STUDY REPORT

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Fire Properties of Wall and Ceiling Linings: Investigation of Fire Test Methods for Use in NZBC Compliance Documents

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Preface

This is the first of a series of reports prepared during research into fire properties of surface products.

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Note

This report is intended for:

- the DBH as a technical basis for reviewing and/or updating provisions contained within the New Zealand Building Code (NZBC) Approved Documents
- manufacturers of wall and ceiling lining products as a basis to evaluate test parameters and real fire performance
- designers to enable a greater understanding between the reaction-to-fire performance of lining materials in laboratory tests and real fire performance
- other researchers involved in reaction-to-fire of lining materials.

FIRE PROPERTIES OF WALL AND CEILING LININGS: NEW FIRE TEST METHODS AND ACCEPTABLE SOLUTION REVISIONS

BRANZ Study Report SR 160 **PCR Collier, PN Whiting and CA Wade**

REFERENCE

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ABSTRACT

This project has demonstrated the effectiveness of the ISO 9705 room corner test method and the AS/NZS 3837/ISO 5660 Cone Calorimeter in evaluating the reaction-to-fire performance of a selection of surface lining materials as applied to walls and ceilings. The measurement of heat release rate (HRR) and smoke production rate (SPR) are direct indicators of the hazard. The growth of the HRR enables a lining material to be classified with respect to time based on if or when flashover occurs. The measurements of gas species, percentage of flame spread area over the lining surface, and compartment temperatures and smoke layer height, are compared to confirm that the conditions generated are consistent with the primary parameters of HRR and SPR and accurately reflect the fire hazard. Recommendations are made for changes to the fire test methods in NZBC Compliance Documents.

KEYWORDS

Ceilings, Cone Calorimeter, ISO 9705, fire testing, flame spread, heat release rate, lining material, smoke production, walls.

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1. INTRODUCTION

International research over the past decade and longer into the reaction-to-fire behaviour of wall and ceiling lining material has identified new fire test methods that more accurately represent the early fire growth hazards associated with ignition and flame spread over room linings.

The motivation for this project was to ensure that regulatory requirements in the NZBC Compliance Documents reflected state-of-the-art research and benefited from the new knowledge that has been generated by this. One of the key features of the research that has been done into the reaction-to-fire area is the strong move towards fire test methods that are either more representative of realistic full-scale scenarios, or small-scale tests that generate engineering data able to be interpreted or utilised in theoretical models for simulating fire spread for full-scale configurations.

The current NZBC Compliance Documents use Early Fire Hazard indices obtained using a long-established Australian fire test method AS 1530 Part 3. For many years, New Zealand and Australia were the only two countries to directly use this test method for regulating the fire properties of wall and ceiling linings. However, in 2005 the Building Code of Australia (BCA) was amended to remove the use of AS 1530 Part 3 for this purpose. New Zealand is now the only country in the world using AS 1530 Part 3 for regulating the fire properties of wall and ceiling linings. This could be seen as representing a trade barrier and is counter to an expressed desire to utilise international standards whenever possible.

2. BACKGROUND

Fire properties of wall and ceiling linings are controlled to make sure that the fire involvement of the surface lining materials does not lead to rapid fire growth and smoke spread such that occupants are prevented from safely evacuating the building.

A review of the New Zealand Fire Service (NZFS) database of fire incidents was carried out to gain an understanding of the scale of fires in which wall and ceiling lining materials were reported to have contributed to fire spread.

2.1 Fire service database of fire incidents

The NZFS database of fire incidents in building structures was searched for those where flame spread across wall and ceiling linings was recorded.

The data in the NZFS database is collected by the senior officer at the fire. For those fires which involve significant structural damage, there will be a subsequent investigation by a trained and competent fire investigator. However, there is no guarantee that the original incident report is modified in light of the fire investigation. There are also no formal definitions or explanations given relating to each field in the database. The fire officer is offered a menu of choices and is expected to select the most appropriate option with no explanation proffered. Thus the definition could be considered to be what the common understanding of the term is among firefighters.

The NZFS database extends back to 1986. However, it was recommended that data for incidents recorded from the year 2000 would be the most reliable.

The database search was limited to building structure fires where the avenue of flame travel across wall and ceiling linings was recorded. The coding of the database permits a breakdown of the flame travel field into any one of the following:

- wall covering
- ceiling covering
- floor covering.

In the following analysis, all incidents with any one of the above fields coded has been included. Incidents in which only the floor covering was involved were identified and excluded. The property classification ‘single house’ was separated to more closely identify the proportion of buildings in which the fire performance of wall and ceiling linings are more likely to be controlled by the NZBC.

The data analysed in Table 1 and Table 2 was taken from fire incidents between 1 January 2000 and 4 December 2005, with a recorded avenue of flame travel across internal wall and/or ceiling linings.

Table 1: Building structure fire incidents involving wall and ceiling linings – 2000 to 2005

Fire incidents	**Building structure fires with recorded avenue of flame travel on internal wall and/or ceiling linings**		
	All	Single house fires*	All excluding single house fires
Number of incidents	3312	2160	1152
Number of fatalities	84	73	11
Number of injuries	355	266	88

* The total number of single house incidents includes all events coded as such under the field ‘General property use’ and those coded only under the ‘Specific property use’. The latter occurs most often when the general property field may be coded as a building for farming, horticulture, agricultural use, and more specifically it is described as a single dwelling.

The fatalities and injuries by building type for all of the incidents recorded in all other buildings (excluding ‘single houses’) are broken down in Table 2. In total, there were 11 fatalities recorded in 11 separate fire incidents, while there were 88 injured in 78 incidents.

Table 2: Building structure fire incidents involving flame travel across wall and ceiling linings by building type (excluding single houses) – 2000 to 2005

Building type	Number of fatalities	Number of injured	Number of incidents
Boarding house		1	10
Church		1	11
Community care		1	2
Farm buildings		7	64
Flats and apartments (1–2 units)	7	53	238
Flats and apartments (3–10 units)	2	5	51
Flats and apartments (11–20 units)		1	6
Flats and apartments (21–30 units)		1	4
Flats and apartments (>40 units)	1		3
Hotel, motel, lodge (without liquor licence)	1	3	33
Industrial		5	75
Playground		1	1
Residential not classified		1	17
Residential garage		1	5
Restaurant, pub, tavern		3	57
School		1	86
Retail shop		1	90
Wharf, jetty		1	2
Vacant building		1	19
Other (not classified)			378
TOTAL	**11**	**88**	**1152**

2.2 Fire incidents in which fires have spread due specifically to wall and/or ceiling linings

Internationally, there have been many incidents in which wall and/or ceiling lining materials were found to have contributed to extensive and life-threatening fire spread. One such recorded incident (Tarran-Jones 1986) was a fire started by a patient in the main dormitory wing of a hospital. The alarm was raised automatically and a nurse dispatched to investigate. She evacuated the patient and proceeded to check and close the doors to all the remaining side wards away from the main dormitory. There was a muffled explosion and the nurse was blown to her knees. She managed to make her escape under a thick layer of smoke. The subsequent investigation found that in less than three minutes the flames had spread along the painted surfaces of walls and ceilings, travelling a distance of 170 ft around two corridors.

In another similar example, a major fire broke out in London at the Kings Cross Underground Station in 1987 (Fennell 1988). The fire began under an escalator and initially appeared to be minor and non-threatening. After about 14 minutes the fire suddenly flashed over, catching many escaping occupants unprepared. It was found that the painted ceiling had a major role to play, both in flashover and smoke production, leading to 31 fatalities.

In 1991, a fire occurred in some furniture left for removal in the stairwell of a multi-storey apartment block located in Southwark, London. Flames from the furniture ignited the painted stair walls causing fire to spread up five floors within three minutes, and resulted in one occupant making a fatal leap to avoid the fire (Murrell 1995). An almost identical incident occurred in 1993 in the London Borough of Lambeth. Fatalities again occurred, although the fire spread extended a height of only three floors (Murrell 1995).

In 2003, a fire at the crowded Station Nightclub in Rhode Island was accidentally started by a pyrotechnics display (Grosshandler et al 2005). To commence a band's performance, the venue lights were dimmed and pyrotechnics set off. The pyrotechnics ignited polyurethane foam lining the walls and ceiling of the stage area. The ensuing fire quickly developed, spreading along the walls and ceiling area over the dance floor. Within 30 seconds of the foam igniting, the band had stopped playing and a general evacuation had commenced. The reaction of occupants was very prompt with cell phone calls to the fire service timed at 36 seconds after ignition, and the fire alarm system activating after 41 seconds. The fire developed very rapidly, with smoke recorded to be at floor level inside after only 90 seconds. One hundred people lost their lives in the fire. The large loss of life was attributed to the inadequate exit provisions and the rapid fire growth fuelled by the polyurethane foam on the wall and ceiling.

The Fire Code Reform Centre (FCRC) report (Fire Code Reform Research Program 1998) cites further examples of serious fires in which the wall and ceiling linings were found to be a primary vehicle in the rapid and catastrophic fire spread. In summary these are:

- A fire killed 50 patrons at the Summerland Leisure complex on the Isle of Man in 1973. The initial fire development was attributed to spread across fibreboard wall linings followed by a rapid spread across the acrylic roof of the auditorium.

- A fire in the Las Vegas Hilton Hotel in 1981 resulted in the death of eight occupants. Carpeting on walls and ceiling along with drapes were found to be responsible for the rapid development of this fire.

- Five people died in an office building fire in Atlanta, Georgia in 1989. Multiple layers of wall coverings contributed to the fire development in the corridor.

- Forty-eight people died when fire swept through the Stardust nightclub in Dublin in 1981. The fire was found to have started in seating and spread rapidly via the combination of carpet tiles covering all internal walls, combustible seating and a low ceiling height.

To summarise (FCRC 1998), in many buildings the contents play a dominant role in the initiation and growth of a fire but the lining only provides a path for fire spread. It is a combination of the contents, lining and building geometry that dictate the outcome of a fire.

3. TEST METHODS

Test methods have traditionally been used to measure the performance of a material or system to permit comparative assessment, rarely attempting to replicate real fire exposure conditions.

More recently, the emphasis has moved towards test methods that test replicate both real fire exposure conditions and end use installation and orientation. While no standard fire test method will be able to replicate all real fires, internationally there are increasing attempts to devise test methods utilising at least as real a fire as possible within the bounds of providing a standard test method to be applied equally to all similar products. In addition, the newer test methods are providing more detailed information on the fire growth potential, HRR and other material specific performance data that can be used directly with models for fire safety engineering.

In New Zealand, the present test method for the regulatory control of wall and ceiling linings is AS/NZS 1530.3:1999 *Methods for fire tests on building materials, components and structures, Part 3: Simultaneous determination of ignitability, flame propagation, and smoke release.* This is more commonly known as the Early Fire Hazard Test. The test method comprises a vertically mounted specimen that is progressively moved towards a vertical radiant panel. A small pilot flame is present to ignite any volatiles driven off during the test, and all combustion products are withdrawn via a chimney in which temperature and light obscuration measurements are made. The results are a set of indices to describe spread of flame, smoke developed, heat evolved and ignitability. None of these indices provide material performance data for use in fire safety engineering. The smoke developed index is particularly weak – since it is determined by measuring the optical density of the exhaust products in the stack and the flow rate in the stack is not monitored during the test, making the smoke measurement extremely unreliable.

Previous research on improving the fire performance of polystyrene insulated panels (PIP) (NZFS 2004) evaluated the reasons for the poor performance and identified the panel jointing and containment of the EPS core as primary areas for improvement. It was also recommended that the current ‘flame barrier’ test in NZBC C/AS1 for foamed plastics – which relies on a qualitative judgement of the joint opening after 10 minutes exposure to AS1530.4 fire resistance test conditions – be re-evaluated. The follow-up study (Collier 2005) subjected four variations of panel jointing to the ISO 9705 room corner fire test and clearly showed that the test method was capable of discriminating the differences in fire performance due to the security of the panel jointing and the timing of their opening/failure.

The FCRC study (FCRC 1998) investigated test methods that were available at that time in Australia to measure the performance of wall and ceiling linings and considered the benefits and disadvantages of each. It was found that the most appropriate test method was the ISO 9705 Room Fire Test, and the parameter best suited to control wall and ceiling linings is the time to flashover. The ISO Room Fire Test allows materials to be grouped into bands based on the time to flashover. This basic approach was consistent with recommendations of the earlier EUREFIC (EUropean REaction to FIre Classification) research project. One of the major recommendations from the EUREFIC program was the adoption of the classification scheme proposed by Sundström and Göransson (1988) for wall and ceiling linings. Despite the different methodologies that were used to derive limits, the group into which each material falls is ascertained by measuring time to flashover in the ISO Room Fire Test.

The FCRC study (FCRC 1998) further concluded that the time to flashover in the ISO 9705 Room Fire Test also gives adequate control on smoke production. Should additional controls be sought, it was recommended that these follow the recommendations of the EUREFIC program and apply limits to the rate of smoke production in the ISO Room Fire Test. Subsequently, an additional investigation was carried out leading to a recommendation that it was prudent to continue to regulate the smoke production characteristics of linings, in addition to the heat release characteristics (Wade 2001), and suggested smoke production criteria were identified depending on which fire test was applied.

Time to flashover in the ISO Room Fire Test can be estimated using data from small-scale tests. Relationships have been developed (by Kokkala, Thomas and Karlsson 1993) that allow data from the Cone Calorimeter to be used for such predictions. The same data can also be used in fire engineering calculations that meet the performance requirements of the BCA. Data from the Early Fire Hazard Test cannot be used to reliably predict time to flashover in the ISO Room Fire Test because the indices are not based on appropriate parameters.

Table 3: Test methods in current use internationally

Reproduced from BRANZ *Study Report 144: Flame Barriers for Foamed Plastics* (Collier 2005).

Test method	Juristiction	Exposure/fuel	Room/sample size	Assessment/classification criteria	Comments
AS ISO 9705	Australia	100/300 kW gas burner	3.6 x 2.4 x 2.4(H)	FCRC Group 1, 2, 3 or 4	Trial tests both within ISO room enclosure and free-standing have shown improved results consistent with improvements in fabrication techniques and small scale correlation based on cone calorimeter ABCB A spec A2.4
ISO 9705	International	100/300 kW gas burner	3.6 x 2.4 x 2.4(H)	Eurific Class A, B, C, D, E and UC	Best chance of getting flashover. And subjecting specimen to a severe test. Quantitative. Reference, Johansson and Van Hees, 2001
ISO 13784-1	International	100/300 kW gas burner	3.6 x 2.4 x 2.4(H) free standing		More severe than ISO 9705 but representative of. Easier to erect and demolish specimens
SBI EN13823	Europe	30 kW for 20 mins gas burner		Euro Class A1, A2, B, C, D, E & F (FIGRA) and for smoke s1, s2, or s3 based on smoke produced	Latest calorimetry std (copy of ISO 9705)
LPS 1181 (LPC corner test)	UK	Wood crib 1 MW peak - an ignition test	10 x 4.5 x 3 (H)	Qualitative post-test examination. No pass/fail criteria. Just reports the extent of damage to specimen on a percentage basis	Fire source creates a severe test of short duration (10 mins) and therefore may not simulate a) a small localised fire which continues to spread or b) a fully developed fire of greater thermal severity. Test rig is too big for practical purposes
LPS 1208	UK	Essentially a fire resistance test			Basically fire resistance test based on BS 476. Unsuitable
FM 4880	USA	1.5m (H) x 1.7 x 1.7 m (340kg wood pallet crib approx 4 MW)	6.1 x 6.1 x 15.2 m(H) Corner test	Propagation of upward flame spread above 6 m.	Qualitative assessment. Too big. Unsuitable
NZBC C/AS1	NZ	ISO 874 furnace TT exposure for 10 mins	2.2 x 1 x 1.2m(H)		Qualitative assessment. Unsuitable

Table 3 compares the test methods in use internationally. The methods listed are evaluated on the basis of exposure intensity of the fire source, sample size, assessment and classification of results. Further comments in Table 3 assess the effectiveness of the various test methods.

4. EXPERIMENTAL TRIALS AND ANALYSIS

4.1 Fire testing

Fire testing involved eight examples of lining materials subjected to evaluation in the ISO 9705 room and Cone Calorimeter with the material performance distributed over the 4 Groups (1 to 4) to give a spread of results and enable an evaluation of the test methods.

4.1.1 ISO 9705 room

A typical ISO room layout is shown in Figure 1. The burner in the corner subjects the test specimen to an exposure of 100 kW for 10 minutes followed by 300 kW for 10 minutes. The exhaust gases are removed by the extraction hood and analysed to determine oxygen, carbon dioxide (CO_2), carbon monoxide (CO) and optical density. The HRR is calculated by oxygen consumption calorimetry and the SPR is determined from the optical density and flow rate in the duct.

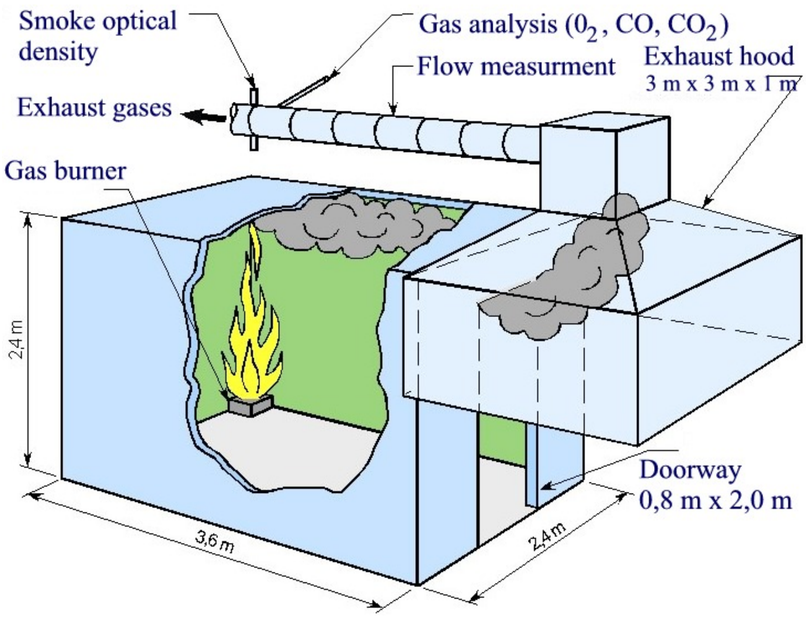

Figure 1: ISO 9705 room and extraction hood (diagram courtesy of SP Swedish National Testing and Research Institute)

The construction of the BRANZ ISO 9705 room is from lightweight concrete panels nominally 100 mm thick and density 560 kg/m^3.

The floor was modified with the addition of 16 mm fire-rated plasterboard over 12 mm plywood covering the floor. This provides a base for securing the bottom edge of the walls to the floor.

The walls and ceiling were fitted with a steel stud frame onto which the lining under test was attached. In the case of flexible fabrics requiring a rigid surface to adhere to, plasterboard was fixed to the framing and the test product was then glued to the plasterboard. In those cases the 'test product' was therefore the combination of the two as listed in Table 4.

Additional thermocouples were mounted in various locations on the surface linings in the room in order to evaluate the rate of surface spread of flame away from the corner burner and enable later comparisons to be made with the heat output.

The reactions to fire performance of the surface lining products tested were classified according to the BCA Group number. (ABCB 2006) Section 10.2 *BCA Specification C1.10a Fire hazard properties – floors, walls and ceilings* as follows:

Group 1 –	materials that do not reach flashover following exposure to 300 kW for 600 seconds, after not reaching flashover when exposed to 100 kW for 600 seconds
Group 2 –	materials that do reach flashover after exposure to 300 kW for 600 seconds, after not reaching flashover when exposed to 100 kW for 600 seconds
Group 3 –	materials that reach flashover in more than 120 seconds, but less than 600 seconds after exposure to 100 kW
Group 4 –	materials that reach flashover in less than 120 seconds after exposure to 100 kW.

4.1.2 Cone Calorimeter

The lining materials tested in this project were exposed to 50 kW/m^2 radiation using the cone heater (Figure 2) and the data recorded was the same as the ISO 9705 room being $O_{2,}$, CO_2, CO and optical density plus mass loss. The results are reported in APPENDIX 1 – , Section 9.3 Cone Calorimeter results and were assessed according to AS/NZS 3837.

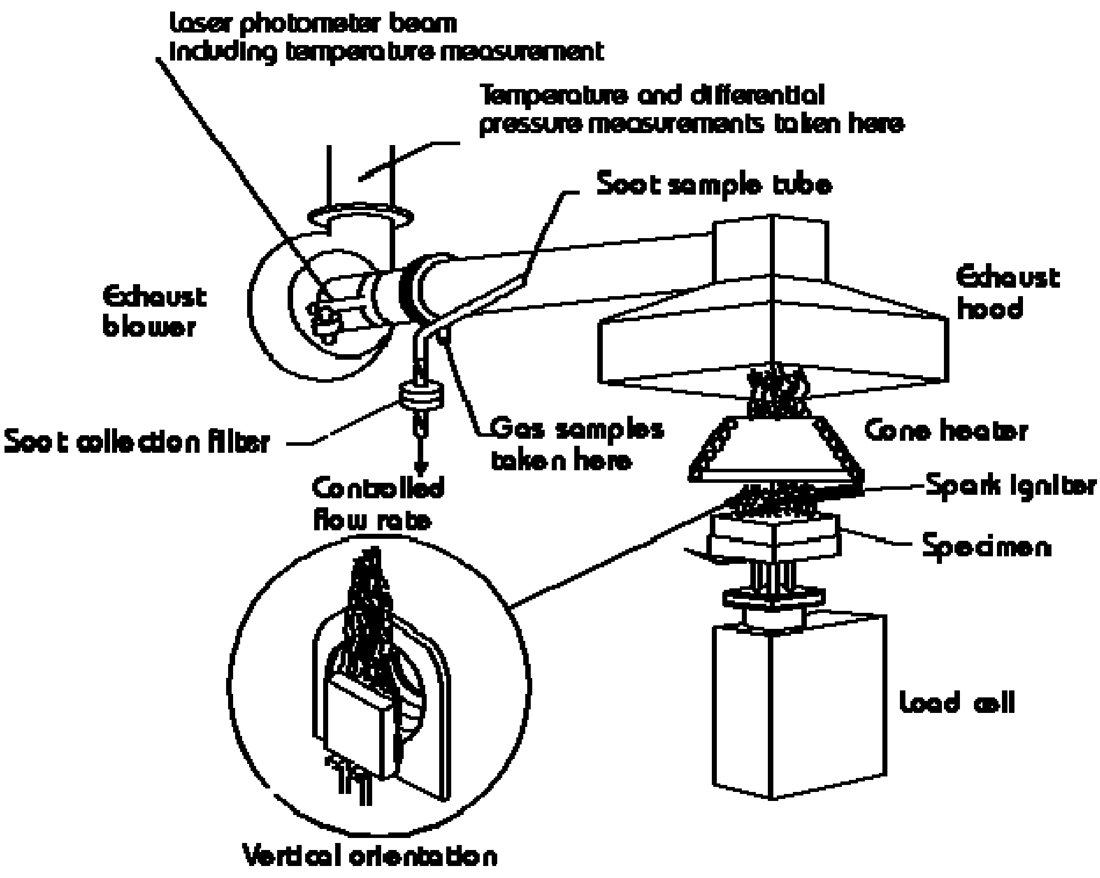

Figure 2: Cone Calorimeter

4.2 Selection of lining products for 'reaction-to-fire' testing

The test programme was developed to assess the effectiveness of the proposed test methods in discriminating the 'reaction-to-fire performance' of a range of lining products available in New Zealand. It was preferred that the selection of products tested covered the range from best to worst and the EFH indices determined by AS 1530.3 were used for this initial ranking. Covering the range of performance was more important than the actual result that a particular product delivered because it was the test method that was under scrutiny rather than the performance of each individual product.

Table 4 and Table 6 show a summary of the selected test products and their physical properties, respectively, of ISO 9705 and Cone Calorimeter samples including some additional linings that were subjected to Cone Calorimeter testing only. These were drawn from a larger selection, and about 50% of the candidates were eliminated on the basis that similar reactions to fire performance would be expected and that the remainder would be adequate to demonstrate the effectiveness of the ISO 9705 room corner test method and Cone Calorimeter.

Table 4: Test products – ISO room and Cone Calorimeter

Product	ISO 9705	AS/NZS 3837	EFH Indices
1. Vinyl wallpaper glued onto plasterboard	*	*	0, 0, 0, 3-6
2. Plywood	*	*	15, 7, 6, 3
3. Plywood+intumescent paint (2)	*	*	-, 0, -, 4
3a.Plywood+intumescent paint (3)	-	*	-, 0, -, 4
4. Glazed fibre-cement board – fixed to steel studs	*	*	0, 0, 0, 0-1
5. Plastic co-polymer fixed to studs	*	*	14, 14, 4, 4
6. 3 mm polyester fibre wall covering fabric glued onto plasterboard	*	*	0, 0, 0, 3
7. 12 mm 100% modified polyester wall covering glued onto plasterboard	*	*	12, 0, 4, 5
8. Rubber based noise barrier – glued onto plasterboard	*	*	?
10. 13 mm softboard+paint	-	*	
11. 13 mm softboard	-	*	

* Tested in this project.

Table 5: Physical properties of test products

Product	Weight kg/m²	Density kg/m³	Thickness mm
1. Vinyl wallpaper	0.21	452	0.46
2. 9 mm plywood	4.67	513	9.1
3. 9 mm plywood with one coat of undercoat and two coats of intumescent paint	4.79	510	9.4
4. 6 mm fibre-cement board with a glazed finish on fire exposed side	6.47	1378	4.7
5. 4.75 mm plastic co-polymer wall lining	4.37	929	4.8
6. 3 mm 100% polyester wall covering	0.38	127	3
7. 12 mm 100% modified polyester wall covering	1.8	150	12
8. 2.6 mm synthetic rubber mass loaded noise barrier with polypropylene scrim backing	5.04	1938	2.6
10. 13 mm wood fibre softboard + paint	3.89	304	12.8
11. 13 mm wood fibre softboard	3.89	299	13

4.3 Cone Calorimeter results

The Cone Calorimeter results at 50 kW/m^2 exposure are summarised in Table 6. A complete set of results are given in APPENDIX 1 – , Section 9.3 Cone Calorimeter results, Table 13 to Table 23. The far right column of Table 6 gives a prediction of the BCA Group number for the lining material in accordance with the method in APPENDIX 2 – Classification of data, Section 10.1.1 Predicting a material's BCA Group number.

Table 6: Cone Calorimeter results at 50 kW/m^2 exposure

Material	Time to sustained flaming secs	End of test secs	Heat release rate peak kW/m^2	Total heat release MJ/m^2	Average specific extinction area (SAE) m^2/kg	Effective heat of com-bustion MJ/kg	Prediction of BCA Group number *
1. Vinyl wallpaper	9	182	166.3	8.1	256.9	6.6	2
2. Plywood	24	343	333.9	47.4	110.4	11.6	3
3. Ply+intumescent x 2	23	84	36	0.6	165	5.0	1
3a. Ply+intumescent x 3	27	88	38.7	0.6	105.9	3.1	1
4. Glazed fibre-cement board	66	190	109.5	3.8	118	5.6	1
5. Plastic co-polymer	32	327	1177.5	119.5	531.2	33.9	4
6. 100% polyester	28	186	462.5	12.4	224.9	11	2
7. 100% modified polyester	37	305	536.7	35.5	414.4	12.5	3
8. Synthetic rubber	31	159	246.6	14.5	322.5	26.4	2
10. Softboard+paint	16	437	181.3	37.9	57.7	11.7	3
11. Softboard	10	437	192.3	42.3	64.1	12.3	3

* Estimated according to BCA 2006 Volume One Spec A2.4-3. See APPENDIX 1 – , Section 10.1.1 Predicting a material's BCA Group number.

The Cone Calorimeter tests were conducted in accordance with AS/NZS 3837 and the end of test conditions are specified as follows:

- no ignition after 10 minutes
- no signs of combustion
- mass loss rate <150g/m^2 averaged over 1 minute
- 60 minutes from start.

Unfortunately there are some limitations in specifying the end of test to the criteria above, in particular for materials where it fails to ignite properly and then the mass loss rate drops below 150 g/m^2 (averaged over a minute). This happened for the plywood with the intumescent paint where the end of test was deemed to occur at 84 and 88 seconds (this essentially meant the material was non-combustible and it was credited with a BCA Group number of 1). Similarly the synthetic rubber test was stopped at 159 seconds on the same mass loss criterion, but actually continued to burn at a rate just below that level for a period exceeding 400 seconds before dropping significantly by 600 seconds (meaning that the BCA Group number of 2 is non-conservative). The basis for determining the end of test and predicting a BCA Group number requires further refinement.

4.4 ISO 9705 results

The ISO 9705 room corner test results for the lining materials selected in Table 4 are summarised in Table 6 and the following sections provide a detailed analysis of the results considering the heat, species evolved and flame spread as a measure of the reaction-to-fire of lining materials. The relationship to Cone Calorimeter data is also examined concluding with a basis for relating reaction-to-fire performance to levels of fire safety.

Table 7: ISO 9705 room corner test results

Product	1	2	3	4	5	6	7	8
Flashover Y/N	Y	Y	Y	N	Y	N	N	Y
Flashover time: min:sec	10:18	3:45	15:51	NA	3:21	NA	NA	2:27
Max HRR 0-2 min (kW)*	209	382	8	5	203	42	123	520
Max HRR 0-10 min (kW)*	209	>900	439	48.6	>900	52.1	122	>900
Max HRR 0-20 min (kW)*	>700	**	>700	191	**	216	122	**
Max SPR 0-2 min (m^2/s)	6.5	1.5	0.59	0.10	0.38	0.48	1.43	6.97
Max SPR 0-10 min (m^2/s)	6.5	**	0.65	0.33	**	0.48	1.66	**
Max SPR 0-20 min (m^2/s)	**	**	**	1.97	**	2.73	1.66	**
Average HRR 0-10 min (kW)*	125	**	-0.83	9.82	**	15.19	20.10	**
Average HRR 0-12 min (kW)*	**	**	36.9	12.63	**	22.55	21.90	**
Average HRR 0-20 min (kW)*	**	**	**	35.13	**	45.56	31.20	**
Average SPR 0-10 min (m^2/s)	0.7	**	0.37	0.18	**	0.23	0.33	**
Average SPR 0-12 min (m^2/s)	**	**	1.45	0.28	**	0.44	0.35	**
Average SPR 0-20 min (m^2/s)	**	**	**	0.68	**	0.85	0.60	**
Group number (BCA)	2	3	2	1	3	1	1	3
FIGRA (kW/s)	1.13	4.7	0.84	0.3	4.76	0.46	1.02	6.18
Max SPR60 (m^2/s)	13.8	5	8.5	1.5	4.5	1.9	1.4	12.4
SMOGRA (m^2/s^2 x 1000)	22.3	27.4	10.8	1.4	22.6	2.5	1.2	84.7

* Excludes burner.
** Post-flashover.

FIGRA = (FIreGRowthRAte) peak HRR of the fire from the product excluding the contribution from the ignition source divided by the time at which this occurs. Units are kW/s (Sundström et al 1998).

SMOGRA = (SMOkeGRowthRAte) 60 second average of peak SPR from the product (up to the point of flashover) divided by the time at which this occurs. The resulting value is multiplied by 1000 to achieve practical values of similar magnitude as the FIGRA index (units are in m^2/s^2). See Section 10.1.2 Predicting a material's smoke growth rate index.

4.4.1 Typical observations – commentary summary

The sequence of events in the ISO room tests followed a similar pattern for each lining product with a few exceptions depending on each product's reaction-to-fire. The exceptions were largely differences in the timing of some of the events, and in some cases where a test did not end in flashover the full sequence of events may not have been completed.

Typical observations and milestones generally in the following order were:

- stable conditions
- limited flaming on surfaces
- smoke production on surfaces
- lining melting and dropping to floor
- extent of flame spread on lining
- cracking and falling off
- extensive flaming
- flames exiting door
- flashover.

In relation to the above milestones, Table 8 summarises the observations recorded in each ISO 9705 test against a timeline on the left hand column. The observations generally correlate with the trends in Figure 3 to Figure 8 and serve as an explanation of any phenomena.

The sequences of photographs in Figure 44 to Figure 51 in APPENDIX 1 – illustrate the developing conditions in the room corroborating the observations and data recorded.

Table 8: Summary of observations in ISO 9705 tests

Time\Test	1	2	3	4	5	6	7	8
	Vinyl paper	Plywood	Plywood + Int	Hardiglaze	Hippolon	Vertiface	Composition	Acoustop
0-	stable conditions	stable conditions	stable conditions	limited flaming on surfaces	limited flaming on surfaces	limited flaming on surfaces and lining melting	stable conditions	lining burning and blistering
0.5	smoke production on surfaces	stable conditions	ditto	ditto	smoke production on surfaces	lining melting dropping to floor	lining melting on outer surface	lining burning and blistering
1	ditto	smoke production on surfaces	ditto	ditto	limited flaming on surfaces	stable conditions		pieces of flaming lining dropping from ceiling to floor
1.5	ditto	ditto	ditto	ditto	lining melting and panels dropping to the floor	limited flaming on surfaces		large pieces of flaming lining dropping to floor and continuing to burn
2	stable conditions	smoke production on surfaces and exiting doorway	ditto	ditto	ditto	ditto	ceiling fabric was dropping and falling to the floor	flaming and smoke from doorway increasing
2.5	ditto	limited flaming on surfaces with smoke production on surfaces	ditto	ditto	extensive flaming from pools of molten hippolon on floor	ditto	ditto	FLASHOVER
3	ditto	burning at edge of burner flame	ditto	stable conditions	significant burning in burner corner	ditto	smoke level had peaked	
3.5-4	ditto	flames exiting door FLASHOVER	ditto	ditto	flames exiting door FLASHOVER	ditto	stable conditions	
4-4.5	ditto	End of test	ditto	ditto	End of test	ditto	ditto	
4.5	ditto		ditto	ditto		ditto	ditto	
5	ditto		ditto	ditto		ditto	ditto	
6	ditto		stable conditions and limited flaming on surfaces	ditto		ditto	ditto	
7	ditto		ditto	ditto		ditto	ditto	
8	ditto		ditto	ditto		ditto	ditto	
9	ditto		ditto	ditto		ditto	ditto	
10	smoke production on surfaces		smoke production on surfaces burning at edge of burner flame	limited flaming on surfaces		limited flaming on surfaces, lining was again melting and dropping to the floor	limited flaming on surfaces	
10.5	increasing smoke production on surfaces		ditto	smoke production on surfaces		ditto		
11	flames exiting door, FLASHOVER			lining cracking and falling off		stable conditions		
12	End of test		burning at edge of burner flame	stable conditions		ditto	ceiling fabric was dropping and falling to the floor in large pieces	
13			flames exiting door	ditto		ditto	lining melting back from flame plume	
14				lining cracking and falling off		some burning of paper face and glue on plasterboard	all ceiling fabric had dropped to floor	
15			flames exiting door FLASHOVER	ditto		stable conditions	stable conditions	
16			End of test	lining cracking and falling off		ditto	ditto	
17				limited flaming on surfaces		ditto	ditto	
18				stable conditions		ditto	ditto	
19				ditto		ditto	minor flaming on back wall	
20				ditto		ditto	stable conditions	
Flashover	10:18	03:45	15:15	No	03:21	No	No	02:27

4.4.2 Heat release rate

The HRRs for the linings in tests 1 to 8 are compared against the burner heat output in Figure 3. In tests 1, 2, 3, 5, and 8 the heat release exceeds 1000 MW signifying flashover and the end of test. Tests 4, 6, and 7 continued for 1200 seconds (20 minutes) without flashover. The margin of the HRR above the burner output of 100/300 kW is the contribution of the lining.

In test 1 (vinyl wallpaper covered plasterboard) the early peak in HRR indicated an initial burning of the lining in the heat-affected region adjacent to the burner that self-extinguished with the heat release returning to the baseline level of the burner output. When the burner output was increased to 300 kW, the preheated vinyl wallpaper very rapidly ignited and exceeded 1000 kW reaching flashover.

In test 2 (9 mm plywood) the HRR steadily increases as the fire spreads across first the ceiling surface followed by the walls to reach flashover at 3 minutes and 45 seconds.

In test 3 (intumescent paint coated 9 mm plywood) the heat release barely rises above the 100 kW of the burner for the first 10 minutes as the fire spread is limited to the immediate vicinity of the burner plume and ceiling jet by the protective cover of the expanding paint layer. The temperature of the painted surface was gradually rising. When the burner output was increased to 300 kW, the preheated but unburnt surface allowed the flame spread to continue until eventually the combined heat release exceeded 1000 kW and flashover occurred.

In test 4 (4.5 mm fibre-cement board with a smooth glazed finish exposed to the fire), the HRR marginally exceeded the burner output indicating that the lining had minimal combustibles to contribute and 20 minutes was reached without flashover.

In test 5 the (4.75 mm plastic co-polymer) lining contributed to a rapid rise in HRR above the burner output as it became involved in the region of the burner plume. A more rapid spread of fire and flashover was delayed by large pieces of the lining melting and dropping onto the floor where some of it continued to burn, but not as rapidly as if it had remained in the hot zone at ceiling level. Eventually sufficient quantity of the lining was burning to increase the heat release to 1000 kW and flashover at 3 minutes 21 seconds.

In test 6 the 3 mm 100% polyester wall covering (glued to plasterboard) contributed marginally to the total heat release during the 100 kW exposure when the polyester fabric covering in the region of the burner plume shrank and melted into globules with minimal burning and dropped to the floor. When the burner output was increased to 300 kW, a brief spike to 450 kW occurred when the preheated fabric burned off and then settled back to about 50 kW above the burner output. A further brief spike to 500 kW occurred and then the HRR settled back to its previous level until the end of the test at 20 minutes.

In test 7 the 12 mm 100% modified polyester wall covering (also glued to plasterboard) contributed a small spike above the initial burner output of 100 kW as the polyester fabric in the vicinity of the burner plume melted and burned back to the boundary of the heat-affected zone, at which point burning of the fabric ceased. As the temperature in the compartment gradually increased in the first 10 minute period at 100 kW burner output, the fabric continued to melt and lose its cohesiveness between the denser grey exposed surface and the less dense backing, resulting in large pieces falling to the floor and not being available for further burning. When the burner output was increased to 300 kW, a large proportion of the fabric had previously fallen to the floor and was not available for burning on the walls and temperature conditions at floor level were not high enough for a pool fire to occur. As a result the total HRR was only marginally above the 300 kW level (of the burner) and some of the additional heat may have been from the remaining glue and paper on the plasterboard.

In test 8 the 2.6 mm synthetic rubber mass loaded noise barrier (glued to the plasterboard) when exposed to 100 kW the lining immediately began to blister in the region of the burner plume and then blistered pieces burnt and fell to the floor contributing to a steady rise in the total HRR. The increasing HRR accelerated the flame spread across the ceiling and then the walls resulting in a very rapid rise to 1000 kW and flashover.

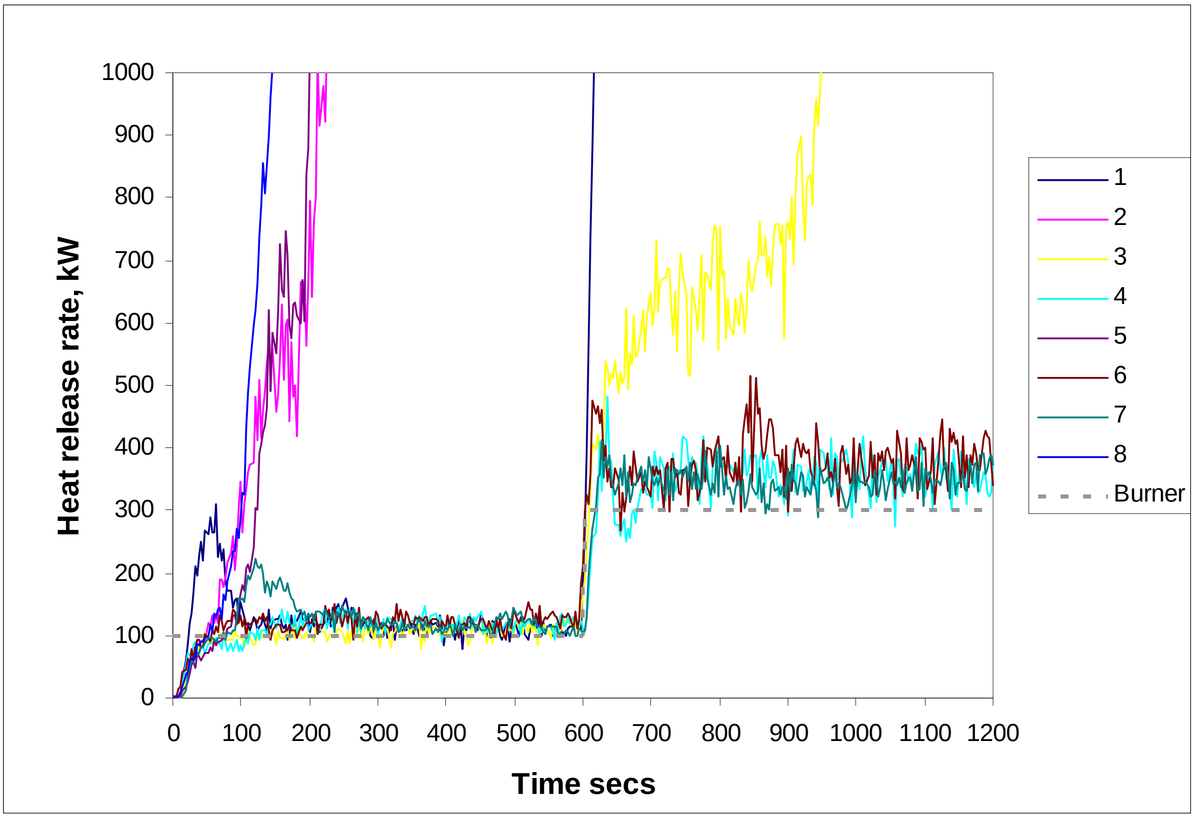

Figure 3: Heat release rates

In all tests, the HRR correlates with the observed spread of flame over the surface of the lining. The phenomenon of preheating was also evident for some materials where the lower level of 100 kW set up conditions leading to rapid growth when the burner output was increased to 300 kW. On the basis of the HRR indicating the occurrence of flashover or not, the ISO 9705 test method was able to rank the lining products in order of best to worst and allocate BCA Group numbers.

4.4.3 Smoke and gas species production

To further validate the reaction-to-fire performance of the linings described in Section 4.4.2 above, consistent trends are indicated in Figure 4, Figure 5 and Figure 6 for the SPR, CO and CO_2 that reflect the HRR. Increases of the SPR generally coincide with increases in the HRR.

Other effects influence the magnitudes of the SPR, such as how much of the combustible products are burning in the hot vitiated (oxygen depleted) atmosphere above the hot layer interface near the ceiling. Rapid increases in the HRR lead to high SPR, CO and CO_2, although the maximums reached coincide with the fire being extinguished after flashover, thus limiting the rise recorded to that time rather than displaying the potential for further increases had the fire continued beyond flashover. And this is perhaps a limitation of the test method in that the full potential for smoke production is not recorded.

An exception to the phenomenon of increasing HRR and SPR was the intumescent painted plywood (test 3) – in this instance the SPR was reducing as the HRR increased slowly from 300 to 1000 kW over a period of 350 seconds. The SPR peaked shortly after the burner output increased to 300 kW, to a level greater than the peak for the unpainted plywood. It then declined, perhaps as the increasing heat and ventilation generated allowed more complete combustion of the pyrolysis products.

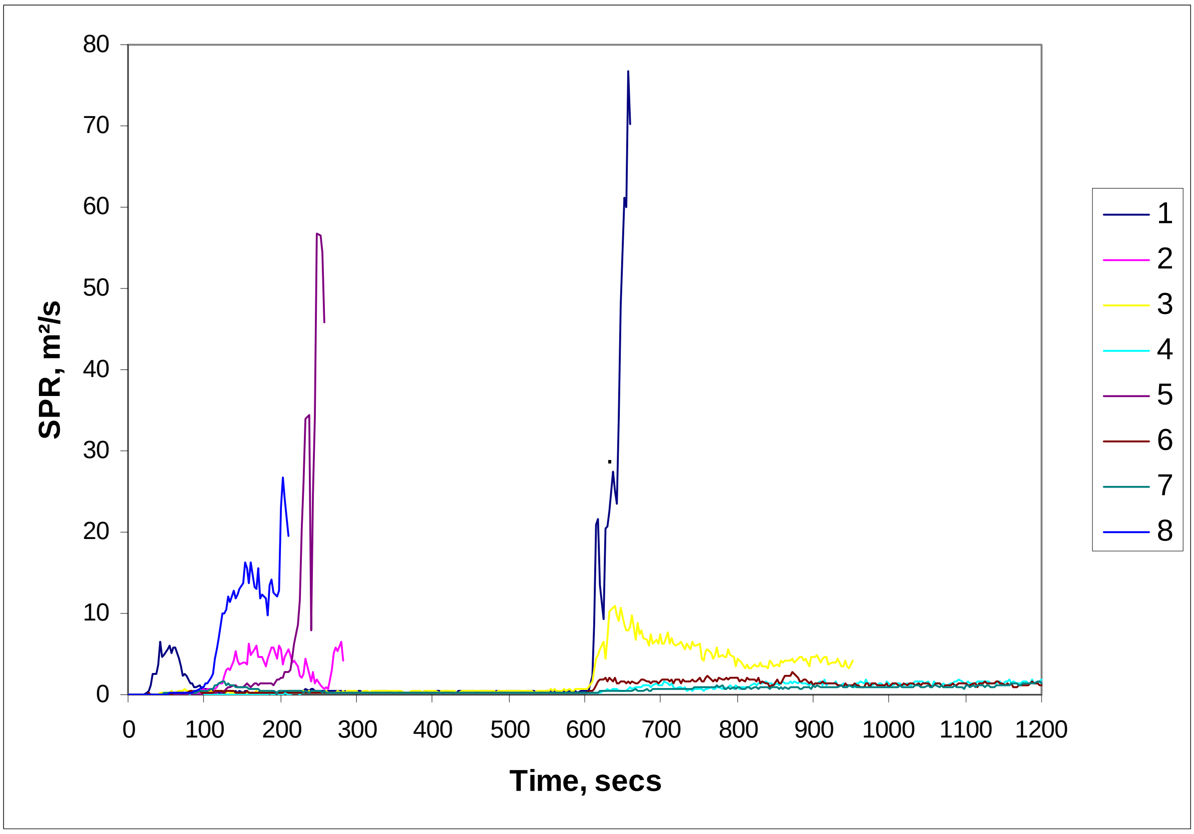

Figure 4: Smoke production rate

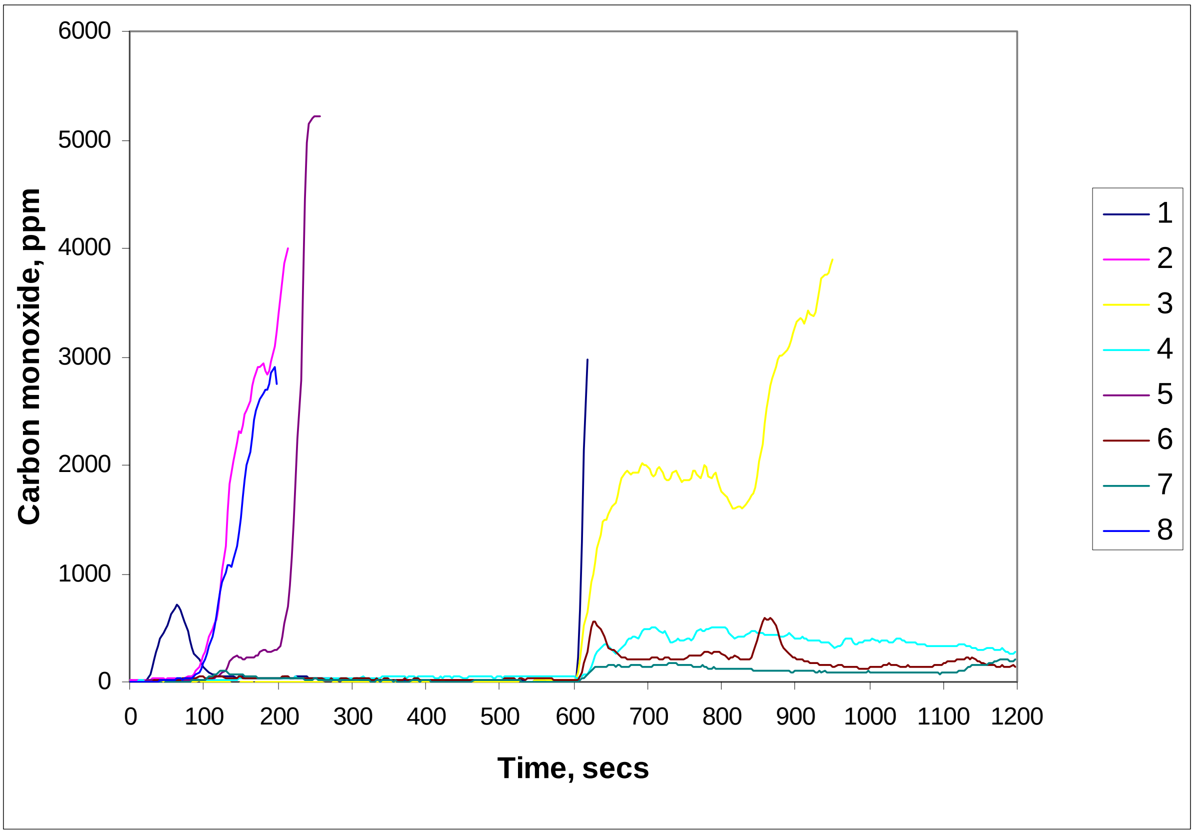

Figure 5: Carbon monoxide production

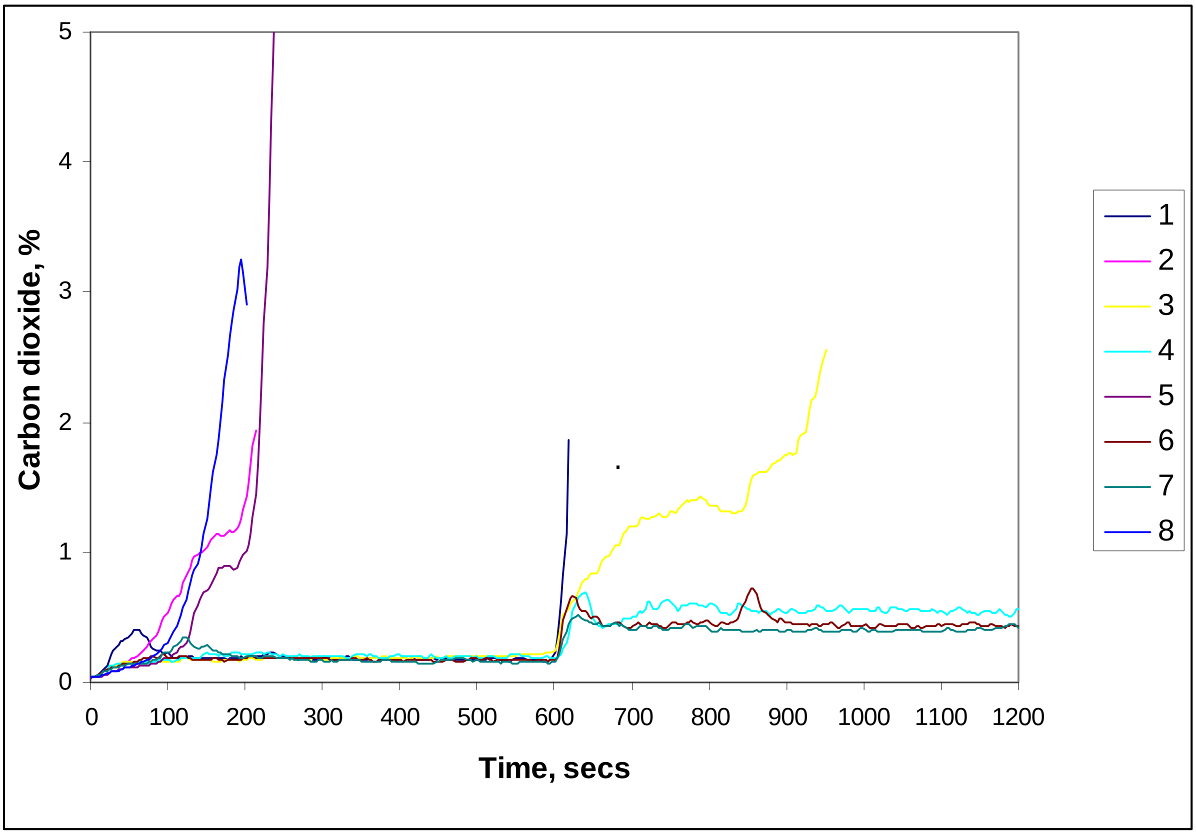

Figure 6: Carbon dioxide production

The levels of CO and CO_2 in Figure 5 and Figure 6 also mimicked the HRR and SPR since they are by-products of the combustion, and the relative proportions indicate the completeness of combustion where an increasing excess of CO over CO_2 indicates the onset of ventilation controlled conditions and flashover.

4.4.4 Flame spread over the lining

The flame spread across the wall and ceiling lining surfaces was monitored by 40 strategically located surface thermocouples spaced at grid locations 600 mm apart near the corner burner and at 1200 mm centres over the remainder. The response of the thermocouples as the flame front approached and passed was to register a rapid increase in temperature of several hundred degrees through a mid-point of 500°C. The results are presented in APPENDIX 1 – as 'two state' temperature contour maps of the walls and ceilings, where the conditions below and above 500°C are shown as areas along with graphs of the % flame spread across the surfaces with respect to time in Figure 12 to Figure 35.

The percentages of surface flame spread for the walls and ceiling are graphed in Figure 7 and Figure 8, respectively. The maximum extent of flame spread is reached at times when the fire is either extinguished after flashover, or at 20 minutes exposure (end of test) when no flashover occurs. The surface flame spread results are summarised and compared with the BCA Group number and SMOGRA index.

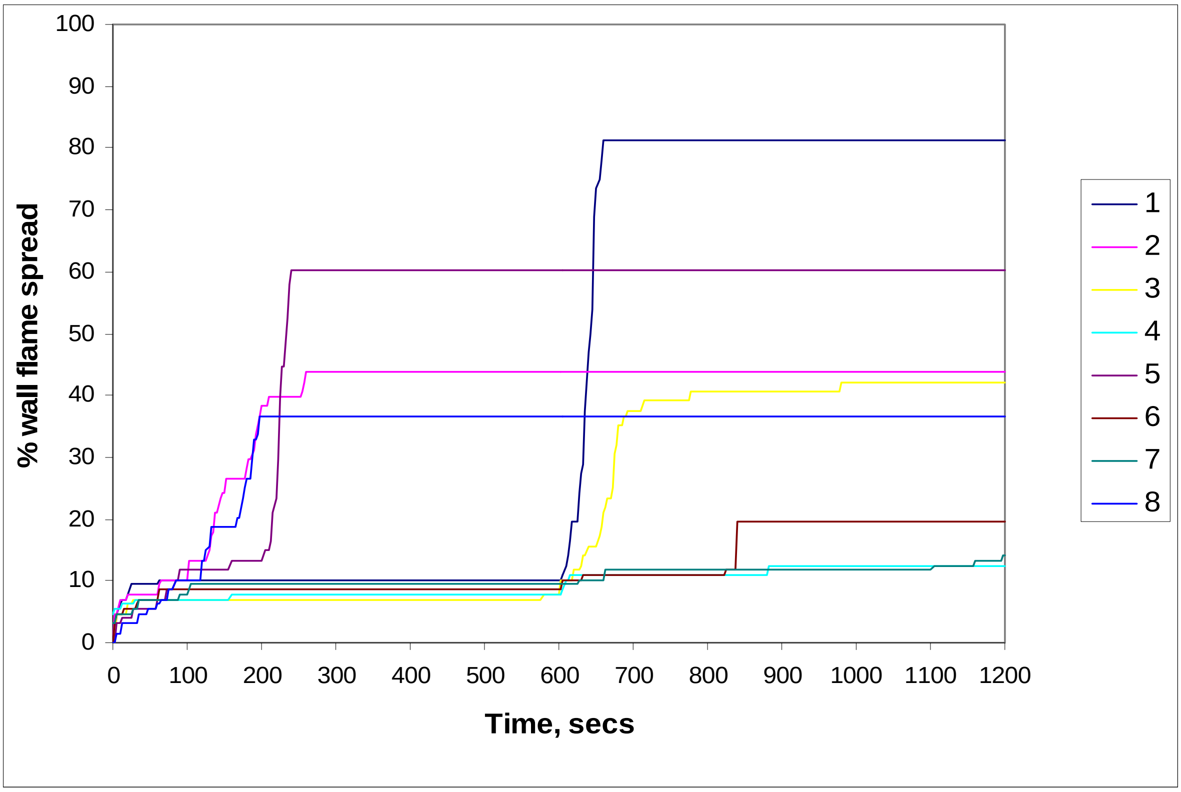

Figure 7:Percentage flame spread on walls

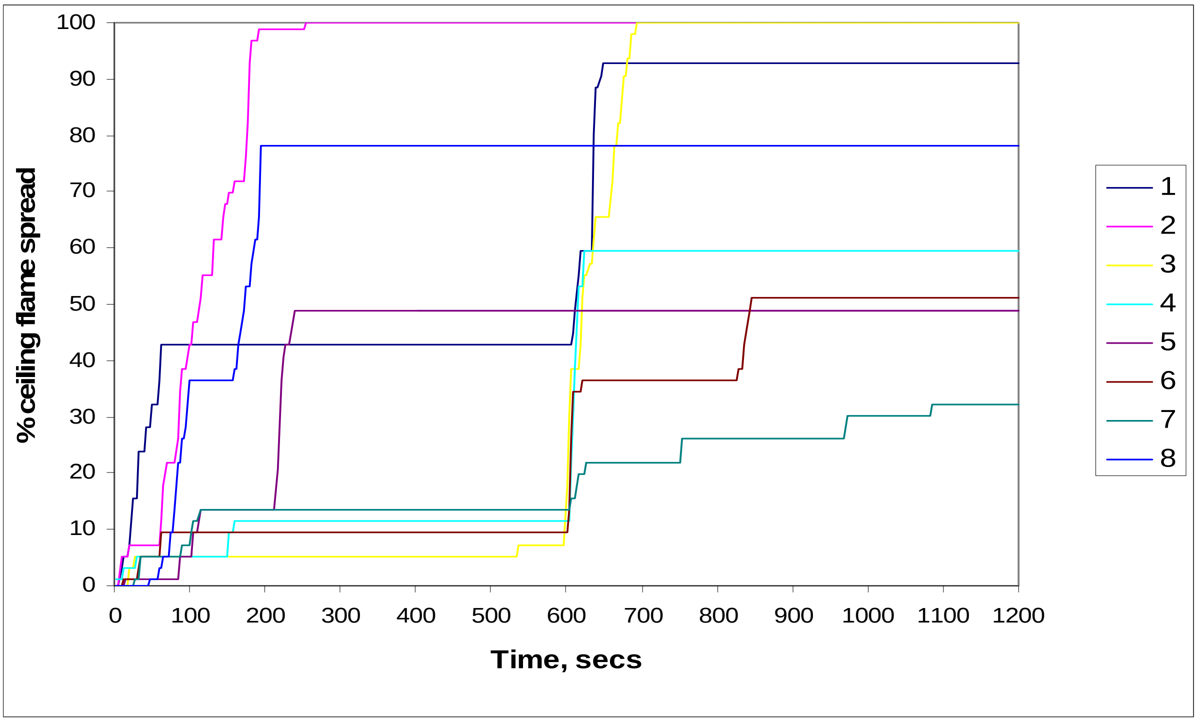

Figure 8:Percentage flame spread on ceiling

Prior to flashover the burning on the walls was predominantly in the upper hot zone, and even after flashover minimal flames were recorded on the lower heights of the walls (the only notable exception was the vinyl wallpaper at 80%).

For the vinyl wallpaper (test 1), the pre-flashover involvement is 10/43% (wall/ceiling % of flame spread) increasing to 20/60% at flashover and reaching a maximum of 80/90 before the fire was extinguished.

In the case of the plywood in tests 2 and 3, approximately the same area of flaming (40-41/99-100%) was required for flashover conditions to be reached, whether it was initially protected with intumescent paint or not. The only difference is in the time taken for the surface flame to spread to consume the intumescent paint coating and thus make sufficient wood available for burning. The intumescent paint delayed the process and flashover occurred 12 minutes later.

In the case of the fibre-cement board (test 4) the glazed surface did gently burn on a flame front (probably only about 50 mm wide) before running out of combustible material. A maximum of 12.5/60% had been reached at 20 minutes and the test was stopped once fairly stable conditions had been reached without flashover.

For the plastic co-polymer lining (test 5), a relatively small amount of flame spread of only 8/23% was required for flashover. Before flashover some had melted and dropped to the floor, thus not contributing to the flashover and probably delaying it. The BCA Group number prediction based on the Cone Calorimeter result was Group 4, but in the ISO 9705 room test the lining melted and dropped to the floor and this was probably responsible for delaying flashover beyond two minutes and being assessed as a Group 3 classification.

The two polyester wall coverings (tests 6 and 7) similarly melted and dropped from the walls and ceiling, requiring only minimal temperature rises for that to happen. Because the lining was effectively removed from the hot zone, the surface flame spread was limited to the boundaries of the burner plume and ceiling jet. The indicated values of flame spread of 20/51% and 14/32%, respectively, at the 20 minutes exposure did not accurately reflect the fire load available due to the shrinking and loss of the lining fabric. This was a significant factor in improving on the Cone Calorimeter Group 2 and 3 predictions in Table 7 into a Group 1 performance in the ISO room. Also the relatively low SMOGRA values are at variance with that indicated by the Cone Calorimeter results, but consistent with the observed detachment of the lining fabric and extinguishment on the floor.

The synthetic rubber lining (test 8) adhered to the walls and ceiling allowing flame spread to rapidly develop to the 18/36% that was sufficient for flashover to occur. The spread then increased further to 37/78% before extinguishment.

Table 9: Percentage of surface flame spread for wall/ceiling at significant events

Test # – Material	Pre-flashover	At flashover	Maximum**	BCA Group number	SMOGRA
1. Vinyl wallpaper	10/43%	20/60%	80/90%	2	22.3
2. 9 mm plywood	8–40/8–99%*	40/99%	43/100%	3	27.4
3. 9 mm plywood with one coat of undercoat and two coats of intumescent paint	5/8%	41/100%	42/100%	2	10.8
4. 6 mm fibre-cement board with a glazed finish on fire exposed side	NA	NA	12.5/60%	1	1.4
5. 4.75 mm plastic co-polymer wall lining	8/23%	8/23%	51/46%	3	22.6
6. 3 mm 100% polyester wall covering	NA	NA	20/51%	1	2.5
7. 12 mm 100% modified polyester wall covering	NA	NA	14/32%	1	1.2
8. 2.6 mm synthetic rubber mass loaded noise barrier with polypropylene scrim backing	18/36%	18/36%	37/78%	3	84.7

*A steady increase to the point of flashover.
** Extinguishment may have prevented further spread.

The lower SMOGRA (Table 9) for 12 mm modified polyester wall covering (test 7) is consistent with the observation of large pieces falling to the floor, and then not burning compared with the lighter weight 3 mm polyester wall covering (test 6) shrinking in the heat and pyrolysing while still adhered to the walls. By comparison, the Cone Calorimeter results in Table 6 show that the magnitude of the smoke parameter (smoke extinction area (SEA)) is the opposite for the two polyester materials and this can be explained by the molten material being contained in a pool and being completely consumed so the total smoke potential is recorded.

4.5 Group number classification using ISO 9705 and Cone Calorimeter

4.5.1 BCA Group number

Comparing the two test methods for determining the BCA Group number in Figure 9, based on the data in Table 10, the Cone Calorimeter prediction method either agrees with the ISO room result or predicts a higher (conservative) or lower (non-conservative) BCA Group number. In the cases of lining samples 1 and 2 the prediction agrees, for linings 5, 6, and 7 the prediction is higher and therefore conservative, but for linings 3 and 8 a lower BCA Group number is predicted which is non-conservative. This raises a concern that Cone Calorimeter testing may credit more hazardous lining products with better reaction-to-fire performances than they are entitled to.

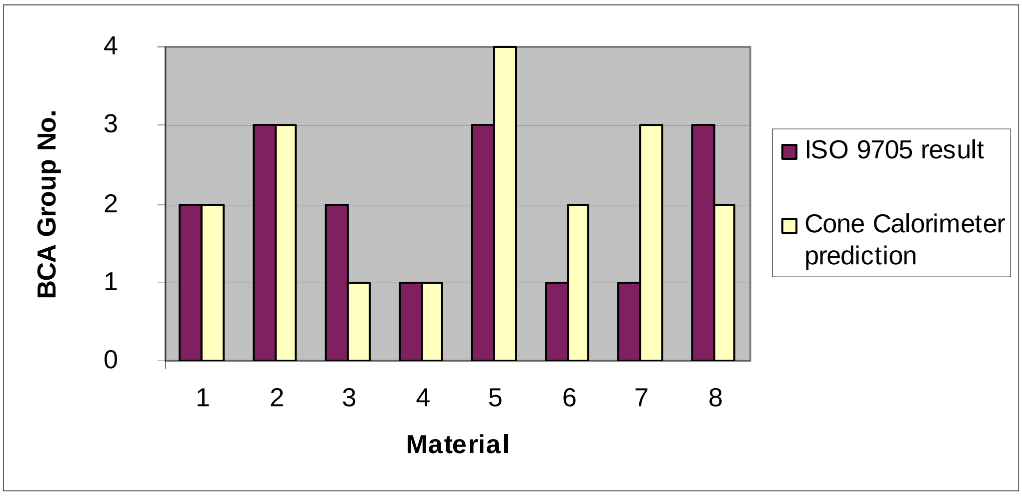

Figure 9: Comparison of Group number obtained from test methods AS/NZS 3837 and ISO 9705

One obvious reason for conservative predictions is that certain lining materials may melt, soften or otherwise become detached from the walls and ceiling in the ISO room and fall to the floor where the heating conditions are not so severe (and in doing so effectively reduce the mass of product subjected to the test). This was the case for tests 5 (plastic co-polymer), 6 (100% polyester) and 7 (100% modified polyester). In the Cone Calorimeter, the test samples were contained so that when a pool of molten product formed it was entirely consumed during the test and data was recorded.

To explain the non-conservative predictions for linings 3 (plywood and intumescent) and 8 (synthetic rubber), the BCA prediction is very dependent on the end of test time prescribed in AS/NZS 3837 as follows:

- no ignition after 10 minutes
- no signs of combustion
- mass loss rate <150g/m^2 averaged over 1 minute
- 60 minutes from start.

Early test terminations due to the mass loss rate of the sample falling below 150 g/m^2 (averaged over 60 seconds) resulted in data from the tests on linings 3 and 8 beyond times of 84 and 136 seconds, respectively, not being considered are responsible for the low BCA prediction of Group number. In the case of the plywood and intumescent paint (lining 3), the paint protected the plywood from ignition while the plywood slowly decomposed with only intermittent ignition (pyrolysed) and a peak of heat release after 600 seconds exposure greater than 200 kW/m^2. However, this was not considered in the BCA prediction as the test was deemed to have finished at 84 seconds according to the mass loss rate criterion of AS/NZS 3837. Similarly the synthetic rubber (lining 8) had a premature end of test criterion due to the same mass loss parameter at 136 seconds. However, after that the HRR levelled off to a plateau at about the critical level (of mass loss rate) and continued to release heat until 400 seconds, and then an exponential decay commenced as the combustibles were fully consumed by about 600 seconds.

So in each case after the end of test criteria indicated an end of test to AS/NZS 3837, there was still a significant amount of heat release that occurred that was not taken into consideration in the assessment of the BCA Group number prediction. The analysis was repeated using an alternative Cone Calorimeter test method ISO 5660-1 (2002) with different end of test criteria as follows:

- no ignition after 30 minutes
- O_2 returns to pre-test value less 0.01 % i.e. 20.95 – 0.01 = 20.95%
- mass = 0
- 32 minutes after ignition.

Then for the two tests in question (#3 and #8), if the end of test time is extended to a point when the HRR has reduced significantly then higher (worse) Group numbers are predicted and the correct or conservative classification results. Therefore, the use of the ISO 5660 test method should be preferred over AS/NZS 3837 for determining the Group number until such time as AS/NZS 3837 is amended. Table 24 and Table 25 compare the BCA predictions based on the AS/NZS 3837 and ISO 5660-1, respectively.

The principal difference between AS/NZS 3837 (see Section 4.3 above) and ISO 5660-1 end of test criteria is the mass loss rate, and that can affect the BCA Group number prediction as well as the average SPR. In testing materials in the Cone Calorimeter, certain product types may also produce results that are unsuitable for assessment using the method above because, for instance, construction details may be critical in an assembly with a combustible core (e.g. insulated panel). For these types of products some judgement is required and, as such, Cone Calorimeter testing may be deemed to be unsuitable and room-scale testing necessary.

4.5.2 Smoke production results

The smoke production measurements recorded in the Cone Calorimeter and ISO 9705 room are compared in Table 10.

Table 10: Cone Calorimeter AS3837 and ISO 9705 room comparisons

Material/test parameter	AS 3837 average specific extinction area SEA m^2/kg	AS 3837 prediction of BCA Group number **	ISO 9705 SPR60 (peak) m^2/s	ISO 9705 SMOGRA, m^2/s^2 x 1000	ISO 9705 BCA Group number	BCA Group number prediction status
1.Vinyl wallpaper	256.9*	2	13.8	22.3	2	agreement
2. Plywood	110.4	3	5	27.4	3	agreement
3. Ply+intumescent x 2	165	1(3†)	8.5	10.8	2	non-conservative
3a.Ply+intumescent x 3	105.9	1(3†)	-	-	-	
4. Fibre-cement board	118	1	1.5	1.4	1	agreement
5. Plastic co-polymer	531.2*	4	4.5	22.6	3	conservative
6. Polyester wall covering	224.9	2	1.9	2.5	1	conservative
7. Mod polyester wall covering	414.4*	3	1.4	1.2	1	conservative
8. Synthetic rubber	322.5*	2(3†)	12.4	84.7	3	non-conservative
10. Wood fibre softboard+paint	57.7	3	-	-	-	
11. Wood fibre softboard	64.1	3	-	-	-	

* 250 m^2/kg exceeded and BCA only permits use in sprinklered premises.
** Estimated according to BCA 2006 Volume One Spec A2.4-3. See APPENDIX 2 – Classification of data, Section 10.1.1 Predicting a material's BCA Group number.
† Prediction of BCA Group number using ISO 5660-1 end of test criteria.

The *BCA Specification C1.10a Fire hazard properties – floors, walls and ceilings* (see APPENDIX 2 – Classification of data, Section 10.2.2) specifies limitations on smoke production only in cases where there is no fire sprinkler system installed. In this case, the maximum smoke production is given by:

1. ISO 9705 – SMOGRA not more than 100 m^2/s^2 x 1000, or
2. AS/NZS 3837 – average SEA less than 250 m^2/kg.

The relationship between the SEA and SMOGRA is plotted in Figure 10 and it appears that no correlation exists. It is supposed that a SMOGRA of 100 m^2/s^2 x 1000 is equivalent to an SEA of 250 m^2/kg. The lack of any correlation should be qualified by acknowledging that in the cases where the ISO room test is stopped at flashover, before the lining has all been consumed, the smoke produced (SMOGRA) does not take into account the full potential of the lining as the Cone Calorimeter does by continuing to collect data until it has been totally consumed. Similarly, in some ISO room tests the lining fell to the floor when heated and its contribution to smoke production and heat release then ceased.

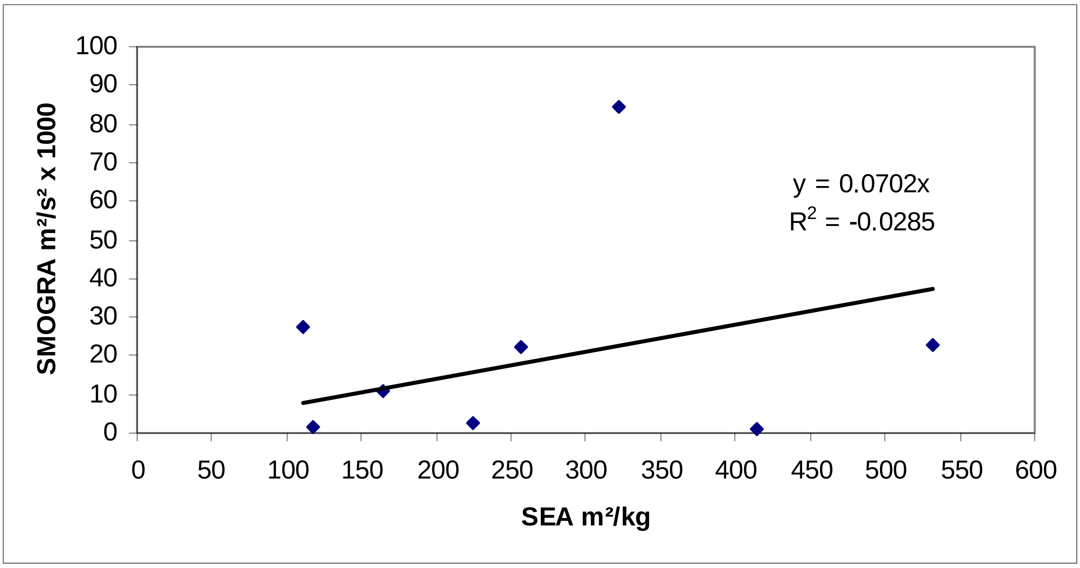

Figure 10: Smoke production comparison of SMOGRA and SEA

The Cone Calorimeter results for SEA that are greater than 250 m^2/kg indicate that sprinklers would be required for the vinyl wallpaper, plastic co-polymer, 12 mm modified polyester and synthetic rubber. However, the corresponding ISO room SMOGRA results do not support this as 100 (m^2/s^2 x 1000) is not exceeded. So there is a similar degree of conservatism with Cone Calorimeter results for smoke as there is for BCA Group number. The less expensive test method (Cone Calorimeter) gives a usable reaction-to-fire result, but the more expensive ISO room may deliver a more favourable result in the above cases.

The poor correlation between SEA and SMOGRA suggests that the smoke production criteria currently used in the BCA method warrants further investigation. For a constant smoke yield the major driver of smoke production is the mass burning rate of the fuel (i.e. the amount of smoke produced is proportional to the amount of fuel pyrolysed), which also directly influences the rate of heat release, therefore it is likely that the BCA Group numbering system which is influenced by the rate of heat release will also serve as a first-order control on the amount of smoke produced. This has been used as an argument for not regulating the SPR from linings at all (FCRC 1998). Wade (2001) discusses this aspect in more detail and concludes that some level of control would still be prudent, if only to ensure that the very worst smoke producers are captured and excluded from use.

4.6 Modelling SPR in the ISO 9705 room

The smoke production results obtained by testing lining materials can be used with fire modelling software such as BRANZFIRE (Wade 2001). For example, the SEA determined from Cone Calorimeter results can be used to estimate an average smoke yield ($Y_{s,}$ kg/kg):

$$Y_s = \frac{SEA}{K_m}$$

where K_m = 7600 m^2/kg (assuming flaming combustion).

BRANZFIRE then uses the Y_s data to calculate the SPR (m^2/s) when modelling a full size scenario, which may be comparing the SPR with an ISO 9705 test result or a more complex problem involving multiple compartments.

This approach is intended for engineering analysis and is not really suitable as a regulatory tool. Of more interest here is research by Van Hees et al (2002) who have proposed a method of predicting the smoke production in the room corner test using Cone Calorimeter data. Their approach uses a multi-variate statistical analysis method. A brief description will be given here as it relates to the current study.

On the understanding that we only wish to apply this prediction method to Group 1 and 2 materials, the first step is to identify the Group number classification. Group 1 contains products that do not flashover in the room, while Group 2 contains products that flashover in the interval 600–1200 seconds.

Van Hees et al (2002) used sets of Fisher's discrimination functions for each group and five variables from Cone Calorimeter testing were identified as being able to distinguish between the three levels of both SPR max and SPR avg. These variables were:

- $w_1 = \rho_{mean}[kg/m^3]$
- $w_2 = THR_{300s}[MJ/m^2]$
- $w_3 = \ln(t_{ign})$
- $w_4 = \ln(FIGRA_{cc})$
- $w_5 = \ln\left(\frac{SPR_{\max}}{HRR_{\max}}\right)$

ρ_{mean} is the mean density of the material within 10 mm depth of the exposed surface.

$FIGRA_{cc}$ is the maximum value of the ratio between HRR and time when the HRR was measured.

THR_{300s} is the total heat released in the 300 seconds following ignition.

t_{ign} is the time to ignition taken as the time when the rate of heat release reaches 50 kW.

$HRR_{\max}$ and $SPR_{\max}$ are the maximum values of rate of heat release SPR over the period of the test. Where the test duration is longer than 15 minutes, only the first 15 minutes are used in the calculations.

The classification functions for predicting the average smoke production in the room corner test for Group 1 materials are:

$$F_{1-avg1} = 0.008004w_1 + 0.07154w_2 - 0.227w_3 + 9.976w_4 - 18.308w_5 - 94.359$$

$$F_{2-avg1} = 0.01445w_1 + 0.09239w_2 - 1.611w_3 + 10.318w_4 - 14.280w_5 - 71.270$$

$$F_{3-avg1} = 0.002022w_1 + 0.01573w_2 + 4.466w_3 + 9.735w_4 - 13.128w_5 - 62.885$$

All three functions are calculated for the case to be predicted and the one that gives the highest result is taken as the predicted level of SPR_{avg}.

Similarly for the Group 2 materials, the classification functions for predicting the average smoke production in the room corner test are:

$$F_{1-avg2} = 0.02123w_1 + 0.158w_2 - 3.567w_3 + 7.893w_4 - 23.272w_5 - 116.94$$

F_{2-avg1} not applicable here

$$F_{3-avg2} = 0.002587w_1 + 0.599w_2 - 4.577w_3 + 3.910w_4 - 19.343w_5 - 84.499$$

This model was applied to the Group 1 and 2 materials in the current study with disappointing results. There were significant discrepancies between the predicted SPRs in the ISO 9705 using the Cone Calorimeter data and the actual measured SPRs. Further research in this area is needed.

4.7 Performance criteria for fire growth and smoke development

Table 11 ranks the performance of the lining materials from best to worst based on the measured time to flashover in the ISO 9705 test. The first three columns giving the BCA Group number, FIGRA and SMOGRA indices were derived from ISO 9705 measurements. The remaining columns of ISO 9705, Cone Calorimeter and EFH derived-data to the right were included to complete a map of performance which in places varies from the order.

While ISO 9705 results are preferred for classification purposes due to the full-scale configuration of the test, the basis for also allowing small-scale Cone Calorimeter (ISO 5660-1 or AS/NZS 3837) results to be used is due to their greater convenience and lower cost. The relative costs of an ISO 9705 room corner test and a Cone Calorimeter test with three replicate samples are \$10,000 versus \$1000 respectively. A preference for the Cone Calorimeter is considered to be quite reasonable, provided the small-scale testing gives a conservative assessment of the full-scale result and this appears to be the case if the ‘end of test criteria’ are in accordance with ISO 5660-1. All the products tested in this project, as shown in Table 11, achieved a Group number classification the same or more conservative than the classification derived from ISO 9705.

However, based on experience with the new Australian classification system using ISO 9705 and ISO 5660 tests, it is apparent that there are certain types of product where classification should not be determined from ISO 5660 testing. Examples include metal clad insulated panels with combustible cores and aluminium composite panels. The difficulty with relying on an ISO 5660 classification for these materials is that in practice their performance is highly dependent on the integrity of the panel jointing methods, and these are not able to be evaluated with test samples measuring only 100 x 100 mm. Other products with thin protective coatings over combustible cores may also prove problematic when assessed using ISO 5660, particularly when mounted in a wall and ceiling configuration where the thin coating is subjected to stresses and deformations from gravity and thermal loads which are not replicated when placed horizontally in a Cone Calorimeter. It is suggested that additional guidance will be needed to ensure that a new regulatory classification system is able to deal with these particular product types so that their classification is commensurate with the actual risk they represent.

Previous research (Collier 2005) has investigated the performance of PIP (as an example of such a product type) and concluded that the ISO 9705 test method was suitable for evaluating its early fire hazard characteristics.

Table 11: Ranking the performance of the lining materials

Material \ Test Parameter	BCA Group	FIGRA, kW/s	SMOGRA, m^2/s^2 x 1000	Average specific extinction area SEA,	Prediction of BCA Group No. **	SPR60 peak, m^2/s	Flashover, secs	% spread walls	% spread ceiling	Tig	HRR peaK, kW	Total Heat MJ/m²	SFI	SDI	EFH Indices, IG, SF, HE, SD
Test method	ISO 9750	ISO 9750	ISO 9750	Cone	Cone ISO5660	ISO 9750	ISO 9750	ISO 9750	ISO 9750	Cone	Cone	Cone	EFH	EFH	EFH
4. Glazed fibre cement board	1	0.3	1.4	118	1	1.5	N	12.6	60	66	109.5	3.8	0	1	0, 0, 0, 0-1
6. 100% polyester	1	0.46	2.5	224.9	2	1.9	N	20	51	28	462.5	12.4	0	3	0, 0, 0, 3
7. 100% modified polyester	1	1.02	1.2	414.4*	3	1.4	N	14	32	37	536.7	35.5	0	5	12, 0, 4, 5
3. Ply+Intumescent x 2	2	0.84	12.8	165	3	8.3	951	41	100	23	36	0.6	0	4	-, 0, -, 4
1.Vinyl wallpaper	2	1.13	22.3	256.9*	2	13.8	618	20	60	9.3	166.3	8.1	0	4	0, 0, 0, 3-6??
2. Plywood	3	4.7	27.4	110.4	3	5	225	40	99	24.7	333.9	47.4	7	3	15, 7, 6, 3***
5. Plastic co-polymer	3	4.76	22.6	531.2*	4	4.5	201	8	23	32	1177.5	119.5	14	4	14, 14, 4, 4
8. Synthetic rubber	3	12.4	84.7	322.5*	3	6.18	147	18	36	31.3	246.6	14.5	0	5	0, 0, 0, 5 ??

As indicated in the previous section, the basis for selection of the smoke production criteria is not as convincing or robust as for the basis for the Group number classification scheme. There seems to be no simple correlation between smoke production in the room fire test and the Cone Calorimeter. This was also the conclusion reached in the EUREFIC study by Östman (1991).

Regarding alternative suggested performance criteria to those already described for the BCA above, the EUREFIC research programme recommended the following criteria for SPR:

$SPR_{\max} < 2.3$ m²/s and $SPR_{\max} < 0.7$ m²/s (excluding the burner contribution) for proposed EUREFIC class A (= Group 1 materials).

$SPR_{avg} < 16.1$ m²/s and $SPR_{avg} < 1.2$ m²/s (excluding the burner contribution) for proposed EUREFIC class B, C, D (= Group 2 materials).

Table 13 shows a possible mapping of the existing early fire hazard properties for interior surface finishes from Table 6.2 of C/AS1. It also indicates the applications where smoke production limitations would be appropriate.

Table 12: Suggested mapping of performance levels in C/AS1

Purpose Group or location	Maximum permitted index (current)		Maximum permitted group number (proposed)	Row
Exitways in all Purpose Groups and sleeping areas in Purpose Groups SC, SD	SFI 0	SDI 3	Group 1 +smoke limits	1
All occupied spaces in Purpose Groups CS and CL excluding exitways (see also Paragraph 6.20.7) All occupied spaces in Purpose Group CM where the occupant load is greater than 50 Sleeping areas in Purpose Group SA (see also Paragraph 6.20.6 for trampers' huts)	SFI 2	SDI 5	Group 2 +smoke limits	2
Passageways, corridors and stairways not being part of an exitway in all Purpose Groups except SH and SR	SFI 7	SDI 5	Group 3	3
Minimum requirements for all occupied spaces in all Purpose Groups except within household units in Purpose Groups SR and SH	SFI 5 or SFI 9	SDI 10 SDI 8	Group 3	4
Within individual household units in Purpose Groups SR and SH	n/a	n/a	Group 3	5

Alternatively a more extensive reworking the Purpose Group concept in alignment with the BCA Class numbers as shown in APPENDIX 2 – Classification of data, Section 10.2.2 Walls and ceilings provisions BCA may be warranted.

5. CONCLUSIONS

Based on investigation of the literature and the results of a series of experiments on selected wall and ceiling surface lining materials conducted in the ISO 9705 (room/corner), and using AS/NZS 3837 (Cone Calorimeter), the following conclusions are drawn:

- New Zealand is the only country currently using the AS1530.3 method for assessing the fire properties of wall/ceiling linings. This is undesirable from an international trade perspective and preference should be given to international standards whenever possible.

- The ISO 9705 room/corner test method is an internationally recognised method and is a suitable means of assessing and comparing the early fire hazard characteristics of wall and ceiling lining materials when exposed to a moderate (100/300 kW) heat source, on the basis that 'time to flashover' is a direct indicator of hazard to occupants. The test method is considered to be an appropriate 'reference scenario' for the purpose of product classification.

- Experimental data included in this report shows that spread of flame across the surface of the linings in the ISO 9705 test is directly related to the rate of rise of HRR and smoke production from the wall/ceiling linings.

- Using the ISO 9705 method, some wall/ceiling linings showed only limited spread of flame at the 100 kW exposure level, but this increased after exposure to 300 kW to reach flashover conditions.

- The Cone Calorimeter method (AS/NZS 3837 and ISO 5660) was shown to produce fire property data that when used as input to an empirical correlation was able to predict the same (or a more conservative) classification when compared to the ISO 9705 test. The Cone Calorimeter method is significantly more convenient and less expensive than the ISO 9705 test.

- The Cone Calorimeter test method ISO 5660 is preferred over the AS/NZS 3837 method. The main difference between the two methods is the end of test criteria where the latter method has been found to give unrealistically short test durations for some materials.

- There are no suitable correlations available for predicting smoke production in the ISO 9705 room based on Cone Calorimeter smoke data meaning that different criteria are needed for each test method. The ability to predict the smoke hazard from small-scale data is less well developed compared to the fire growth hazard. However, since there is a direct relationship between the rate of heat release and the total amount of smoke produced, this is not a serious deficiency in the overall methodology proposed here.

- Previous research on the performance of insulated panels showed that for some wall/ceiling systems the construction details played a critical role in the overall fire behaviour of the panel, and these details cannot be assessed using the Cone Calorimeter method. Product types where the Cone Calorimeter is not suitable for product classification purposes should be identified as part of the regulatory solution and ISO 9705 testing used for these cases.

- The findings of this study support the adoption of new fire test methods (ISO 9705 and ISO 5660) based on actual fire performance parameters rather than ranking indices from AS1530.3. Such data is also an essential input to fire models should they be used as part of Alternative Solutions as permitted by the NZBC.

- Fire testing using ISO 9705 for foamed plastics materials could be used to replace the current ‘flame barrier’ test for foamed plastics in C/AS1. This means that wall and ceiling products that include foamed plastics materials (including insulated panel) could be assessed using the same methods and criteria as applied to other wall and ceiling products.

6. RECOMMENDATIONS

It is recommended that:

- The early fire hazard characteristics of wall and ceiling linings as required by NZBC Compliance Document C/AS1 be assessed using the fire test methods ISO 5660 (Cone Calorimeter) and ISO 9705 (room test) similar to the approach recently included in the BCA.

- The same performance requirements for wall and ceiling surface lining materials also be applied to foamed plastics building materials where they form part of the wall or ceiling lining, replacing the existing requirements in C/AS1 relating to use of ‘flame barriers’ and ‘foamed plastics’.

- Wall and ceiling products be classified into four groups (1 – best to 4 – worst) based on actual or predicted time to flashover in the ISO 9705 room, following the groups identified in the BCA.

- Smoke production from wall and ceiling linings should only be regulated for Group 1 and 2 products and only in buildings not protected with automatic fire sprinkler systems. Restricting SPRs should be considered a secondary control with the objective of identifying only the poorest performers.

- Group 4 materials, which are indicative of extremely rapid fire growth, should not be permitted as wall or ceiling linings in any occupied space (including houses).

- AS/NZS 3837 should be reviewed and amended to align with the end of test criteria used in ISO 5660.

7. FUTURE WORK

The ISO 9705 data collected in the course of this project (including the flame spread over the surface of the linings) has provided useful experimental data for further development and validation of flame spread models at some future time.

The smoke production criteria for surface linings needs further work to ensure better consistency in the criteria used between small-scale cone and room-scale testing. Currently suitable correlations for predicting smoke production in the ISO 9705 room based on Cone Calorimeter data have not been identified.

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9. APPENDIX 1 – ANALYSIS OF TEST DATA

9.1 Flame spread

The wall and ceiling linings were instrumented with surface thermocouples to record the spread of flame over the wall and ceiling positioned at 600 mm centres close to the burner and 1200 mm further away as shown in Figure 11. The extent of the thermocouple coverage exceeded the requirements of ISO 9705 (1993).

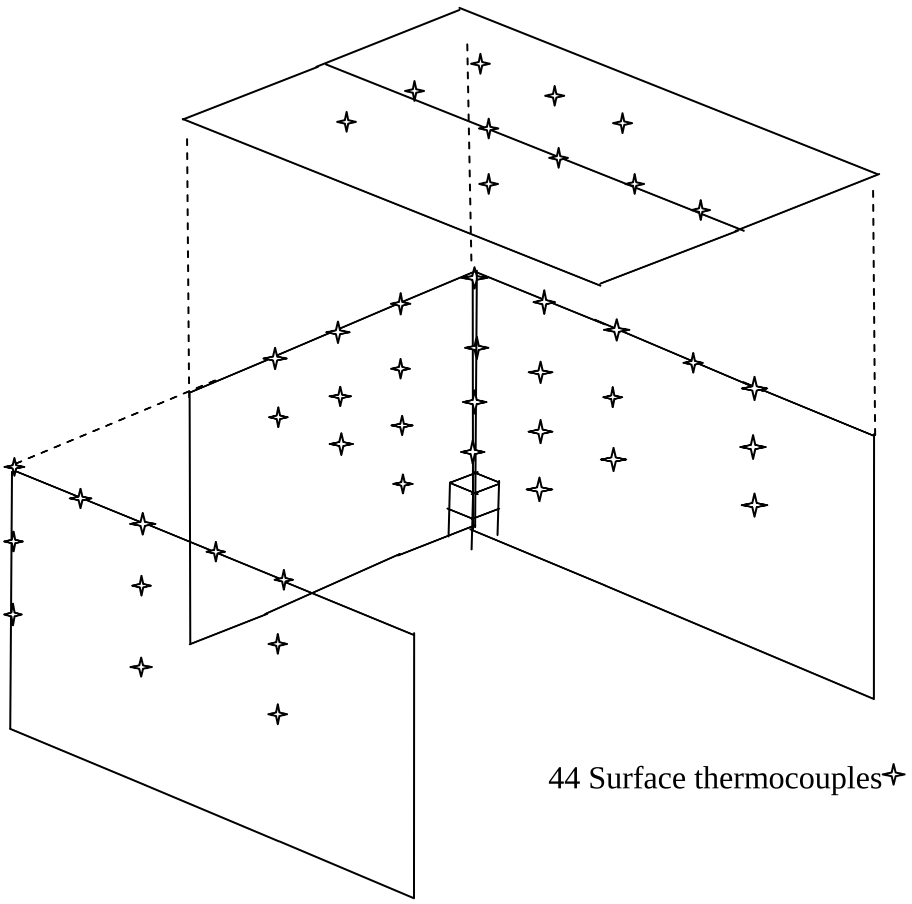

Figure 11: Exploded view of ISO 9705 room with thermocouples on lining surfaces

The following graphs in Figure 12 to Figure 35 show the extent of flame spread at flashover giving an indication of how much surface area in terms of flaming is required. It is assumed that for temperatures greater than 500°C, flaming has reached those thermocouples. This is a reasonable assumption based on the observation of rapid temperature rises to well above 500°C as the flame front passes each thermocouple location. In some of the 'time vs % flame spread' graphs it is obvious that the flame front reaches a certain point and then recedes as the surface burns to a certain distance away from the burner and then extinguishes (the maximums indicate the periodic limits).

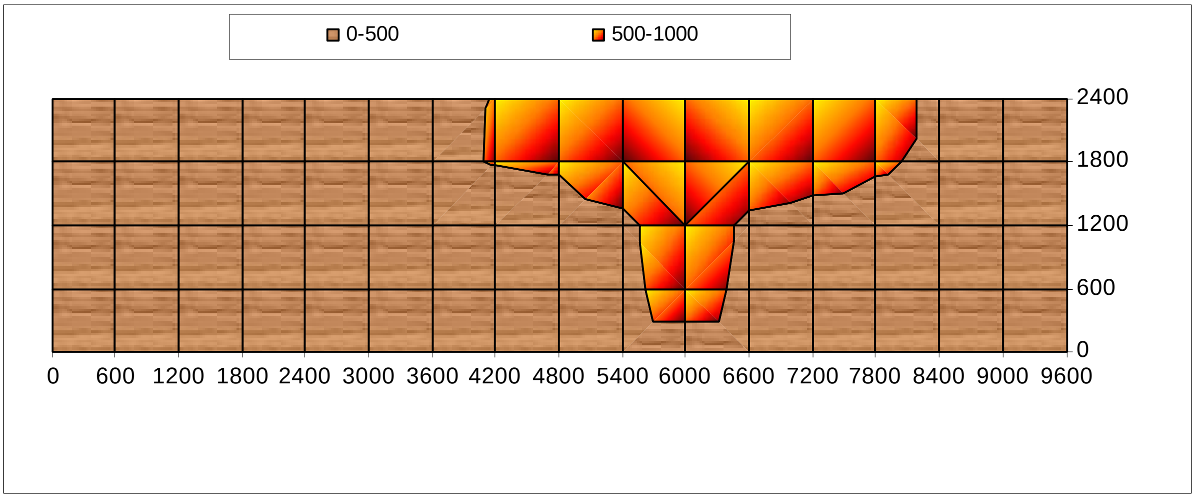

Figure 12: Flame spread on walls at flashover, 618 seconds, test 1

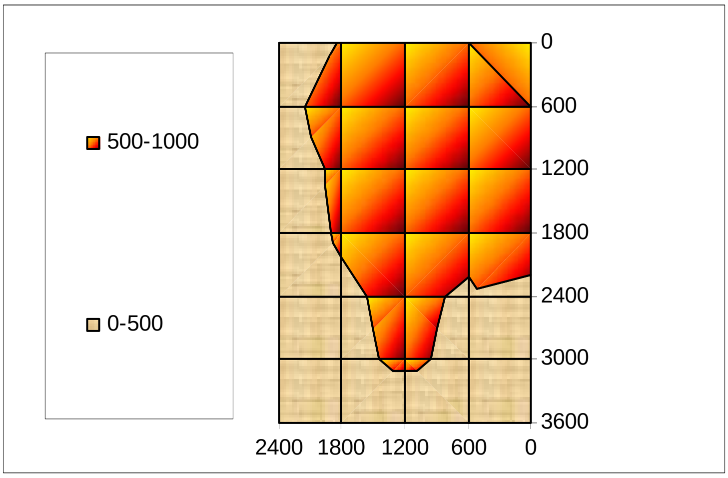

Figure 13: Flame spread on ceiling at flashover, 618 seconds, test 1

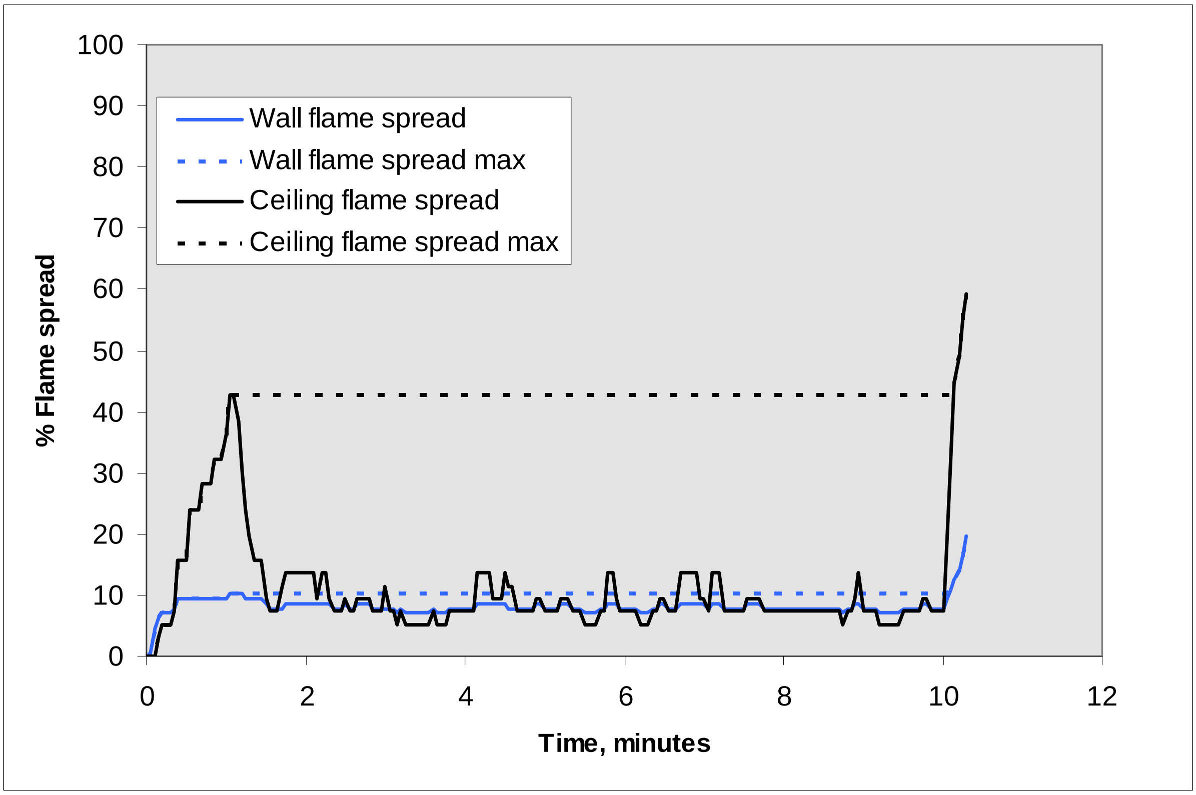

Figure 14: Flame spread flashover at 618 seconds, test 1

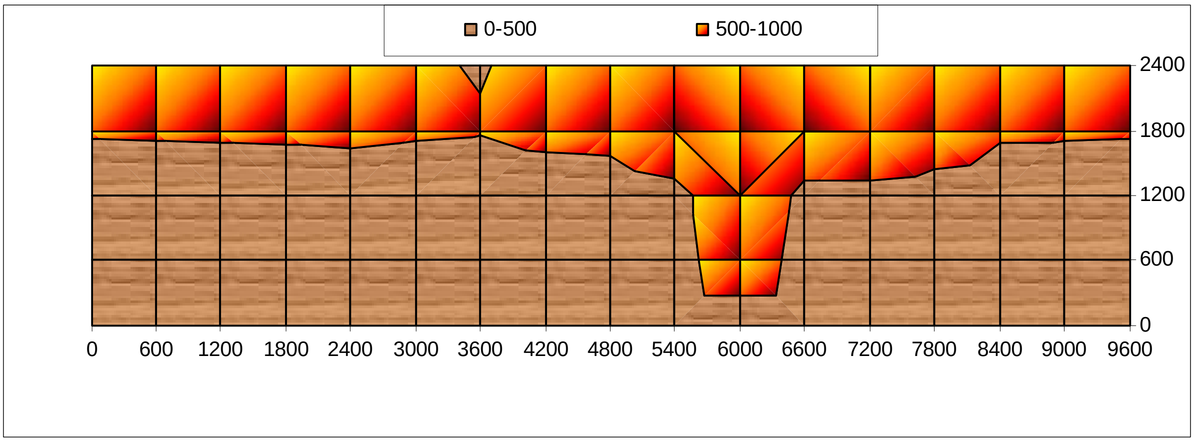

Figure 15: Flame spread on walls at flashover, 225 seconds, test 2

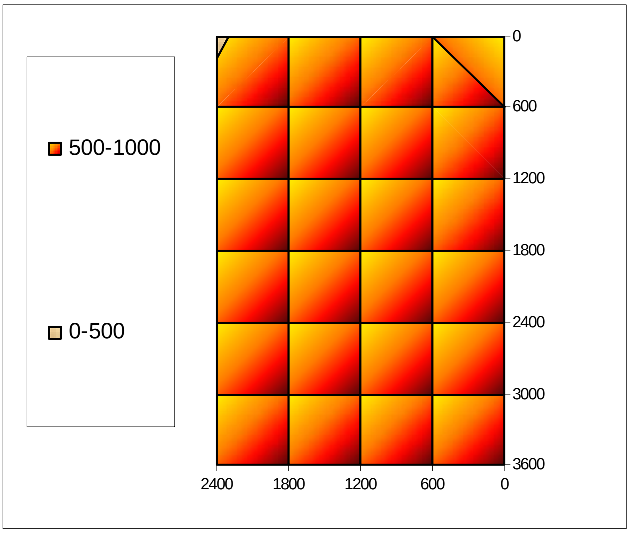

Figure 16: Flame spread on ceiling at flashover, 225 seconds, test 2

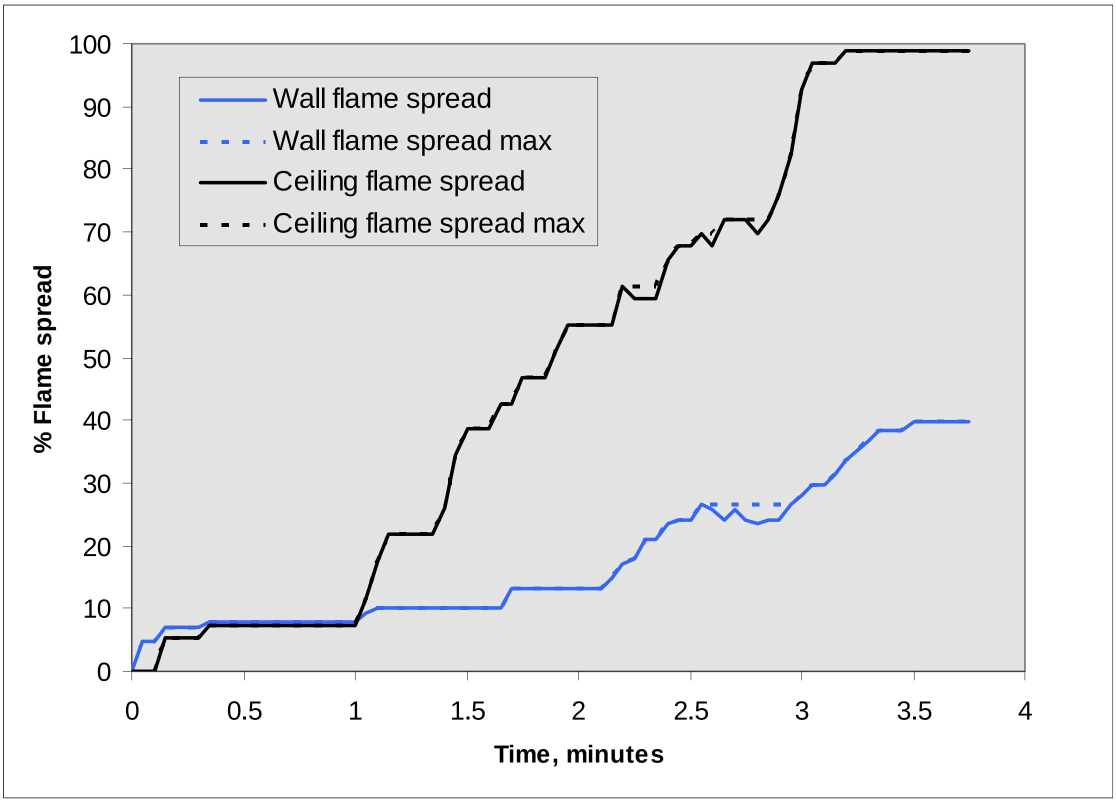

Figure 17: Flame spread flashover, 225 seconds, test 2

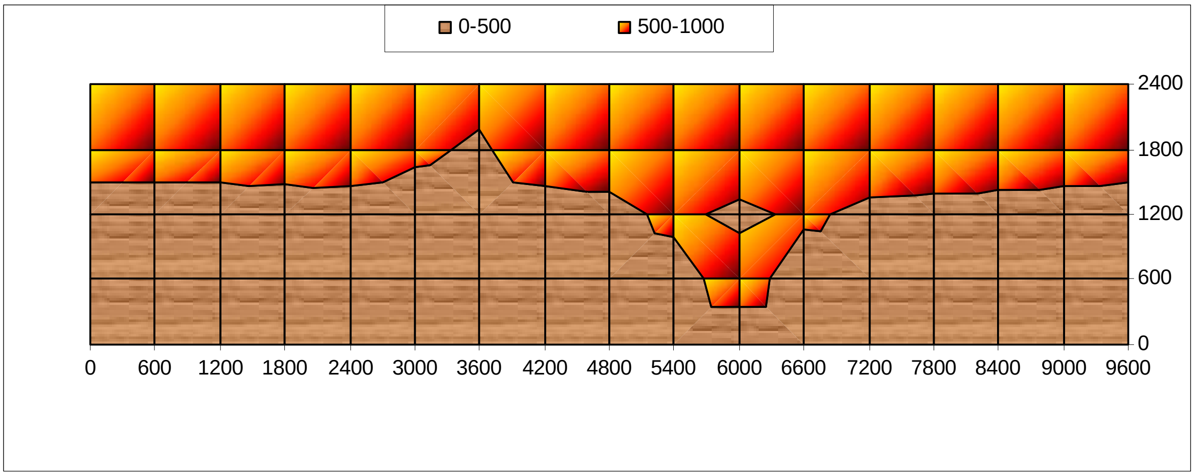

Figure 18: Flame spread on walls at flashover, 951 seconds, test 3

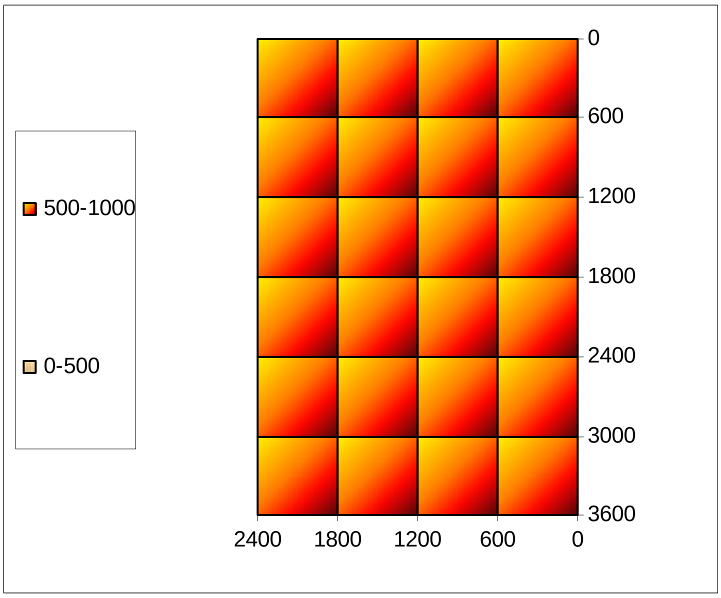

Figure 19: Flame spread on ceiling at flashover, 951 seconds, test 3

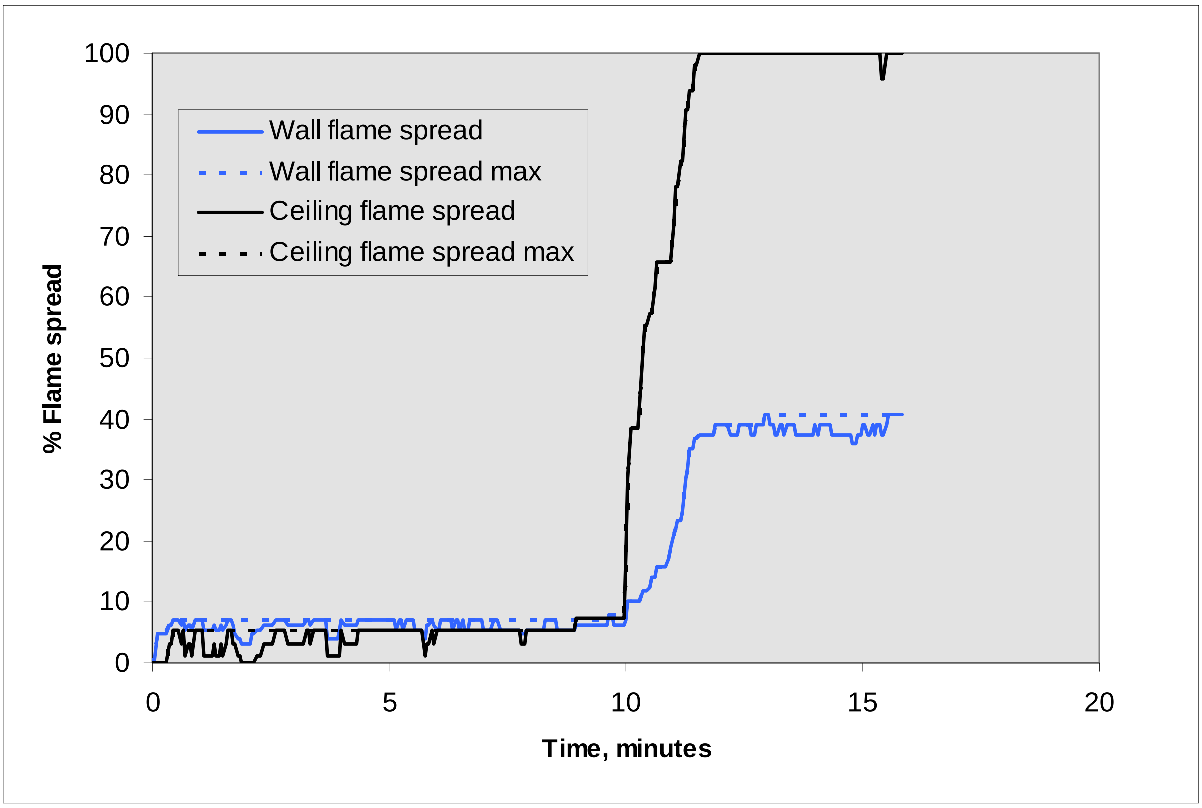

Figure 20: Flame spread flashover at 951 seconds, test 3

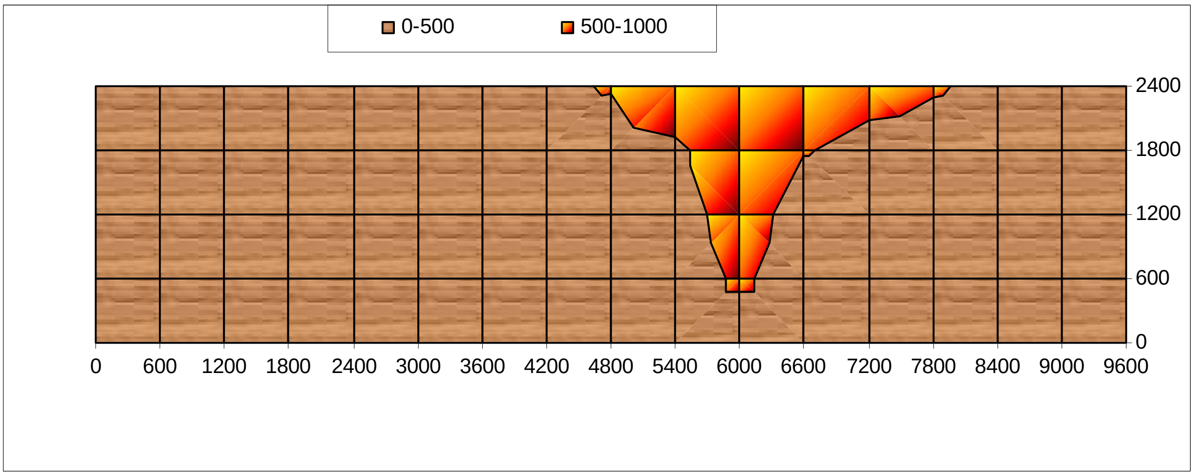

Figure 21: Flame spread on walls at 1200 seconds no flashover, test 4

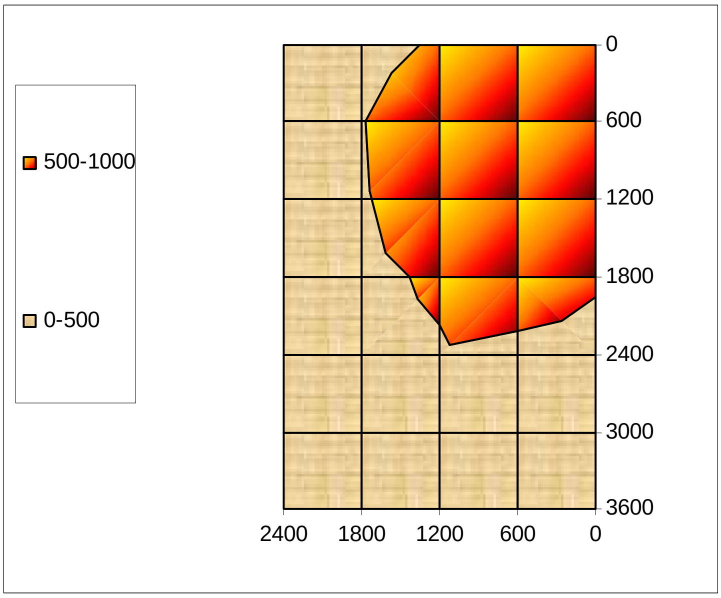

Figure 22: **Flame spread on ceiling at 1200 seconds no flashover, test 4**

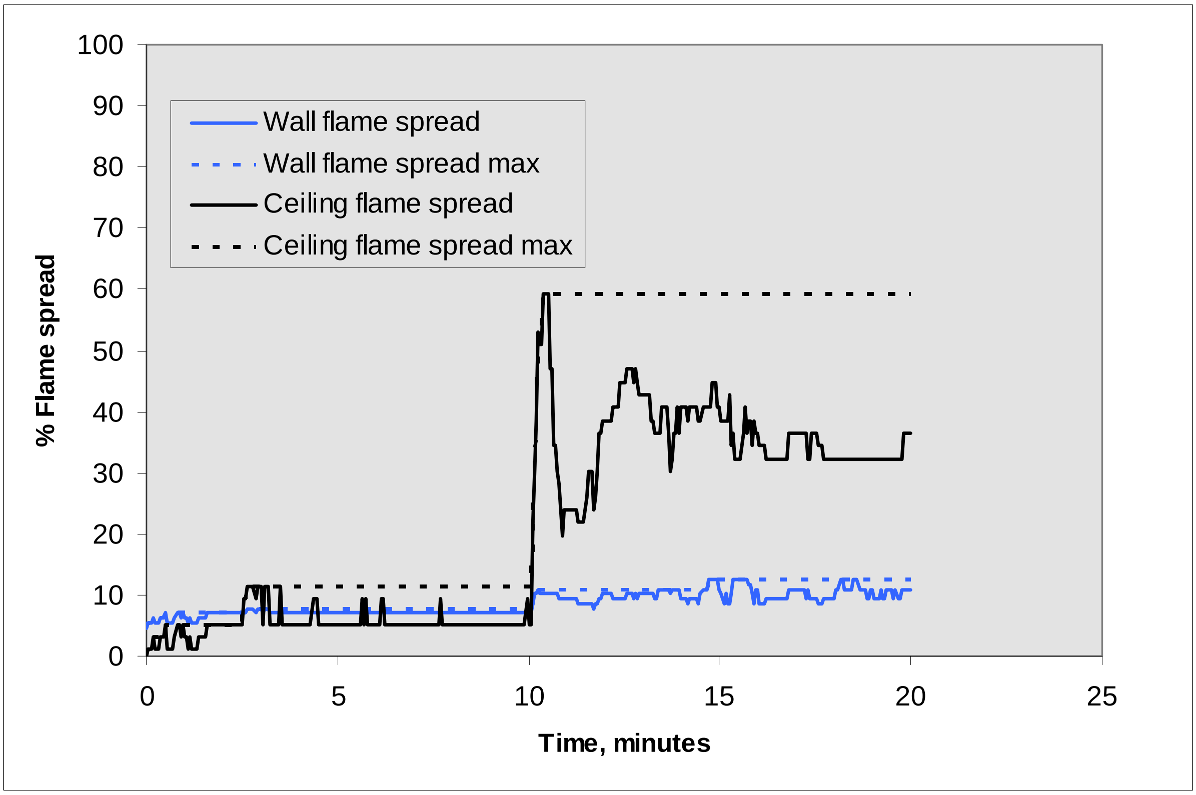

Figure 23: **Flame spread at 20:00 test 4, no flashover**

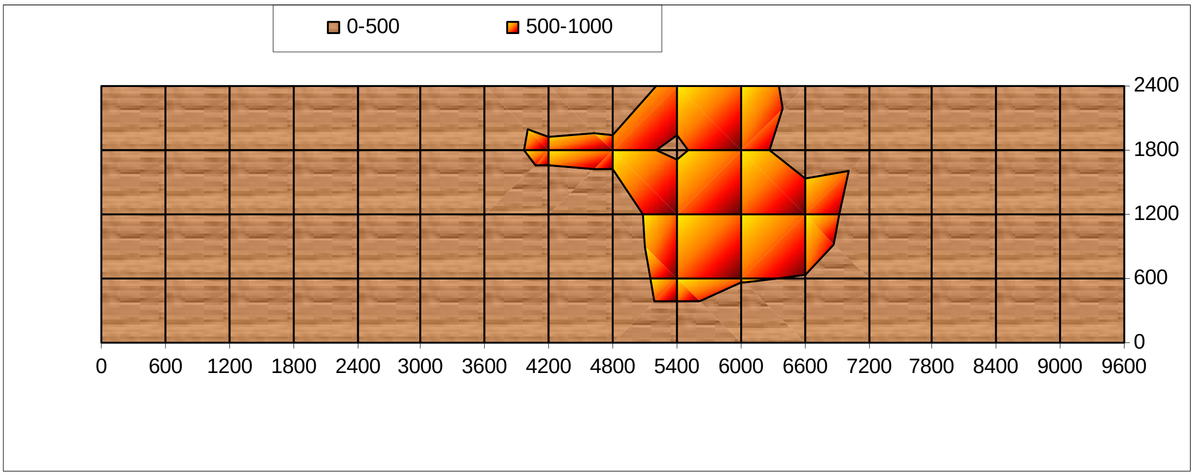

Figure 24: Flame spread on walls at flashover, 201 seconds, test 5

The limited flaming area indicated on the ceiling in test 5 (Figure 25) at flashover compared with the extensive spread in tests 1, 2, and 3 is due to the loss of several ceiling thermocouples due to the melting and dropping of the plastic co-polymer to the floor and the loss of the thermocouples in the process. In spite of this, flashover still occurs as the remaining lining ignites.

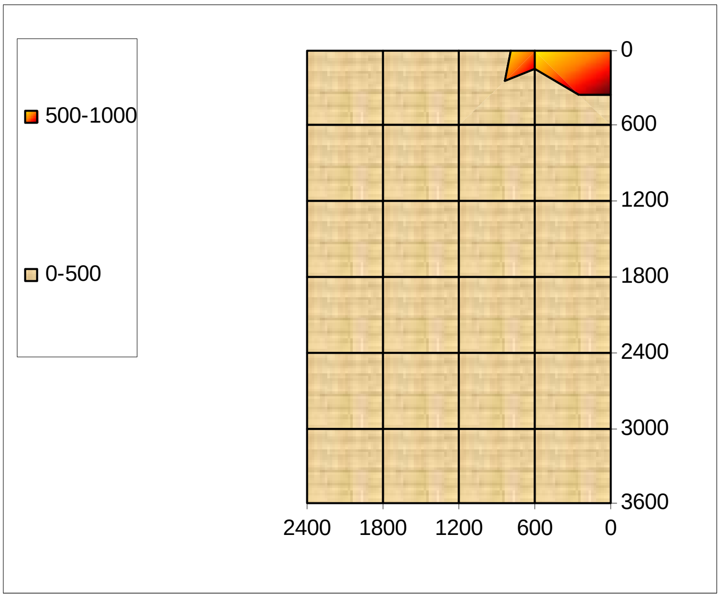

Figure 25: Flame spread on ceiling at flashover, 201 seconds, test 5

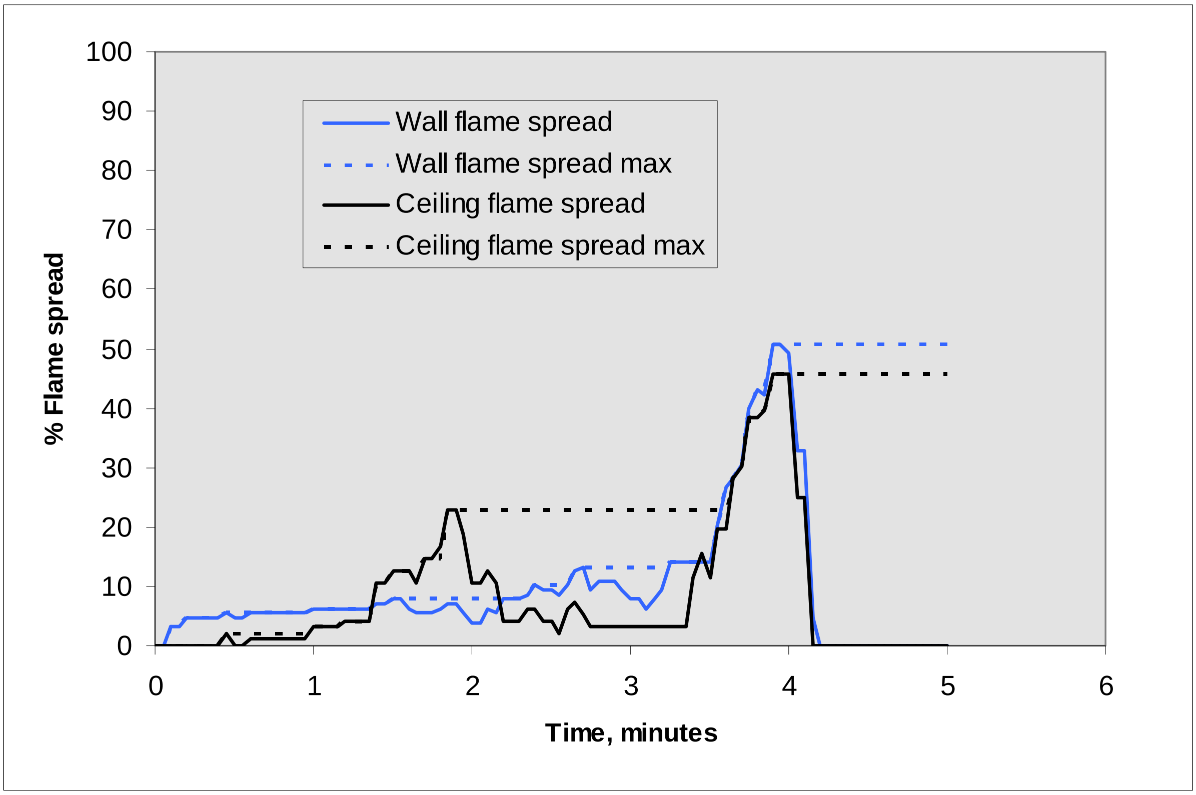

Figure 26: Flame spread test 5 (beyond flashover)

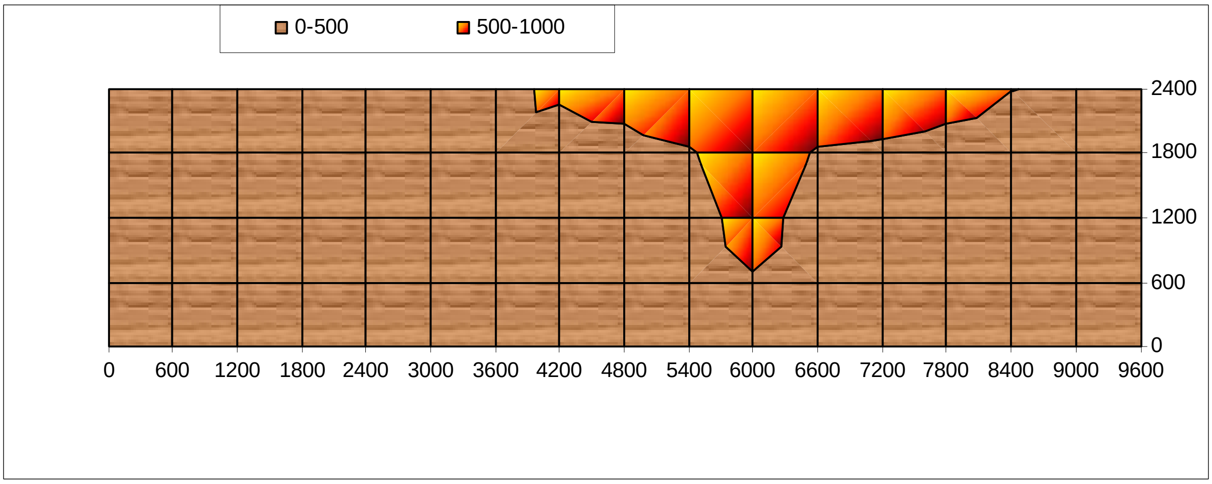

Figure 27: Flame spread on walls at 20 minutes, test 6

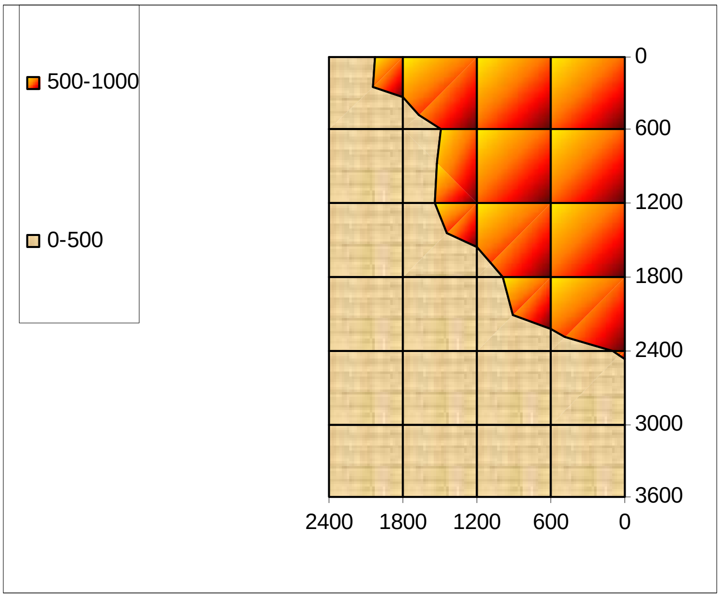

Figure 28: Flame spread on ceiling at 20 minutes, test 6

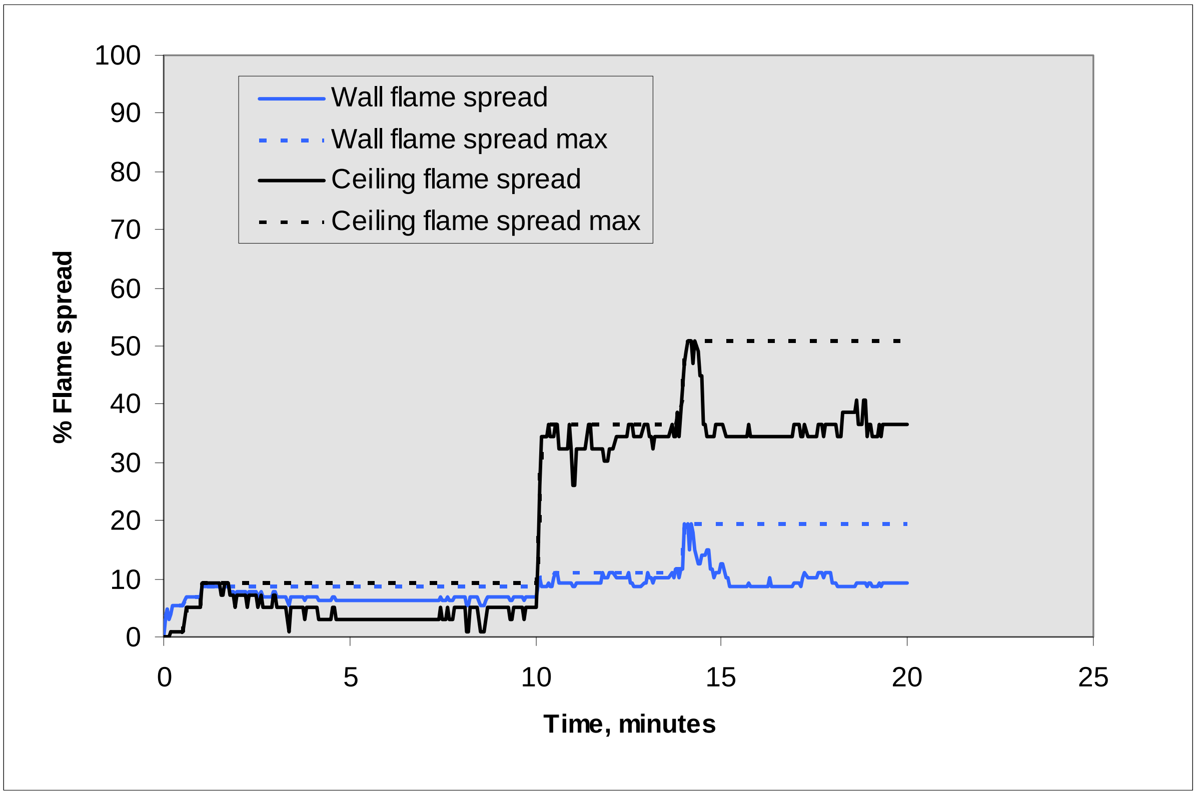

Figure 29: Flame spread test 6 to 20 minutes

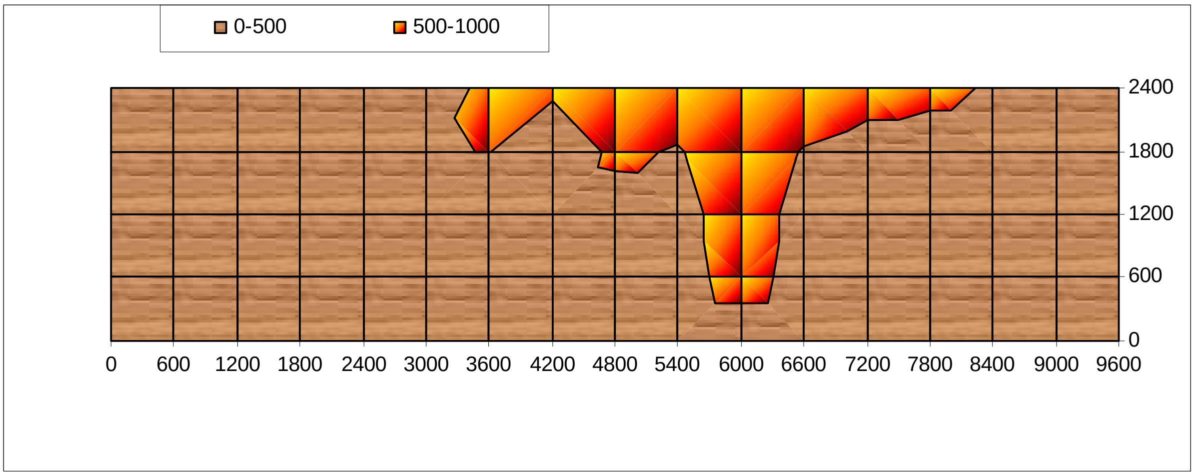

Figure 30: Flame spread on walls at 20 minutes, test 7

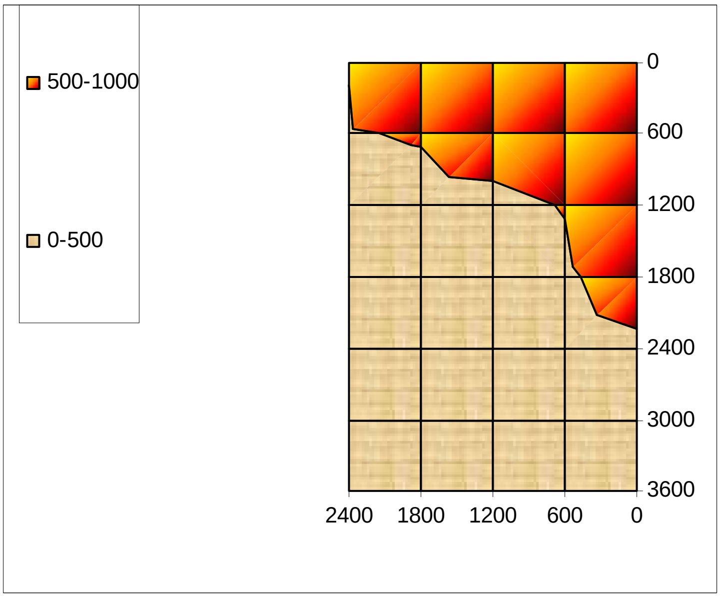

Figure 31: Flame spread on ceiling at 20 minutes, test 7

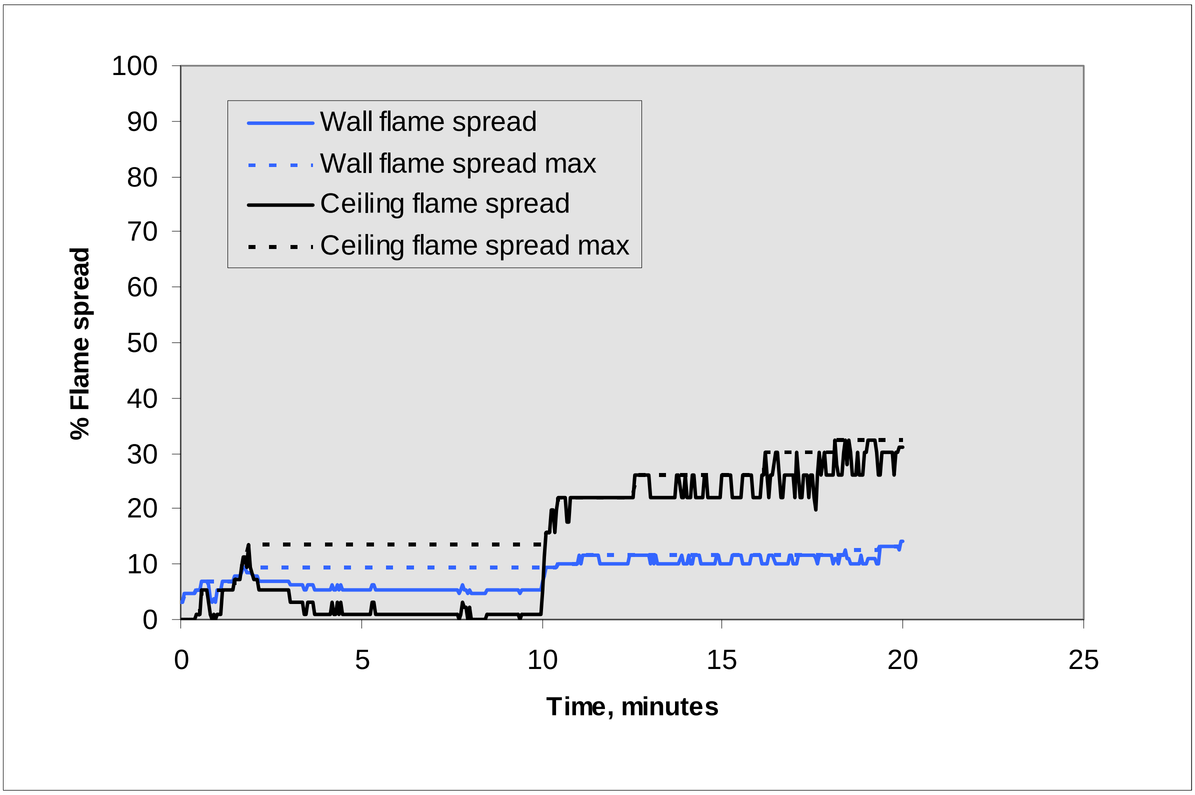

Figure 32: Flame spread test 7 to 20 minutes

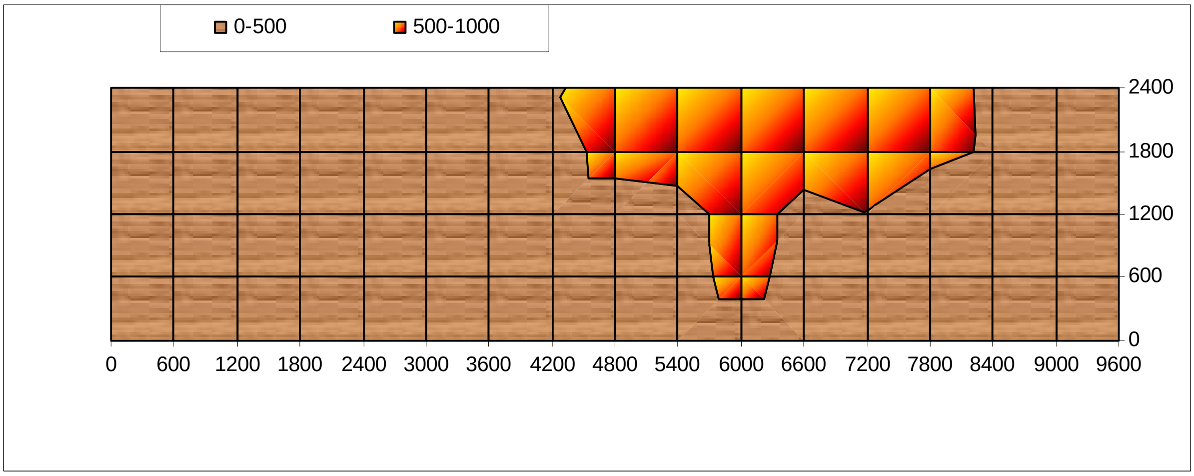

Figure 33: Flame spread on walls at 147 seconds flashover, test 8

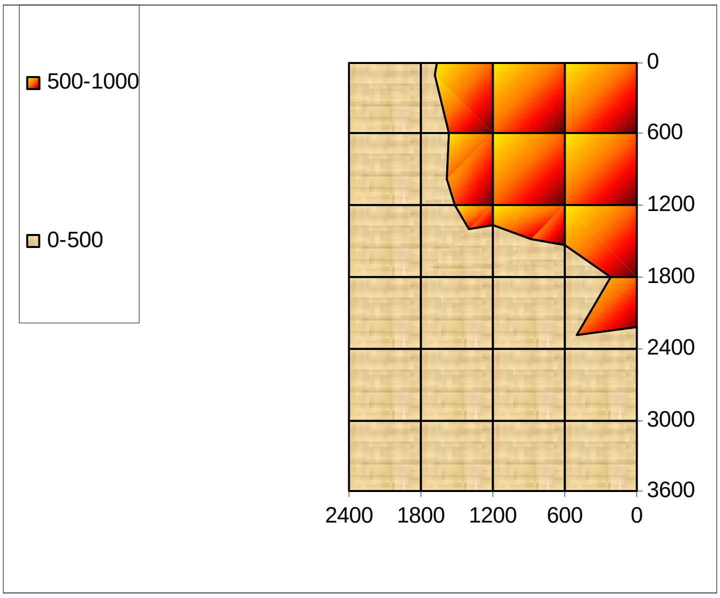

Figure 34: Flame spread on ceiling at 147 seconds flashover, test 8

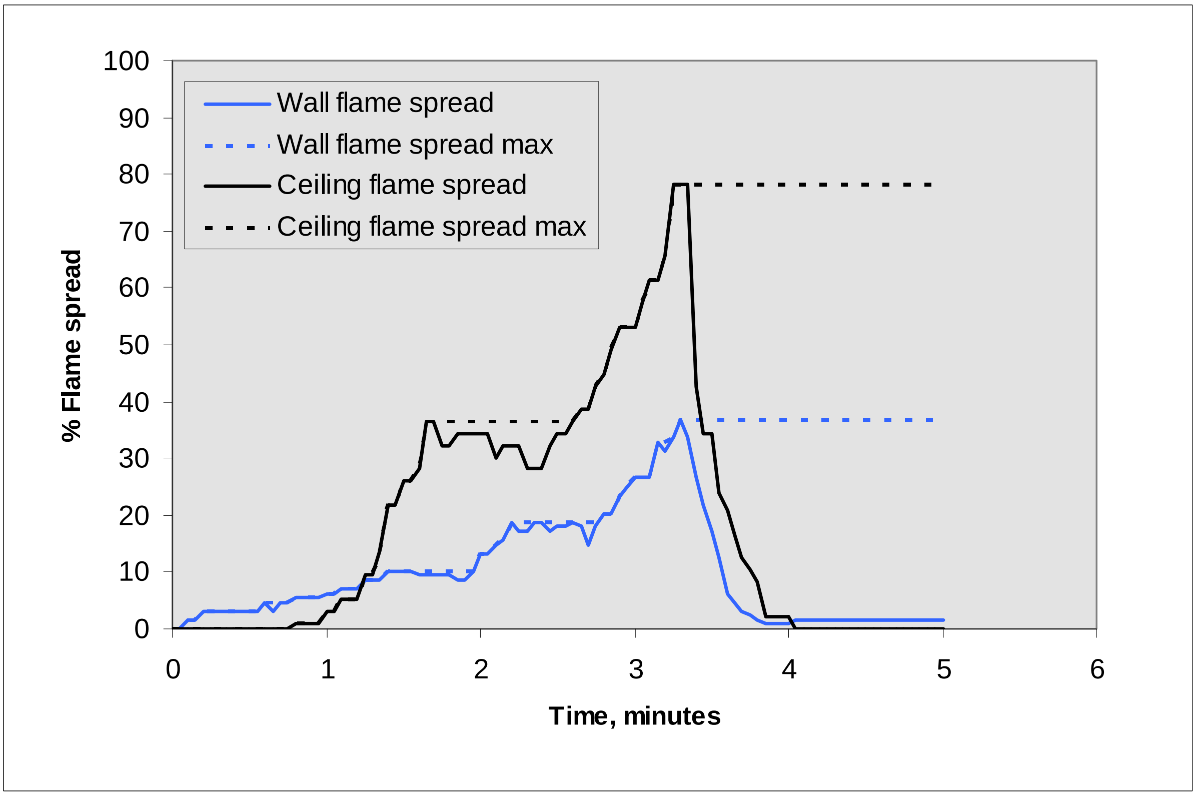

Figure 35: Flame spread flashover at 147 seconds, test 8

9.2 Compartment conditions

The following graphs, in Figure 36 to Figure 43, show the derived temperature data in the ISO 9705 room trials. Temperatures were recorded in the corner opposite the burner at a distance of 300 mm from each wall at heights of 260, 670, 970, 1270, 1420, 1570, 1720, 1910 and 2100 mm as recommended in ISO 9705 (1993). The layer height was derived on the basis that the temperature increases with height and the interpolated elevation where the temperature rise from the lowest level to 10% of the difference between that and the maximum temperature is deemed to be the layer height. The temperature of each layer is then the weighted mean temperature above or below the layer height.

The upper layer integrated average temperature in the upper layer is lower than the individual temperatures recorded near the ceiling, which are in turn expected to be lower than those closer to the burner. The differences range from 300°C down to 100°C, but depending on whether it is in a high temperature range such as 500 to 800°C or a low range such as 200 to 300°C in either condition the peak temperature at that time is about 50% greater than the derived temperature for the hot layer. A similar relationship holds for the lower layer.

The upward trend of the upper and lower layer temperatures are directly related to the HRRs as indicated by the burner increase to 300 kW at 600 seconds and the onset of flashover when it occurs. Similarly the rapid drop of the layer height below 600 mm is an indicator that flashover has occurred.

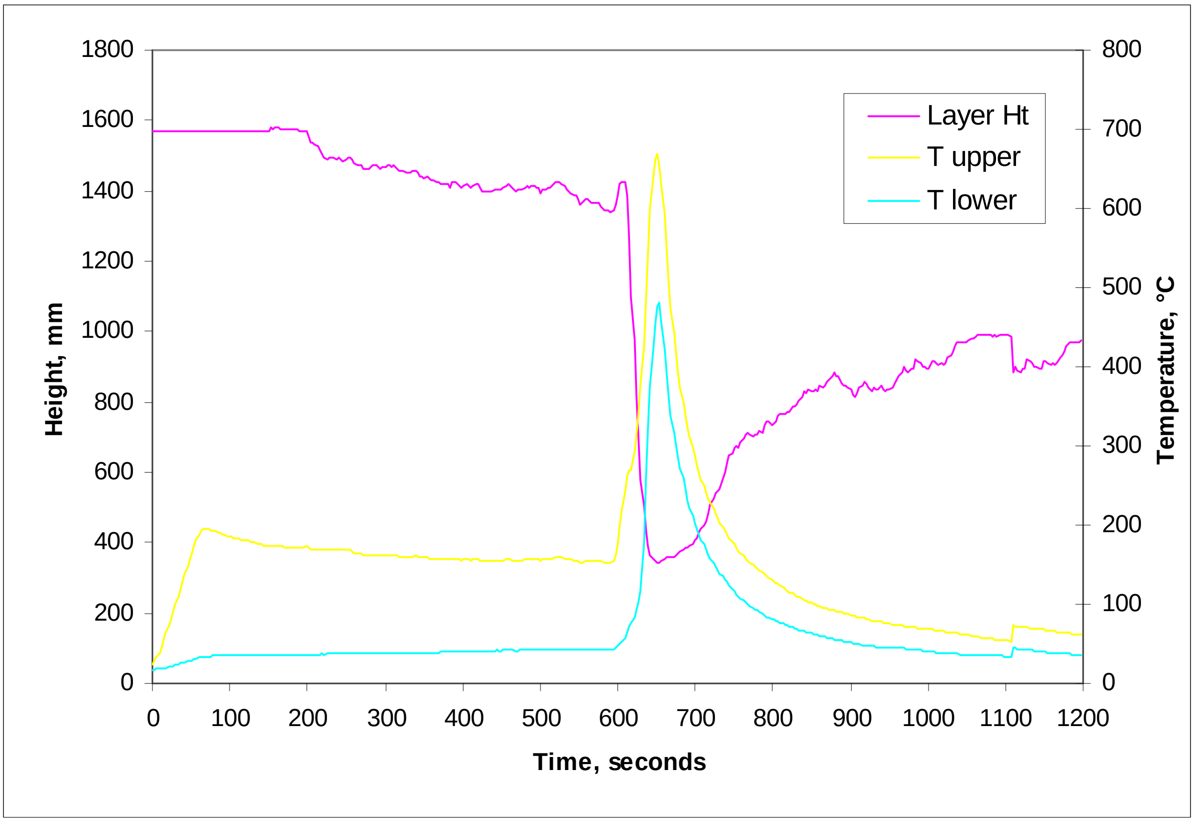

Figure 36: Fire conditions in ISO room space in test 1

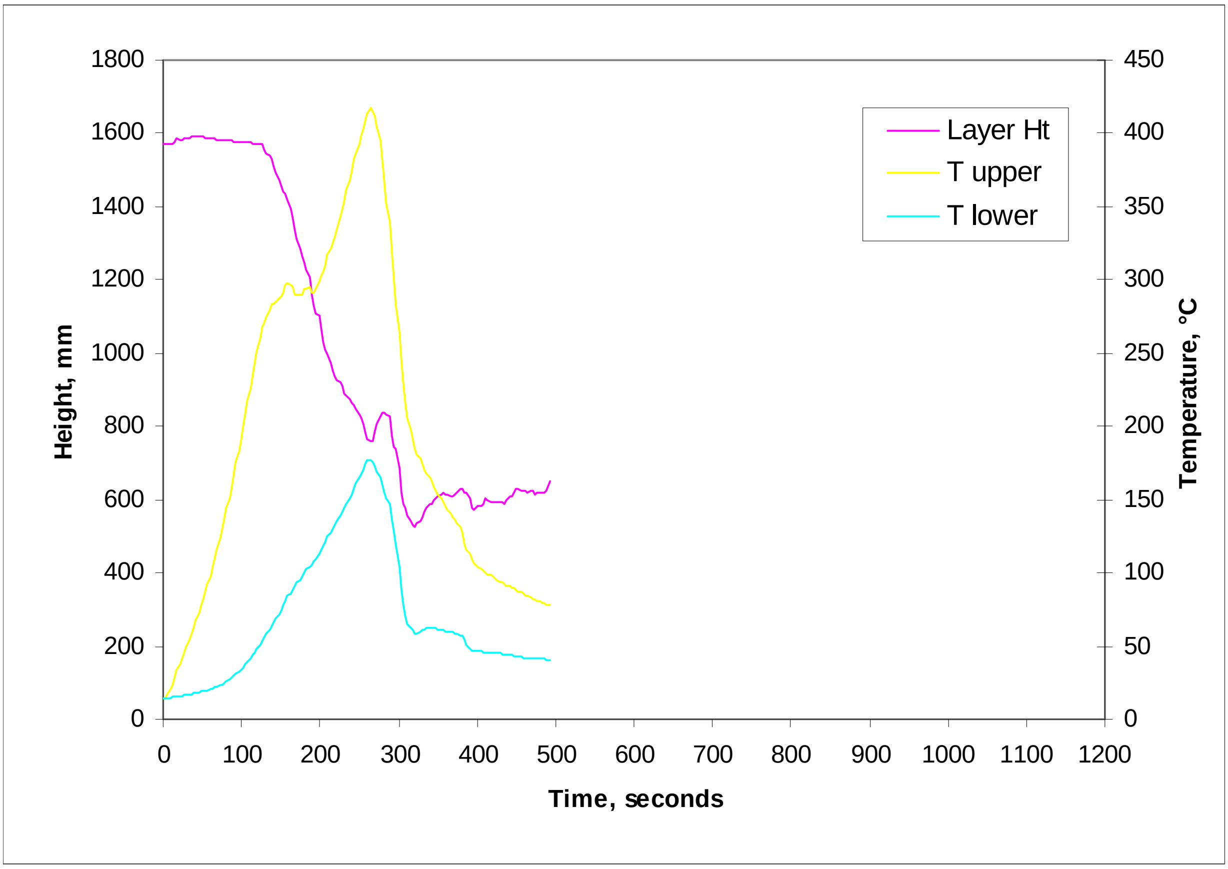

Figure 37: Fire conditions in ISO room space in test 2

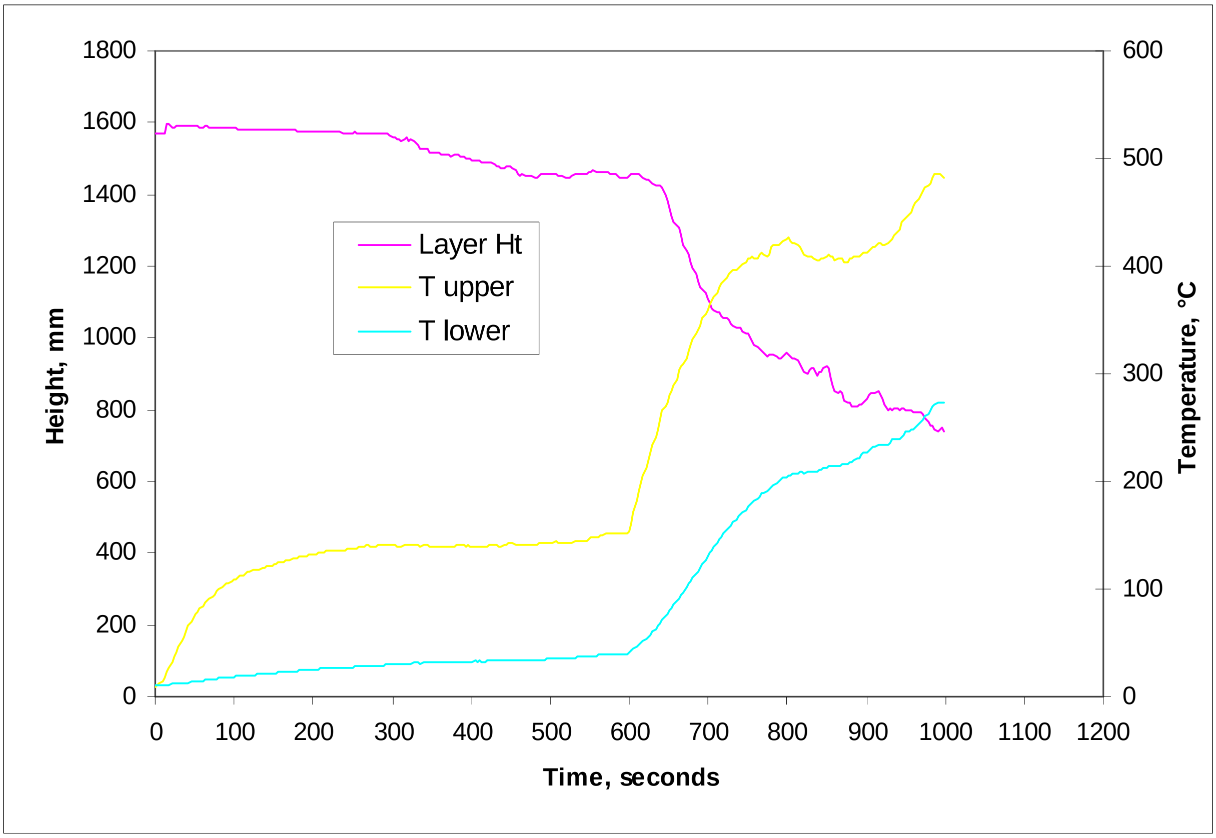

Figure 38: Fire conditions in ISO room space in test 3

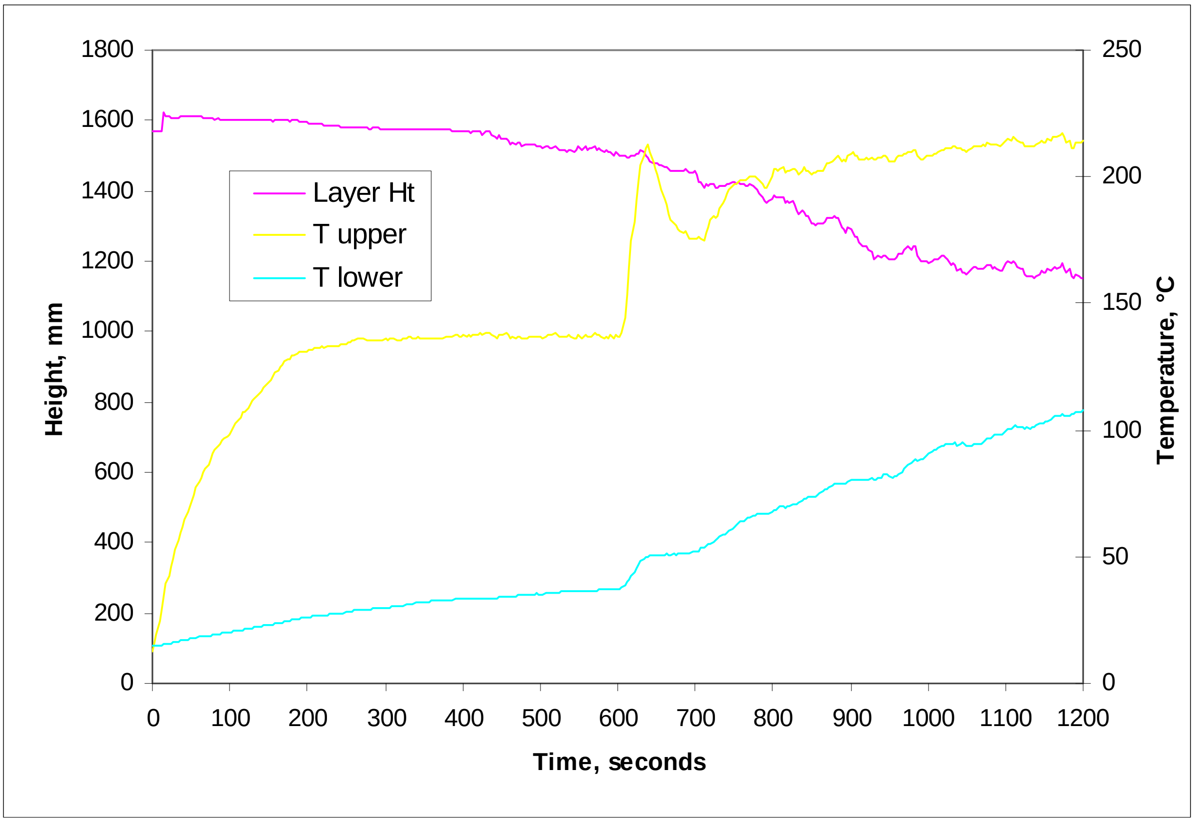

Figure 39: Fire conditions in ISO room space in test 4

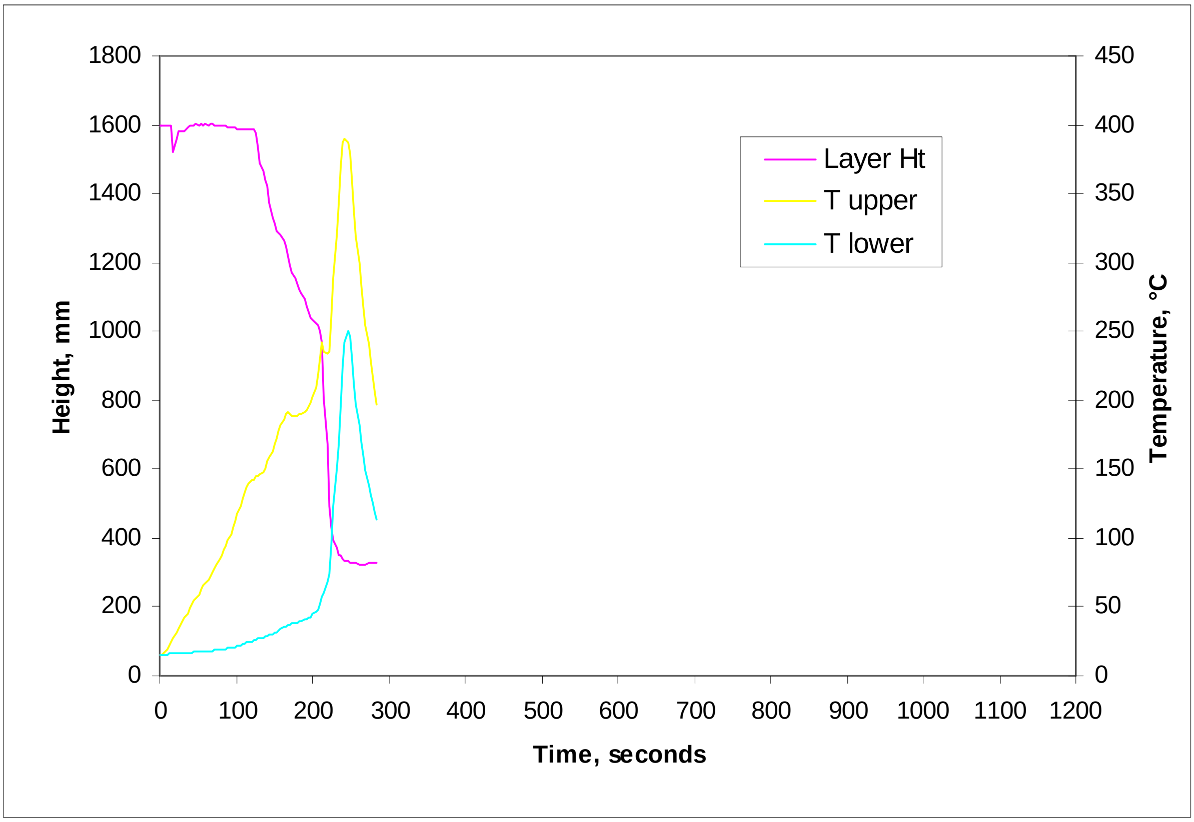

Figure 40: Fire conditions in ISO room space in test 5

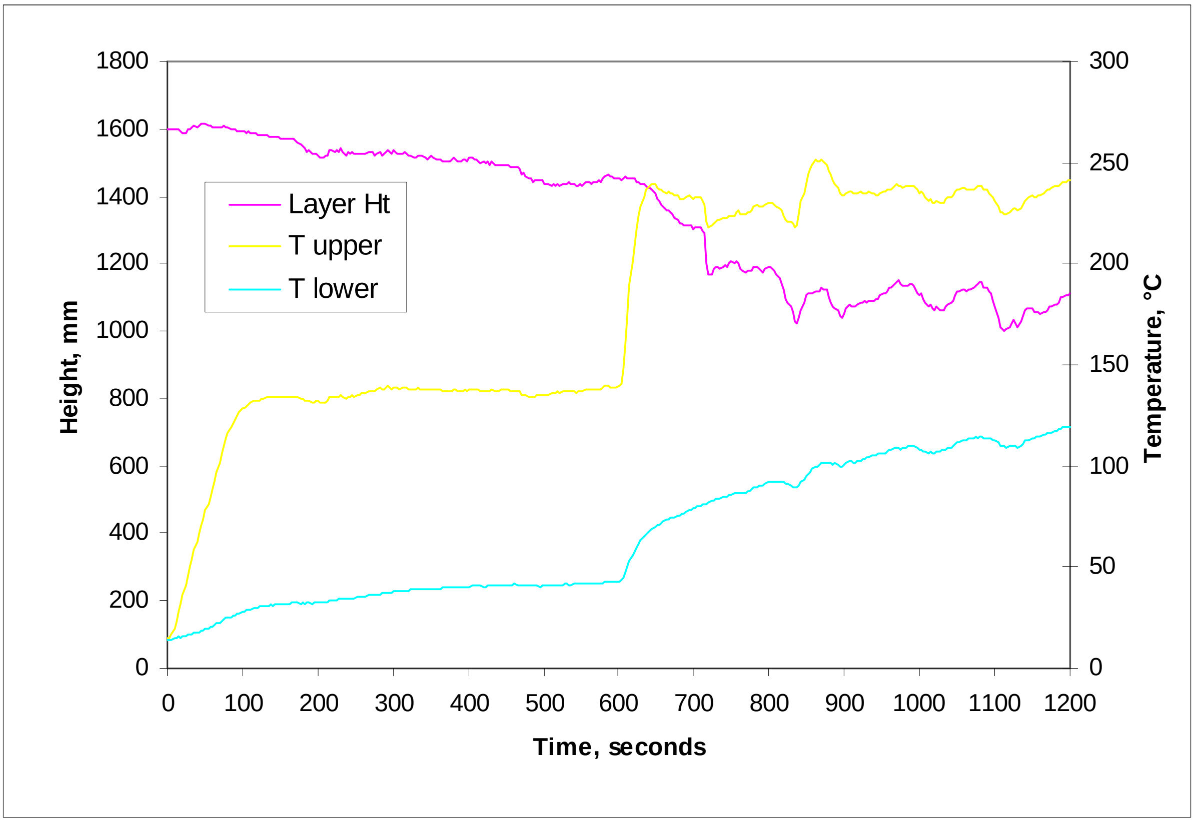

Figure 41: Fire conditions in ISO room space in test 6

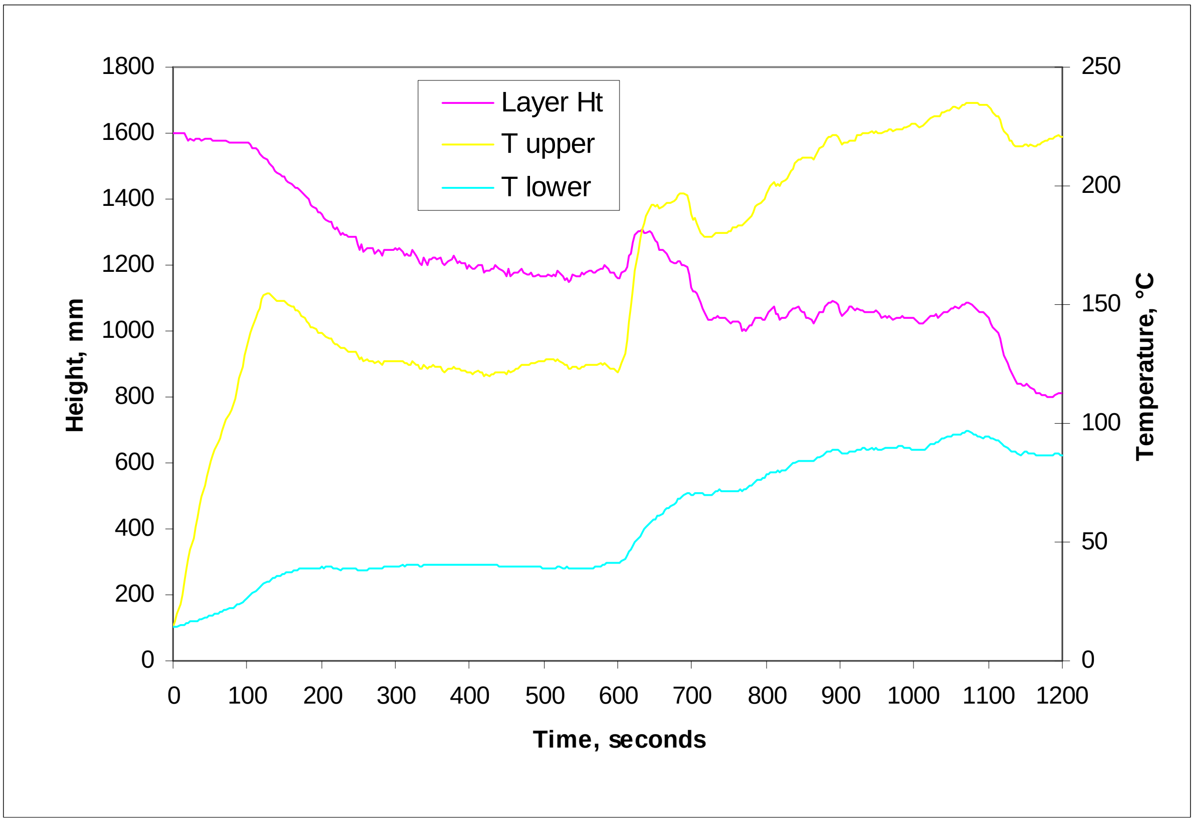

Figure 42: Fire conditions in ISO room space in test 7

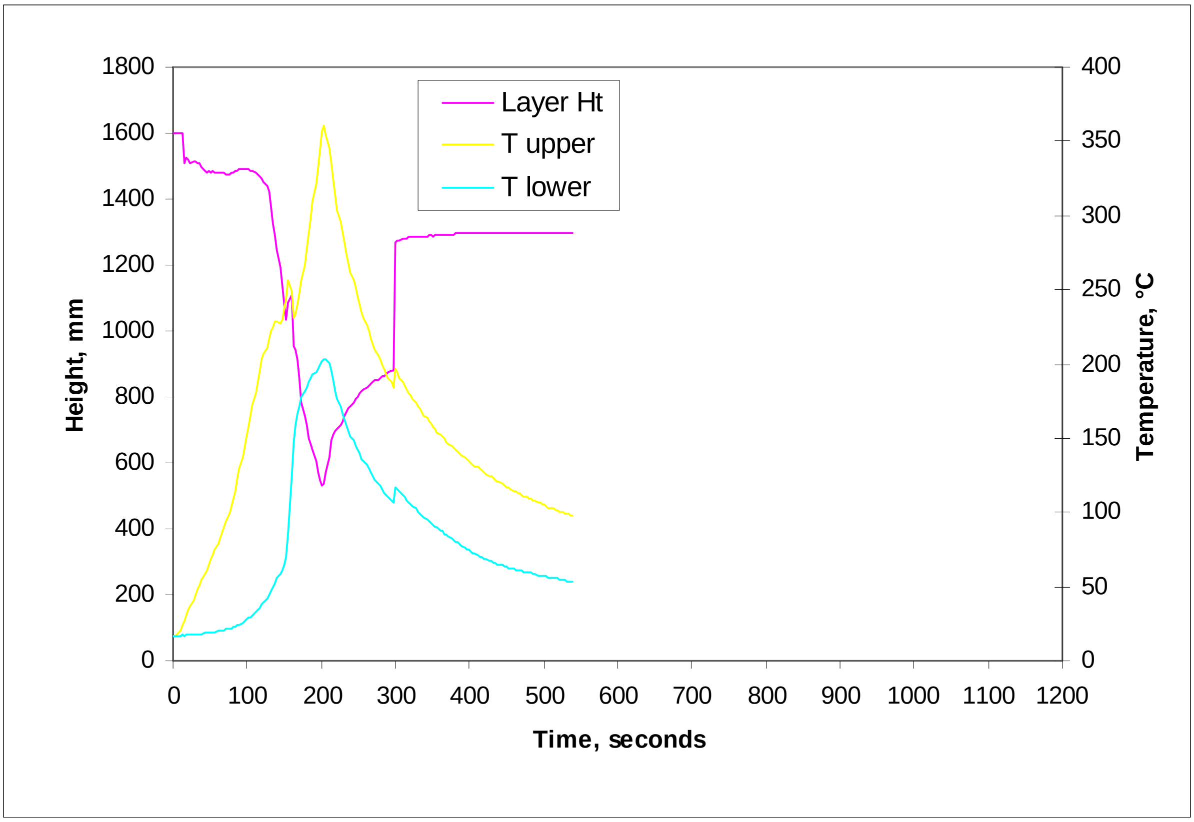

Figure 43: Fire conditions in ISO room space in test 8

Photographic montages of the progression of the fire development for each ISO 9705 room test are shown in Figure 44 to Figure 51. The fire development and involvement of the surface linings, formation of a hot smoke laden upper layer, loss of lining material by falling to the floor, loss of visibility, and flashover are clearly illustrated. The pictorial record can be compared with the previous analysis.

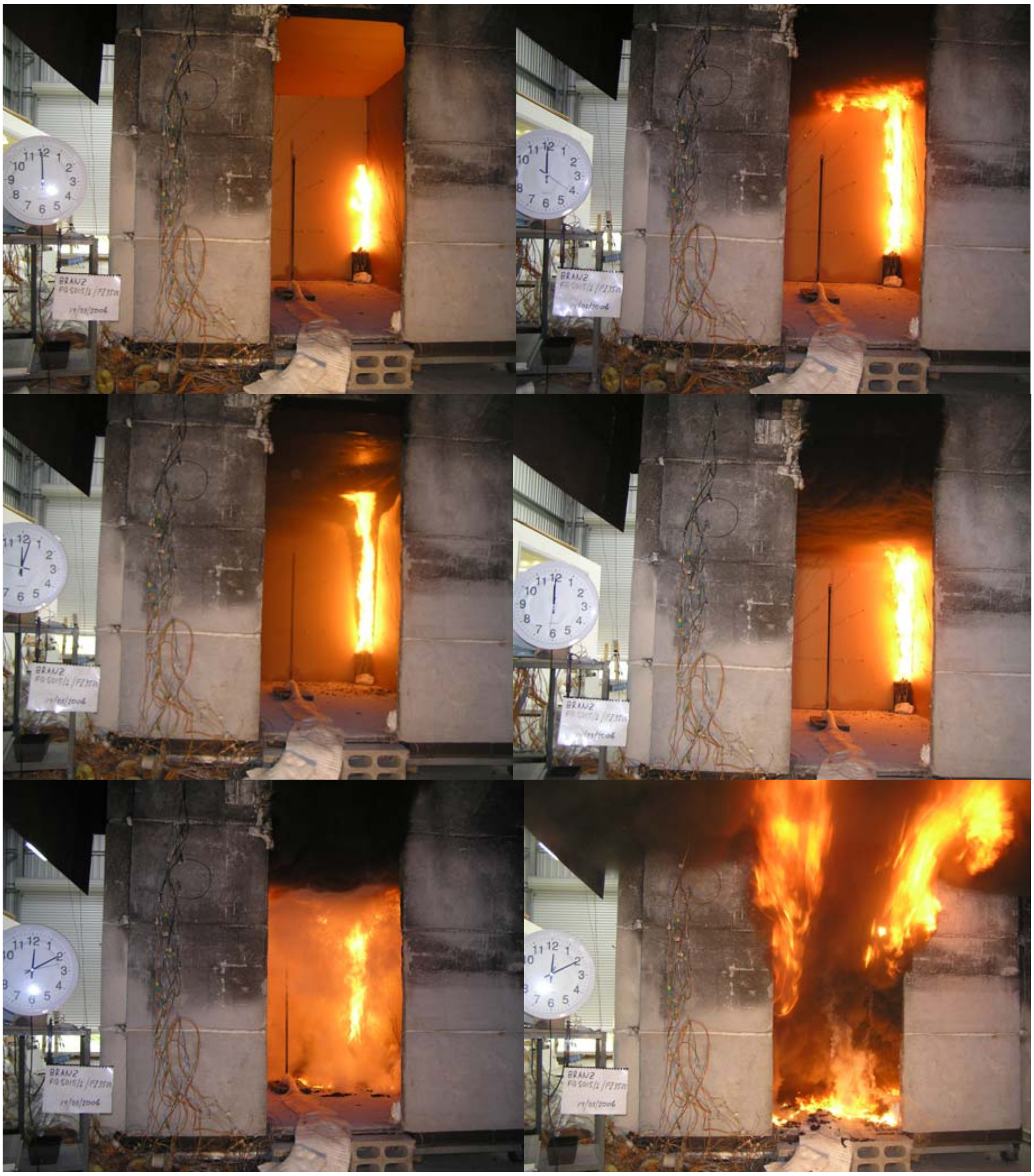

Figure 44: Events leading to flashover in trial 1, vinyl wallpaper

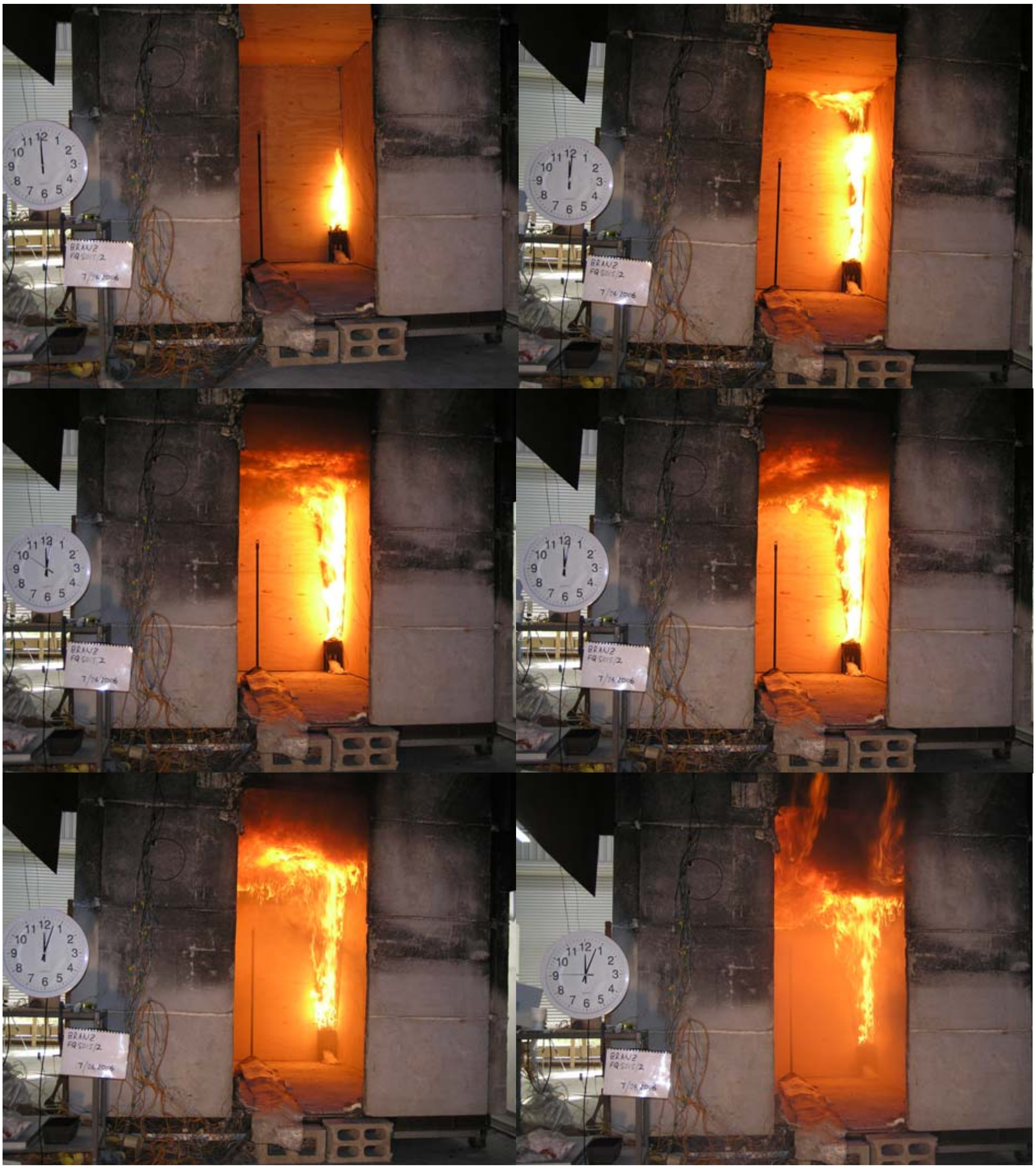

Figure 45: Events leading to flashover in trial 2, plywood

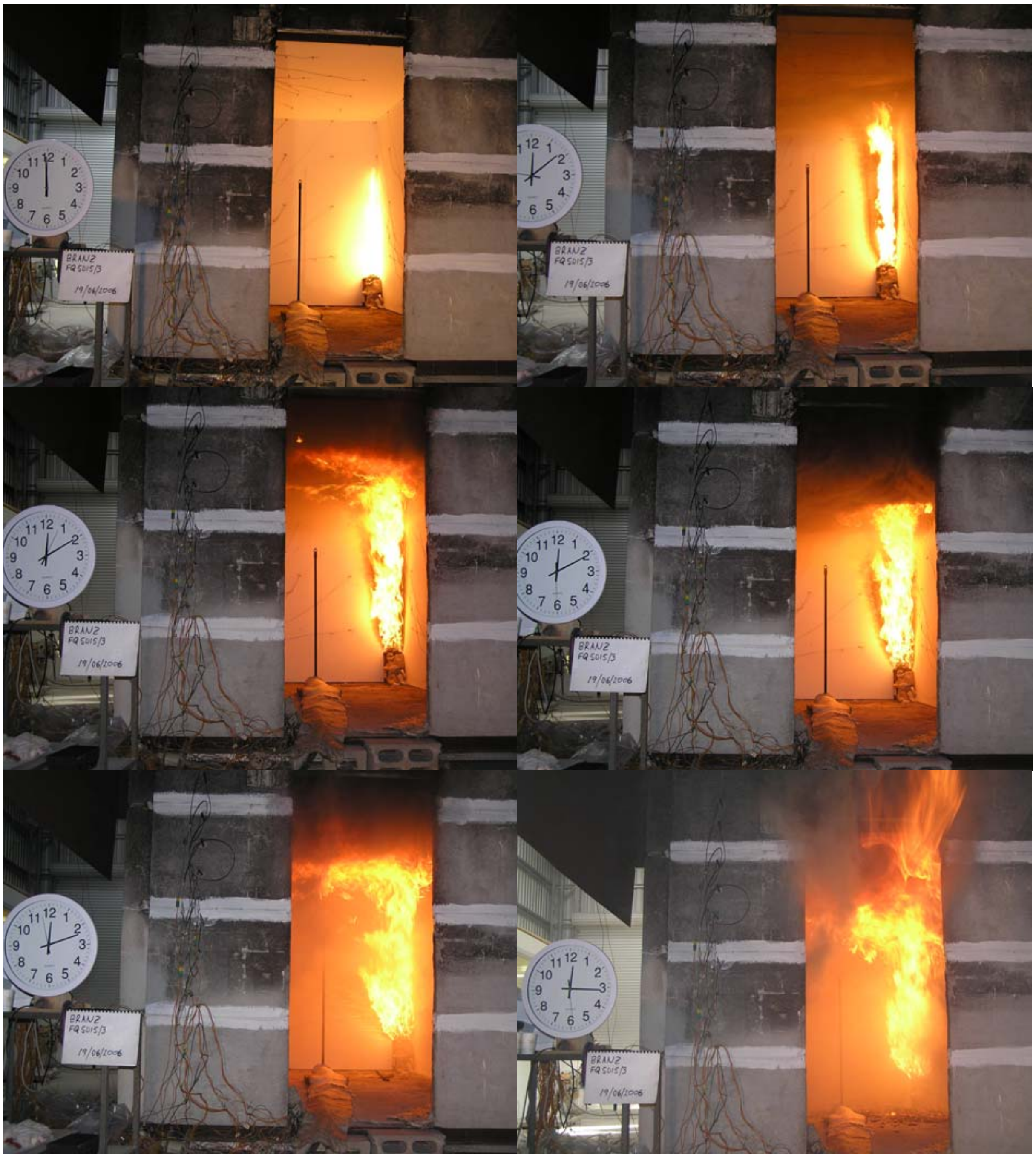

Figure 46: Events leading to flashover in trial 3, plywood + two coats of intumescent paint

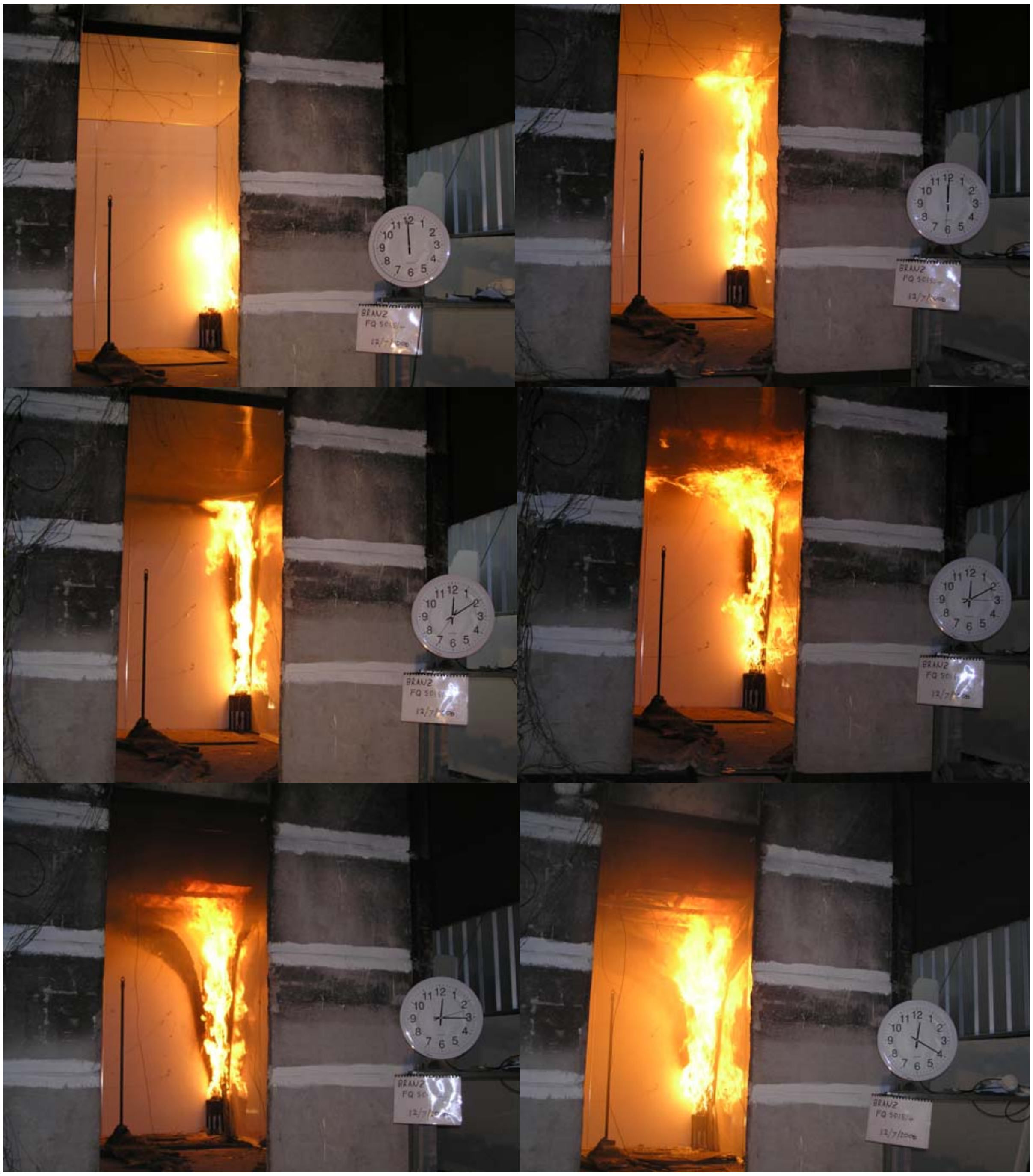

Figure 47: Events in trial 4 with glazed fibre-cement board, no flashover

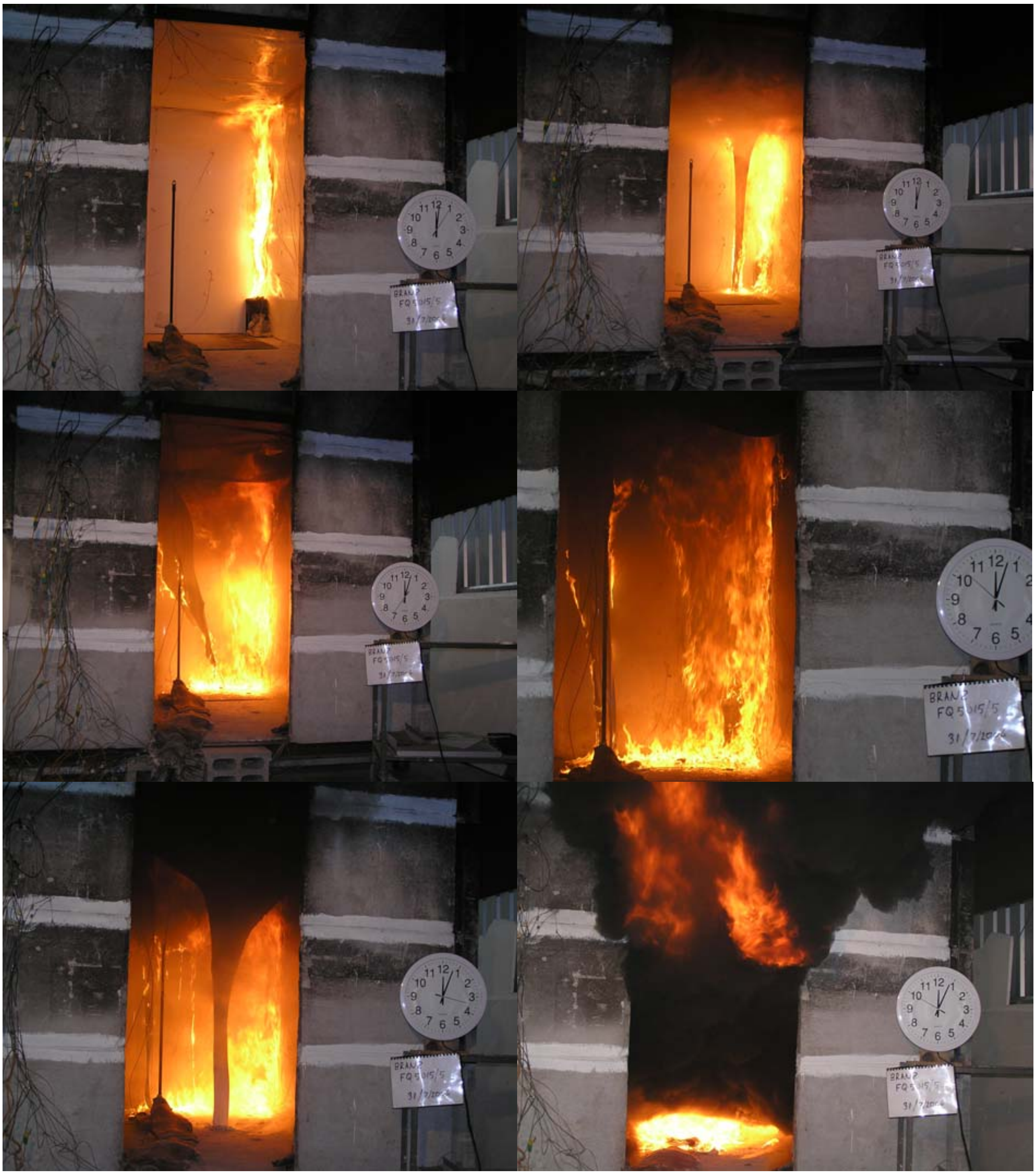

Figure 48: Events leading to flashover in trial 5, plastic co-polymer

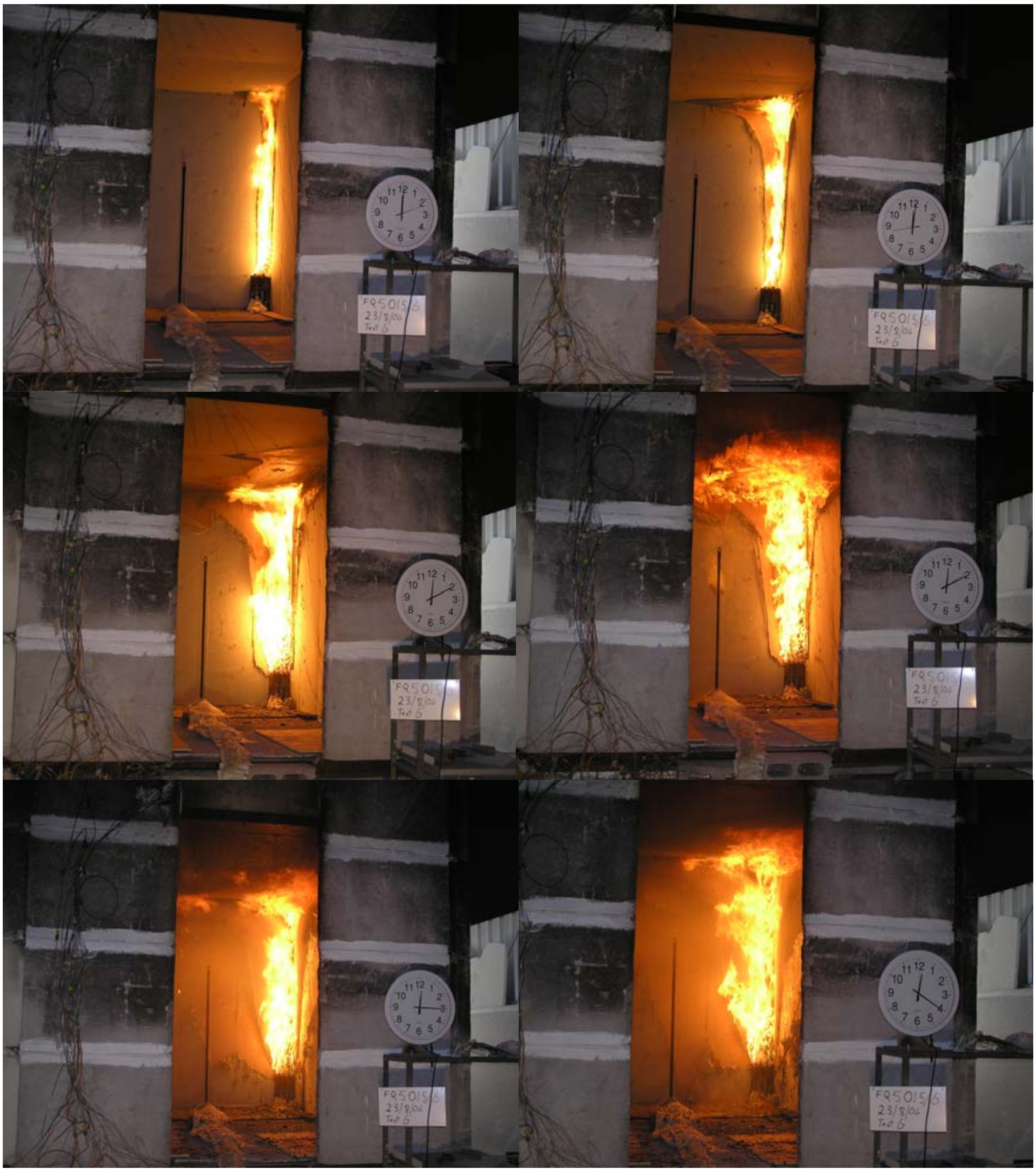

Figure 49: Events in trial 6 with 100% polyester wall covering, no flashover

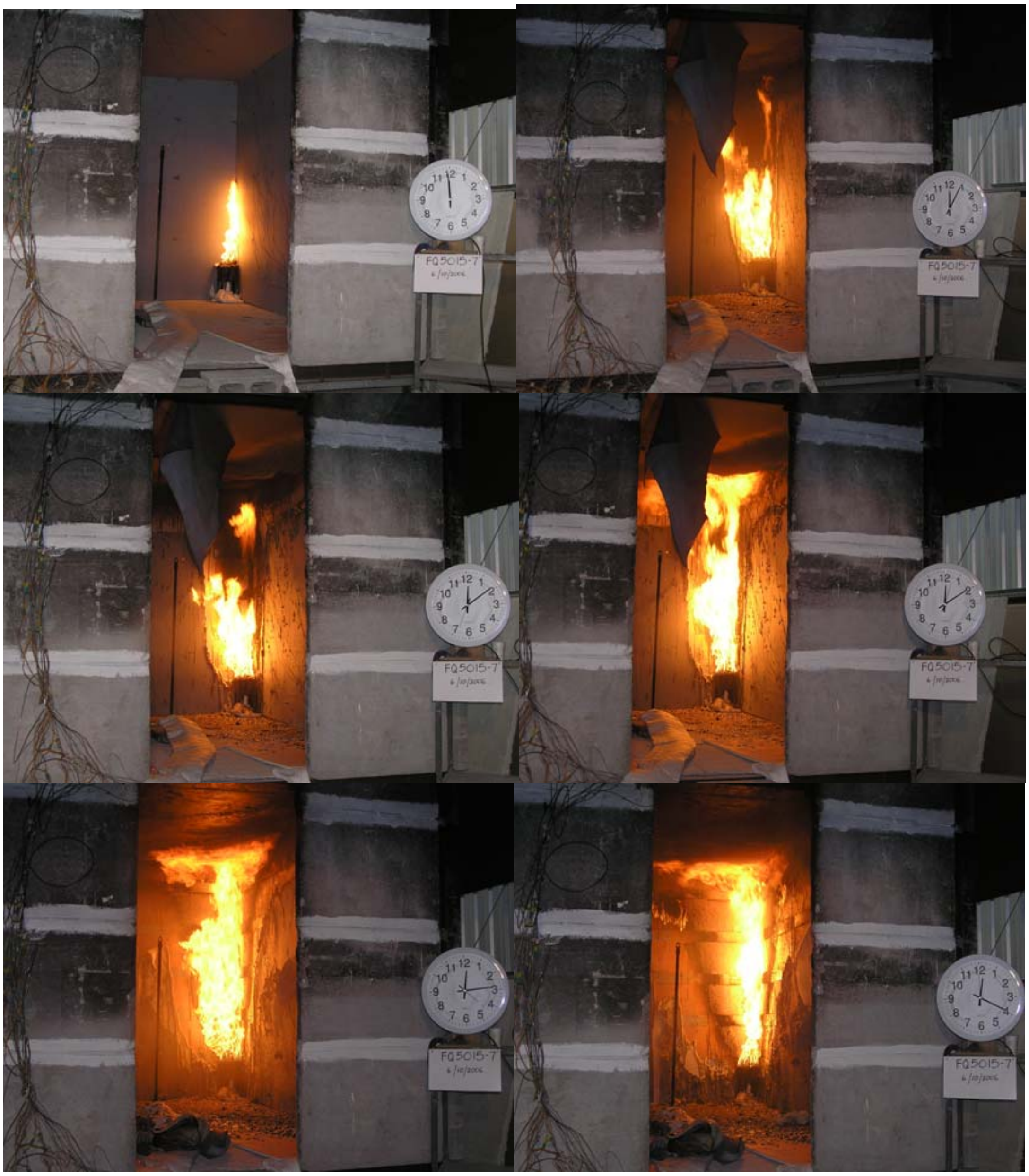

Figure 50: Events in trial 7 with 100% modified polyester wall covering, no flashover

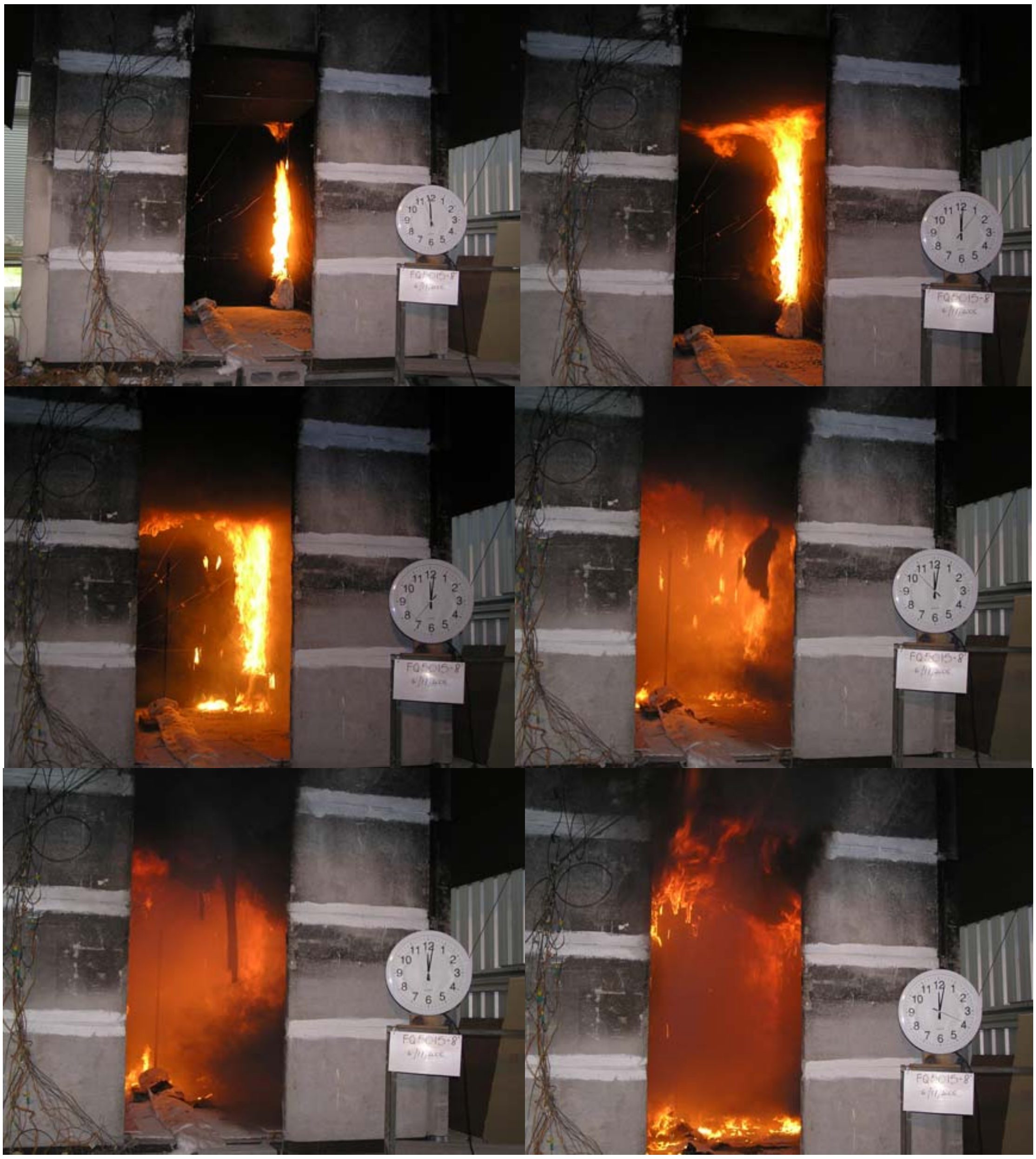

Figure 51: Events leading to flashover in trial 8, synthetic rubber mass loaded noise barrier

9.3 Cone Calorimeter results

All ISO 9705 samples were tested in the Cone Calorimeter with AS/NZS 3837 end of test conditions. Additional samples of softboard (painted and unpainted) were included as materials 10 and 11.

Table 13: Cone Calorimeter results for vinyl wallpaper glued onto 10 mm plasterboard

Material		**Data Files**			Mean
Specimen test number		Vinyl wallpaper 1	Vinyl wallpaper 2	Vinyl wallpaper 3	
Initial specimen mass	g	74.8	74.8	74.6	74.7
Mean specimen thickness	mm	10.4	10.4	10.4	10.4
Apparent overall specimen density	kg/m^3	719.2	719.2	717.3	718.6

Material		**Data Files**			**Mean Value**
Specimen test number		**Vinyl wallpaper 1**	**Vinyl wallpaper 2**	**Vinyl wallpaper 3**	
Time to sustained flaming	s	10	9	9	9.3
Observations		i	i	i	
Test duration	s	184	182	181	182
Mass remaining, m_f	g	63.9	63.7	64.2	63.9
Mass pyrolyzed	%	14.6%	14.8%	14.0%	14.5%
Specimen mass loss[a]	kg/m^2	1.18	1.20	1.20	1.19
Specimen mass loss rate[a]	$g/m^2.s$	6.8	6.9	7.0	6.9
Heat release rate					
$\dot{q}''_{max}$ peak,	kW/m^2	164.6	168.8	165.6	166.3
$\dot{q}''_{avg}$ average,					
Over 60 s from ignition	kW/m^2	100.2	102.1	101.0	101.1
Over 180 s from ignition	kW/m^2	45.5	47.0	46.9	46.5
variation from mean		-2.0%	1.1%	1.0%	OK
Over 300 s from ignition	kW/m^2	45.5	47.0	46.9	46.5
Total heat release[b]	MJ/m^2	7.9	8.1	8.1	8.1
Average Specific Extinction Area	m^2/kg	255.5	257.2	258.0	256.9
Effective heat of combustion,	MJ/kg	6.4	6.5	6.8	6.6

Table 14: Cone Calorimeter results for plywood

Material		Data Files			Mean
Specimen test number		FQ5015-50-1 PLYWOOD	FQ5015-50-2 PLYWOOD	FQ5015-50-3 PLYWOOD	
Initial specimen mass	g	45.8	47.6	46.7	46.7
Mean specimen thickness	mm	9.1	9.1	9.1	9.1
Apparent overall specimen density	kg/m^3	503.3	523.1	513.2	513.2
Material		**Data Files**			**Mean Value**
Specimen test number		**FQ5015-50-1 PLYWOOD**	**FQ5015-50-2 PLYWOOD**	**FQ5015-50-3 PLYWOOD**	
Time to sustained flaming	s	23	26	25	24.7
Observations		i	i	i	
Test duration	s	332	350	346	343
Mass remaining, m_f	g	10.5	10.6	10.6	10.6
Mass pyrolyzed	%	77.0%	77.6%	77.3%	77.3%
Specimen mass loss[a]	kg/m^2	3.92	4.05	4.00	3.99
Specimen mass loss rate[a]	$g/m^2.s$	12.7	12.5	12.5	12.5
Heat release rate					
$\dot{q}''_{max}$ peak,	kW/m^2	314.7	346.6	340.5	333.9
$\dot{q}''_{avg}$ average,					
Over 60 s from ignition	kW/m^2	148.2	143.0	143.1	144.8
Over 180 s from ignition	kW/m^2	134.3	131.1	126.6	130.6
variation from mean		2.8%	0.3%	-3.1%	OK
Over 300 s from ignition	kW/m^2	150.6	157.7	154.2	154.2
Total heat release[b]	MJ/m^2	45.7	49.0	47.5	47.4
Average Specific Extinction Area	m^2/kg	86.2	111.4	133.6	110.4
Effective heat of combustion,	MJ/kg	11.5	11.7	11.6	11.6

Table 15: Cone Calorimeter results for plywood plus two coats of intumescent paint

Material		Data Files			Mean
Specimen test number		FQ5015-50-3A	FQ5015-50-3B	FQ5015-50-3C	
Initial specimen mass	g	49.3	51.2	42.9	47.8
Mean specimen thickness	mm	9.3	9.4	9.4	9.4
Apparent overall specimen density	kg/m^3	530.1	544.7	456.4	510.4

Material		Data Files			Mean Value
Specimen test number		**FQ5015-50-3A**	**FQ5015-50-3B**	**FQ5015-50-3C**	
Time to sustained flaming	s	23	23	23	23.0
Observations		i	i	i	
Test duration	s	84	84	84	84
Mass remaining, m_f	g	48.1	49.9	42.1	46.7
Mass pyrolyzed	%	2.4%	2.5%	1.8%	2.3%
Specimen mass loss[a]	kg/m^2	0.07	0.11	0.11	0.10
Specimen mass loss rate[a]	$g/m^2.s$	1.2	1.8	1.8	1.6
Heat release rate					
$\dot{q}''_{max}$ peak,	kW/m^2	36.7	35.7	35.4	36.0
$\dot{q}''_{avg}$ average,					
Over 60 s from ignition	kW/m^2	8.4	10.2	8.5	9.0
Over 180 s from ignition	kW/m^2	8.3	10.1	8.4	9.0
variation from mean		-6.8%	12.9%	-6.1%	NOT OK
Over 300 s from ignition	kW/m^2	8.3	10.1	8.4	9.0
Total heat release[b]	MJ/m^2	0.5	0.7	0.6	0.6
Average Specific Extinction Area	m^2/kg	150.4	128.1	216.3	165.0
Effective heat of combustion,	MJ/kg	4.0	4.7	6.3	5.0

Table 16: Cone Calorimeter results for plywood plus three coats of intumescent paint

Material		Data Files			Mean
Specimen test number		FQ5015-50-3aA	FQ5015-50-3aA	FQ5015-50-3aC	
Initial specimen mass	g	54.5	54.5	51.9	53.6
Mean specimen thickness	mm	9.5	9.5	9.4	9.5
Apparent overall specimen density	kg/m^3	573.7	573.7	552.1	566.5

Material		**Data Files**			**Mean Value**
Specimen test number		**FQ5015-50-3aA**	**FQ5015-50-3aA**	**FQ5015-50-3aC**	
Time to sustained flaming	s	28	28	24	26.7
Observations		i	i	i	
Test duration	s	88	88	84	87
Mass remaining, m_f	g	52.9	52.9	50.1	52.0
Mass pyrolyzed	%	2.9%	2.9%	3.5%	3.1%
Specimen mass loss[a]	kg/m^2	0.11	0.11	0.09	0.10
Specimen mass loss rate[a]	$g/m^2.s$	1.8	1.8	1.4	1.7
Heat release rate					
$\dot{q}''_{max}$ peak,	kW/m^2	38.1	38.1	39.9	38.7
$\dot{q}''_{avg}$ average,					
Over 60 s from ignition	kW/m^2	8.3	8.3	9.0	8.5
Over 180 s from ignition	kW/m^2	8.3	8.3	9.0	8.5
variation from mean		-2.6%	-2.6%	5.2%	OK
Over 300 s from ignition	kW/m^2	8.3	8.3	9.0	8.5
Total heat release[b]	MJ/m^2	0.6	0.6	0.6	0.6
Average Specific Extinction Area	m^2/kg	111.4	111.4	94.9	105.9
Effective heat of combustion,	MJ/kg	3.2	3.2	3.0	3.1

Table 17: Cone Calorimeter results for glazed fibre-cement board

Material		Data Files			Mean
Specimen test number		FQ5015-50-1	FQ5015-50-2	FQ5015-50-3	
Initial specimen mass	g	65.2	63.8	65.4	64.8
Mean specimen thickness	mm	4.7	4.7	4.7	4.7
Apparent overall specimen density	kg/m^3	1387.2	1357.4	1391.5	1378.7

Material		Data Files			Mean Value
Specimen test number		**FQ5015-50-1**	**FQ5015-50-2**	**FQ5015-50-3**	
Time to sustained flaming	s	68	65	65	66.0
Observations		i	i	i	
Test duration	s	205	152	212	190
Mass remaining, m_f	g	59.0	58.7	58.4	58.7
Mass pyrolyzed	%	9.5%	8.0%	10.7%	9.4%
Specimen mass loss[a]	kg/m^2	0.54	0.47	0.60	0.54
Specimen mass loss rate[a]	$g/m^2.s$	3.9	5.4	4.0	4.5
Heat release rate					
$\dot{q}''_{max}$ peak,	kW/m^2	111.5	108.4	108.4	109.5
$\dot{q}''_{avg}$ average,					
Over 60 s from ignition	kW/m^2	53.0	55.7	56.7	55.1
Over 180 s from ignition	kW/m^2	27.2	40.2	27.3	31.6
variation from mean		-13.8%	27.3%	-13.5%	NOT OK
Over 300 s from ignition	kW/m^2	27.2	40.2	27.3	31.6
Total heat release[b]	MJ/m^2	3.9	3.6	4.1	3.8
Average Specific Extinction Area	m^2/kg	135.6	103.6	114.8	118.0
Effective heat of combustion,	MJ/kg	5.5	6.2	5.1	5.6

Table 18: Cone Calorimeter results for plastic co-polymer

Material		Data Files			Mean
Specimen test number		FQ5015-50-1	FQ5015-50-2	FH5015-50-3	
Initial specimen mass	g	44.7	44.2	44.9	44.6
Mean specimen thickness	mm	4.8	4.8	4.8	4.8
Apparent overall specimen density	kg/m^3	931.3	920.8	935.4	929.2

Material		Data Files			Mean Value
Specimen test number		**FQ5015-50-1**	**FQ5015-50-2**	**FH5015-50-3**	
Time to sustained flaming	s	32	32	32	32.0
Observations		i	i	i	
Test duration	s	358	332	290	327
Mass remaining, m_f	g	11.0	13.2	14.5	12.9
Mass pyrolyzed	%	75.4%	70.1%	67.8%	71.1%
Specimen mass loss[a]	kg/m^2	3.80	3.58	3.43	3.61
Specimen mass loss rate[a]	$g/m^2.s$	11.7	11.9	13.3	12.3
Heat release rate					
$\dot{q}''_{max}$ peak,	kW/m^2	1271.1	1153.1	1108.5	1177.5
$\dot{q}''_{avg}$ average,					
Over 60 s from ignition	kW/m^2	256.6	264.8	272.5	264.6
Over 180 s from ignition	kW/m^2	619.5	548.0	532.0	566.5
variation from mean		9.4%	-3.3%	-6.1%	OK
Over 300 s from ignition	kW/m^2	446.1	397.9	429.8	424.6
Total heat release[b]	MJ/m^2	134.8	119.5	111.0	121.7
Average Specific Extinction Area	m^2/kg	523.1	558.8	511.8	531.2
Effective heat of combustion,	MJ/kg	35.3	34.1	32.2	33.9

Table 19: Cone Calorimeter results for 100% polyester wall covering on 13 mm plasterboard

Material		Data Files			Mean
Specimen test number		FQ5015-50-6A	FQ5015-50-6B	FQ5015-50-6C	
Initial specimen mass	g	110.6	110.5	113.9	111.7
Mean specimen thickness	mm	16.4	16.5	16.2	16.4
Apparent overall specimen density	kg/m^3	674.4	669.7	703.1	682.4

Material		Data Files			**Mean Value**
Specimen test number		**FQ5015-50-6A**	**FQ5015-50-6B**	**FQ5015-50-6C**	
Time to sustained flaming	s	34	22	28	28.0
Observations		i	i	i	
Test duration	s	166	195	197	186
Mass remaining, m_f	g	102.6	99.2	102.9	101.6
Mass pyrolyzed	%	7.2%	10.2%	9.7%	9.0%
Specimen mass loss[a]	kg/m^2	0.93	1.29	1.19	1.14
Specimen mass loss rate[a]	$g/m^2.s$	7.1	7.5	7.0	7.2
Heat release rate					
$\dot{q}''_{max}$ peak,	kW/m^2	479.8	434.4	473.4	462.5
$\dot{q}''_{avg}$ average,					
Over 60 s from ignition	kW/m^2	167.2	183.0	177.8	176.0
Over 180 s from ignition	kW/m^2	87.0	74.9	74.0	78.6
variation from mean		10.6%	-4.8%	-5.8%	NOT OK
Over 300 s from ignition	kW/m^2	87.0	74.9	74.0	78.6
Total heat release[b]	MJ/m^2	11.6	13.0	12.6	12.4
Average Specific Extinction Area	m^2/kg	266.0	200.4	208.3	224.9
Effective heat of combustion,	MJ/kg	12.8	10.2	10.1	11.0

Table 20: Cone Calorimeter results for 100% modified polyester wall covering on 13 mm plasterboard

Material		Data Files			Mean
Specimen test number		FQ5015-50-7A	FQ5015-50-7B	FQ5015-50-7C	
Initial specimen mass	g	123.5	126.2	126.3	125.3
Mean specimen thickness	mm	22.1	23	22.5	22.5
Apparent overall specimen density	kg/m^3	558.8	548.7	561.3	556.3

Material		**Data Files**			**Mean Value**
Specimen test number		**FQ5015-50-7A**	**FQ5015-50-7B**	**FQ5015-50-7C**	
Time to sustained flaming	s	36	44	31	37.0
Observations		i	i	i	
Test duration	s	356	194	365	305
Mass remaining, m_f	g	95.5	107.9	95.1	99.5
Mass pyrolyzed	%	22.7%	14.5%	24.7%	20.6%
Specimen mass loss[a]	kg/m^2	3.12	1.96	3.51	2.86
Specimen mass loss rate[a]	$g/m^2.s$	9.8	13.1	10.5	11.1
Heat release rate					
$\dot{q}''_{max}$ peak,	kW/m^2	552.7	543.4	512.6	536.2
$\dot{q}''_{avg}$ average,					
Over 60 s from ignition	kW/m^2	273.2	293.9	228.4	265.2
Over 180 s from ignition	kW/m^2	183.4	202.7	200.6	195.6
variation from mean		-6.2%	3.6%	2.6%	OK
Over 300 s from ignition	kW/m^2	118.2	202.7	131.2	150.7
Total heat release[b]	MJ/m^2	35.9	30.5	40.1	35.5
Average Specific Extinction Area	m^2/kg	363.8	506.3	373.0	414.4
Effective heat of combustion,	MJ/kg	11.3	14.8	11.4	12.5

Table 21: Cone Calorimeter results for mass loaded noise barrier on 13 mm plasterboard

Material		Data Files			Mean
Specimen test number		FQ5015-50-8A	FQ5015-50-8B	FQ5015-50-8C	
Initial specimen mass	g	158.3	154	153.0	155.1
Mean specimen thickness	mm	14.5	15.2	15.3	15.0
Apparent overall specimen density	kg/m^3	1091.7	1013.2	1000.0	1035.0

Material		**Data Files**			**Mean Value**
Specimen test number		**FQ5015-50-8A**	**FQ5015-50-8B**	**FQ5015-50-8C**	
Time to sustained flaming	s	31	31	32	31.3
Observations		i	i	i	
Test duration	s	136	120	222	159
Mass remaining, m_f	g	153.9	149.8	147.3	150.3
Mass pyrolyzed	%	2.8%	2.7%	3.7%	3.1%
Specimen mass loss[a]	kg/m^2	0.38	0.32	0.61	0.44
Specimen mass loss rate[a]	$g/m^2.s$	3.7	3.6	3.2	3.5
Heat release rate					
$\dot{q}''_{max}$ peak,	kW/m^2	247.0	240.9	252.0	246.6
$\dot{q}''_{avg}$ average,					
Over 60 s from ignition	kW/m^2	135.2	127.4	141.2	134.6
Over 180 s from ignition	kW/m^2	119.8	117.0	107.5	114.7
variation from mean		4.4%	2.0%	-6.3%	OK
Over 300 s from ignition	kW/m^2	119.8	117.0	106.0	114.3
Total heat release[b]	MJ/m^2	12.7	10.5	20.3	14.5
Average Specific Extinction Area	m^2/kg	356.8	306.6	304.2	322.5
Effective heat of combustion,	MJ/kg	25.7	21.9	31.7	26.4

Table 22: Cone Calorimeter results for softboard and paint

Material		Data Files			Mean
Specimen test number		FQ5015-50-10A	FQ5015-50-10B	FQ5015-50-10C	
Initial specimen mass	g	39.1	39	38.1	38.7
Mean specimen thickness	mm	12.9	12.7	12.7	12.8
Apparent overall specimen density	kg/m^3	303.1	307.1	300.0	303.4

Material		Data Files			**Mean Value**
Specimen test number		**FQ5015-50-10A**	**FQ5015-50-10B**	**FQ5015-50-10C**	
Time to sustained flaming	s	17	15	15	15.7
Observations		i	i	i	
Test duration	s	448	438	424	437
Mass remaining, m_f	g	9.7	10.4	9.9	10.0
Mass pyrolyzed	%	75.3%	73.4%	73.9%	74.2%
Specimen mass loss[a]	kg/m^2	3.70	3.16	3.16	3.34
Specimen mass loss rate[a]	$g/m^2.s$	8.6	7.5	7.7	7.9
Heat release rate					
$\dot{q}''_{max}$ peak,	kW/m^2	172.7	189.6	181.6	181.3
$\dot{q}''_{avg}$ average,					
Over 60 s from ignition	kW/m^2	72.6	65.6	66.8	68.3
Over 180 s from ignition	kW/m^2	70.4	69.0	70.8	70.1
variation from mean		0.4%	-1.6%	1.1%	OK
Over 300 s from ignition	kW/m^2	82.0	81.7	84.6	82.8
Total heat release[b]	MJ/m^2	38.5	37.7	37.4	37.9
Average Specific Extinction Area	m^2/kg	52.8	57.2	63.1	57.7
Effective heat of combustion,	MJ/kg	11.6	11.7	11.7	11.7

Table 23: Cone Calorimeter results for softboard

Material		Data Files			Mean
Specimen test number		FQ5015-50-11A	FQ5015-50-11B	FQ5015-50-11C	
Initial specimen mass	g	38.8	39.1	39.0	39.0
Mean specimen thickness	mm	13.4	12.8	12.9	13.0
Apparent overall specimen density	kg/m^3	289.6	305.5	302.3	299.1

Material		**Data Files**			**Mean Value**
Specimen test number		FQ5015-50-11A	FQ5015-50-11B	FQ5015-50-11C	
Time to sustained flaming	s	10	10	9	9.7
Observations		i	i	i	
Test duration	s	438	432	440	437
Mass remaining, m_f	g	8.5	8.5	8.7	8.6
Mass pyrolyzed	%	78.1%	78.2%	77.6%	78.0%
Specimen mass loss[a]	kg/m^2	3.23	3.41	3.39	3.34
Specimen mass loss rate[a]	$g/m^2.s$	7.5	8.1	7.9	7.8
Heat release rate					
$\dot{q}''_{max}$ peak,	kW/m^2	195.3	188.2	193.3	192.3
$\dot{q}''_{avg}$ average,					
Over 60 s from ignition	kW/m^2	139.9	135.4	133.6	136.3
Over 180 s from ignition	kW/m^2	109.7	109.4	107.4	108.9
variation from mean		0.8%	0.5%	-1.3%	OK
Over 300 s from ignition	kW/m^2	101.2	104.1	101.8	102.4
Total heat release[b]	MJ/m^2	42.0	42.4	42.5	42.3
Average Specific Extinction Area	m^2/kg	58.7	66.5	67.3	64.1
Effective heat of combustion,	MJ/kg	12.3	12.3	12.4	12.3

10. APPENDIX 2 – CLASSIFICATION OF DATA

10.1 BCA classifications based on Cone Calorimeter and ISO 9705 test data

The method of Kokkala, Thomas and Karlsson (1993) is used to determine the BCA Group number, and this is based on the rate of heat release over the duration of the Cone Calorimeter test.

The SMOGRA index is determined from ISO 9705 smoke production data.

10.1.1 Predicting a material's BCA Group number

For a material tested to AS 3837, the material's group must be determined in accordance with the following:

(a) Data must be in the form of time and rate of heat release pairs for the duration of the test. The time interval between pairs should not be more than 5 seconds. The end of the test (tf) is determined as defined in AS/NZS 3837.

(b) At least three replicate specimens must be tested. The following procedure must be applied separately to each specimen:

(i) Determine time to ignition (t_{ig}) – defined as the time (in seconds) when the rate of heat release reaches or first exceeds a value of 50 kW/m^2.

(ii) Calculate the Ignitability index (I_Q) expressed in reciprocal minutes.

$$I_Q = \frac{60}{t_{ig}}$$

(iii) Calculate the following two rate of heat release indices:

$$I_{Q1} = \int_{t_{ig}}^{t_f} \left[\frac{q''(t)}{(t - t_{ig})^{0.34}} \right] \qquad I_{Q2} = \int_{t_{ig}}^{t_f} \left[\frac{q''(t)}{(t - t_{ig})^{0.93}} \right]$$

t = time (in seconds)

$q''(t)$ = rate of heat release (in kW/m^2) at time t

These definite integral expressions represent the area under a curve from the ignition time until the end of the test, where the parameter $q''(t)/(t - t_{ig})^m$ is plotted on the vertical axis and time (t) is plotted on the horizontal axis.

(iv) Calculate the following three integral limits.

$$I_{Q,10\min} = 6800 - 540 I_{ig}$$

$$I_{Q,2\min} = 2475 - 165 I_{ig}$$

$$I_{Q,12\min} = 1650 - 165 I_{ig}$$

(v) Classify the material by applying the following rules

If $I_{Q1} > I_{Q,10\min}$ and $I_{Q2} > I_{Q,2\min}$ the material is a *Group 4 material*

If $I_{Q1} > I_{Q,10\min}$ and $I_{Q2} \leq I_{Q,2\min}$ the material is a *Group 3 material*

If $I_{Q1} \leq I_{Q,10\min}$ and $I_{Q2} > I_{Q,12\min}$ the material is a *Group 3 material*

If $I_{Q1} \leq I_{Q,10\min}$ and $I_{Q2} \leq I_{Q,12\min}$ the material is a *Group 1 material*

(vi) Repeat steps 1 to 5 above for each replicate specimen tested. Where a different classification group is obtained for different specimens tested, then the highest (worse) classification for any specimen shall be taken as the final classification for that material.

The data recorded in the Cone Calorimeter testing was processed according to the above method and the data is entered in Table 24.

Table 24: BCA classifications based on Cone Calorimeter results according to AS/NZS 3837 end of test criteria

Parameter		Vinyl wallpaper	Plywood	Plywood and Int(2)	Plywood and Int(3)	Glazed fibre cement board	Plastic co-polymer	100% polyester	100% modified polyester	Synthetic rubber	Softboard + paint	Softboard
Time to Ignition (sec) =		14.0	32	0	0	73	40	41	41	40	25	17
Ignitability Index (1/min) =		4.276	1.88	#DIV/0!	#DIV/0!	0.82	1.48	1.47	1.45	1.52	2.37	3.61
End of Test (sec) =		184	332	84	88	206	332	166	356	136	448	438
Rate of Heat Release Index (m=0.34) =		2863.4	9908	0	0	1551	25491	4356	10297	4202	7163	8733
	10 minute limit =	4491	5783	#DIV/0!	#DIV/0!	6358	5999	6006	6015	5980	5519	4850
Rate of Heat Release Index (m=0.93) =		1360.4	1736	0	0	1103	2853	1678	1940	1476	1350	1668
	2 minute limit =	1769	2164	#DIV/0!	#DIV/0!	2340	2230	2233	2235	2224	2084	1879
	12 minute limit =	944	1339	#DIV/0!	#DIV/0!	1515	1405	1408	1410	1399	1259	1054
BCA Group Classification		**2**	**3**	**?**	**?**	**1**	**4**	**2**	**3**	**2**	**3**	**3**

In Table 24 the end of test criteria has an influence on the results and in particular the BCA Group Classification. The short duration of the two plywood with intumescent paint tests of 84 and 88 seconds meant that there was insufficient data to determine a BCA Group Classification, and as such it is deemed to be non-combustible meaning Group numbers of 1 should be applied by default.

Table 25: BCA classifications based on Cone Calorimeter results according to ISO 5660 end of test criteria

Parameter		Vinyl wallpaper	Plywood	Plywood and Int(2)	Plywood and Int(3)	Glazed fibre cement board	Plastic co-polymer	100% polyester	100% modified polyester	Synthetic rubber	Softboard + paint	Softboard
Time to Ignition (sec) =		14	31.9	395	627	73	40	41	41	40	25	17
Ignitability Index (1/min) =		4.28	1.884	0.15	0.10	0.82	1.48	1.47	1.45	1.52	2.37	3.61
End of Test (sec) =		308	600	600	900	348	600	600	600	600	600	600
Rate of Heat Release Index (m=0.34) =		3137	11607.1	5062	6958	1701	26172	4559	10639	8291	7708	9457
	10 minute limit =	4491	5783	6718	6748	6358	5999	6006	6015	5980	5519	4850
Rate of Heat Release Index (m=0.93) =		1372	1784.1	1224	1326	1110	2874	1687	1950	1647	1364	1687
	2 minute limit =	1769	2164	2450	2459	2340	2230	2233	2235	2224	2084	1879
	12 minute limit =	944	1339	1625	1634	1515	1405	1408	1410	1399	1259	1054
BCA Group Classification		**2**	**3**	**1**	**3**	**1**	**4**	**2**	**3**	**3**	**3**	**3**

In Table 25 the end of test criteria is extended to illustrate the influence on the resulting BCA Group Classification. In the cases of the plywood with intumescent paint, the BCA Group number was dependent on the end of test time where extending the duration delivered a worse result. For the synthetic rubber the result of extending the duration was the same, increasing a Group 2 to 3.

10.1.2 Predicting a material's smoke growth rate index

The instantaneous rate of light-obscuring smoke R_{inst} expressed in square metres per second (m^2/s) is measured in the exhaust duct at not more than 6 second intervals in the ISO 9705 room test.

Determine the 60 second running average (R_{60}) at time, *t*. This is the average rate of light-obscuring smoke over the period *t*-30 to *t*+30 seconds (in m^2/s). This may also be expressed mathematically as:

$$R_{60} = \frac{1}{60}\int_{t-30}^{t+30} R_{inst}\,dt$$

(a) Find the time (in seconds) at which the maximum value of the 60 second running average occurs (t_{60}).

(b) Calculate the $SMOGRA_{RC}$ value (in m^2/s^2 x 1000)

$$SMOGRA_{RC} = \frac{1000R_{60}}{t_{60}}$$

The $SMOGRA_{RC}$ index is based on the results of a single test.

10.2 BCA Specification C1.10a Fire hazard properties – floors, walls and ceilings

Deemed-to-Satisfy Provisions

10.2.1 Scope

This specification sets out requirements in relation to the *fire hazard properties* of floor materials and coverings and wall and ceiling linings.

10.2.2 Walls and ceilings provisions BCA

(a) For the purposes of this Clause, the Group number of a material is determined by either:

(i) physical testing in accordance with AS ISO 9705; or

(ii) prediction in accordance with Clause 3 of Specification A2.4 using data obtained by testing the material at 50 kW/m2 irradiance in the horizontal orientation with edge frame in accordance with AS/NZS 3837.

(b) The Group number of a material is as follows when tested or predicted in accordance with sub-clause (a):

(i) A Group 1 material is one that does not reach flashover when exposed to 300 kW for 600 seconds after not reaching flashover when exposed to 100 kW for 600 seconds.

(ii) A Group 2 material is one that reaches flashover following exposure to 300 kW within 600 seconds after not reaching flashover when exposed to 100 kW for 600 seconds.

(iii) A Group 3 material is one that reaches flashover in more than 120 seconds but within 600 seconds when exposed to 100 kW.

(iv) A Group 4 material is one that reaches flashover within 120 seconds when exposed to 100 kW.

(c) A material used as a finish, surface, lining or attachment to a wall or ceiling must be a *Group 1*, *Group 2* or *Group 3 material* used in accordance with Table 2 and, for buildings not fitted with a sprinkler system complying with Specification E1.5, have:

(i) A smoke growth rate index not more than 100; or

(ii) An average specific extinction area less than 250m²/kg.

Table 2

WALL AND CEILING LINING MATERIALS (Material Groups Permitted)

BCA Building Class	Fire isolated exits	Public corridors		Specific areas		Other areas
	Wall/ceiling	Wall	Ceiling	Wall	Ceiling	Wall/ceiling
Class 2 & 3						
Excluding accommodation for the aged, disabled and children						
Unsprinklered	1	1, 2	1, 2	1, 2, 3	1, 2, 3	1, 2, 3
Sprinklered	1	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3
Class 3 & 9a						
Accommodation for the aged, disabled and children, health care buildings						
Unsprinklered	1	1	1	1, 2	1, 2	1, 2, 3
Sprinklered	1	1, 2	1, 2	1, 2, 3	1, 2, 3	1, 2, 3
Class 5, 6, 7, 8 & 9b schools						
Unsprinklered	1	1, 2	1, 2	1, 2, 3	1, 2	1, 2, 3
Sprinklered	1	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3
Class 9b –						
Theatres, halls etc						
Unsprinklered	1	1	1	1, 2	1, 2	1, 2 3
Sprinklered	1	1, 2	1, 2	1, 2, 3	1, 2, 3	1, 2, 3

Notes:

1. "Sprinklered" refers to a building fitted with a sprinkler system complying with Specification E1.5.
2. "Specific areas" refers to:
   (a) for Class 2 and 3 buildings, a sole-occupancy unit
   (b) for Class 5, open-plan offices with a minimum floor dimension/floor to ceiling height ratio >5
   (c) for Class 6, shops with a minimum floor dimension/floor to ceiling height ratio >5
   (d) for Class 9a health care buildings, patient care areas
   (e) for Class 9b theatres and hall etc, an auditorium
   (f) for Class 9b schools, a classroom.

10.3 NZBC Purpose Groups

Amend 5 Oct 2005

Table 2.1: Purpose Groups
Paragraphs 1.3.4, 2.1.3, 2.2.1, 2.2.10, 5.6.11 and 5.6.13

Purpose group	Description of intended use of the building space	Some examples	Fire hazard category
CROWD ACTIVITIES			
CS or CL	For *occupied spaces*. CS applies to *occupant loads* up to 100 and CL to *occupant loads* exceeding 100.	Cinemas when classed as CS, art galleries, auditoria, bowling alleys, churches, clubs (non-residential), community halls, court rooms, dance halls, day care centres, gymnasia, lecture halls, museums, eating places (excluding kitchens), taverns, enclosed grandstands, indoor swimming pools.	1
		Cinemas when classed as CL, schools, colleges and tertiary institutions, libraries (up to 2.4 m high book storage), nightclubs, restaurants and eating places with cooking facilities, *early childhood centres theatre* stages, opera houses, television studios (with audience).	2
		Libraries (over 2.4 m high book storage).	3
CO	Spaces for viewing open air activities (does not include spaces below a grandstand).	Open grandstands, roofed but unenclosed grandstand, uncovered fixed seating.	1
CM	Spaces for displaying, or selling retail goods, wares or merchandise.	Exhibition halls, retail shops.	2
		Supermarkets or other stores with bulk storage/display over 3.0 m high.	4
SLEEPING ACTIVITIES			
SC	Spaces in which *principal users* because of age, mental or physical limitations require special care or treatment.	Hospitals. Care institutions for the aged, children, *people with disabilities*.	1
SD	Spaces in which *principal users* are restrained or liberties are restricted.	Care institutions, for the aged or children, with physical restraint or detention. Hospital with physical restraint, detention quarters in a police station, prison.	1
SA	Spaces providing transient accommodation, or where limited assistance or care is provided for *principal users*.	Motels, hotels, hostels, boarding houses, clubs (residential), boarding schools, dormitories, halls, *wharenui*, community care institutions.	1
SR	Attached and multi-unit residential dwellings.	*Multi-unit dwellings* or flats, apartments, and includes *household units* attached to the same or other *purpose groups*, such as caretakers' flats, and residential accommodation above a shop. *Household unit firecells* may contain garages which are used exclusively by the occupants of that *household unit*.	1
SH	Detached dwellings where people live as a single household or family.	Dwellings, houses, being *household units*, or *suites* in *purpose group* SA, separated from each other by distance. Detached dwellings may include attached self-contained *suites* such as granny flats when occupied by a member of the same family, and garages whether detached or part of the same *building* and are primarily for storage of the occupants' vehicles, tools and garden implements.	1

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Errata Jul 2001

Table 2.1: Purpose Groups *(continued)*

Purpose group	Description of intended use of the building space	Some examples	Fire hazard category
WORKING, BUSINESS OR STORAGE ACTIVITIES			
WL	Spaces used for working, business or storage – low *fire load*.	Manufacturing, processing or storage of *non-combustible* materials, or materials having a slow heat release rate, cool stores, covered cattle yards, wineries, grading or storage or packing of horticultural products, wet meat processing.	1
		Banks, hairdressing shops, beauty parlours, personal or professional services, dental offices, laundry (self-service), medical offices, business or other offices, police stations (without detention quarters), radio stations, television studios (no audience), small tool and appliance rental and service, telephone exchanges, dry meat processing.	2
WM	Spaces used for working, business or storage – medium *fire load* and slow/medium/fast *fire* growth rates (e.g. <1 MW in 75 sec) **(Note 1)**.	Manufacturing and processing of *combustible* materials not otherwise listed, including bulk storage up to 3 m high (excluding *foamed plastics*).	3
WH	Spaces used for working, business or storage – high *fire load* and slow/medium/ fast *fire* growth rates (e.g. <1 MW in 75 sec) **(Note 1)**.	Chemical manufacturing or processing plants, distilleries, feed mills, flour mills, lacquer factories, mattress factories, rubber processing plants, spray painting operations, plastics manufacturing, bulk storage of *combustible* materials over 3 m high (excluding *foamed plastics*).	4
WF	Spaces used for working, business or storage – medium/ high *fire load* and ultra fast *fire* growth rates (e.g. >1 MW in 75 sec) **(Note 1)**.	Areas involving significant quantities of highly *combustible* and flammable or explosive materials which because of their inherent characteristics constitute a special *fire hazard*, including: bulk plants for flammable liquids or gases, bulk storage warehouses for flammable substances, bulk storage of *foamed plastics*.	4 (The critical factor in this *purpose group* is the rate of *fire* growth.)
INTERMITTENT ACTIVITIES			
IE	*Exitways* on *escape routes*.	*Protected path, safe path*.	1
IA	Spaces for intermittent occupation or providing intermittently used support functions – low *fire load*.	Car parking, garages, carports, enclosed corridors, unstaffed kitchens or laundries, lift shafts, locker rooms, linen rooms, open balconies, *stairways* (within the *open path*), toilets and amenities, and service rooms incorporating machinery or equipment not using solid-fuel, gas or petroleum products as an energy source **(Note 2)**.	1
ID	Spaces for intermittent occupation or providing intermittently used support functions – medium *fire load*.	Maintenance workshops and service rooms incorporating machinery or equipment using solid-fuel, gas or petroleum products as an energy source **(Note 2)**.	3

Notes:

1. Refer to NFPA 92B for more information on *fire* growth rates.
2. Service rooms are spaces designed to accommodate any of the following: boiler/plant equipment, furnaces, incinerators, refuse, caretaking/cleaning equipment, airconditioning, heating, plumbing or electrical equipment, pipes, lift/escalator machine rooms, or similar services.

10.4 NZBC surface finish requirements

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Table 6.2: Requirements for Interior Surface Finishes and Suspended Flexible Fabrics to Inhibit Fire Spread
Paragraphs 6.18.2 d), 6.20.2, 6.20.5, 6.20.7, 6.20.16, 6.20.20 and 6.20.21

Building elements	Purpose group or location (Note 1)	Maximum permitted index SFI	SDI	FI	Row
Walls, ceilings (Note 2)	*Exitways* in all *purpose groups*. Sleeping areas in *purpose groups* SC and SD.	0	3	-	1
	All *occupied spaces* in *purpose groups* CS and CL excluding *exitways* (see also Paragraph 6.20.7). All *occupied spaces* in *purpose group* CM where the *occupant load* is greater than 50. Sleeping areas in *purpose group* SA (see also Paragraph 6.20.6 for trampers' huts).	2	5	-	2
	Passageways, corridors and *stairways* not being part of an *exitway* in all *purpose groups* except SH and SR.	7	5	-	3
	Minimum requirement for all *occupied spaces* in all *purpose groups* except within *household units* in *purpose groups* SR and SH.	5 or 9	10 8	- -	4
	Within individual *household units* in *purpose groups* SR and SH.	Nil requirement			5
Flooring (coverings)	*Exitways*. Any *occupied space* in *purpose groups* SC and SD.	*Non-combustible*, or have low radius of effects of ignition (see Paragraph 6.20.8).			6
Ducts for *HVAC* systems	Internal surfaces.	0	3	-	7
	External surfaces.	7	5	-	8
Acoustic treatment and pipe insulation	Within air-handling plenum in *purpose groups* SC, SD, SA and SR.	7	5	-	9
Suspended flexible fabrics	*Exitways* serving *purpose groups* SC, SD, SA, SR and CO. All *occupied spaces* in *purpose groups* CS and CL including *exitways*. All *occupied spaces* including *exitways* in *purpose group* CM where *occupant load* is greater than 50. Underlay to exterior cladding or roofing when exposed to view in *occupied spaces* in *purpose groups* SC, SD, SA, WL, WM, WH, WF, CO, CM, CS, CL and IE.	-	-	12	10
Membrane structures	*Purpose groups* CM, CS and CL.	Pass the *standard test* for flammability of membrane structures.			11
Column 1	2	3			
Key:	**SFI = spread of flame index** **SDI = smoke developed index** **FI = flammability index**	**(The smaller the index number the more stringent the requirement)**			

Notes:

1. For the purposes of this table, the term *"occupied spaces"* means a space that can be expected to be occupied during normal use of the *building* by its intended occupants. It does not include *concealed spaces* or ceiling cavities which may be accessed only through a hatch, or plant rooms and the like occupied only for maintenance purposes.
2. **Sprinklered firecells:** see Paragraph 6.20.5 for reduced requirements in sprinklered *firecells*.