Patrik Johansson
Patrick Van Hees

Development of a Test Procedure for Sandwich Panels using ISO 9705 Philosophy

Nordtest Project nr 1432-99

SP Swedish National Testing and Research Institute
SP Fire Technology
SP REPORT 2000:26

Patrik Johansson
Patrick Van Hees

Development of a Test Procedure for Sandwich Panels using ISO 9705 Philosophy

Nordtest Project nr 1432-99

SP Swedish National Testing and Research Institute
SP Fire Technology
SP REPORT 2000:26

Patrik Johansson
Patrick Van Hees

Development of a test procedure for sandwich panels using ISO 9705 philosophy - Nordtest project nr 1432-99

SP Rapport 2000:26
Fire Technology
Borås 2000

Abstract

Development of a test procedure for sandwich panels using ISO 9705 philosophy

Assessment of the fire behaviour of sandwich panels often requires large scale testing. The fire behaviour of these panels is a combination of material characteristics such as the core material and mechanical behaviour of the panels such as joints, dilations etc. Thus, the use of small or intermediate scale test can be questioned for such type of products. Testing in full-scale is often the most appropriate solution. Even in large scale tests, however, conditions and mounting practice should be considered carefully. This project has aimed to develop a full-scale test procedure which fully allows the end-use mounting of the panels but retains the philosophy of the room corner test scenario as given in NT FIRE 025 and ISO 9705.

The results of this project show that it is possible to use a so called "free-standing set-up" of the room structure and to measure HRR and SPR. This set-up is more severe than the mounting inside an ISO 9705 room as new effects, such as dilation and joint finishing, appear which should be considered when using such a set-up. Within this project a limited amount of SBI tests were performed which indicate that the SBI test method does not fully reflect the behaviour of sandwich panels in full and real scale and that more research is needed.

Key words: fire, sandwich panels, room tests

SP Sveriges Provnings- och Forskningsinstitut
SP Rapport 2000:26
ISBN 91-7848-827-0
ISSN 0284-5172
Borås 2000

SP Swedish National Testing and Research Institute
SP Report 2000:26
Postal address:
Box 857, SE-501 15 BORÅS, Sweden
Telephone: +46 33 16 50 00
Telefax: +46 33 13 55 02
E-mail: info@sp.se
Internet: www.sp.se

Contents

Preface

The authors would like to thank Nordtest (Nordtest project nr. 1432-99) and all industrial sponsors for their financial support and discussions in the reference group of this project. The authors would like also to thank the SP project team for support, mounting and general assistance in facilitating this project. Finally, the authors would like to thank their colleagues from DIFT in Denmark for their collaboration.

Summary

A number of tests have been performed on different types of sandwich panels. The chosen sandwich panels included most common core materials. Two types of full-scale tests were performed. One set was conducted according to ISO 9705 i.e. tests where the panels were mounted inside a non-combustible room. Another set of full-scale tests was performed using a free standing room under a large calorimeter. This calorimeter allowed HRR and SPR measurements not only until flashover but also after. The tests revealed that such full-scale testing of a free standing room is possible and that it allows for correct mounting of the sandwich panels so that end-use conditions are reliably represented.
The results showed that the free standing set-up is slightly more severe than a set-up where the panels are mounted inside the ISO 9705 room. It was, however, not easy to make such a comparison as mounting always differs due to the changed set-up. The major task of this project was, however, to investigate the feasibility of testing a free standing set-up with HRR and SPR measurements while retaining the philosophy of ISO 9705. This objective was achieved.
A small study was also performed on the link between the SBI test and the full-scale tests. It appears to be difficult to establish a link between the SBI test and the full-scale tests with the present procedure.

Sammanfattning

Ett antal försök på olika typer av sandwichpaneler har genomförts. De valda sandwichpanelerna inkluderar de vanligaste kärnmaterialen. Två olika fullskaletester har genomförts. En av dem var utförd enligt ISO 9705 dvs. försök där panelerna var monterade inuti ett obrännbart rum. Det andra sättet av fullskaletesten var utförd genom att använda ett fristående rum under en stor kalorimeter. Denna kalorimeter tillät inte bara mätning av HRR och SPR till övertändning utan också efter. Försöken visade att fullskaletest av fristående rum är möjlig och att det tillåter korrekt montering av panelerna så att det motsvarar verklig användning.
Resultaten visade att det fristående ger högre brandpåverkan jämfört med där panelerna är monterade inomhus. Men det var inte lätt att göra en sådan jämförelse då monteringen alltid skiljer sig vid skiftande utförandet. Huvuduppgiften för projektet var att utvärdera möjligheterna att testa fristående montering med HRR och SPR mätningar samt behålla filosofin från ISO 9705. Detta mål uppfylldes.
En liten studie om sambandet mellan SBI test och fullskaleprovning har också genomförts. Studien visade på dålig korrelation mellan SBI och fullskaleförsöken.

1 Background

Sandwich panels are built up as composite construction products. In most cases they consist of two metal sheets with an inner insulation. This inner insulation can be either combustible or non combustible. The metal can cause a delay of ignition but still transfers heat to the core. Once on fire such panels with a combustible core are known to be difficult to extinguish.

The number of fires involving sandwich panels with combustible core has increased substantially and they are considered as a growing fire problem especially in e.g. cold storage rooms, warehouses etc. Fires in so called food factories in the UK have caused much concern for insurance companies and fire fighters. The total loss for fire in e.g. the UK food industry where panels are often used was more than 300 MSEK in 1995.

Regulations concerning sandwich panels are under way in different countries in Europe but information is still lacking about how to test sandwich panels in their end use conditions.

When assessing the fire risk of sandwich panels, most small-scale tests are insufficient because of the importance of joints and mechanical fastening. Therefore a full-scale test is necessary. In view of the actual situation within ISO and European harmonisation using the Euroclasses system the most suitable approach is the use of the ISO 9705 scenario (similar to NT FIRE 025). However some practical problems concerning e.g. end use conditions arise if ISO 9705 (NT FIRE 025) is applied directly. Therefore some development was necessary. The project was sponsored by Nordtest with project number 1432-99 and industrial involvement made it possible to extend the project. The project was a collaboration between DBI Denmark and SP Sweden.

2 Scope

The scope of this project was to develop a test method for sandwich panels using the ISO 9705 (NT FIRE 025) philosophy and allowing sandwich panels to be tested under end use conditions. The outcome of this project is important for a correct fire assessment of these products and it will contribute to international progress of fire test standardisation both at European (CEN) and International level (ISO).

3 Testing programme

When performing tests on sandwich panels in ISO 9705 (NT FIRE 025) the panels are positioned inside the room. This has three main drawbacks:

1. Due to the fact that the dimensions are fixed the internal room size will depend on the thickness of the panels. When panels for cold storage rooms are tested actual thickness may be greater than 30 cm implying that the volume of the room is greatly decreasing.
2. In many cases the joints have an important effect on the fire behaviour of the complete system. That is why complex joint systems are developed within the sandwich panel industry and why these joints have to be exactly the same in the test as in reality. With the actual mounting technique inside the test room it is not possible to do this as the outer walls of the room corner structure prevents adequate finishing of the joints located on the backside of the panel (i.e. those between the sandwich panel construction and the walls of the room corner itself).
3. Testing panels inside the ISO 9705 (NT FIRE 025) room does not allow observations to be made outside the construction: Such observations include flaming or excessive deformation.

These drawbacks can only be solved by testing either

1. The construction as ”stand alone” connected to a ISO 9705 hood ;or
2. As a construction where an enclosure is built around the sandwich panel construction at a sufficient distance to allow proper finishing of the joints and the observations or;
3. Using a large hood under which the stand alone system is placed.

Such set ups will result in a correct evaluation of the product.

In order to attain the objectives of this project the following work programme was set up:

1. Selection of products for the tests
2. Room tests according to ISO 9705
3. Room tests with a free standing set-up under a large hood
4. Comparison of the two test set ups
5. A limited number of SBI tests to compare the full-scale behaviour with the SBI test results

In the original Nordtest project 4 products were to be selected and the SBI tests were not scheduled. Due to the industry involvement and the strategic importance of this project a limited number of SBI tests were also performed. Both the tests included in the Nordtest project and the additional tests are reported in this report in order to obtain an overall report.

4 Selection and description of the specimens

The selection criteria in the Nordtest proposal were the following:

1. 4 different types of panels. The panels were to be selected based on the fire performance of the core material.
2. The selection should include one panel with a core of non-combustible insulation material and panels with a core of the two main common combustible insulation products (PS and PUR/PIR).

From the discussions with the industrial partners the following selection as given in table 1 was made. The selection fulfils the criteria of the project description. Table 2 gives also a generic description of the products. As this project does not aim to compare products but only to investigate the different test methods, the description is kept to a minimum. Further, the results should be seen as typical for the specific panel construction rather than as general behaviour.
In order to avoid any problems of different room sizes in both set-ups or between different products it was decided to keep the thickness of the product identical in all tests. It should be noted that the thickness for the same insulation value can differ but that for this project the requirement of keeping the internal volume constant was predominant.

TABLE 1 OVERVIEW OF THE PRODUCTS

Product	Insulation material	Thickness of the panel (mm)	Application
A	Stone wool	100	Industrial or cooling houses
B	Polystyrene	100	Cooling houses
C	PIR	100	Cooling houses
D	PUR	100	Cooling houses

5 Mounting of the specimens

As this project is not intended to compare different products no detailed construction information is provided.
It is important to note that most products have been installed by the suppliers (Products B, C, and D) with assistance of SP. In case of product A the instructions of the supplier were followed by SP.
In every case the mounting was thoroughly discussed with the supplier and the possible differences between the mounting of the specimens inside the room and the free standing set-up were discussed in detail.
It is important to emphasise the fact that the joints were not at all identical for all products.

5.1 ISO 9705 room tests

All panels were mounted in an identical manner inside the ISO 9705 room and according to the instruction as given in ISO 9705. Figure 1 shows a schematic of the ISO 9705 room.
The mounting was as follows. First the wall panels were mounted. On top of these wall panels the roof panel was mounted. Specific corner profiles and/or sealants were used depending on the practice used by the supplier of the product. The ends of the panels close to the door wall were sealed with ceramic or mineral wool to avoid ignition of exposed core material.

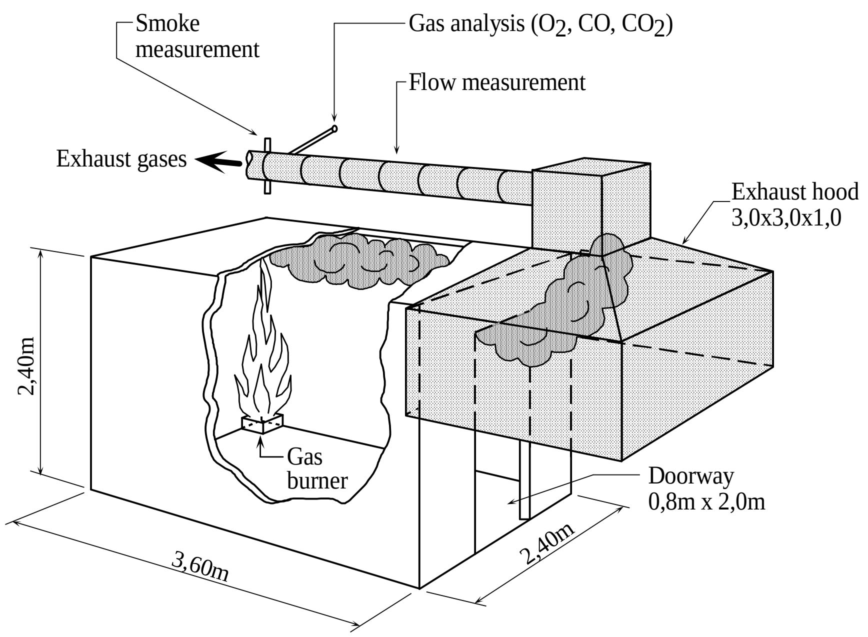

Figure 1. Schematic drawing of the room corner test set-up according to ISO 9705.

5.2 Free standing set-up

In the free standing set-up the product formed the walls and ceiling of the test rig. This means that the wall with the door opening was also constructed using the same product as the other walls. In certain cases supporting structures were necessary as this is accepted in practice. In Table 2 an overview is given which products were used with supporting structure. The actual way of mounting was decided by the supplier of the product.
The supporting steel frame was constructed of U profiles on the outside of the panel system in which the products could be fixed by self drilling and tapping screws or by means of bolts.
For each product corner profiles and sealants were used as instructed by the supplier of the product.

TABLE 2 OVERVIEW OF MOUNTING FREE STANDING SET-UP

Product	Use of supporting frame	Fixed to supporting frame	Type of supporting frame
A	Yes	Yes	Steel
B	Yes	No	Steel
C	No	No	Not applicable
D	Yes	Yes	Steel

In figure 2 an example of a mounting of such system is given. The picture is taken during a test and shows the free standing sandwich panel construction. The fire and smoke plume entering the large hood can also be observed. Figure 3 is given a schematic of the set-up.

Figure 2. Example of mounting of a panel system

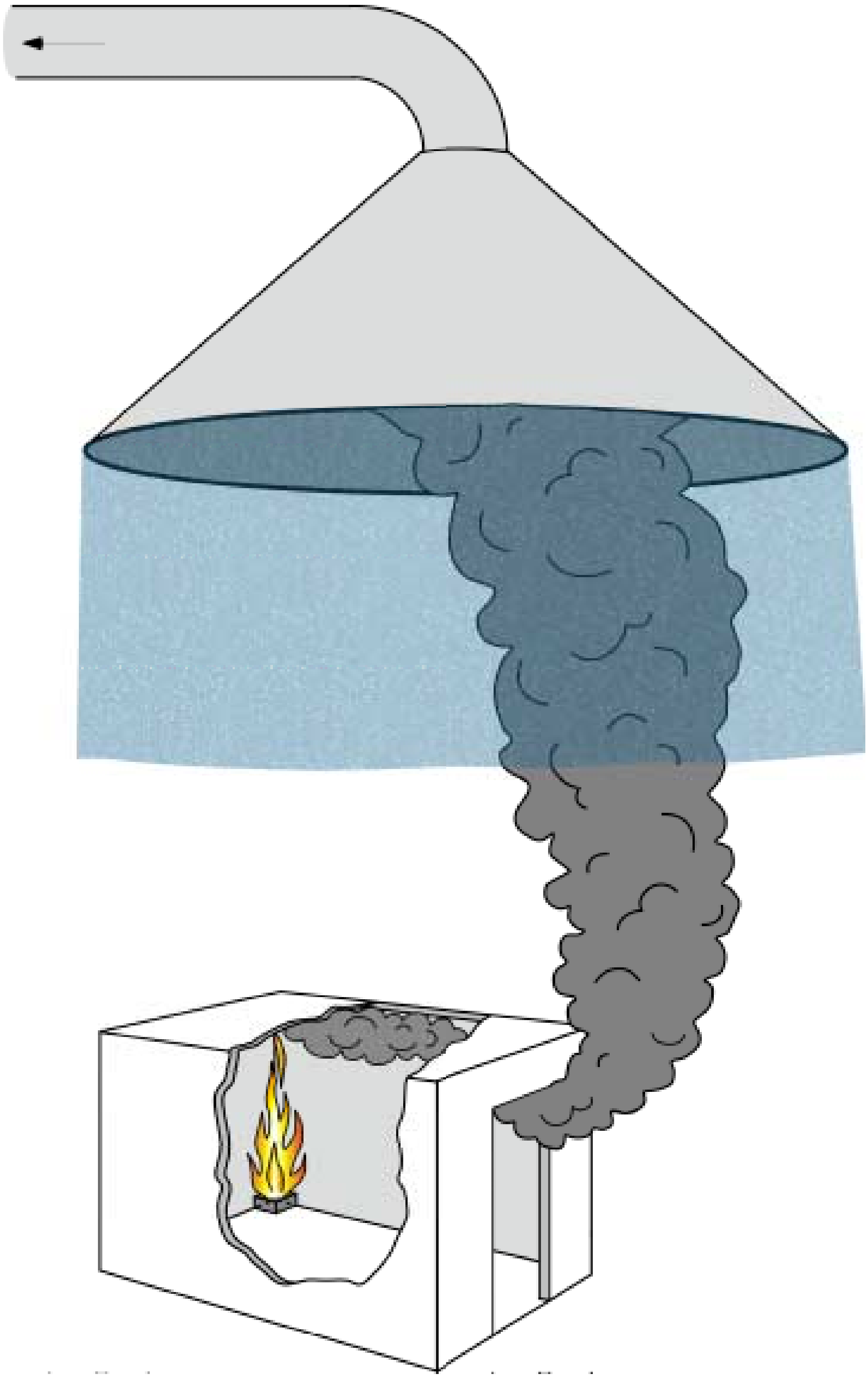

Figure 3. Schematic drawing of free-standing set-up

6 Test results

The following paragraphs give an overview of the test results using the different test procedures.

6.1 Test results according to ISO 9705

TABLE 3 TESTS RESULTS ACCORDING TO ISO 9705				
Parameter	Product A	Product B	Product C	Product D
Flashover time (time to 1000 kW) (min:s)	No FO	6:54	No FO	14:42
Max HRR 0-2 min (kW) excl. burner	10	59	17	16
Max HRR 0-10 min (kW) excl. burner	15	>900**	49	24
Max HRR 0-12 min (kW) excl. burner	74	>900**	206	80
Max HRR 0-20 min (kW) excl. burner	74	>900**	317	>700**
Max SPR 0-2 min (m^2/s)	0.18	2.3	0.3	0.15
Max SPR 0-10 min (m^2/s)	0.3	131**	3	1.5
Max SPR 0-12 min (m^2/s)	1.2	*	16.5	19
Max SPR 0-20 min (m^2/s)	2.3	*	27	72**
Average HRR 0-10 min excl. burner (kW)	7	317**	26	10
Average HRR 0-12 min excl. burner (kW)	10	*	37	14
Average HRR 0-20 min excl. burner (kW)	26	*	126	*
Average SPR 0-10 min (m^2/s)	0.2	10**	1.2	0.5
Average SPR 0-12 min (m^2/s)	0.2	*	2.5	1.7
Average SPR 0-20 min (m^2/s)	0.7	*	9.4	*
Euroclass according to ISO 9705 [2]	≥B	D	≥B	C

6.2 Test results according to the free standing set-up

TABLE 4 TESTS RESULTS ACCORDING TO FREE STANDING SET-UP				
Parameter	Product A***	Product B	Product C	Product D
Flashover time (time to 1000 kW) (min:s)	No FO	12:08	11:44	9:10
Max HRR 0-2 min (kW) excl. burner	34	232	49	81
Max HRR 0-10 min (kW) excl. burner	34	232	278	>900**
Max HRR 0-12 min (kW) excl. burner	132	587	>700**	>900**
Max HRR 0-20 min (kW) excl. burner	195	>700**	>700**	>900**
Max SPR 0-2 min (m^2/s)	0.17	10	1.2	1.0
Max SPR 0-10 min (m^2/s)	0.36	11	41	190
Max SPR 0-12 min (m^2/s)	4.8	38	122**	*
Max SPR 0-20 min (m^2/s)	4.8***	260*	*	*
Average HRR 0-10 min excl. burner (kW)	10	60	150	*
Average HRR 0-12 min excl. burner (kW)	20	87	182**	*
Average HRR 0-20 min excl. burner (kW)	55	*	*	*
Average SPR 0-10 min (m^2/s)	0.2	3.1	19	*
Average SPR 0-12 min (m^2/s)	0.5***	5.1	28**	*
Average SPR 0-20 min (m^2/s)	1.5	*	*	*
Euroclass according to ISO 9705 principle [2]	≥B	C	C	D

* Not appropriate due to flashover (FO.
** Note that flashover (FO) occurred during this period. Values calculated until flashover.
*** Smoke values corrected for soot deposit after 12 minutes.

6.3 Test results according to SBI test method

In order to get a first impression of the link between the two test methods and the SBI method (EN 13823 [8], see figure 4) a number of SBI tests were performed. The results are given in table 5 and in annex C. According to the manufacturer, material A would be A1 or A2 if the additional tests of ISO 1182 and ISO 1716 were performed. All materials were mounted in the SBI using the end-use mounting but with no joint at 200 mm. Materials A, C and D were later tested in a mounting set-up with a joint at 200 mm. The results show a slightly higher burning behaviour for materials C and D but not change in classification.

TABLE 5 TEST RESULTS ACCORDING TO THE SBI METHOD

Product	FIGRA	THR 600s	SMOGRA	TSP 600s	Droplets	Expected Euroclass*
A**	0	0.4	4	46	No	Bs1d0
B	92	1.8	38	87	No	Bs2d0
C	60	5.5	30	377	No	Bs3d0
D	36	2.9	16	164	No	Bs2d0

*Not taking into account the results of the small flame test (EN ISO 11925-2).
** average of three test results. For one test the TSP600s was 51 m^2.

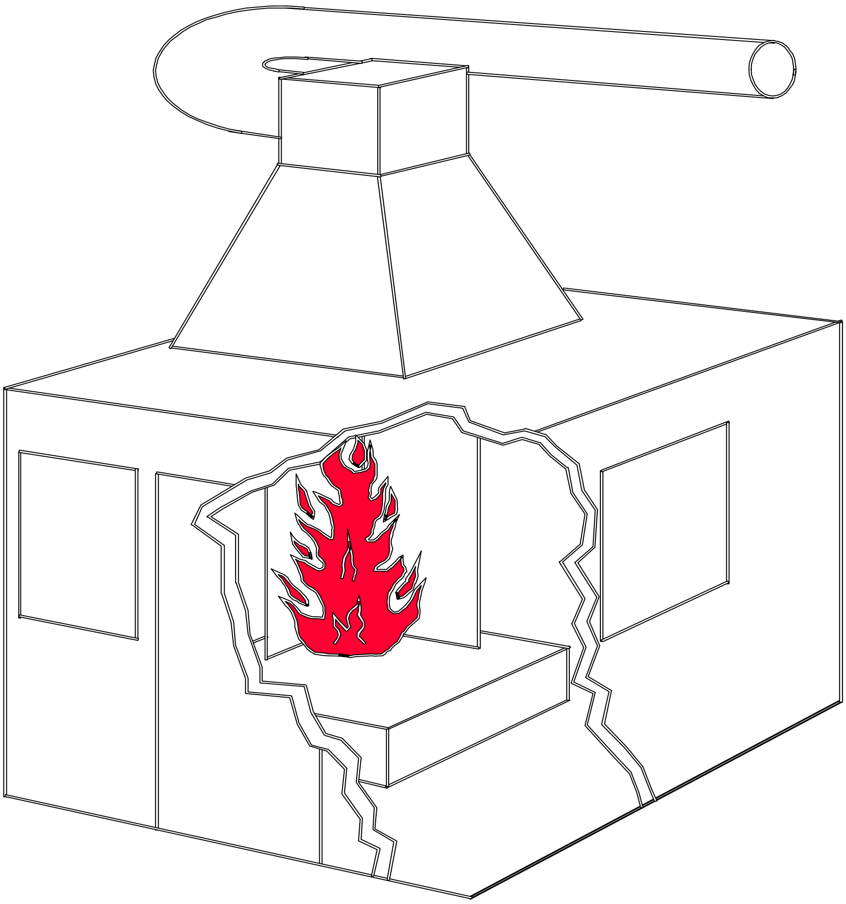

Figure 4. Schematic drawing of the SBI method.

6.4 Comparative Test results

Table 6 gives a summary of the test results for all full scale test methods in order to be able to quickly compare the test results. Table 7 gives a comparison of the Euroclasses obtained by means of the different test methods involved in this project. Results according to the classification parameters used in the Eurefic project [1] can be found in Annex E. This is important as some Nordic countries use this system for classification.

TABLE 6 TEST RESULTS ACCORDING TO THE FULL SCALE TEST METHODS				
Flashover time (time to 1000 kW) (min:s)				
Parameter	Product A	Product B	Product C	Product D
ISO 9705	No FO	6:54	No FO	14:42
Freestanding	No FO	12:08	11:44	9:10
Max HRR (kW) 0-20 min				
Parameter	Product A	Product B	Product C	Product D
ISO 9705	74	>900**	317	>700**
Freestanding	195	>700**	>700**	>900**

** Note that flashover occurred during this period. Values only calculated until flashover.

TABLE 7 EUROCLASS ACCORDING TO THE DIFFERENT TEST METHODS				
	Product A	Product B	Product C	Product D
ISO 9705	≥B	D	≥B	C
Freestanding	≥B	C	C	D
SBI	Bs1d0	Bs2d0	Bs3d0	Bs2d0

7 Discussion

1. The free standing set up allows an identical mounting as in practice both with and without supporting structure. For this project a large calorimeter allowed for HRR and SPR measurements. If such a calorimeter is not present extended hoods can be used which was applied successfully at SP within another project [3]. Such extended hoods are also described in ISO 13784 part 1.
2. The free-standing test procedure can be pointed out as being more severe than the ISO 9705 test procedure despite one product. This product differed a great deal in mounting between the two test set-ups (improvement of the joints in the free-standing test set-up). One should take into account that no exactly similar mounting is possible in both set-ups. It is clear that for most products an earlier flashover is observed in the free-standing set-up.
3. In both test procedures varied fire behaviour was observed from early flashovers to no flashover at all.
4. Finishing of the joints between different sandwich panels and mounting of the panels are important factors influencing the fire behaviour of the panels. For this reason, the free-standing set-up is more suitable as it allows an identical mounting and finishing of the joint as in practice.
5. It is also observed that mounting a free-standing set-up was easier than in the ISO 9705 room. Similarly, dismounting was much easier than in the ISO 9705.
6. A first comparison with the SBI test results shows that there is little correlation with the test results of both full-scale test procedures. This can be explained by the limited capabilities of the SBI method to mimic the influence of the mechanical behaviour of panels and joints. All products show limited burning in the SBI test as the joints remain rather closed and little deformation occurs. All products are classified in a higher class than in the ISO 9705 test. In one case the result is the same while in another case the SBI test results is two classes better compared to the reference scenario. Hence it is questionable if sandwich panels should be classified solely based on the SBI and the small flame test. It would no doubt also be wrong to change the mounting conditions in the SBI method so that they are no longer reflecting end use conditions. Examples of such changes would be leaving the top ends open or not using joint profiles. Such solutions would be unfair to systems which obtain good fire performance by means of advanced joint and mounting systems.

8 Conclusions

Simulating end-use conditions in a realistic way is very important when evaluating the burning behaviour of sandwich panels. Based on the results of a series of test conducted both in free-standing test rooms, the ISO 9705 room/corner test configuration and according to the SBI test protocol a number of conclusion can be drawn:

- Mounting technique and especially joint behaviour are important factors for the fire behaviour. Any test used for evaluation of the fire risk of sandwich panels should be able to cover the so-called end-use conditions.
- A first comparison with the SBI test shows poor correlation with both full-scale set-ups. The products behave in most cases much better in the intermediate scale SBI test. Use of the SBI method for sandwich panels is therefore questionable.
- The free-standing test set-up allows for correct mounting in end-use conditions of panels and allows easier mounting and dismounting.
- The free-standing test set-up used for the project allows for measurement of heat release rate (HRR) and smoke production rate (SPR). This means that the procedure for HRR and SPR measurements as mentioned in ISO 13784 part 1 can be used.
- The free-standing test set-up is more severe than the ISO 9705 room tests.

9 References

1. Proceedings of the Eurefic Seminar, 11-12 September 1991, Interscience Communications, London 1991.
2. prEN 13501-1, Fire Classification of construction products and building elements - Part 1 Classification using test data from reaction to fire tests, September 2000.
3. Fire Performance of Electrical Cables - FIPEC, final report contract SMT4-CT96-2059, December 1999.
4. ISO 9705:1993(E), Fire Tests - Full-scale room test for surface products, ISO 1993.
5. ISO DIS 13784 Part 1Fire tests Reaction to Fire Part 1: Small-scale room test for sandwich panel products for industrial buildings, June 2000.
6. NT FIRE 025 Edition 2 Surface Products - Room fire tests in full-scale, Nordtest 1991.
7. Serious fires in food industry premises during 1995, Fire prevention 302, September 1997
8. prEN13823 Reaction to fire tests for building products - Building products excluding floorings - exposed to the thermal attack by a single burning item, CEN, September 2000

Annex A HRR and SPR Graphs for ISO 9705 tests

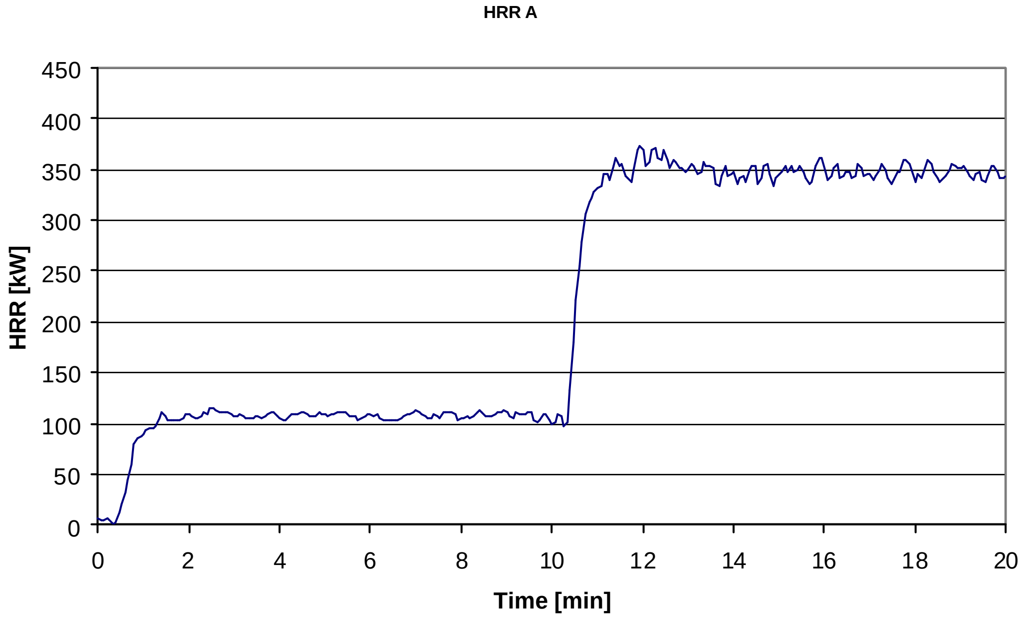

Figure A.1 Heat release rate for product A in ISO 9705

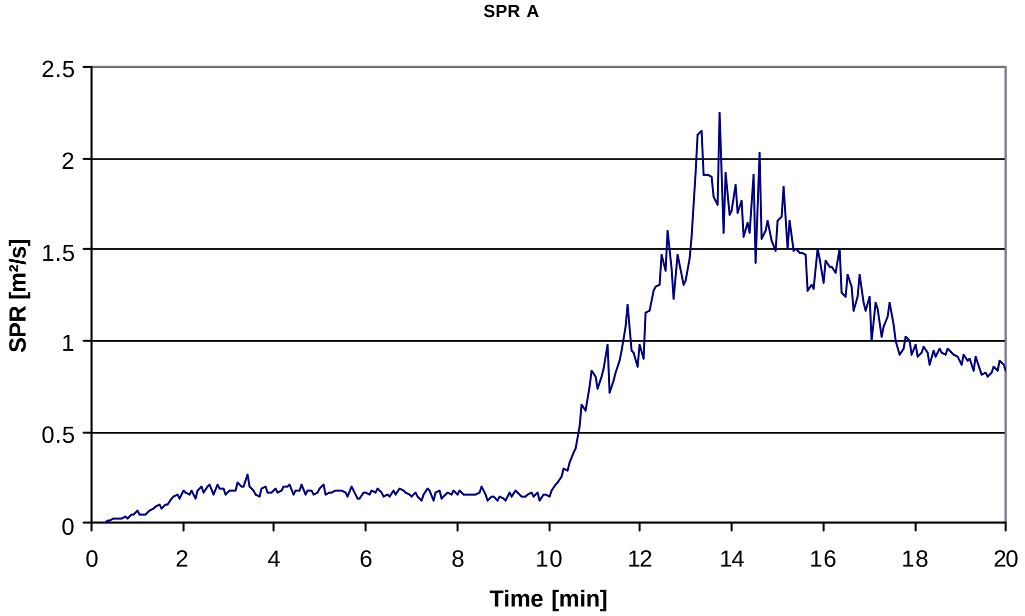

Figure A.2 Smoke production rate of product A in ISO 9705

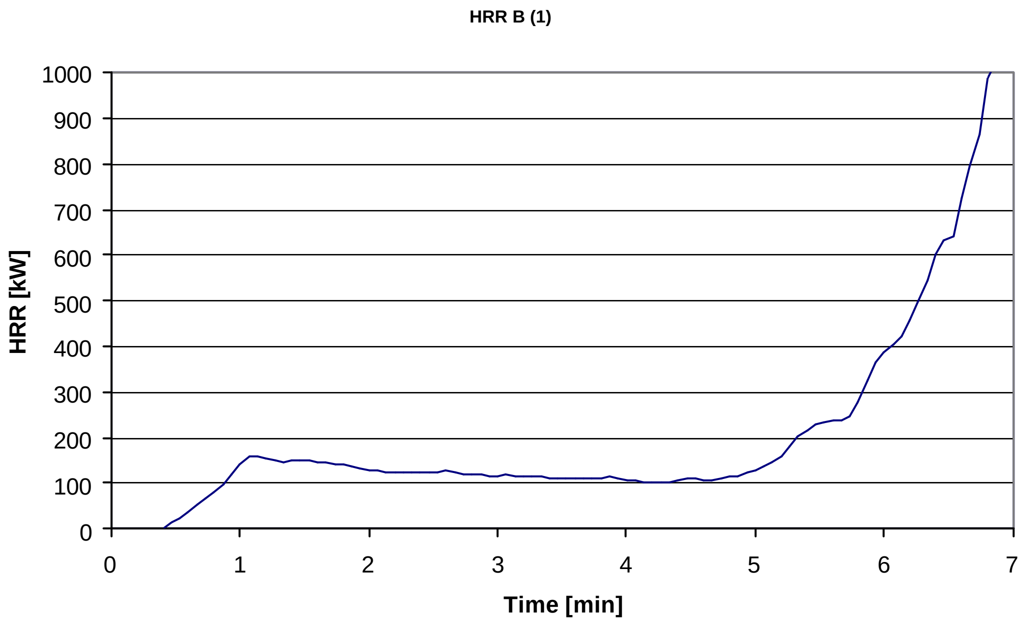

Figure A.3 Detail of heat release rate of product B in ISO 9705

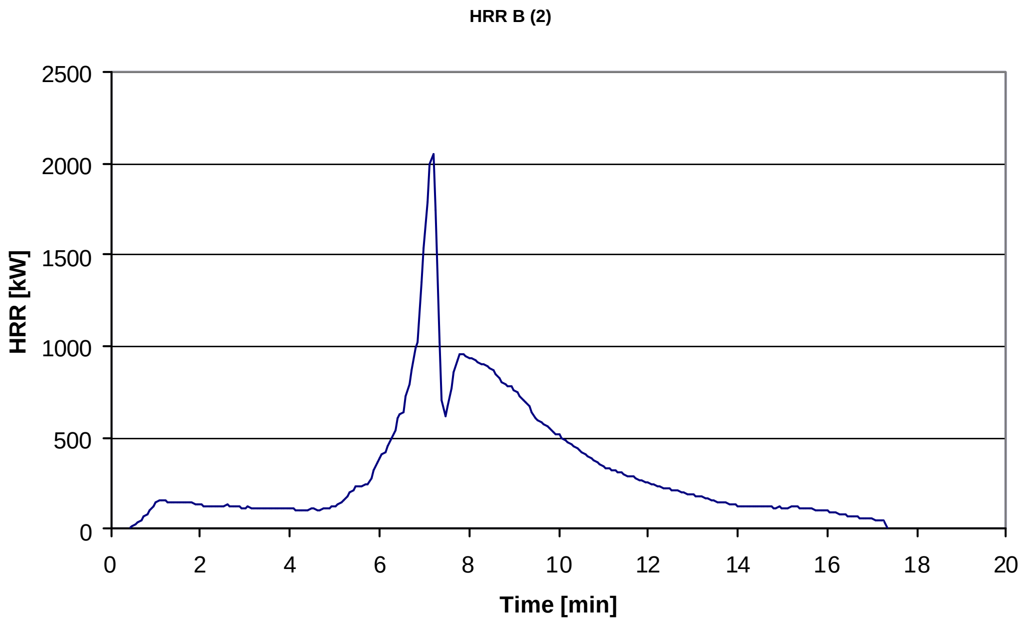

Figure A.4 Heat release rate of product B in ISO 9705

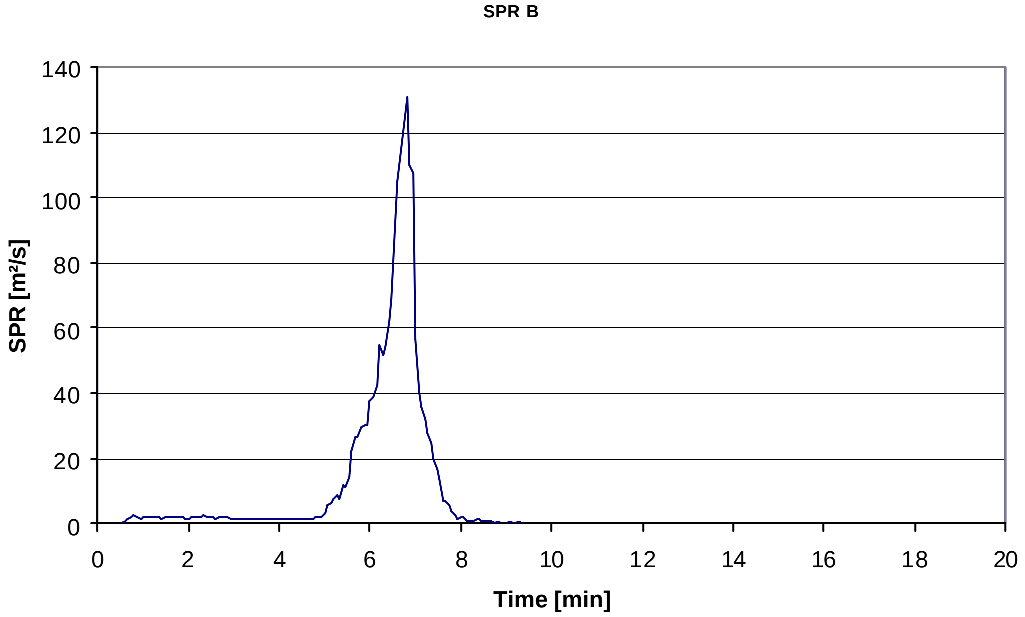

Figure A.5 Smoke production rate of product B in ISO 9705

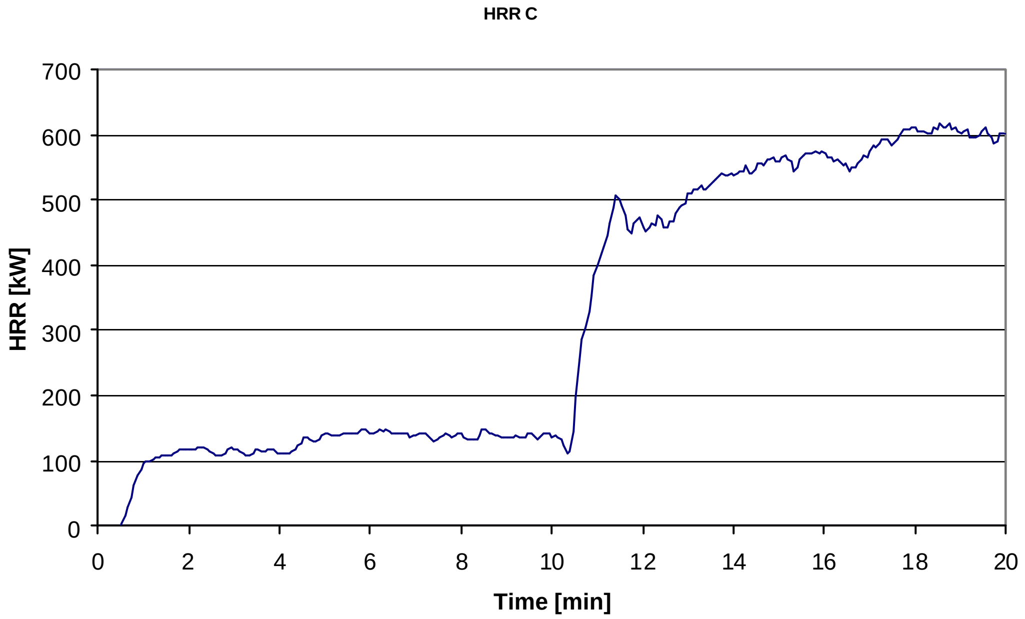

Figure A.6 Heat release rate of product C in ISO 9705

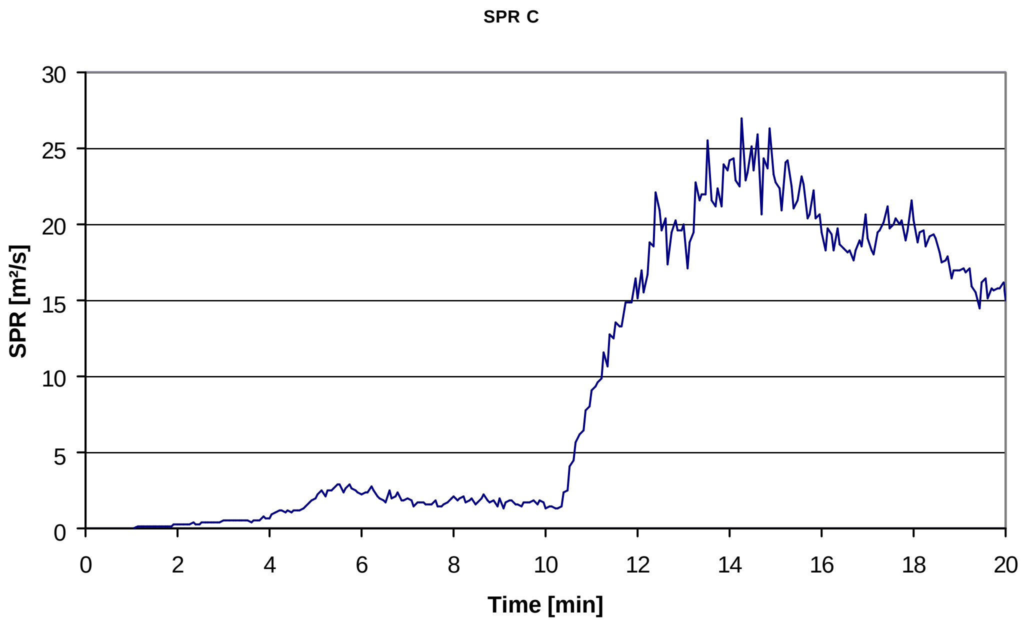

Figure A.7 Smoke production rate of product C in ISO 9705

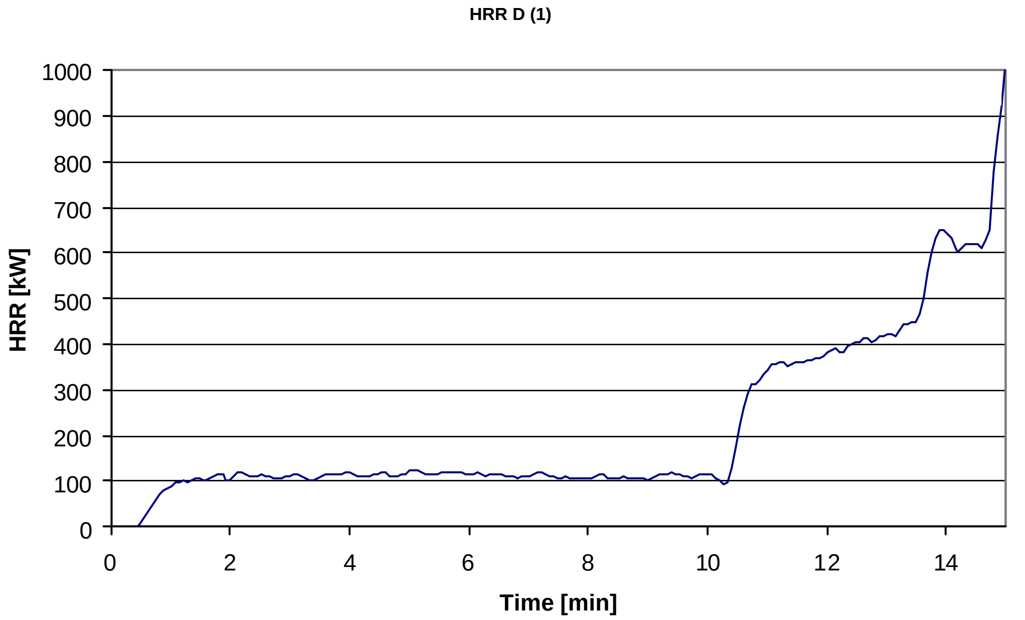

Figure A.8 Detail of heat release rate of product D in ISO 9705

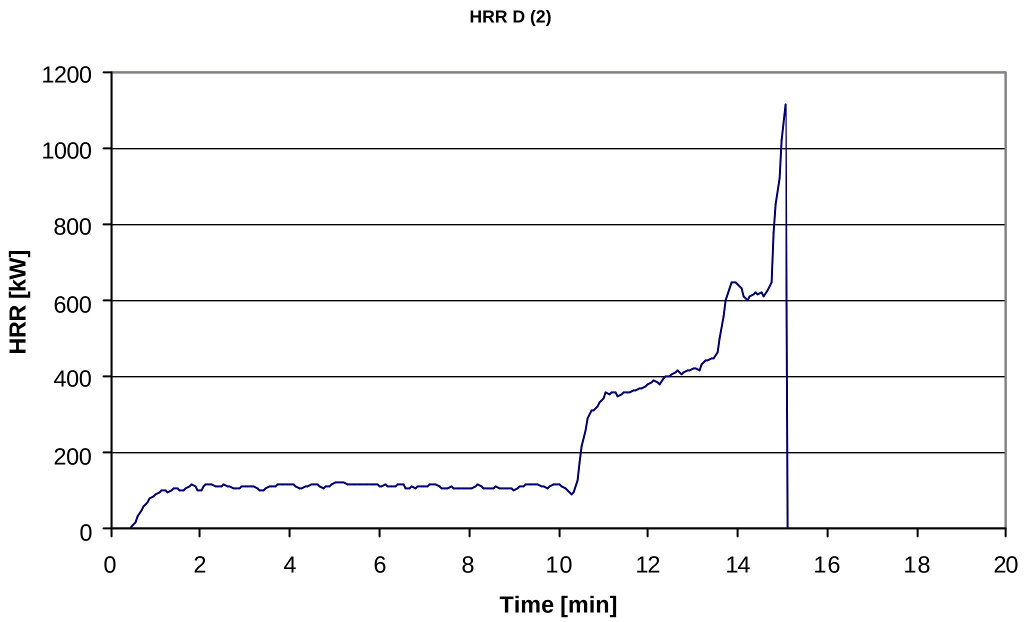

Figure A.9 Heat release rate of product D in ISO 9705

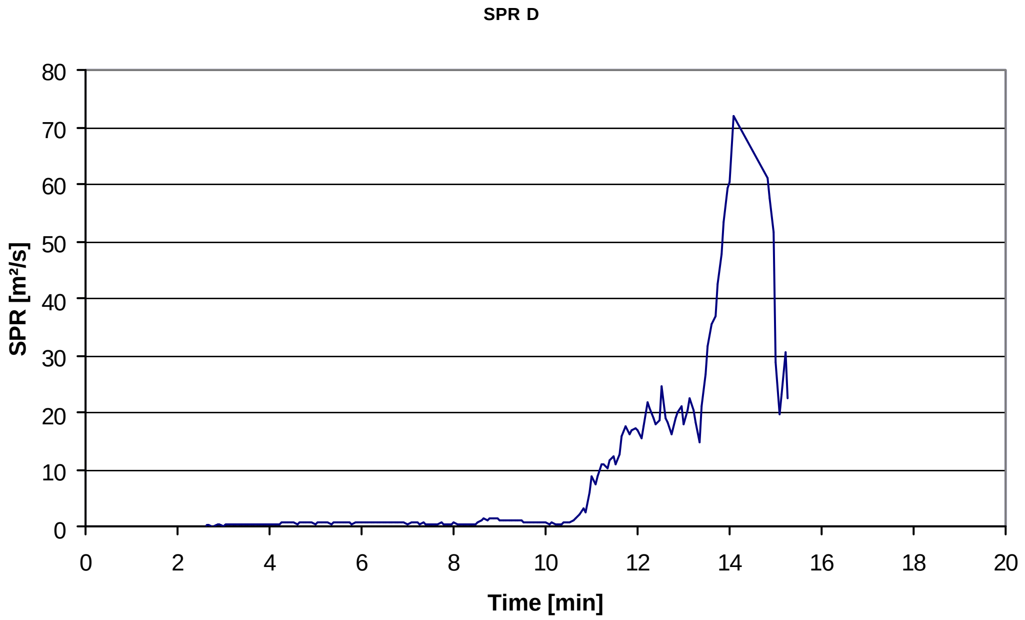

Figure A.10 Smoke production rate of product D in ISO 9705

Annex B HRR and SPR Graphs for free standing tests

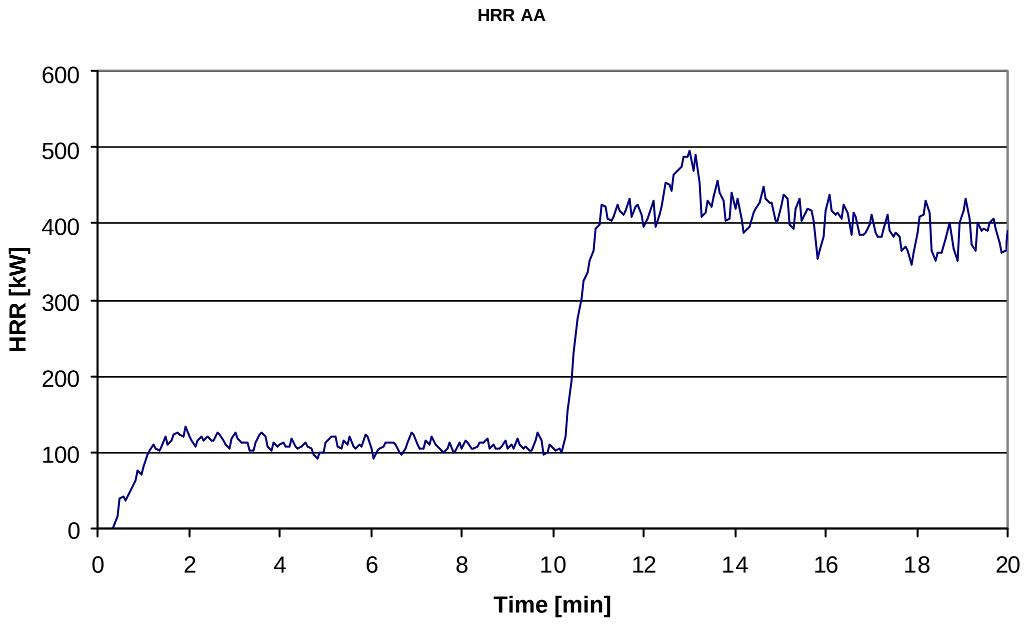

Figure B.1 Heat release of product A in free standing set-up

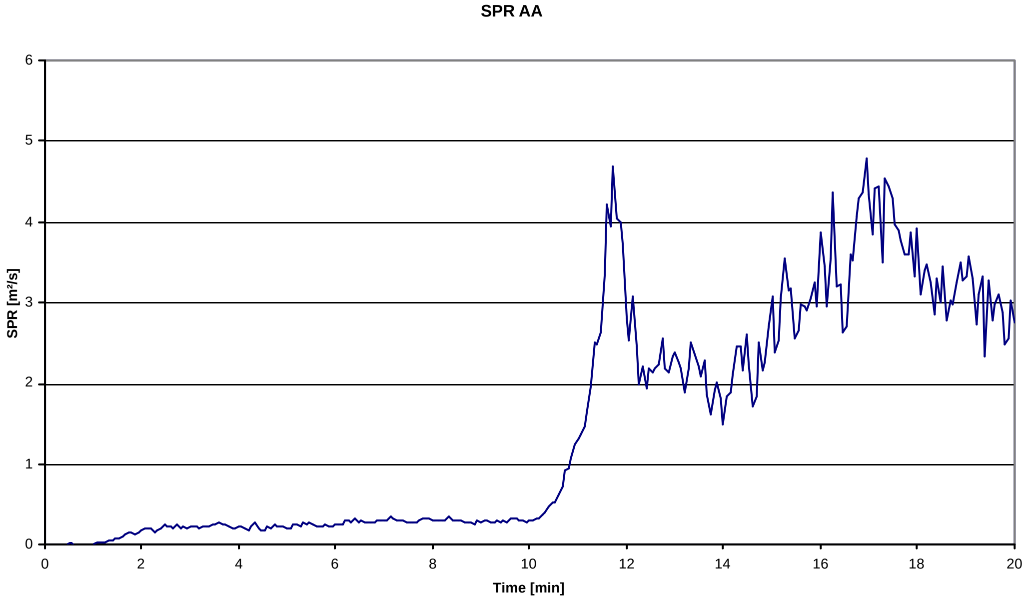

Figure B.2 Smoke production rate of product A in free standing set-up (corrected for soot deposit after 12 minutes)

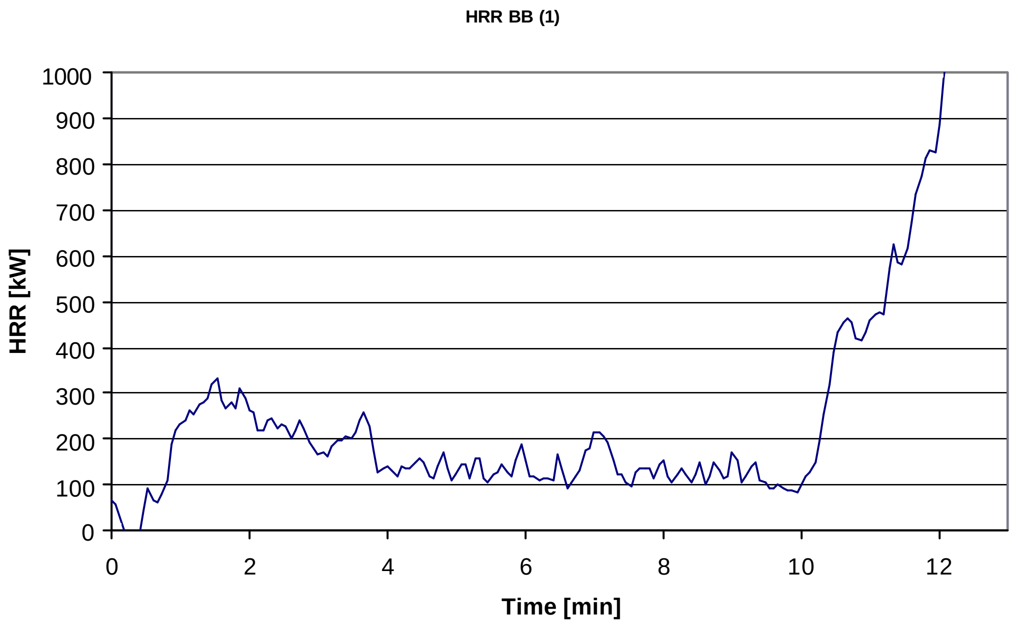

Figure B.3 Detail of heat release rate of product B in free standing set-up

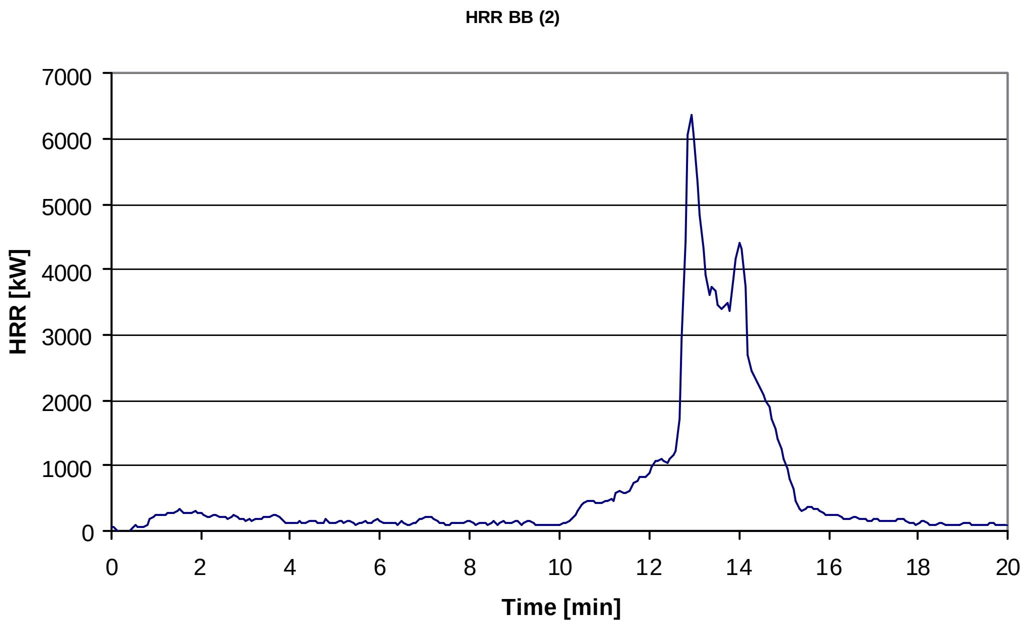

Figure B.4 Heat release rate of product B in free standing set-up

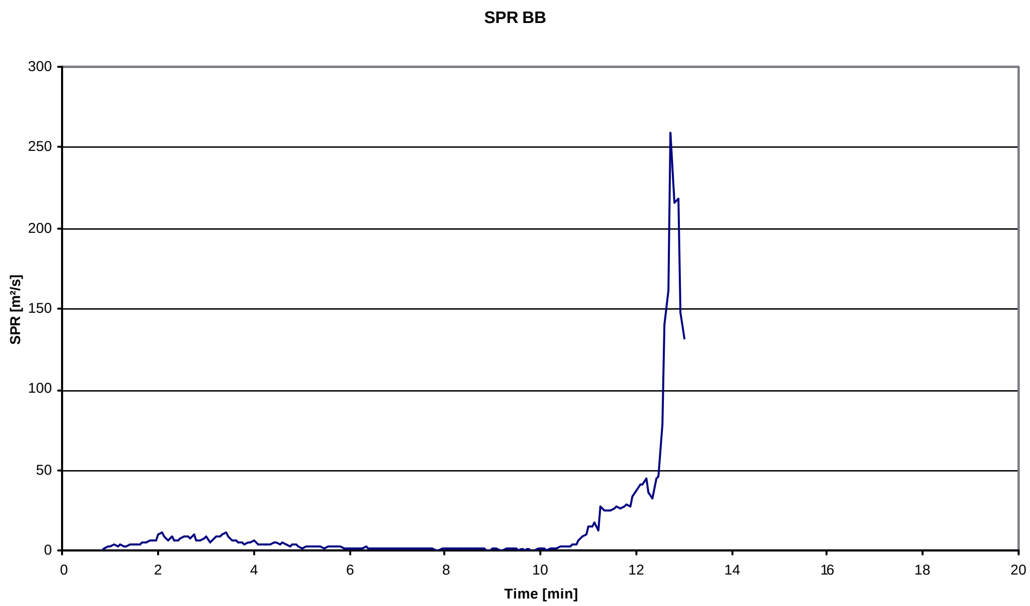

Figure B.5 Smoke production rate of product B in free standing set-up (values up to flashover)

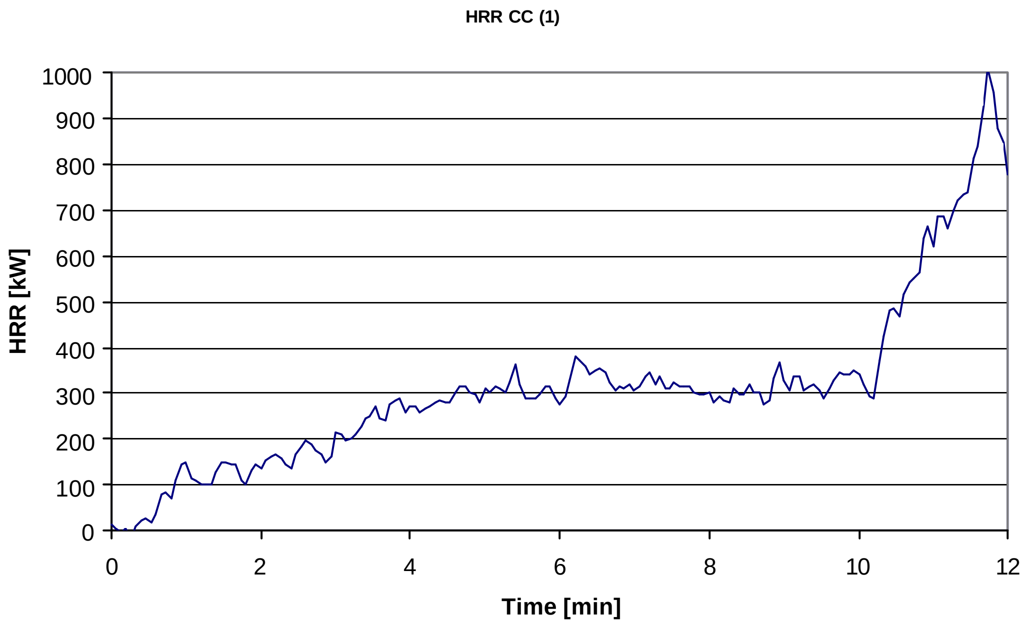

Figure B.6 Detail of heat release rate of product C in free standing set-up

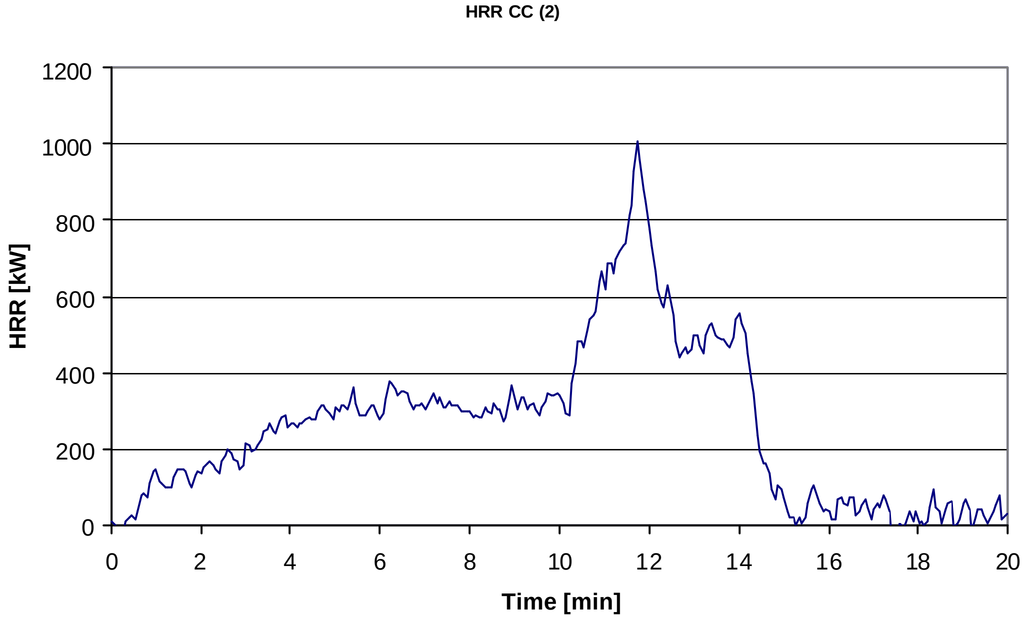

Figure B.7 Heat release rate of product C in free standing set-up

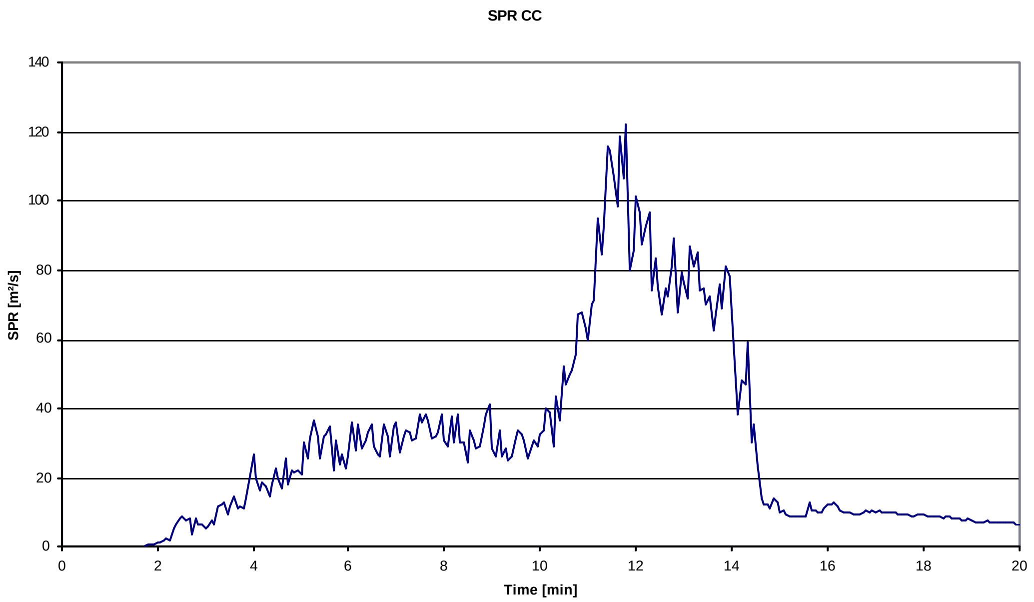

Figure B.8 Smoke production rate of product C in free standing set-up

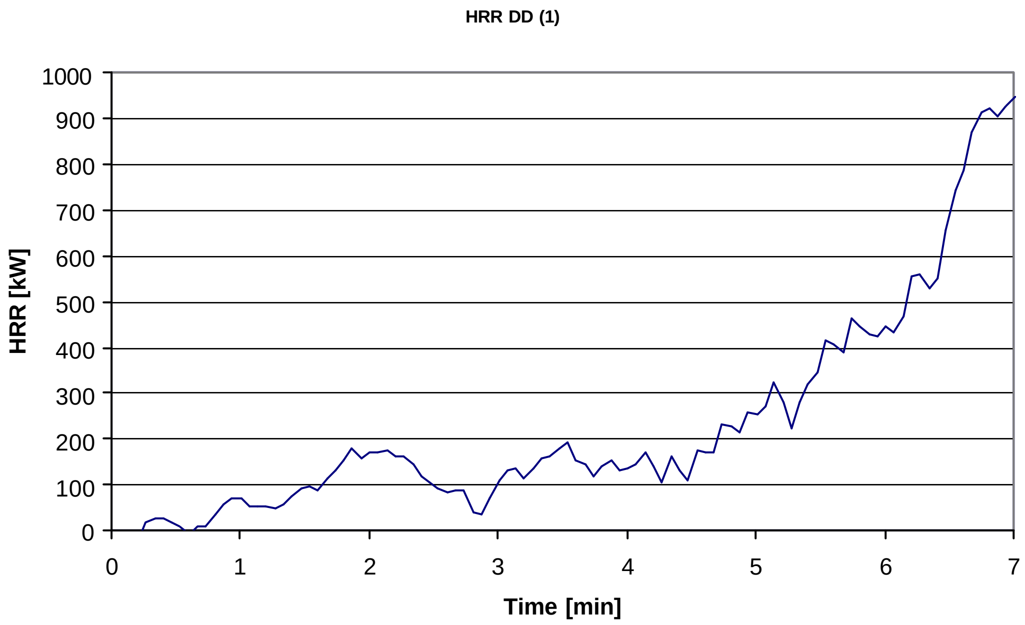

Figure B.9 Detail of heat release rate of product D in free standing set-up

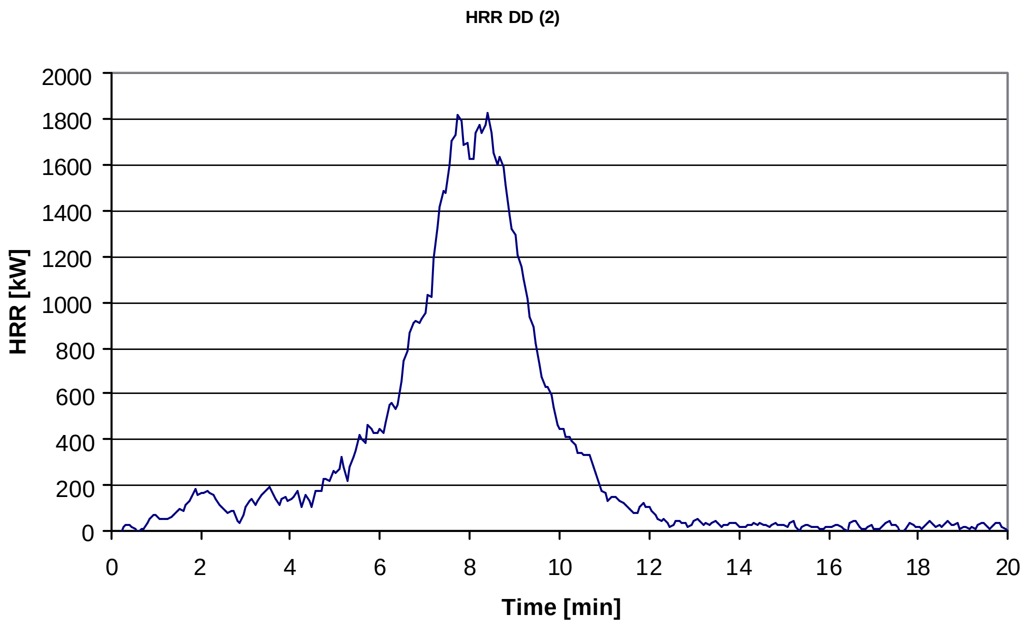

Figure B.10 Heat release rate of product D in free standing set-up

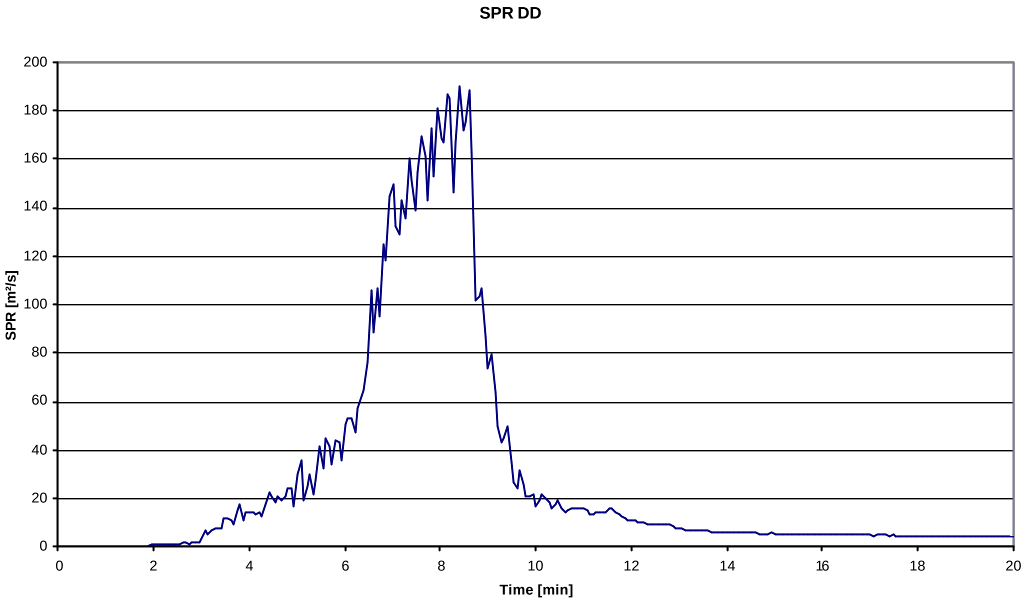

Figure B.11 Smoke production rate of product D in free standing set-up

Annex C Graphs of HRR and SPR for SBI test

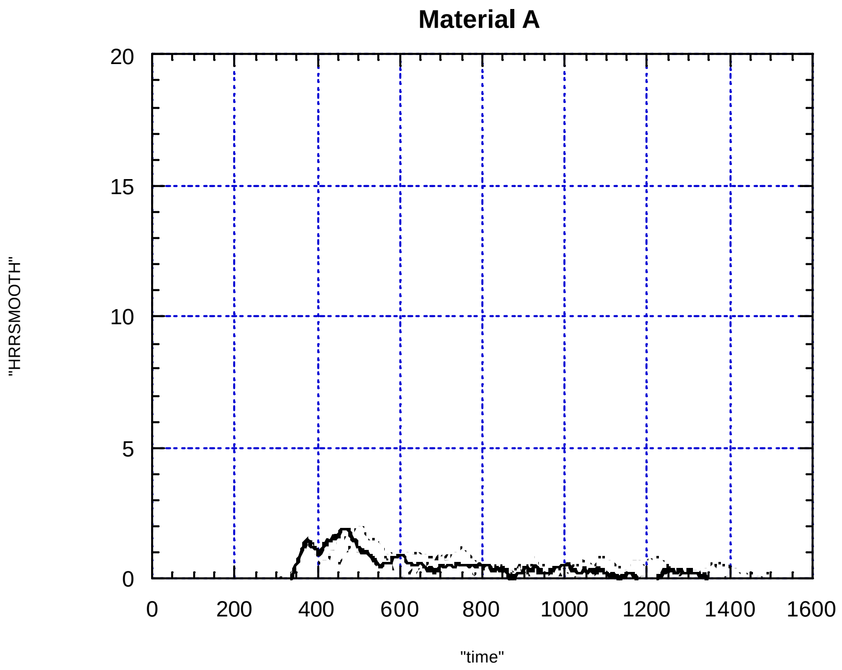

Figure C.1 Smoothed heat release rate of product A in the SBI test

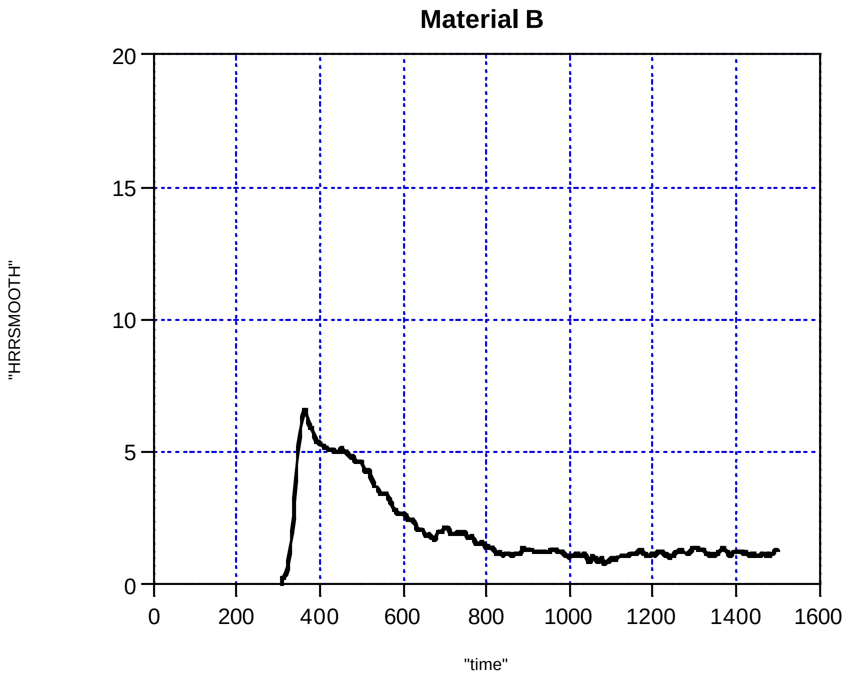

Figure C.2 Smoothed heat release rate of product B in the SBI test

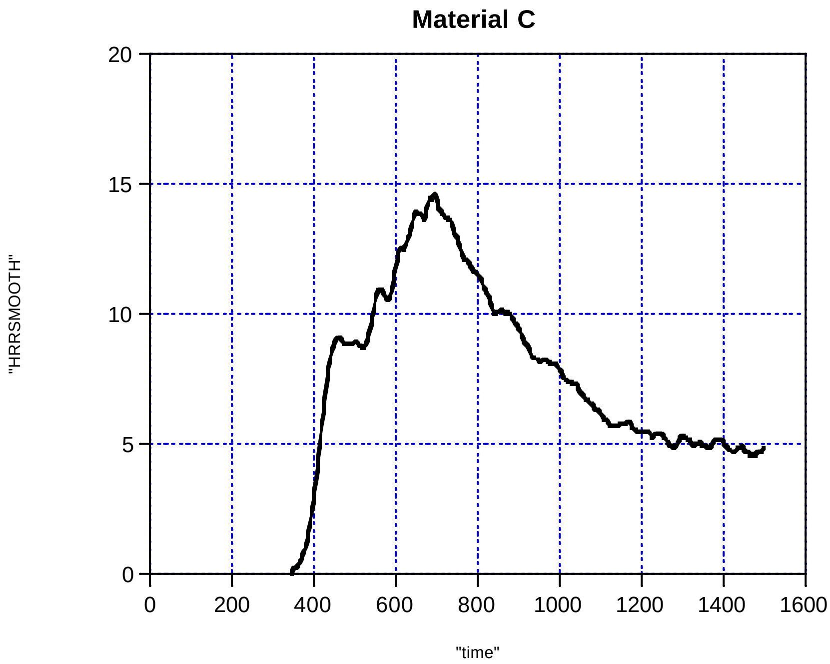

Figure C.3 Smoothed heat release rate of product C in the SBI test

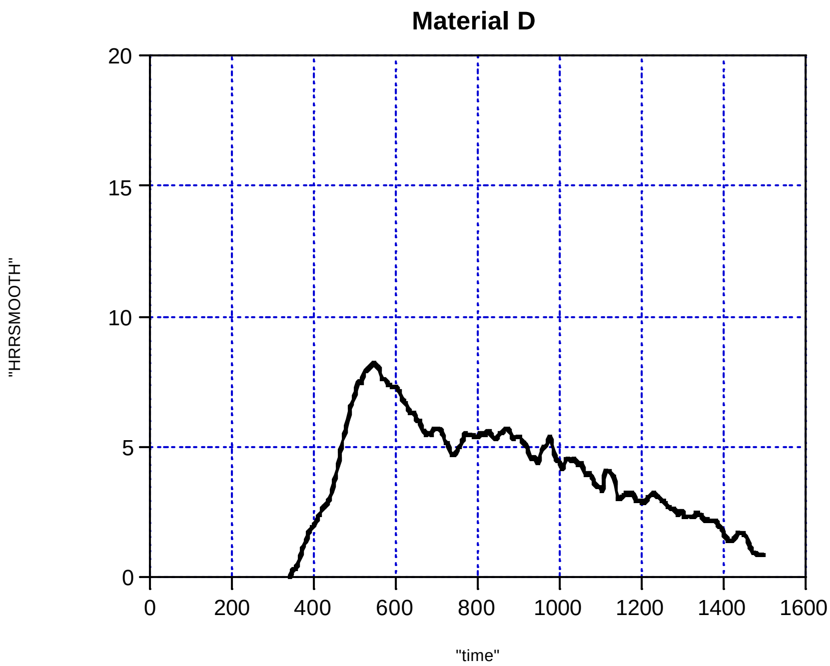

Figure C.4 Smoothed heat release rate of product D in the SBI test

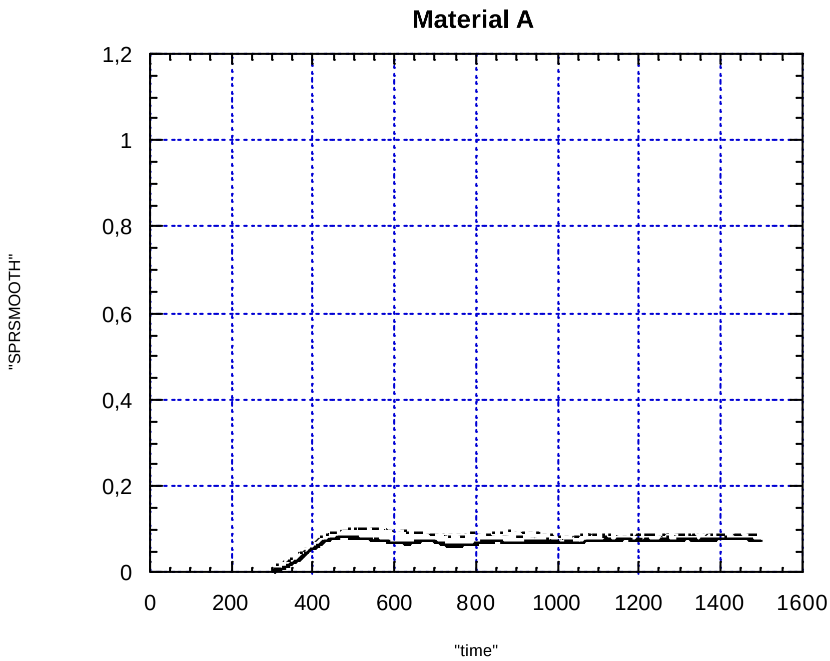

Figure C.5 Smoothed smoke release rate of product A in the SBI test

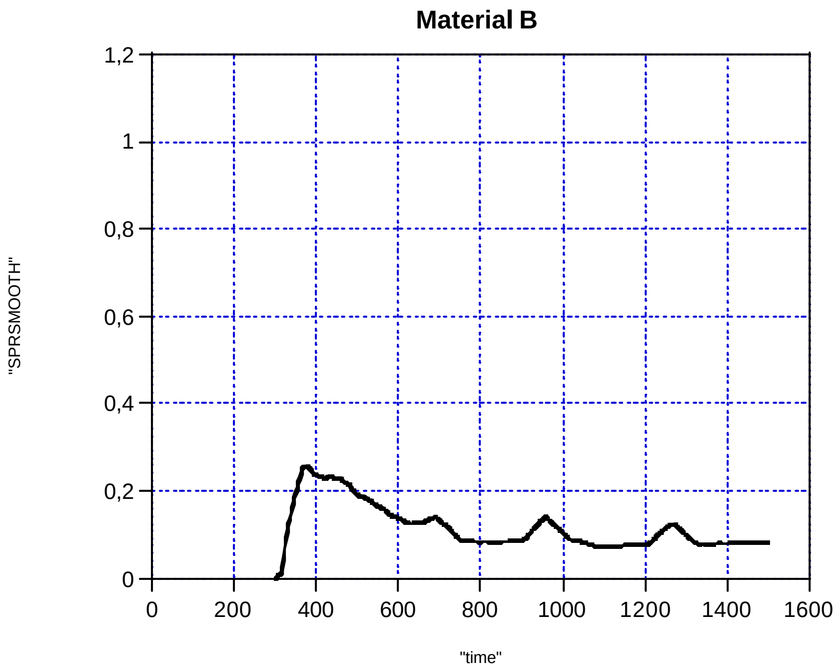

Figure C.6 Smoothed smoke release rate of product B in the SBI test

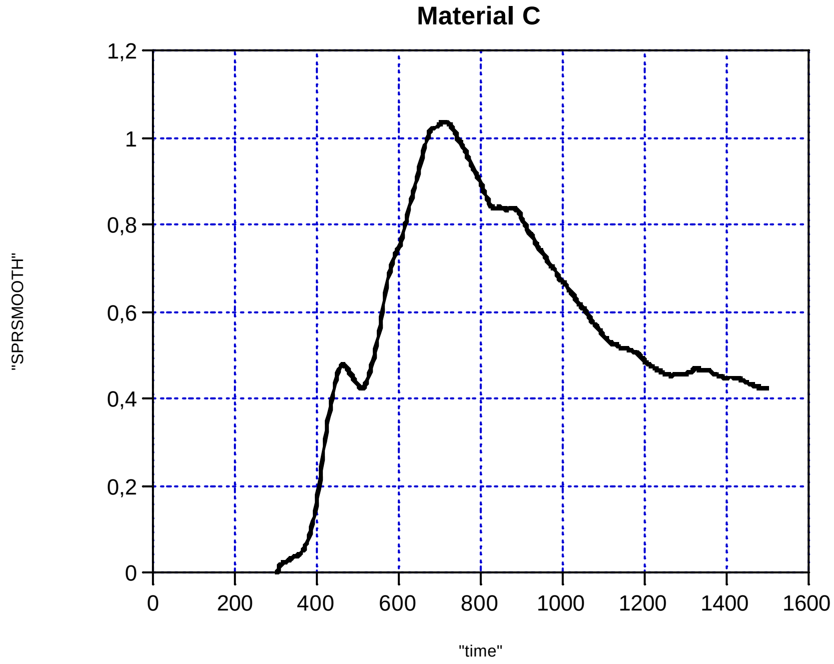

Figure C.7 Smoothed smoke release rate of product C in the SBI test

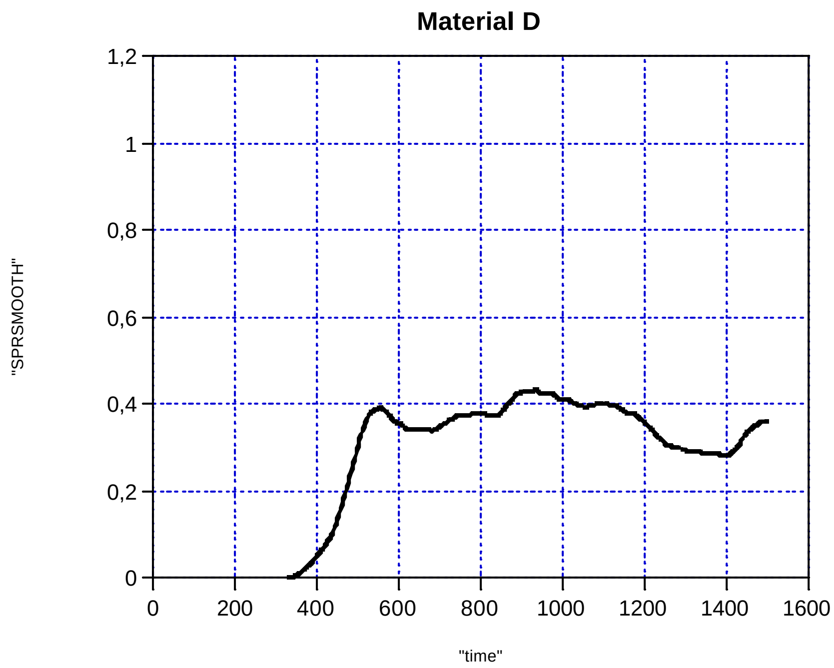

Figure C.8 Smoothed smoke release rate of product D in the SBI test

Annex D Observations during the tests

D. 1 Product A

Test results - ISO 9705

Observations during test

Time, min:s	Observations during test
00:00	The burner was ignited. Burner heat output 100 kW.
00:30	The metal sheets expanded.
00:50	The paint in the burner corner ignited.
02:00	White smoke came out through the gaps under the wall sections.
10:00	The burner heat output was increased to 300 kW.
10:40	Flame spread was seen in the gaps in the ceiling along the long walls.
12:00 - 15:00	The smoke production increased slowly. White smoke in the whole room. The ceiling was visible.
15:00	The white smoke production increased.
20:00	Burner shut off.
20:00 - 23:00	Small flames were seen in the gaps in the ceiling.

Observations after fire test

The paint on the surface of the panels was gone or discoloured.

Test results - Free standing

Observations during test

Time, min:s	Observations during test
00:00	The burner was ignited. Burner heat output 100 kW.
00:30 - 10:00	White smoke came out through the gaps in the burner corner outside the room.
00:45	The paint in the burner corner ignited and the metal sheets expanded.
10:00	The burner heat output was increased to 300 kW.
10:30	The smoke production increased. The colour of the smoke was black.
10:30 - 11:55	The paint in the ceiling was burning.
11:55	Flames emerged from the room.
15:50	Flames emerged from the room through a gap on the left long wall.
20:00	Burner shut off.
20:00 - 27:00	Small flames were seen in the gaps in the ceiling.

Observations after fire test

The painting on the surface of the panels was gone or discoloured. The gaps on the left wall were opened too much before the test.

D.2 Product B

Test results - ISO 9705

Observations during test

Time, min:s	Observations during test
00:00	The burner was ignited. Burner heat output 100 kW.
00:20	The paint in the burner corner ignited and the smoke production increased. The metal sheets expanded.
00:40	A black smoke gas layer was formed under the ceiling. The ceiling was not visible.
01:15	The smoke production decreased and the ceiling was visible.
02:30	Small flames were seen in the gaps in the ceiling in the ceiling above the burner.
03:30	The aluminium profile in the burner corner fell down.
04:00	The fire increased.
05:00	The fire and the smoke production increased.
05:20	Burning particles started to fall down.
05:45	A lot of burning particles fell down in the whole room.
06:15	Flames emerged from the room for the first time.
06:54	Flames emerged from the room (HRR=1000 kW), flashover. Heavy smoke production.
	Burner shutoff. Extinguishment of the fire.

Observations after fire test

The internal insulation of the panel was melted after the test. The painting on the surface of the panels was completely burned.

Test results - Free standing

Observations during test

Time, min:s	Observations during test
00:00	The burner was ignited. Burner heat output 100 kW.
00:20	The paint ignited.
00:30 - 10:00	Grey smoke came out through the gaps in the burner corner outside the room.
00:45	A black smoke gas layer was formed under the ceiling. The ceiling was not visible.
00:50	Burning particles fell down in the vicinity of the burner.
03:10	The fire and the smoke production increased and small flames emerged out of the room.
04:20	The fire and the smoke production decreased.
06:00	The fire decreased.
10:00	The burner heat output was increased to 300 kW.
10:45	Flame spread was seen in the ceiling. The smoke production increased.
11:00	Burning particles fell down.

11:23	Flames emerged from the room for the first time.
12:08	Flames emerged from the room (HRR=1000 kW), flashover. Heavy smoke production.
	Burner shut off. Extinguishment of the fire.

Observations after fire test

The internal insulation of the panel was melted after the test. The painting on the surface of the panels was completely burned. The inside metal construction was totally collapsed.

D.3 Product C

Test results - ISO 9705

Observations during test

Time, min:s	Observations during test
00:00	The burner was ignited. Burner heat output 100 kW.
00:35	The paint ignited and the metal sheets expanded.
01:00	White smoke came out through the gaps under the wall sections.
02:00	The smoke production increased slightly.
03:58	The smoke in the vicinity of the burner ignited and the smoke production increased.
10:00	The burner heat output was increased to 300 kW.
10:30	The smoke production increased.
10:45	The smoke production was black and yellow and the ceiling was not visible. A lot of smoke in the whole room.
11:00	There were flaming from the gaps between the wall sections.
15:00	The flame spread in the roof reached the front wall and the smoke production increased.
16:00	Small flames emerged from the room.
20:00	Burner shut-off.
20:00 - 22:40	Small flames were seen under the walls.
22:40	Extinguishment of the fire.

Observations after fire test

The internal insulation of the panel was carbonised after the test. The painting on the surface of the panels was completely burned.

Test results - Free standing

Observations during test

Time, min:s	Observations during test
00:00	The burner was ignited. Burner heat output 100 kW.
00:40	The metal sheets expanded.
00:50	The paint ignited.
01:00	White smoke came out through the gaps under the wall sections.
02:00	The smoke production increased. A black smoke gas layer was formed under the ceiling. The ceiling was not visible.
04:30	The smoke production and the fire increased.
08:00	Flames emerged from the room for the first time.
09:15	There were flaming from the vertical gaps in the wall.
10:00	The burner heat output was not increased to 300 kW because the fire was close to flashover.
10:32	The corner profile between the ceiling and the rear wall fell down.

11:44 Flames emerged from the room (HRR=1000 kW), flashover. Heavy smoke production.

Burner shut-off. Extinguishment of the fire.

Observations after fire test

The internal insulation of the panel was carbonised after the test. The painting on the surface of the panels was completely burned.

D. 4 Product D.

Test results - ISO 9705

Observations during test

Time, min:s	Observations during test
00:00	The burner was ignited. Burner heat output 100 kW.
00:30	The paint ignited.
00:40	The metal sheets expanded.
01:35	White smoke came out through the gaps in the walls.
03:40	Flames were seen in the gaps in the ceiling above the burner.
08:25	The second gap from the rear wall between the ceiling sections opened up.
10:00	The burner heat output was increased to 300 kW.
10:40	There were flaming from the gaps between the wall sections, the fire increased.
11:40	The fire and the smoke production increased.
12:55	Flames emerged from the room for the first time.
14:42	Flames emerged from the room (HRR=1000 kW), flashover. Heavy smoke production.
	Shut-off of the burner. Extinguishment of the fire.

Observations after fire test

The internal insulation of the panel was carbonised after the test. The painting on the surface of the panels was completely burned.

Test results - Free standing

Observations during test

Time, min:s	Observations during test
00:00	The burner was ignited. Burner heat output 100 kW.
00:20	The paint in the burner corner ignited.
00:40	The metal sheets expanded.
01:30	Yellow smoke came out through the gap under the wall sections outside the right wall of the room.
01:35	A grey smoke gas layer was formed under the ceiling. The ceiling was visible.
02:45	The fire in the ceiling corner above the burner increased. The smoke production increased and changed colour to black.
03:10	The smoke production increased and the ceiling was no longer visible.
03:45	Smoke came out through the vertical gaps in the walls.
05:13	Flames emerged from the room for the first time.
05:20	Some burning particles fell from the ceiling.
05:35	There were flaming from the vertical gaps between the wall sections. The fire and the smoke production increased.

07:04	Flames emerged from the room (HRR=1000 kW), flashover. Heavy smoke production.
	Burner shut-off. Extinguishment of the fire.

Observations after fire test

The internal insulation of the panel was carbonised after the test. The painting on the surface of the panels was completely burned.

Annex E Test results according to Eurefic project

1.1 Test results according to ISO 9705

TABLE 3 TESTS RESULTS ACCORDING TO ISO 9705				
Parameter	Product A	Product B	Product C	Product D
Flashover time (time to 1000 kW) (min:s)	No FO	6:54	No FO	14:42
Max HRR 0-2 min (kW) excl. burner	10	59	17	16
Max HRR 0-10 min (kW) excl. burner	15	>900**	49	24
Max HRR 0-12 min (kW) excl. burner	74	*	206	80
Max HRR 0-20 min (kW) excl. burner	74	*	317	>700**
Max RSP 0-2 min (m^2/s)	0.8	10	1.2	0.7
Max RSP 0-10 min (m^2/s)	1.2	568**	13	6.5
Max RSP 0-12 min (m^2/s)	5.2	*	72	76
Max RSP 0-20 min (m^2/s)	9.8	*	117	312**
Average HRR 0-10 min excl. burner (kW)	7	317**	26	10
Average HRR 0-12 min excl. burner (kW)	10	*	37	14
Average HRR 0-20 min excl. burner (kW)	26	*	126	*
Average RSP 0-10 min (m^2/s)	0.6	45**	5.4	2.3
Average RSP 0-12 min (m^2/s)	1.0	*	11	7.4
Average RSP 0-20 min (m^2/s)	2.9	*	41	*
Eurefic class with smoke [1]	A	E	E	D
Eurefic class without smoke [1]	A	E	C	C

* Not appropriate due to flashover

** Note that flashover occurred during this period. Values only calculated until extinguishment

1.2 Test results according to the free standing set-up

TABLE 4 TESTS RESULTS ACCORDING TO FREE STANDING SET-UP				
Parameter	Product A***	Product B	Product C	Product D
Flashover time (time to 1000 kW) (min:s)	No FO	12:08	11:44	7:04
Max HRR 0-2 min (kW) excl. burner	34	232	49	81
Max HRR 0-10 min (kW) excl. burner	34	232	278	>900**
Max HRR 0-12 min (kW) excl. burner	132	587	>700**	>700**
Max HRR 0-20 min (kW) excl. burner	195	>700**	>700**	>700**
Max RSP 0-2 min (m^2/s)	0.75	43	5.2	4.3
Max RSP 0-10 min (m^2/s)	1.5	48	178	828**
Max RSP 0-12 min (m^2/s)	20	163	532**	*
Max RSP 0-20 min (m^2/s)	21***	1130*	*	*
Average HRR 0-10 min excl. burner (kW)	10	60	150	*
Average HRR 0-12 min excl. burner (kW)	20	87	182**	*
Average HRR 0-20 min excl. burner (kW)	55	*	*	*
Average RSP 0-10 min (m^2/s)	1.0	14	84	*
Average RSP 0-12 min (m^2/s)	2.1	22	123**	*
Average RSP 0-20 min (m^2/s)	6.4***	*	*	*
Eurefic class with smoke [1]	C	E	E	E
Eurefic class without smoke [1]	B	C	E	E

* Not appropriate due to flashover

** Note that flashover occurred during this period. Values only calculated until flashover

*** Smoke values corrected for soot deposit after 12 minutes.

SP Swedish National Testing and Research Institute
Box 857, SE-501 15 BORÅS, Sweden
Telephone: +46 33 16 50 00, Telefax: +46 33 13 55 02
E-mail: info@sp.se, Internet: www.sp.se

SP REPORT 2000:26
ISBN 91-7848-827-0
ISSN 0284-5172