Sandwich panels for external cladding – fire safety issues and implications for the risk assessment process.

A report by

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Executive Summary

- This report demonstrates that fire safety guidance is essential for external sandwich panel cladding – the building envelope.

- The report maintains that the risk posed by combustible-cored sandwich panels in the external building envelope, as well as that for internal partitioning, should be recognised by building owners, employers and designers for the purposes of their risk assessments. It is contended that none of the risk assessment guidance currently available helps the specifier to come to a decision as to whether or not the risk, in using combustible-cored panels is acceptable

- Combustible-cored sandwich panels are today being used in building envelopes other than those for low life risk warehousing and temperature-controlled environments. Schools, hospitals, prisons, retail outlets and other public buildings make use of this type of construction without appropriate regulation or guidance.

- Sandwich panel construction offers fast track, cost effective energy efficient building envelopes, with an array of aesthetically pleasing shapes and finishes. Sandwich panels which incorporate non-combustible insulation cores and properly attached steel faces, can be safely specified in all relevant building applications.

- Sandwich panels with combustible foamed plastic insulation cores – polystyrene and polyurethane materials – carry the risk of being a potential hazard in fire. Official DETR guidance currently recognises this risk in Appendix F of Approved Document B of the Building Regulations Fire Safety 2000 Edition, but only for internal structures. However it is advisable that a risk assessment be carried out to determine the suitability of combustible-cored sandwich panels for external cladding and in other applications.

- The Report reviews a number of ad hoc fire tests currently being used to provide data on the fire performance of sandwich panels. It demonstrates that the fire sources used in these tests are smaller than the fire sources generally present in UK buildings. Therefore the data obtained from such tests could give employers, designers and regulators a misleading view of fire safety.

- Where a risk to property and business economies exists, and where a risk of environmental contamination [air and water] is identified, then employers and designers should be appraised of the advantages of choosing sandwich panels with non-combustible insulation cores.

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GLOSSARY OF TERMS

Fire terms

Fire effluent
The total gaseous, particulate or aerosol effluent from combustion products.

Fire hazard
The potential for loss of life or injury and/or damage to property by fire

Fire risk
Probability of fire causing a loss of life or injury and/or damage to property

Fire load
The sum of the calorific energies which could be released by the complete combustion of all the combustible materials in a space, including the facings of the walls, partitions, floor and ceiling.

Fire load density
The fire load per unit floor area

Fire retardant
A substance added, or a treatment applied to, a material in order to suppress, significantly reduce or delay the combustion of the material

Fire risk
Probability of fire causing a loss of life or injury and/or damage to property

Flashover
The rapid transition to a state of total surface involvement in a fire of combustible materials within an enclosure

Fully developed fire
The state of total involvement of combustible materials in a fire

Heat release rate
The calorific energy released per unit time by a material during combustion under specified test conditions

Non-combustible
Not capable of undergoing combustion under specified test conditions

Reaction to fire
The fundamental behaviour of a material in fire described in terms of rate of heat release, potential energy release, surface burning, smoke release, tendency to produce burning

droplets or particles.

Resistance to fire
The ability of an element of building construction to fulfil for a stated period of time the required load-bearing function [resist collapse], integrity [resist fire penetration] and insulation [resist the transfer of excessive heat]

Product term

Sandwich panel
A composite product comprising outer thin rigid metal sheet (usually coated steel or aluminium alloy) either side of a bonded core of insulating material.

Core insulating materials

Polyurethane foam (PUR)
An organic insulation material made from a reactive mixture of two principal liquid components and a number of additives, to produce highly cross linked polymers with a closed cell structure. The liquid components may be a hydroxyl group of a polyester, polyether, or polyalcohol with a di-isocyanate.
The foam produced will not normally be ignited by a small heat source, but a larger flame will cause ignition and fire spread, with abundant smoke and toxic decomposition giving off hydrogen cyanide, oxides of nitrogen, and carbon monoxide.

The Flash Ignition temperature is 320-420 degrees C. The self ignition temperature is 420-550 degrees C.

Polyisocyanurate foam (PIR)
Polyisocyanurate is made in the same way as polyurethane, but the ratio between the components and the type of additives is usually different, to produce a polymer containing chemical bonds with a higher temperature resistance.

The increase in the decomposition temperature depends entirely on the concentration of these bonds and on the aromatic content. Process control factors are more critical than with PUR. The smoke and decomposition products are similar to PUR.

Polystyrene foam
Expanded Polystyrene (EPS) is an organic insulation material made by the addition of catalysts and a blowing agent (normally pentane) to a styrene monomer derived from crude oil, by a combination of ethylene and benzene. The bead is then made into a foamed product containing entrapped air.

Extruded Polystyrene (XPS) is manufactured, using the same materials as EPS, by a continuous extrusion process where blowing agents are added to produce a closed cell material. The process creates superior properties to EPS.

The flash ignition temperature is 290-350 degrees C. The self ignition temperature is 490 degrees C.

When exposed to a small flame, polystyrene melts and shrinks away from the heat source. A larger heat source will produce flaming molten droplets and rapid emission of dense black smoke/soot.

Stone woo]
Stone or rock wool is produced by melting naturally occurring rock with coke and dolomite and/or slag. The molten rock is formed into stone wool by contact with spinning wheels. The woollen structure entraps air, and is bonded together with cured resin, to form non-combustible insulation in a variety of densities with very low calorific content. The fibre direction can be selected to optimise shear and tensile strength properties suitable to the application.

1.0 INTRODUCTION

1.1 Sandwich panels are being extensively used in the external envelope and internal partitioning of single storey retail, industrial and storage buildings. They are also being used in some hospital, prison and school buildings. Such panels are quick to erect, energy efficient, aesthetically attractive and require minimal maintenance.

1.2 It is widely known that combustible-cored panels present a fire hazard. The specifier wants to know what criteria to use when specifying such panels. Similarly the employer wants to know what criteria should be applied if the building, occupied by employees for whom he/she is responsible, comprises combustible-cored panels in the external envelope

1.3 Sandwich panels with combustible cores of foamed plastic, e.g. expanded/extruded polystyrene foam or polyurethane foam can contribute to the severity and speed of fire development[1] and this has led to massive fire losses and business interruption.

1.4 In the food processing industry alone the fires have been many and expensive – 39 fires were reported to the Fire Protection Association• in the period 1992-97, while there were 24 large fires between January 1996 and December 1997 which resulted in a total cost of £24 million excluding business interruption.

1.5 The passive and active fire precautionary recommendations of the insurer are often more severe than those of the life safety regulator. The insurer is concerned with reducing damage to the building and contents, not only during the period in which occupants are escaping (the prime interest of the life safety regulator) but

• only fires on premises with UK insurance contracts are part of FPA data.

also afterwards when more fire damage may occur. The insurer wants higher periods of fire resistance and requires more reliance on the use of non-combustible materials and fire suppression systems than the life safety regulator.

1.6 Combustible-cored sandwich panels have been implicated as contributors to life loss, notably in the fire in the Sun Valley food-processing factory in Hereford in 1993 in which two fire-fighters died.

1.7 Following the Sun Valley fire, the DOE (now the DETR) and the Home Office sponsored research into the fire behaviour of sandwich panels and this work continues. The Fire Research Station (now Fire Risk Sciences) of the Building Research Establishment has carried out research and several reports have been produced [2,3,4].

1.8 The Fire Brigades Union, which represents the interests of fire fighters and others placed at risk by fire in buildings, is justifiably concerned about the life risk associated with plastic foam cored sandwich panels used in buildings. It has been foremost among those trying to influence the regulatory and control authorities to raise awareness of the limitations and appropriate use of such panels.

1.9 The Fire Engineers Journal has published a three-part series of papers 'When are sandwich panels safe in fire?' These are reproduced as Annex 1 of this Report. by kind permission of the Institution of Fire Engineers. Part 1[5] [6] describes panel advantages, potential problems, fire safety objectives and presents a simple way of calculating and comparing the fire load of panels and fire load of building contents. Part 2[6] deals with the prevention of panel collapse and presents a method for calculating catenary forces developed in ceiling panel faces when properly fixed. Part 3[7] looks at fire scenarios and fire testing, gives a checklist for designers, and recommends caution in the use of combustible-cored sandwich panels. Some engineering principles and good practice are illustrated elsewhere[8]. A book[9] prepared by a joint working group of the ECCS and CIB will include much useful guidance on fire safe design of sandwich panels.

1.10 The Loss Prevention Council has prepared a code of practice[10] which covers the design and use of sandwich panels in the food and drink industry. This code recommends that a risk assessment should consider ease of ignition and production of smoke and toxic products for panels as two of the important risk factors. A table is given which shows for each core type a number of fire factors, and this is reproduced below.

Core type	Fire load *note 1*	Ease of ignition	Fire spread	Fire resistance *note 2*	Thermal insulation *note 3*	Smoke production *note 4*
Expanded	5	5	5	5	2	5

polystyrene						
Polyurethane foam	5	5	3	5	1	4
Polyisocyan-urate foam	5	3	3	4	1	4
Modified phenolic foam	5	2	3	3	?	3
Glass foam	1	1	1	1	?	1
Mineral wool	1	1	1	1	3	1

Key: ? = data not yet available.

Notes:

1. These comparisons are based on current designs and construction. Developments in design, particularly joint construction, may lead to improved fire performance.

2. Fire resistance is measured for a complete construction, including the supporting structure and joint detail. Even core types rated 1 for fire resistance will only achieve that if properly constructed and installed.

3. Thermal insulation in this table refers to the thermal insulation provided by the panel during normal use and not to the insulation value under fire conditions as defined in 3.3.1 (of the code). The values given are intended as a guide to the relative insulation properties of the different cores. In practice, equivalent insulation performances may be obtained by increasing or decreasing the thickness of the core.

4. These values give an indication of the relative levels of smoke and toxic gases produced by the core material once exposed during a fire.

TABLE 1. Fire data for composite panels.

[The numbers give an approximate comparison of the performance or properties of each type of panel (1 is the best performance, 5 is the worst)].

The kind of information given in Table 1 is now also given in Construction Design and Data Sheet No 6.2.1 and 6.4.1 in the new LPC design guide[11]

The LPC code of practice also includes data on fire load of panel core materials which shows that the fire load of sandwich panels can represent a large addition to the fire load of the building contents. These data are important and are reproduced in Annex 3 of this Report. The annex shows that in a flat roofed building 40 m x 40 m x 10 m high externally clad with 50 mm thick PUR/PIR panels the fire load of the panels represents more than one third of the fire load of the contents assuming the building is in the low fire load category i.e. has a fire load density of 300 MJ/m^2 of floor area.

1.11 In parallel the European Division of the International Association of Cold Storage Contractors has produced a design guide[12] which deals with insulated envelopes for temperature controlled environments. This 250 page guide recognises the fire risk of plastic cored sandwich panels and recommends a risk assessment approach as part of a fire engineering study. It also advocates a panel labelling scheme which is intended a) to prevent panels with the wrong fire characteristics being installed in the wrong application and b) to inform fire-fighters of the presence and location of hazardous panels so that they can modify their firefighting strategy. The strategy may include the option of not entering the burning building because of the unacceptably high life risk.

1.12 The recently published Approved Document AD B Fire Safety – 2000 which takes effect in July 2000 provides official technical guidance for fire safety in new and altered buildings in England and Wales[13]. It includes Appendix F Fire behaviour of insulating core panels used for internal structure, which recognises that internal panels having cores of polystyrene or polyurethane foam pose a unique combination of problems for fire-fighters namely:

- hidden fire spread within the panels
- production of large quantities of black toxic smoke and
- rapid fire spread leading to flashover.

1.13 AD B Appendix F, reproduced as Annex 2 in this Report, also highlights the stability problem i.e. irrespective of panel core material, all panel systems are susceptible to delamination of the steel facing, collapse of the system and hidden fire spread behind the system.

1.14 AD B makes it clear that mineral fibre cored panels can be safely used in all applications provided that panel stability is assured, but there is little useful simple guidance on where and how combustible-cored panels can be safely used other than as enclosures used for food storage and processing.

1.15 To decide where plastic foam cored panels can be safely used internally AD B suggests that a risk assessment is made in the following way:

- identify fire risks within the enclosures formed by the panel system
- remove the risk
- separate the risk from the panels by an appropriate distance
- provide a fire suppression system for the risk
- provide a fire suppression system for the enclosure
- provide fire resisting panels
- specify appropriate materials/fixing and jointing systems.

1.16 Before examining the practical difficulties encountered in making such a risk assessment it is important to note that AD B suggests that the designer, builder or manager of most buildings incorporating sandwich panels should follow the guidance in Chapter 8 of the IACSC document (intended for temperature controlled environments) which, again, reflects a risk assessment approach as an alternative to meeting prescriptive requirements

1.17 This risk assessment approach may well be appropriate for industrial cold stores, where clearly identifiable fire hazards exist, but for other kinds of buildings where the fire load of the building contents or fire hazard is not in discrete areas, the risk assessment approach is more difficult and may require a different set of criteria.

1.18 The IACSC guide provides much practical guidance on fire precautions of the kind found in traditional codes of practice such as the BS 5588 series. It introduces the subject of fire safety engineering as an alternative to prescriptive guidance and touches on the subject of risk analysis.

1.19 This Report contends that the information on risk analysis given in the IACSC guide for temperature controlled environments is not helpful to a specifier or manager of the external building envelope who needs to know under what sets of conditions it is safe, or unsafe, to use plastic foam cored sandwich panels.

1.20 A worked example is given for part of a food processing factory in which numbers are assigned to i) area of building according to the magnitude of fire load (high, high medium, low medium and low) and ii) value of probability of ignition according to risk (high, medium and low). The risk hazard probability is then calculated thus:
Risk hazard probability = numerical value of fire load hazard x numerical value of probability of ignition.

Note that it is confusing to be confronted with probabilities greater than unity and the term ‘risk hazard’. The total risk for a particular internal wall is then calculated by summing the maximum risk from either side (for unexplained reasons). The total risk is then, without justification, arbitrarily related to fire resistance as periods of integrity and insulation according to BS 476: Part 22. The external walls are automatically assigned a 0:0 rating i.e. they require no fire resistance. <u>This approach, of relating risk hazard to fire resistance, ignores the heat release, smoke production and toxic hazard of combustible-cored panels.</u>

1.21 The hazard of plastic foam insulation has been recognised for many years[1]. It is generally acknowledged, for example, that it is unacceptable to use expanded polystyrene foam as an internal lining without a fire protecting layer. BS 6203[14] suggests (Clause 5.2) that 9 mm thick plasterboard can be used to delay ignition as long as the integrity of the facing is preserved. In Clause 5.5 it is stated that “in a flaming fire expanded polystyrene materials produce more smoke than most other materials” and that “in general the density of smoke produced from burning expanded polystyrene material containing flame retardant additives is higher than that from untreated expanded polystyrene materials”.

1.22 The IACSC guide recognises the fire hazards posed by metal faced sandwich panels with expanded polystyrene cores and recommends that individual panels should be subdivided with non combustible fire breaks. There is no test data evidence that these so called hybrid mixed core panels behave satisfactorily in fire.

1.23 The IACSC guide as referenced in Appendix F to AD B provides no suggestions on how to reduce the hazards and risks associated with polyurethane and polyisocyanurate foam cored panels.

1.24 As noted by the Building Research Establishment in a recent report[4] for the Home Office, sandwich panels are being specified in non-industrial buildings and there is particular concern about their safety when used to clad hospitals, schools and public assembly buildings.

1.25 Fire risk assessment is now a requirement in the building approval process, but while it is generally recognised that combustible-cored sandwich panels pose a fire risk, there is no explicit guidance on how a risk assessment should be carried out, taking their presence into account.

1.26 Most building designers are content to follow the minimal guidance in AD B for the majority of buildings. It appears that if sandwich panels are specified in <u>any building,</u> the designer is encouraged to carry out a risk assessment using guidance taken from a guide prepared by, and for, the cold storage industry. Furthermore this is a guide which does not recognise the hazards of heat, smoke and toxic combustion products produced by plastic foam cored sandwich panels.

1.27 This Report examines two important aspects. First, some of the difficulties in making a risk assessment which is sufficiently robust and sensitive to have credibility. Secondly, whether or not current fire tests used on sandwich panel assemblies are representative of real fire scenarios. The two aspects are related: if it proves to be the case that the risk assessment procedure is unworkable, then the designer will continue to rely on the results of ad hoc tests many of which do not adequately challenge the test specimens.

1.28 Designers, specifiers and employers should be aware of European developments affecting responsibility for product safety. The European Commission's Precautionary Principle is concerned with the dilemma of balancing the freedom and rights of individuals, industry and organisations with the need to reduce the risk of adverse effects to the environment, human, animal or plant health. A recent document from the Commission[15] can be interpreted to mean that if there is any doubt about the safety of a product, the manufacturer may be liable.

2.0 FIRE RISK ASSESSMENT

2.1 Fire risk assessment is not a new technique. The process of matching the passive and active fire precautions to the perceived life risk in and around buildings is a process that has been used for hundreds of years. The process is also used by fire insurance surveyors. Fire risk assessment is used in several life safety regulatory schemes. It forms part of a fire engineering study for new buildings and alterations to existing buildings under The Building Regulations 1991 if the designer chooses not to use the prescriptive guidance in AD B. It also forms part of the fire certification process for buildings under The Fire Precautions Act 1971.

2.2 More recently risk assessment has been recognised as the vital ingredient in assuring safety in the workplace under the Fire Precautions (Workplace) Regulations 1997 as amended. These regulations make it clear that the employer has the ultimate responsibility for the safety of his employees in case of fire. The risk assessment is made by the employer or his agent and is vetted by the fire authority and, if a process risk is present, by the Health and Safety Executive.

2.3 NB. As the employer now has a statutory duty to carry out an 'appropriate' risk assessment it is essential that those responsible have access to appropriate guidance on the risk assessment process. The legal implications of failing to do so could be severe. In the event of a fire which affects life safety, employer liability will undoubtedly be a key issue.

2.4 The workplace regulations do not give a format for the risk assessment but the Home Office "Fire Safety. An Employers Guide" [16] suggests a five step approach which is shown in Figure 1. Plastics, rubber and foam such as polystyrene or polyurethane are given as items that should be included in the list of sources of fuel in Step 1 and large areas of flammable or smoke-producing surfaces on either walls or ceilings would represent a high fire risk category for assessing means of escape in Step 3.

2.5 Aside from the Home Office employers guide it is interesting to note the diverse range of risk assessment options available. A recent Seminar paper[17] by the Chief Fire Officer of West Midlands states that "a bewildering array of differing methodologies for the completion of a risk assessment exist and with them guidance" and he cites a dozen documents. This makes it difficult for the employer or his agent and the local authority officer responsible for scrutinising the assessment to approach the problem in a common way.

2.6 The Regulations bring a large number of new workplaces under the control of the fire authority, for instance museums and art galleries, uncertificated hotels and uncertificated parts of schools and hospitals. The Home Office wishes to ensure that the fire brigade inspects premises of the type which represent the highest risk.

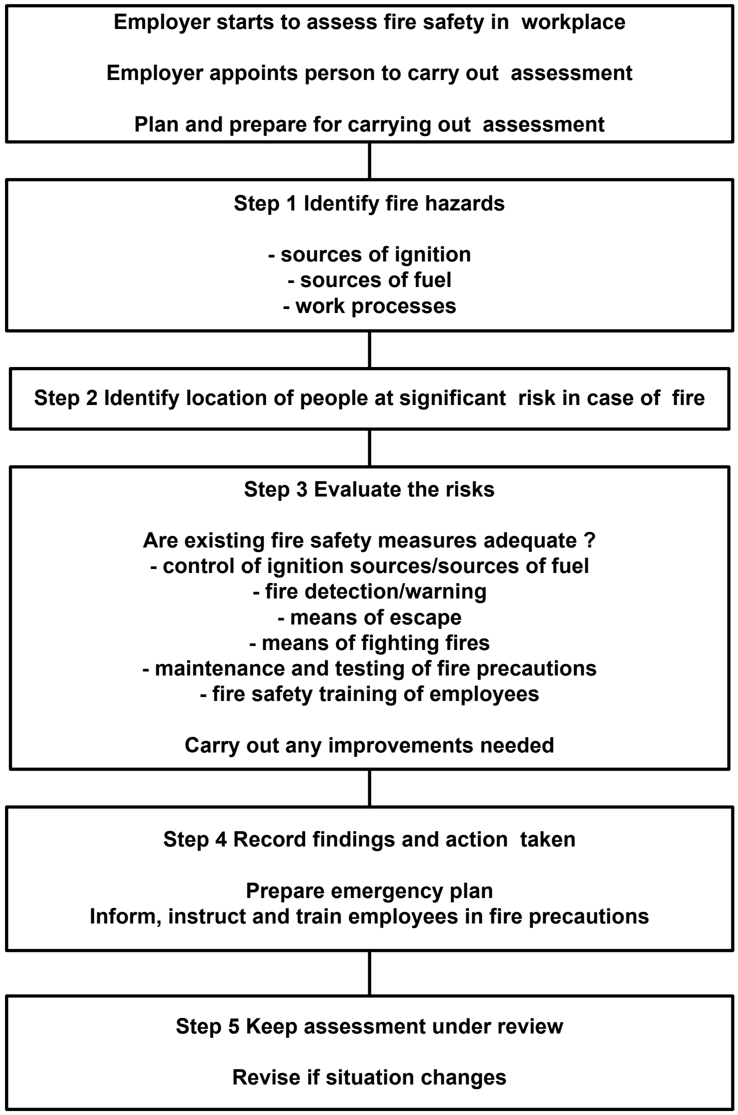

Figure 1 Flowchart of an action plan for risk assessment (taken from HSE guide for employers)

It has been suggested[18] that the Home Office will issue guidance on the development of risk assessment based inspection plans to assist in this. With this increased workload it is important that the fire authority has the best available guidance for checking risk assessments.

2.7 There are many definitions of risk assessment. The definition given in Reference 17 is repeated below

> "A risk assessment is a systematic and structured evaluation of workplace tasks, processes or features of the premises that may cause harm. It is carried out to identify any significant hazards that may exist and evaluate the level of risk to which persons may be exposed. This enables decisions

to be made on the effectiveness of any existing control measures or the need for further provision".

Although this is slanted toward the workplace it reflects the essence of risk assessment: to identify all the hazards and evaluate the attendant risks (i.e. assess the consequences of the hazard occurring).

2.8 Another important document which gives a structured approach to risk assessment is BSI Draft for Development 240[19]. DD 240 states that the possible consequences of failures in the fire protection systems and management procedures should be considered. For the identification of hazards it suggests that the following factors are considered

- general layout
- potential ignition sources
- nature of activities
- anticipated occupancy
- materials of construction
- combustible contents
- any unusual factors.

It should be noted that 'materials of construction' feature in the above list so the presence of hazardous building products, such as plastic foam cored sandwich panels, should certainly be included in the assessment.

2.9 According to DD 240 and the corresponding ISO documents, a life risk assessment should involve a 3-step analysis.

i) Determine the nature of the fire effluent (i.e. temperature, opacity and toxicity of the combustion products) and the location of the effluent in the building.

ii) Determine the behaviour of the occupants and their location in the building.

iii) Compare data obtained in i) and ii) to establish if the conditions are tenable.

The analysis is carried out as time proceeds from time of ignition for all locations in the building

2.10 With regard to quantifying the risk DD 240 recognises that a probabilistic risk assessment (PRA) is complex. PRA also suffers from the fact that there is a paucity of data on, for example, frequency of fire starts in certain parts of buildings. Note that while there are data on the probability of fire starting in some occupancies, such data are not sufficiently focused on the initiating hazard. Therefore they do not provide a suitable basis on which to assess the impact that a building product, for example a sandwich panel, has on the fire phenomena or life threat scenario.

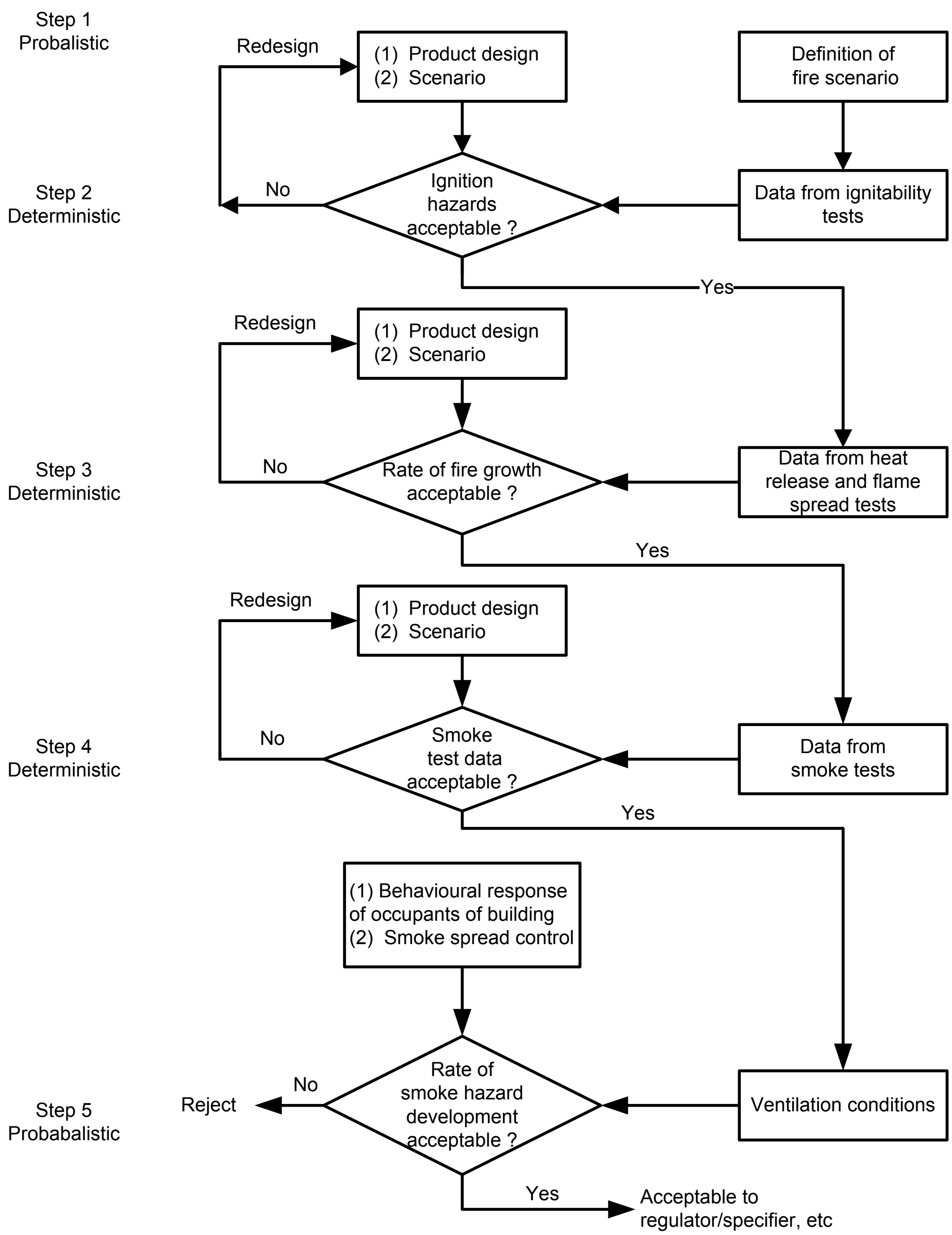

Figure 2 Decision tree for fire hazard assessment (taken from ISO/TR 11696)

2.11 Most fire safety engineers working in the building industry have never made a probabilistic risk assessment, and it is highly unlikely that the building owner, occupier or employer will have the expertise and data to make a PRA. This means that the risk assessment has to be qualitative with a large dependence on rules, prescriptive guidance and professional judgement. The idea, promoted in the IACSC design guide, that a meaningful quasi-probabilistic risk assessment can be made is impractical.

2.12 If DD 240 does not give guidance on how to assess the risk posed by a building product, is it possible that other guidance is available? The International Organisation for Standardisation (ISO) has prepared Technical Report 11696 on how to assess reaction to fire test results for construction products[20, 21]. Part 1 deals with the application of test results to predict performance of internal linings and other building products. It should therefore be relevant to a consideration of the hazard presented by combustible-cored sandwich panels used in the same building context. Part 1 shows how results of the ISO toolkit of fire tests can be extended by the use of mathematical modelling but it is recognised that only a relatively small number of people and organisations are able to use the test data in this way.

Part 2 of Report 11696 is for people who do not have the ability or computer facilities for modelling. It adopts a fire hazard approach using a decision tree which includes the 5 steps shown in Figure 2. Evaluation of the factors affecting fire growth and their importance, which are listed in the report, shows that the guidance is too complex to be of practical use to those responsible for carrying out risk assessment in buildings. This is confirmed in the scope of Part 2 which states that the guidance is aimed at material manufacturers and converters, designers, wholesalers and retailers, specifiers and regulating bodies, and consumer representatives.

2.13 To illustrate the difficulty of making an appropriate risk assessment which takes account of the hazard of combustible sandwich panels, this Report briefly looks at the problem qualitatively in the following section.

3.0 A QUALITATIVE UNDERSTANDING OF THE HAZARD OF COMBUSTIBLE-CORED SANDWICH PANELS

3.1 The core material context

3.1.1 All plastic core materials are intrinsically combustible, even with the addition of flame retardants. However the behaviour of the core material will be modified by the presence of any facing, i.e. the core's context

3.1.2. When a combustible core is directly exposed (e.g. as with a lining of polyurethane or polystyrene foam with or without a facing of paper or aluminium foil), an extremely hazardous condition may be caused even though a good result may be obtained in the British Standard test for surface spread of flame. This difference is mainly because the intensity of thermal radiation used in the BS test is less than the level of radiation experienced in severe local fires or fires which have gone beyond flashover.

3.1.3 When the core has two metal faces, as in structural sandwich panels, the fire behaviour is modified. The best behaviour is achieved when the facings are steel, assuming the facings are properly fixed.

Steel melts at around 1500degC whereas combustion gas temperatures in building fires rarely exceed 1200degC, hence steel faces do not melt in real fires . Nor is the oxidation rate of steel at the elevated temperatures reached in fires a limiting criterion – tests have shown that faces approximately 0.8 mm thick have resisted the severe ISO 834 time-temperature exposure used as a basis of fire resistance testing for more than 4 hours. There are many examples of steel faced panels with non-combustible cores of stone wool achieving well in excess of 2 hour fire resistance, provided that the faces are suitably fixed and supported.

3.1.4 Sandwich panels with aluminium faces behave differently to those with steel faces. Because aluminium alloy melts at 650degC a sandwich panel with aluminium faces will lose its fire exposed facing when the flames or hot gases adjacent to the face reach a temperature of around 650degC. This temperature may result from direct flame impingement from a localised fire or from flashover which generally occurs when the hot gas layer under the ceiling or roof reaches 600degC. The high thermal insulation of the core material and the negligible heat capacity of the metal face means that there is little difference between the temperature of the fire gases and the temperature at the face/core interface. Once the aluminium face has melted the core, if it is combustible, will contribute heat and smoke, assuming the panel joint had not failed earlier on. However, depending on the thermal insulation and burning/charring characteristics of the core material it may be some time before the panel as a whole is penetrated by the fire.

3.1.5 Good integrity (resistance to penetration or collapse) will be beneficial in fire separating elements, such as internal fire walls and external walls near the site boundary which require fire resistance, but disadvantageous in some roofing applications where collapse of the roof cladding serves beneficially to vent the heat of the fire which reduces lateral fire spread and assists fire fighters. Such venting would not occur early enough to prevent lateral spread of smoke and the damage this entails. However, because aluminium faced panels can be penetrated by fire they should not be used in external walls or roofs where adjacent to a fire separating wall.

3.1.6 Thus the fire behaviour of combustible-cored sandwich panels depends critically on the behaviour of the facings and panel joints. Specifiers should insist on having evidence of acceptable fire behaviour for realistic fire scenarios. Test evidence from the ISO 9705 room test should assist in this.

3.2 The mechanical hazards of sandwich panels.

3.2.1 There are two potential fire hazards associated with sandwich panels. The first is the missile hazard presented by metal faces that become detached unexpectedly in the pre-flashover stage of a fire. This is dangerous for fire fighters. This hazard can be avoided where panels have their faces mechanically attached to the supporting structure and this feature is particularly important for large ceiling panels. Effective means of attaching the faces of sandwich panels are shown in Annex 1

3.3 The combustible hazard of sandwich panels

3.3.1 This hazard arises from the combustible nature of the core material. If the core material is non-combustible, e.g. stone wool, there is no hazard. With combustible cores the hazard arises from the potential high rate of heat release and production of large amounts of smoke and toxic gas and, in the case of foamed polystyrene, the production of flaming molten droplets which can cause secondary fires.

3.3.2 Theoretically, if the core material was hermetically sealed between the steel faces and remained so during a fire, a combustible core material would decompose by pyrolysis and, arguably, would add little to the hazard of the initiating fire. However in practice it is likely that an initiating fire which is representative of the size of fire source found in real buildings will cause distortion of the fire exposed steel face due to thermal stresses and associated thermal expansion.

3.3.3 Distortion of panel face may cause panel joints to open up thus allowing air to enter the panel cavity to support combustion within the panel adding to the fire severity and making fire extinguishment difficult for fire fighters. After flashover the amount of distortion in the panel support structure and the panel faces may be so great as to result in the core material becoming fully involved in fire. The additional heat added to the initiating fire by panels with combustible cores can be substantial (see 1.10 and Annex 1)

3.4 Vertical transport of panel effluent

3.4.1 Panel face distortion may also allow pyrolysis gases to travel within the panel to exit some distance away, perhaps into an upper storey. This is of concern because plastic foam cored panels are being used in life risk buildings of more than one storey, such as schools, nursing homes, hospitals and prisons. There appears to have been very little study of this mode of fire effluent transfer and it is noteworthy that existing ad hoc fire tests (reviewed later in this Report) are not designed to examine this phenomenon.

3.4.2 It would seem sensible to develop a fire test specification which assesses the vertical transport of combustion gases from one storey to another, via the panel cavity and panel joints.

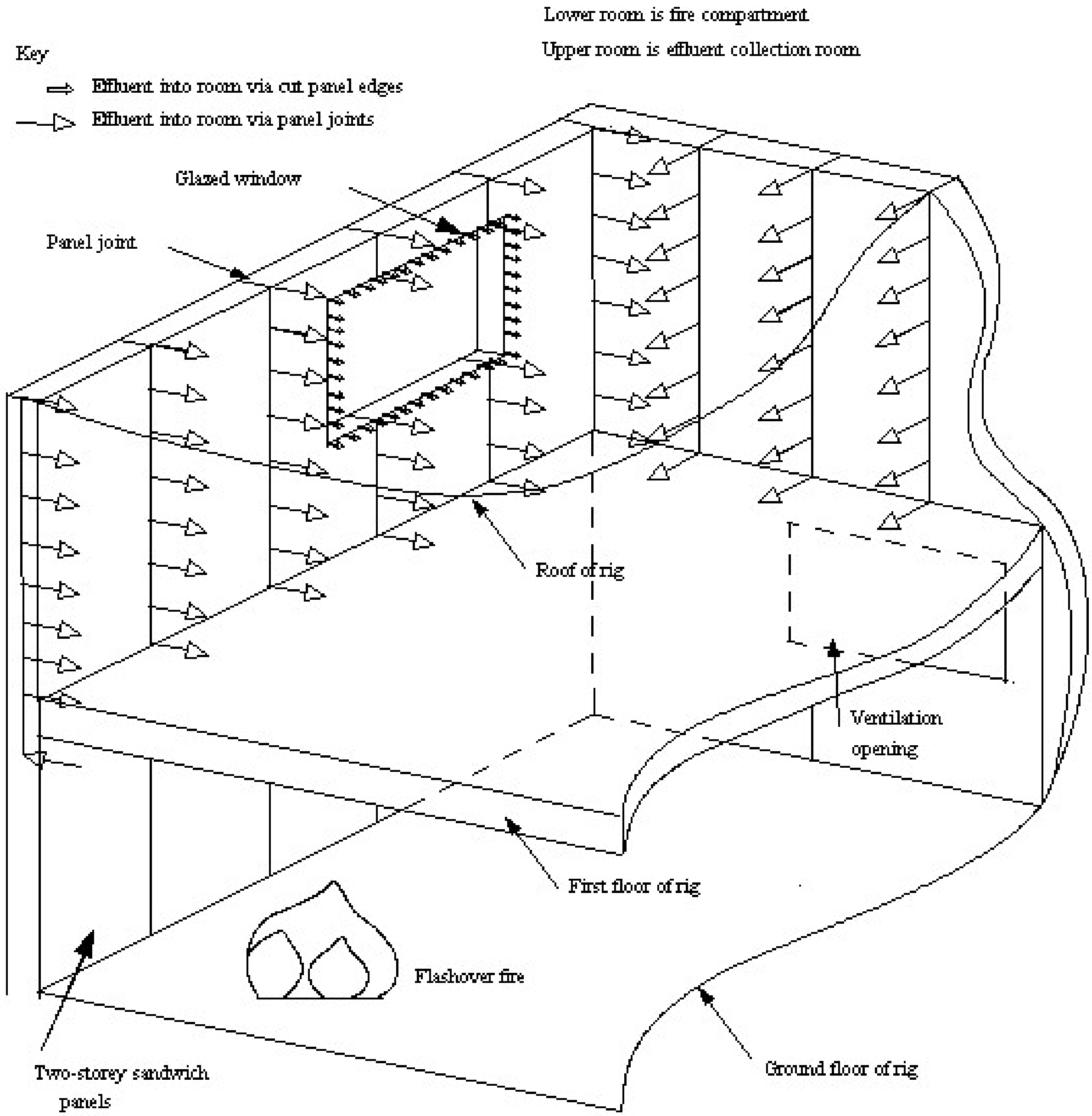

Figure 3 Test rig for assessing vertical transport of panel influent

3.4.3 An appropriate fire test rig would involve two rooms, one above the other. The lower room (the fire compartment) would have a ventilation opening of a size which would promote flashover conditions. The upper room would have no openings in the walls or ceiling so that fire gases would be contained. At least two of the four external walls would be constructed with sandwich panels. Figure 3 shows a cut-away view of the test rig and indicates where panel effluent could penetrate into the upper room via panel joints and window reveals. Fire stopping (heat and smoke resisting) would be used between the face of the sandwich panel wall and the edge of the floor at first floor level of the test rig so that any combustion gases entering the measuring room above could only travel via any cavity formed between the panel faces. A timber crib fire load would be used to create flashover conditions in the lower room while measurements of the amount of smoke and toxicity of gases entering the upper room via the panel cavity and joints would be made.

3.4.4 This Report therefore proposes that research into vertical transport of fire effluent via the panel cavity should be undertaken to examine

i) the toxicity and amount of fire effluent transported into the upper room when the panel cavity and panel joints are the only possible routes of effluent transport (this requires effective fire stopping between the inner face of the sandwich panels and the edge of floor in the test rig).

ii) the toxicity and amount of fire effluent transported into the upper room when a practical and fully representative method of fire stopping is used. In this case the effluent entering the upper room comprises effluent from within the panel and any effluent from the timber crib fire load bypassing the fire stopping.

Comparison of the data obtained from i) and ii) would enable the relative hazard to be quantified.

3.5 Where the fire effluent goes

3.5.1 The fire effluent may originate from the panel or from the room contents or from both. The amount of effluent resulting from combustion of the core, and the time at which it occurs, depends on the protection of the panel faces and the size of the initiating fire. If the roof or external wall panel could be designed so that the panel effluent was directed to the outside air, the smoke and toxic hazard produced within the building would be minimised (although pollution of the atmosphere near and downstream of the building would occur).

3.5.2 Panels with combustible plastic cores which have desirable low rates of heat release tend to char (this may be the objective of the chemical formulation). The production of the char, which may occur with PIR and some PUR's, unfortunately delays the breakdown of the panel joints in the external steel face through which it is hoped the panel effluent will escape to the outside air. Hence any claims by manufacturers of foamed plastic cored panels that the heat and smoke escapes safely to the outside should be viewed with caution - much depends on the formulation, the panel jointing system, and the fire scenario.

3.5.3 The amount of effluent produced by the panel core depends on the surface area which is burning or pyrolysing, which depends on the integrity of the panel faces and whether or not flashover has occurred. After flashover all the panel surfaces are, by definition, involved in fire. In many scenarios the importance of the panel effluent depends on the amount of effluent produced by the panels in relation to the amount of effluent produced by the burning room contents. In this Report this ratio is designated by P - the larger the value of P the more significant the hazard presented by the panel effluent. This ratio will depend on the shape of the room and this is illustrated in Figure 4. For a given storey height, Room A has an external wall panel area which is small in relation to the floor area, i.e. P = (a x b)/b is small, whereas in Room B the reverse is true. In a room forming an external corner of a building, i.e. Room C, the ratio is different again. The value of P should be considered in the risk assessment. Note that an increase in height of room increases the area of external wall (and thus the amount of panel effluent) but has no effect on the amount of effluent produced by the room contents as the plan area of the room remains unchanged. When the room additionally has a ceiling of panels it is clear that a different relationship will apply, but Figure 4 is sufficient to illustrate the simple concept. Thus the fire hazard of combustible panels depends on the aspect ratio of the room.

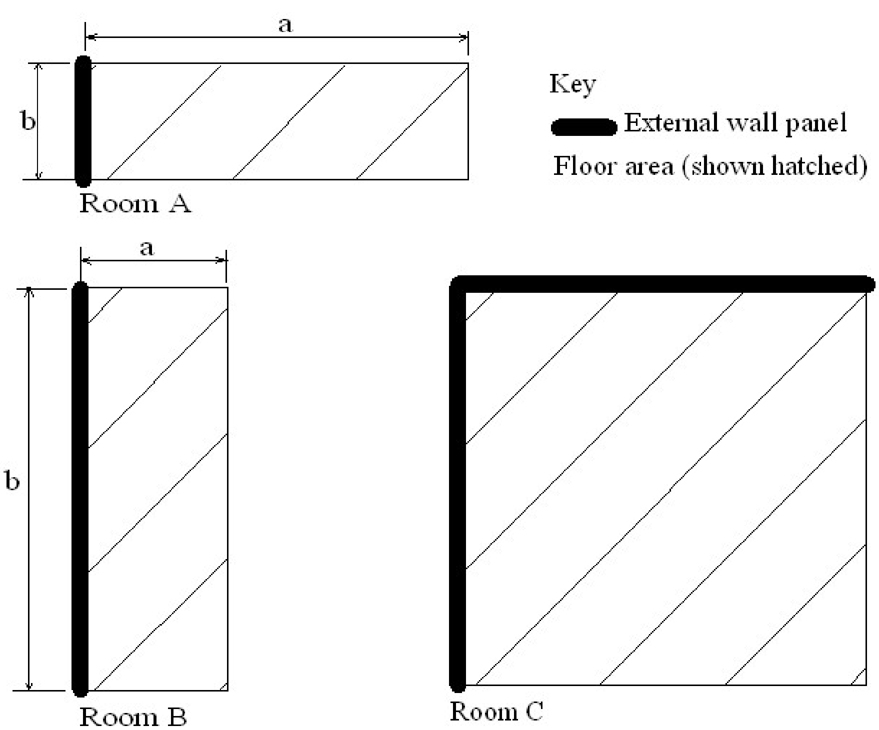

Figure 4 Room plan shapes

3.5.4 Where the effluent travels will depend on the size and position of ventilation openings. If there is no window and no door or other openings in the enclosure the effluent will be contained although it will of course spread into other parts of the room. Where there are openings the effluent will spread due to buoyancy effects and wind action and the location of doors, windows and stairways will have a decisive effect on the spread of effluent. The various routes of fire spread are shown in Annex 1

3.5.5 A bad scenario is where the enclosure has a low ceiling and is tunnel-like. Hence all the fire effluent is forced to travel in one direction (rather than spreading radially) so that the speed of effluent travel below the ceiling is high. In this geometry there is no space below the ceiling which can be used as a beneficial smoke reservoir so that occupants may have little time to escape. Escape corridors are unfortunately often of this shape. Plastic-cored sandwich panels should not be used in this context.

3.5.6 A good scenario involves an enclosure with a high ceiling, early alarm, small number of occupants, no sleeping or mobility risks, good escape route design, small area of combustible-cored panels, late involvement of the panel core and a low rate of heat release and smoke production of panel core material. Ideally, of course, the panel should have a non-combustible core such as stone wool. There are buildings such as public assembly buildings where some of these desirable features are absent but it is beyond the scope of this Report to deal with the attendant implications.

4.0 FIRE LOAD CONSIDERATIONS

4.01 In this section of the report the question is asked "Is the fire load used in ad hoc tests representative of the fire load in real buildings?" The question is addressed by first presenting published fire load data which is accepted as a basis for the fire safety engineering design of buildings. A number of ad hoc fire tests are then examined to establish the nature and amount of the fire load used in the test scenario.

4.02 In most ad hoc tests the fire loading is in the form of a timber crib since this gives a reproducible fire provided that the crib uses sticks of the same moisture content, size and spacing. Softwood is usually chosen and has a typical upper calorific value of 18 MJ/kg. To convert a timber crib fire load from kg to MJ the timber crib mass is multiplied by 18.

4.1 Fire loads in buildings

4.1.1 Data on fire loads represented by the contents of rooms have been collected by making surveys of buildings and noting the mass and calorific value of the different materials from which the total fire load of the room contents is calculated. The fire load density is obtained by dividing the fire load (MJ) by the floor area (m^2). Such data were reported in a CIB Workshop in 1983 and are included in DD 240. They are reproduced in the table below.

Occupancy	Fire load density			
	Average MJ/m²	Fractile[2)]		
		MJ/m²		
		80%	90%	95%
Dwelling	780	870	920	970
Hospital	230	350	440	520
Hospital storage	2000	3000	3700	4400
Hotel bedroom	310	400	460	510
Offices	420	570	670	760
Shops	600	900	1100	1300
Manufacturing	300	470	590	720
Manufacturing and storage	1180	1800	2240	2690
Libraries	1500	2250	2550	----
Schools	285	360	410	450
[1)] Derived from surveys: see CIB W14 Workshop Report, 1983 [2)] The 80% fractile is the value that is not exceeded in 80% of the rooms or occupancies. [3)] Storage of combustible materials at less than 150 kg/m²				
Note 1. The fire load densities given in this table assume perfect combustion, but in real fires the heat of combustion is usually considerably less. Note 2. The values given in this table include only the variable fire loads (i.e. building contents). If significant quantities of combustible materials are used in the building construction, this should be added to the variable fire load to give the total fire load.				

Table 2 Fire load density in different occupancies.

4.1.2 If it is assumed that a typical room in a dwelling is 4m x 3m the total fire load of the contents is (4 x 3) x 780 = 9360 MJ assuming average fire load conditions, but note that in 5% of such rooms (corresponding to the 95% fractile) the fire load could be more than (4 x 3) x 970 = 11,640 MJ. Assuming average fire load conditions this corresponds to a total timber crib mass of 520 kg (i.e. 9360/18). For an office room of the same size the mass of timber crib needed to represent the average fire load condition is 280 kg. For rooms larger than the 4m x 3m chosen the size of timber crib would be correspondingly larger.

4.2 Fire loads used in ad hoc fire tests for sandwich panels

4.2.1 There are several ad hoc tests. The tests are at full scale so as to include representative panel joints which, in combustible-cored panels, can affect the overall fire behaviour. The fire source (fire load) used in these tests is reviewed below.

4.2.2 The Loss Prevention Council has developed LPS 1181 for wall and ceiling lining products and is also used for individual panels[22]. It uses a single 35 kg timber crib placed near the corner of a 4.5m x 10m x 3m high test room.

4.2.3 ISOPA (European Isocyanurate Producers Association) carried out tests in 1992 on foamed polyurethane metal faced sandwich panels used as external cladding[23] .

The 10m high panels were arranged in an L-shape with the primary face 7m wide and the return wing 2.26m wide. A single 40 kg timber crib, placed at the base of the panel assembly, was chosen, it is said, to simulate the window flame effect from a 500 MJ/m^2 room fire. The conclusions stated that "The thermal attack of ignition sources up to a room flashover will lead only to a very limited lateral flame spread on the façade".

4.2.4 Following a fire in a multi-storey block of flats in Scotland in 1999 in which the external cladding was implicated, a Parliamentary Inquiry by the Environment Sub-Committee of DETR produced a report which recommended that a BRE test method[24] be adopted, and this method is now cited in AD B 2000. The full scale test uses an L-shaped specimen at least 9m high and 2.4m wide on the primary face and 1.2m on the return wing. The fire source is designed to simulate a post-flashover fire emerging through a window opening producing an incident heat flux of nominally 90 kW/m^2 for 20 minutes at 1m above the opening. The test method is currently (June 2000) being reviewed within BSI with a view to making it a British Standard test method and it would be useful if this test was applied to external sandwich panels. In the current draft[25] the test fire can be a timber crib of nominal mass 300 kg. Compare this with the 40 kg crib used in the ISOPA tests.

4.2.5 A series of ad hoc fire tests were sponsored by EPIC (Engineered Panels in Construction) which represents the UK rigid urethane insulated panels industry. The tests were designed to compare the performance of external cladding systems. The following systems were tested

- built up systems with glass fibre and rock fibre insulants
- rigid urethane foam cored systems
- a rock fibre cored system
- a foamed polystyrene core system.

The tests were made in a large room with most of one wall open as ventilation. The tests used the standard LPS recommended 35 kg timber crib. The test, like the LPS 1181 test method, is a reaction to fire test and, as mentioned earlier, does not adequately challenge the test specimen. A summary of the results is available[26].

4.2.6 Eurisol has sponsored a series of fire tests on steel sheet faced sandwich panels conducted by BRE. The tests adopted the size of rig used in the draft ISO test for industrial sandwich panels. The internal dimensions of the room were 4.8m x 4.8m x 4.0m high with an opening in one side with a down stand of 0.8m. The fire source was a 780 mm x 780 mm propane fuelled sandbox burner with a heat release rate of 500 kW for up to 30 minutes. The core materials examined were

- built-up system using glass wool
- polyurethane (free standing)
- stone wool (free standing)
- polyisocyanurate (supported by structural frame)

Unlike the EPIC tests, measurements of rate of heat release and smoke production were made with the aid of the FRS large scale calorimeter. A report of the test results[27] confirms that the PUR panels rapidly went to flashover (i.e. within 3½ minutes) and the rate of heat release exceeded 10,000 kW. In contrast the other panel systems performed well and the maximum rate of heat release for the PIR panels did not exceed 270 kW. It should be recalled however that the test is a reaction to fire test.

BRE procured the panels for these tests and were initially supplied with PUR-cored panels whereas BRE had ordered the more costly PIR-cored panels. If confusion can occur it is vital that the proposed panel labelling scheme unambiguously identifies the foam system used in the panels leaving the manufacturer's works.

4.2.7 With the exception of the proposed BRE test for external cladding, it is clear from the review of ad hoc tests made above that the fire loads used in the tests are not representative of fire loads in rooms in buildings - it seems that the fire loads are intended to represent a single burning item and such tests therefore may be described as reaction to fire tests. This Report contends that larger fire loads should be used in conjunction with enclosure sizes which encourage flashover. In this way the gap between reaction-to-fire tests and the fire resistance test would be bridged and this would reflect the reality of flashover conditions. The use of the ISO 9705 room test would seem to be appropriate for this purpose and this strategy has been accepted by the European Union in support of the Construction Products Directive - the ISO 9705 test is to be used as a reference test.

4.3 Flashover – can it be caused by sandwich panels?

4.3.1 Flashover is a very important phenomenon having serious consequences. It occurs when the radiation from the hot gas layer below the ceiling reaches the value at which spontaneous ignition of materials near the fire (i.e. the room contents) occurs leading to total involvement of the room/compartment contents in fire. This normally happens when the temperature of the hot gas layer reaches about 600degC. The 600degC criterion cannot be applied regardless. It can be applied for rooms in which the upper surfaces of the unburnt fuel are not more than a couple of metres below the underside of the hot gas layer. As this distance increases, the likelihood of spontaneous ignition reduces, because the configuration factor reduces. This results from the relation:
incident radiation intensity = configuration factor x emitted radiation intensity.

4.3.2 After flashover the rate of heat release and production of fire effluent increases greatly and combustion gas temperatures can reach 1300degC in well insulated compartments[28]. Flashover presents a major hazard to fire fighters because of the speed and unpredictability with which it can occur. While flashover conditions are clearly untenable to any occupant in the room of origin, it is often hazardous to occupants outside the room of origin because of the increased speed and amount of fire effluent flowing into other rooms and spaces and because of the failure of construction elements (walls, ceilings, doors) bounding the room of origin.

4.3.3 Not all fires which start in the contents of a room proceed to flashover. It is unlikely to occur in large rooms or buildings having high ceilings and a low fire load density, as in an airport passenger terminal or art gallery for example. As the enclosure gets smaller, the ceiling lower, the fire load density higher and the ventilation more restricted, flashover is more likely to occur. Flashover can be initiated by combustible-cored sandwich panels whose faces have become detached and this is clearly shown by the results of tests using the ISO 9705 room test - see Figure 4 of Part 3 of Annex 1 which demonstrates that PIR causes flashover if the fire source is increased to 300 kW.

4.3.4 Several factors affect fire severity[29] and their relationship is shown in Figure 5. In the 1960's the Fire Research Station and the then British Iron and Steel Federation sponsored a series of large scale compartment tests principally to explore the effect of varying the fire load density and ventilation on fire severity and the temperatures attained by steelwork.. The brick built compartment had internal dimensions of 7.7m x 3.7m x 3m high and had a ventilation opening in the long wall. In tests using the same fire load density and ventilation opening it was found that adding a mineral wool lining made little difference to the fire severity. The report[30] stated "that covering the walls and ceilings with a mineral wool insulation resulted in only slightly higher temperatures inside the fire compartment". It would be reasonable to say that steel faced stone wool cored sandwich panels would similarly result in only slightly higher temperatures for the same values of fire load density and ventilation used in the tests.

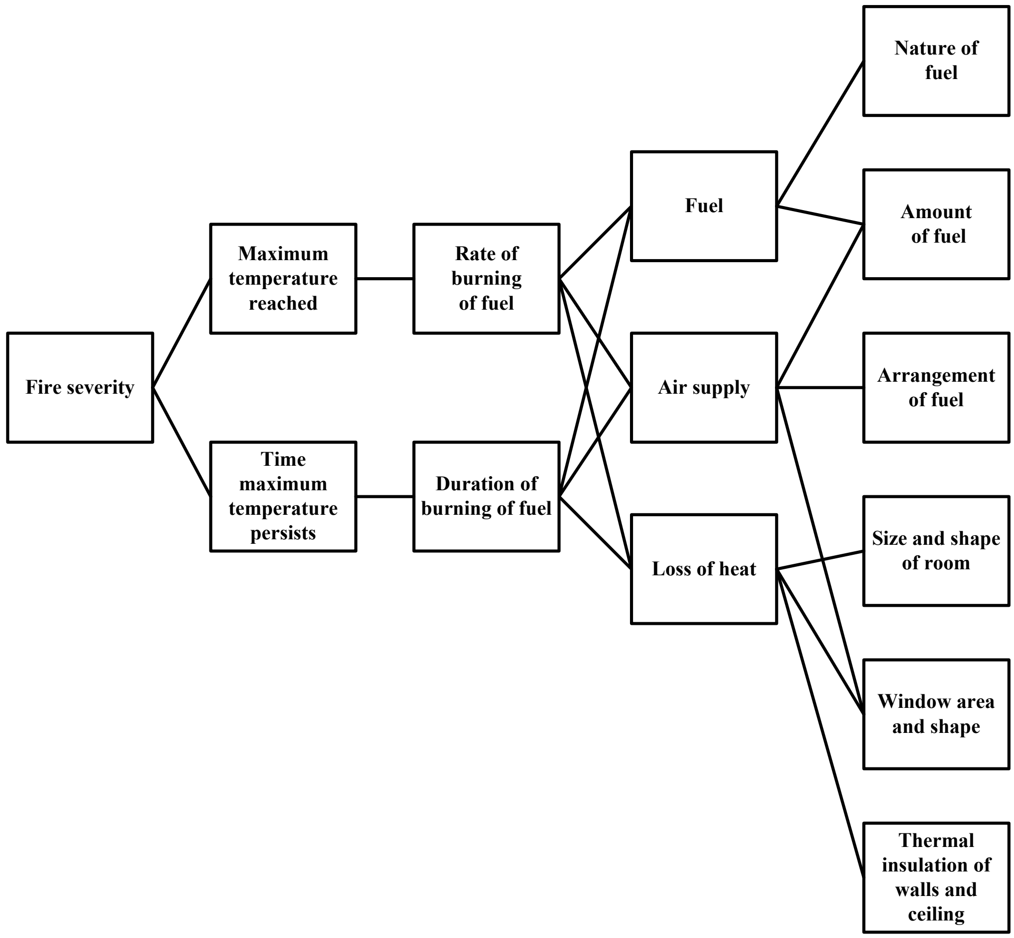

Figure 5 Factors affecting fire severity

However, to determine the effect of using a combustible lining two tests were made with the same ventilation area of 60 ft^2 ($6m^2$). In one test the fire load was timber cribs having a fire load density of 7.5 kg/m^2 (the smallest fire load density in the test range, which went up to 60 kg/m^2). In the other test wood fibre insulating boards were fixed to the walls and ceiling and no cribs were used. The total calorific value of the wood fibre linings was the same as the timber cribs. The combustion gas temperatures are compared in Figure 6.

The wood cribs underwent localised flaming while the combustible linings resulted in rapid flashover and produced much higher compartment temperatures. A combustible-cored sandwich panel which has lost its facing would produce similar conditions. This has been verified in a recent (1999) test using a steel faced PUR-cored sandwich panel assembly tested at the BRE Fire Research Station in which flashover occurred after 3½ minutes from ignition of the fire source

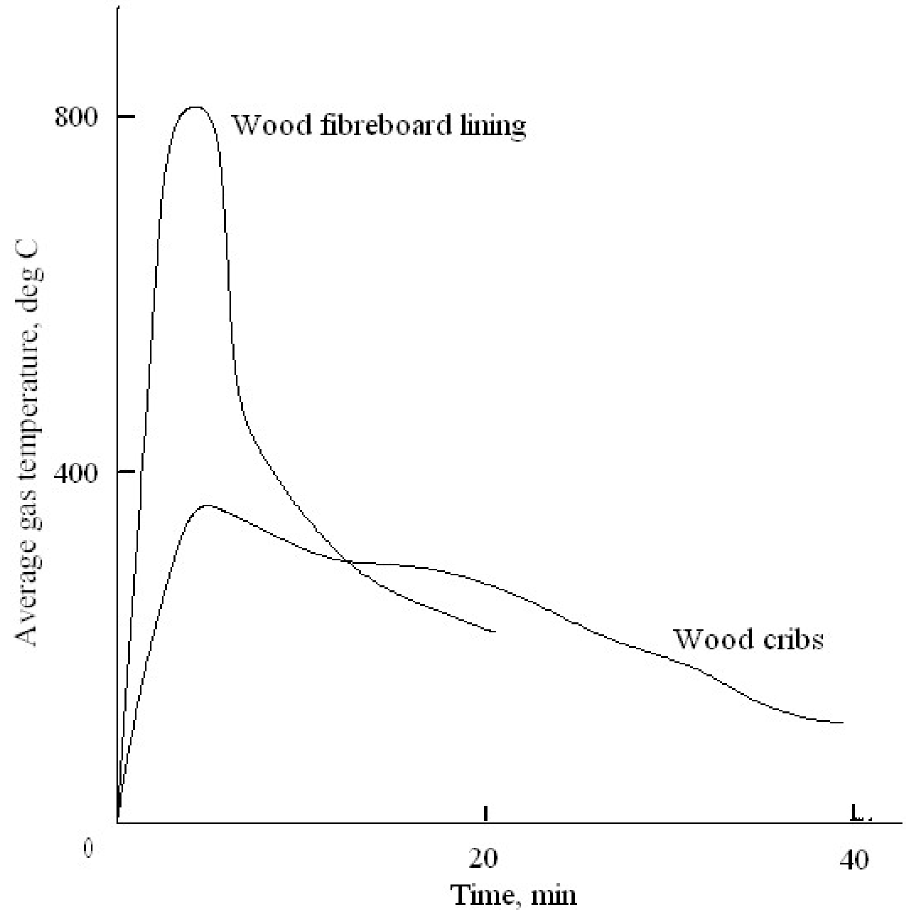

Figure 6 Effect of insulation board linings on flashover

4.3.5 Like all full scale ad hoc testing, undertaking full-scale fire tests to determine flashover conditions is expensive and time consuming and often only provides information relevant to the scenario tested unless it is combined with other small scale reaction to fire data especially calorimetric data obtained from the cone calorimeter. It would be useful if flashover could be numerically modelled. So far as the writer is aware there are no zone models capable of doing this, although it may be possible to calculate time to flashover from information on the fire growth curve and the heat release rate needed to cause flashover. Computational fluid dynamics (CFD) may hold the key but again there is not this capability at present. The application of rate of heat release data from small scale and large scale calorimeters has potential but an examination of the principal ISO document[20] on the subject (ISO/TR 11696) shows that the calculation of flashover is not in the practical arena.

4.3.6 Is it possible that flashover can be inferred from the use of a heat balance derived from full scale tests? We can say that the heat released by fuel = heat absorbed by the enclosure + heat lost in escaping effluent and heat lost by radiation through the ventilation opening + heat absorbed by the fuel. In the BISF/FRS tests[30] conducted in a plastered brick and concrete test room the major heat loss (typically 50-60%) was in the escaping gases while the heat loss to the enclosure was less than 30%. We can at least conclude that the insulation characteristics of the enclosure do not dominate the heat balance: if the enclosure was formed by insulating sandwich panels instead of plastered brick the fraction of heat loss to the enclosure would be reduced below the 30% figure but it is not possible to determine that this would initiate flashover.

4.3.7 If results of full scale tests are needed which reflect the reality of flashover conditions it is appropriate to use the ISO 9705 room test (this now has the status of a British Standard (BS 476: Part 33)). This uses a heat source of 100 kW for 10 minutes then 300 kW for a further 10 minutes during which time rate of heat release and smoke production are continuously monitored and the time to flashover is observed. This test can discriminate between plastic foams (PIR, PUR and polystyrene) and non-combustible insulations such as stone wool and this is clear from Figure 4 of Part 3 of Annex 1 which demonstrates that even PIR causes flashover if the fire source is increased to 300 kW.

4.3.8 The conclusion is that combustible wall and ceiling linings lead to flashover. Furthermore if it is accepted that the metal faces of a plastic foam cored sandwich panel may become detached (as in the recent BRE test for example) or very badly distorted then the potential for a very severe fire undisputedly exists.

5.0 Fire checklist for specifiers and employers

The following checklist is intended to encourage a systematic questioning approach to the design and specification of sandwich panels used in external walls and roofs.

5.1 What are the fire safety objectives of the building? These may include
- life safety (occupants, people nearby and fire-fighters)
- loss prevention (building, contents and business continuity)
- environmental protection (protection against pollution of the ground and water by firefighting water and protection of the air against excessive smoke pollution).

5.2 Has the fire risk assessment been carried out? There is now a requirement under life safety legislation and recommendations for insurance purposes for many existing buildings. What provisions are being made for compliance with the Fire Precautions (Workplace) Regulations 1997 as amended, for the safety of workers and emergency services personnel? Have the fire precautionary recommendations in the LPC Design Guide been followed?

5.3 Is the building designed to comply with Approved Document B ? Is there a requirement for the building to be compartmented? Where the roof system covers a compartment fire wall, does it satisfy the requirement of Approved Document B that a strip of roof 1.5 metres wide either side of the wall should have a designation of AA, AB or AC and involve the use of materials of limited combustibility – stone wool and foamed glass insulation are non-combustible but foamed plastic insulants are not. Note that Clause 3.2.1 of the LPC Design Guide 2000 recommends that a roof has to have a protected zone either side of a fire wall. The different requirements of Approved Document B and the LPC Design Guide should be considered in detail, not forgetting the requirements for ceilings and walls such as Class O.

5.4 If the fire safety strategy relies primarily on active measures, such as smoke vents and automatic sprinklers, will they be adequately maintained and are they alone capable of doing the job?

5.5 Has fire resistance been considered? A roof is not normally required to satisfy fire resistance criteria unless it forms part of an escape route. However, the intrinsic fire resistance of steel-faced panels with non-combustible stone wool cores will eliminate the potential for fire spread between faces. This makes it easier for the fire brigade to extinguish a fire at roof level implying less personal threat and less fire damage, including damage by fire fighting water.

5.6 Are maintenance or refurbishment operations on the external cladding and roof likely to involve hot working processes? If so, it would be wise to specify non-combustible components.

5.7 If the roof is to be penetrated by flues, has this been taken into account with regard to the potential for ignition of any combustible material in the roofing system?

5.8 In the event of fire, is the cladding system likely to be involved at an early stage? If this is the assessment, then avoid the use of insulants such as foamed polystyrene which can ignite and produce flaming droplets. One effect of this is the ignition of secondary fires away from the initial source of fire, even before flashover. Such fires are difficult to extinguish and make fire fighting hazardous. They produce dense smoke which, if not vented, adds to the smoke damage and air pollution.

5.9 Is the cladding constructed with components able to minimise the effects of arson ? Low level or overhanging roofs could be prone to an arson attack from outside the building? Arson is inexorably increasing and now accounts for more than 50 percent of all fires.

5.10 Does the roof adjoin a different height building? If so, consider designing a fire resisting ‘skirt’ to prevent the risk of fire spread via the roof from the lower building into the higher building.

5.11 What are the chances of fire spreading from a nearby building? Although space separation requirements in Approved Document B may not apply to buildings on the same site, the potential for fire spread from neighbouring premises should be considered for insurance purposes. Also, if fire started by radiated heat is a possibility then it may be prudent to specify a non-combustible cladding system.

5.12 If the cladding panels employ aluminium alloy faces, has the design been checked vis-à-vis compartment fire walls? Aluminium alloy sheet melts at around 660degC – roughly the temperature at which flashover occurs (steel melts at around 1,550degC – above the temperature reached by severe fully developed fires). Therefore it is unwise to specify aluminium alloy panels over/past a fire wall.

5.13 Is there an understanding of the performance of fire retardants? Fire retardants in combustible insulation materials only prevent ignition for small ignition sources. They will have little or no effect in most developed building fires. They may indeed add to the smoke production and toxicity of the fumes once fire has taken hold

5.14 Specifiers should acquaint themselves with the variety of test scenarios available and ensure they rely on appropriate test data

5.15 The external cladding may need to provide certain values for thermal insulation, sound insulation and sound absorption. (A doubling of the mass improves the sound insulation by approximately 5 dB). A high density stone wool specification will achieve both sound and fire protection.

5.16 Is there an awareness of the large number of recent major fire losses in the food processing and storage industry which have involved combustible foamed plastic insulation? These fires have demonstrated the real life performance of rigid polyurethane or polystyrene cored composite panels which can increase the fire load (the building envelope itself) and contribute to the rapid spread of heat and smoke. As a result of the danger to fire-fighters (two died in a food factory blaze at Sun Valley Foods, Hereford), guidance is being given by the Home Office as to operational procedures. Unless there is a threat to life, fire-fighters are now reluctant to enter such premises. The food industry is increasingly turning to non-combustible insulation for new build and refurbishment to minimise fire damage, business interruption, loss and damage. Cladding designers and fire safety engineers should be aware of this trend.

6.0 FACTORS TO CONSIDER IN A FIRE RISK ASSESSMENT FOR COMBUSTIBLE-CORED PANELS

6.1 From Sections 2 to 4 of this report it is possible to identify factors which ought to be considered in a risk assessment for buildings containing sandwich panels.

Assuming that panel faces are of steel and that they are properly fixed and supported, there is no risk in using panels with non-combustible cores. The following list therefore deals with combustible-cored panels.

6.2 It is proposed that further research be carried out to find a way of enabling the factors to be built in to a fire risk assessment method. The use of decision trees or flow charts has been accepted by the regulatory bodies for use in codes of practice for fire precautions in buildings. A notable good example is BS 5588 Part 7: 1997 which deals with atrium buildings. A risk assessment for combustible-cored panels could adopt this format

6.3 Factors to consider should include:

Panel context

- where used in building (roof or wall)
- extent of panel usage in each enclosure (surface area of panels, ratio of panel area to floor area)
- presence of any additional lining (e.g. plasterboard) used, any contribution to fire protection expected from the lining)
- proximity to fire walls
- areas where there are penetrations by hot items (flues)
- use of enclosure as part of an escape route
- use as a low ceiling
- where panels can act as a fire bridge to spread fire
- areas susceptible to vandalism or arson

Panel construction

- face material (steel, aluminium alloy, etc.)
- face fixing method
- panel jointing method
- fire stopping (within panel and around perimeter of panel)*
- extent of unsealed panel edges
- places where molten droplets from thermoplastic cores (e.g. polystyrene) can escape (joints and panel ends)*
- continuous cavities within panel (e.g. where profiled metal face is not in contact with sheet core material)
- possibility of migration of panel effluent behind panel faces*

Panel core material

- type of foam core material (polyurethane, polyisocyanurate, polystyrene, phenol, and whether flame retarded)
- core material audit according to officially-recognised and monitored panel labelling scheme
- ignitability*
- rate of heat release*
- smoke production*
- production of flaming molten droplets*

- dominant and/or particularly toxic species (e.g. CO and HCn respectively)*
- charring/burning behaviour when behind face*
- Ratio of panel fire load to room-contents fire load

The asterisked items are phenomena which can only be determined by test. Specifiers should be careful to ensure that the test scenario reflects reality. Data should be made available from small scale and large scale fire tests. Tests should be able to assess performance in flashover conditions- the ISO 9705 room test data will be appropriate for this purpose

6.4 The above mentioned factors should, of course, be considered within the global fire risk assessment. The global assessment would include consideration of the following factors:

- fire safety objectives (life safety; reduction of property damage due to heat, smoke and water; business continuity; environmental protection)
- occupant characteristics (population density, familiarity with building, mobility, alertness, social affiliation etc.)
- means of escape
- compartmentation
- fire suppression systems and their reliability
- fire/smoke venting systems and their reliability
- fire fighting facilities
- fire safety management (quality and reliability)

7.0 CONCLUSIONS

7.1 Sandwich panels serve an important role in buildings primarily because they are fast track, energy efficient, and aesthetically attractive. When constructed with non-combustible cores of stone wool and properly secured steel sheet faces their performance in fire is unsurpassed on a weight basis – they can achieve considerably more than 2 hour fire resistance and being non-combustible they release negligible amounts of heat or smoke

7.2 Sandwich panels with combustible cores can be a fire hazard posing a risk to life and /or property. In some applications they may represent a small fire hazard, in others a high fire hazard. They have proven to be a high fire hazard in the food processing and storage industry where fire-fighters have lost their lives and many £ millions have been lost in damage to property and business continuity

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7.3 Today combustible-cored sandwich panels are being specified in buildings other than the food processing industry. There is concern about this especially among those organisations which represent the interests of fire-fighters and those designers and employers who are ultimately liable for the life safety of people in their buildings.

7.4 The government departments responsible for fire safety legislation and guidance, i.e. the Department of Environment, Transport and the Regions (DETR) and the Home Office, recognise that some kinds of sandwich panels present a fire hazard. These government departments have sponsored research, testing and surveys of buildings which has been undertaken by BRE Fire Risk Sciences (formerly the Fire Research Station).

7.5 As a result of the BRE research the latest guidance from the DETR contained in Appendix F of Approved Document B Fire Safety 2000 recommends that:
[1] panel faces are adequately fixed to prevent delamination and facing collapse, and prevent the (combustible) core materials from becoming exposed to the fire and contributing to the fire load, and
[2] by example, combustible cores should not be used in some internal applications.

However, AD B only concerns panels used for internal structures and suggests that further information on a fire risk assessment for combustible-cored panels used in other applications can be obtained from a design guide intended for cold storage premises.

This Report contends that the fire risk assessment method proposed in the guide is unsatisfactory:

- it makes a quantitative connection between fire hazard and Fire Resistance with no justification
- it ignores the crucial issue of heat release and smoke production of the panel core material

7.6 This Report suggests that important questions to consider in a risk assessment are:

- what is at risk – life, property or eh business?
- how much, and fire time history of fire effluent (heat, smoke) is released from the panels and from the room contents?
- the transportation routes for the panel effluent and room-contents effluent which may possibly be different?
- likelihood that panel effluent reaches risk areas that the room-contents effluent cannot?
- the frequency of fires in different rooms in buildings of different occupancy (essential if a probabilistic risk assessment is to be attempted)?

Further research is needed to address these questions

7.7 Those who draft building regulations and official technical guidance should develop appropriate guidance on risk assessment methods.

In the particular case of plastic foam cored sandwich panels it is argued that there should certainly be more guidance concerning their use. Adopting the precautionary principle (advocated by the European Commission) the use of such panels should be seriously questioned where used internally (i.e. for membrane ceilings and internal partitions) in life risk situations

7.8 This Report contends that in support of government policy to encourage a risk assessment approach for mitigating hazards in all environments, government regulators should be careful to ensure that risk assessment is viable in the particular case and that supporting reference documents are made available which properly cover the subject.

7.9 This Report contends that in support of government policy to encourage a risk assessment approach for mitigating hazards in all environments, the government regulators should ensure that risk assessment is viable in the particular case and that supporting reference documents are made available which properly cover the subject

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7.10 This report contends that none of the risk assessment guidance currently available (mid 2000) helps the specifier to come to a decision as to whether or not the risk in using combustible-cored panels is acceptable.

7.11 An examination of the fire sources (fire loads) used in most ad hoc fire tests on sandwich panels reveals that the fire load is not representative of fire sources in real buildings. It might seem that some manufacturers of foamed plastic cored sandwich panels are marketing test data which show their panels in the best light. The ISOPA test programme used a timber crib of 40 kg while a recent BRE test method for the same scenario used a more realistically sized timber crib of 250 kg.

7.12 In many fires where large property losses are sustained, the damage is the consequence of flashover. With the exception of the ISO 9705 room fire test method, it seems that the ad hoc fire test scenario is designed to avoid flashover by the use of open-sided rigs, high or absent ceilings and, as mentioned above, the use of fire sources which are too small. This Report contends that fire sources used for ad hoc fire tests should be more representative of fire loads in buildings so that flashover conditions are obtained

7.13 Research is needed to explore the possible migration of products of combustion behind metal faces of combustible-cored sandwich panels where they may emerge in a life risk area outside the room of fire origin. This is especially important in areas where people may be sleeping. A test method has been proposed.

7.14 The use of plastic foam cored sandwich panels in the building envelope (external walls and roofs) is difficult to justify when considering life safety. It is proposed that a qualitative fire engineering study be carried out to explore the practical feasibility of using flow charts or decision trees for deciding panel usage.

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NB Asterisked references are reproduced in Annex 1 of this Report

8 ANNEXES

Annex 1. IFE-published articles 'When are sandwich panels safe in fire?' Parts 1, 2 & 3. Full text of these papers are on the author's website www.cookeonfire.com (click on Publications then Sandwich panels)

Annex 2. Approved Document B Appendix F (see government website)

Annex 3. Fire load of sandwich panels

As part of the fire risk assessment it will be helpful to have a knowledge of the fire load (calorific content) of the sandwich panels as this gives an indication of the amount of heat the panels can produce in a fire. The amount of smoke and toxic fumes is often related to the fire load and in the interests of life safety and property protection it is desirable to minimise the heat, smoke and toxic fumes given off by the panels.

The heat produced comes from the panel core material, as the protective/decorative plastic coating on sheet metal facings is very thin and can be ignored. The fire load per unit area (MJ/m^2) of the core of a panel of a particular thickness equals the calorific value (MJ/kg) times the density (kg/m^3) times the thickness of panel (m). This relationship has been used in the following table to calculate the fire loads of different thicknesses of different core material of appropriate density

Core material	Fire load (MJ/m^2) for core thickness of:		
	50 mm	100 mm	200 mm
Polyurethane foam*	58	117	234
Polystyrene foam•	46	86	166
Stone wool•	11	16	25

∗ Data for polyisocyanurate foam are similar

• The figures include a value of 6 MJ/m^2 for polyurethane adhesive for bonding core to facings. The value for stone wool will be less if inorganic adhesives are used

It is clear that for thick panels, e.g. panels used in food storage rooms requiring a high level of thermal insulation, the fire load represented by combustible-cored panels is high - almost a factor of ten higher when compared with non-combustible-cored panels containing rock wool.

To obtain the fire load represented by all the panels in a building the data in the table have to be multiplied by the total area of the panels in square metres. For example, in a flat roofed building 10 m high by 40 m long by 40 m wide entirely clad in sandwich panels, the area of the roof is $40 \times 40 = 1600\ m^2$ and the area of the walls is $4 \times 40 \times 10 = 1600\ m^2$ so the total area is $3200\ m^2$. In this example using 50 mm thick polyurethane foam cored panels would give a fire load of $58 \times 3200 = 1.85 \times 10^5$ MJ. If the contents of the building were in the low fire load category (i.e. having a fire load density of 300 MJ/m^2 of floor area) the fire load of the panels would represent over a third of the fire load of the building contents, and if the panels were 100 mm thick the factor would be two-thirds.

Fire load amounts are difficult for the lay person to visualise but an experienced fire safety engineer should be able to advise on their importance.

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