

	Cost (£k)	**Continuous**	**One-off**
Third party product certification, factory production control certification or product testing			
Manufacturer's documented factory production control			
Re-tooling or product re-engineering to meet new standards			
Revisions of product literature and promotional information for clients			
Staff training and familiarisation			

Q9. Could any of the above costs be absorbed in the normal review cycle for product development and marketing?

Q10. What time period would you anticipate would be necessary to enable the EN testing of your full product range(s) ?

Q11. Do you anticipate any cost savings?

Nature of cost saving	**Saving (£k)**
Reduced need for multiple product testing	
Reduced need for multiple product variations	
Reduced cost of quality management, overheads, packaging and other trade related costs	

Q12. Do you anticipate an increase in exports as a result of the possible introduction of these options? Can you quantify this?
