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RAPPORT

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National Standard Fire Tests in Small Scale Compared with the Full-Scale ISO Room Test

TräteknikCentrum
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C O N T E N T S

SAMMANFATTNING

Tretton olika byggnadsmaterial för vägg- och takbeklädnad har brandprovats enligt de nationella standardmetoderna i fem europeiska länder: Storbritannien, Frankrike, Västtyskland, Holland och Sverige. Samtliga metoder avser provning i liten skala. Resultaten jämförs med tidigare provning i full skala, där väggar och tak i ett provrum beklätts med samma material. Efter antändning med en standardiserad tändkälla, typ brinnande papperskorg, mäts tiden till övertändning.

Avsikten har varit att underlätta införandet av de nya internationella brandprovningsmetoder som f n utvecklas bl a inom ISO, det internationella standardiseringsorganet. Härigenom kan tekniska handelshinder undanröjas. I det svenska arbete inom området, som bedrivs vid Lunds tekniska högskola, Statens provningsanstalt och TräteknikCentrum, har en uppsättning av tretton olika material använts. Häri ingår trämaterial och gipsskivor med olika ytskikt samt några syntetiska polymerer. Exakt samma material har nu provats även enligt nuvarande nationella provmetoder.

Resultaten visar generellt att nuvarande småskalemetoder efterliknar ett långsammare brandförlopp än fullskalemetoden och att tiden till övertändning i flera fall inte kan förutsägas. De visar också att vissa material som expanderad polystyren och laminat på spånskiva är svåra att prova i liten skala och ger missvisande resultat jämfört med fullskaleprovning. Om endast den stegvisa rangordningen enligt liten och full skala bedöms blir överensstämmelsen bättre, men även här ger vissa material stora avvikelser.

Nya provmetoder behövs således. Det finns redan förslag, men några direkta jämförelser kan inte göras eftersom det saknas system för kravspecificering. Utveckling av sådana system bör få högsta prioritet i fortsatt arbete.

SUMMARY

A set of 13 building materials has been tested according to seven different European national standard small-scale fire tests. The results are compared with results from a full-scale corner test which is assumed to simulate at least one "real" fire scenario. The aim has been to provide a link between present and new fire tests for a given set of materials which has been used in several studies for the development of new international fire tests.

The national standard tests are from Britain, France, Germany, the Netherlands and Sweden.

Several of the small-scale tests are able to distinguish between those materials giving less than three minutes to flash-over in the full-scale test, i.e. eight of the thirteen materials tested, but the relative ranking is not exactly the same, especially not for the materials with very short times to flash-over. All these materials show a wider range of fire behavior in the small-scale tests than in the full-scale test. Expanded polystyrene and to some extent also melamine-faced particle board exhibit a peculiar behavior in many small-scale tests and achieve a better classification than would be expected from full-scale testing.

Few of the small-scale tests can predict the longer times to flash-over for gypsum board with different wall-coverings, but in most cases gypsum board without any covering gets the best classification.

The general relation between small-scale and large-scale tests indicates that most of the small-scale tests simulate a fire scenario with a less rapid fire development than the full-scale test.

Simple stepwise ranking orders according to small-scale and full-scale tests provide a reasonable agreement for many materials, but also large deviations for certain others.

New small-scale test methods are thus needed and in development, e.g. rate of heat release. However, no means of how to use the results from those new tests for classification of materials are still available. Such a work should have high priority.

The financial support from the Swedish Board for Fire Research (Brandforsk) is kindly acknowledged. We are also grateful to all the participating laboratories.

INTRODUCTION

It has been known for quite a long time that different national fire test methods for building materials correlate badly with each other (Emmons, 1974). Östman (1981) has reported a comparison between some European fire tests and the ISO ignitability test and found a poor agreement between the different fire tests. Vandevelde (1981) has also reported a comparison but found a surprisingly high correlation between certain methods, but this correlation is strongly destroyed by classification limits. Some general criticism has been given as well (Clark, 1981). A poor correlation between the national methods is, in fact, not surprising since they often test different parameters.

Most of these national methods have not been verified by full-scale tests. One exception is the Swedish hot-box test which reproduces a fire spread out of the doorway from one room to another (Bergström och Larsson, 1958).

In this report, a set of 13 building materials has been tested in seven different national fire tests. The results are compared with the results from a full-scale corner test which is assumed to simulate at least one "real" fire scenario (Wickström et al, 1983; Sundström, 1986).

Exactly the same materials have been used in several studies of new international fire test methods, especially within Scandinavia.

EXPERIMENTAL

Small-scale fire tests

The following small-scale fire tests have been included in this study:

The British fire propagation test (BS 476:Part 6) is a box method. An index is calculated from the gas temperatures at different periods of time and materials can be classified only as class 0, i.e. a class better than that from the surface spread of flame method mentioned below. The fire propagation method is therefore used only for materials which exhibit a rather slow fire propagation.

The British surface spread of flame test (BS 476:Part 7) separates materials into four classes: class 1, 2, 3 and 4 according to the extent of the spread of flame along the surface of the specimen after 1.5 and 10 min.

The French radiation method ("épiradiateur") (French standard) is the only method used here which tests both sides of the board simultaneously. Four indices are calculated: for the ignition, the combustion development, the length of flame and the gas temperature. According to a number of maximum values for these indices, materials are divided into six classes, M0 to M5.

The German chimney test (DIN 4102) identifies class B1 after the length of undestroyed sample and the gas temperature measured in a chimney. Materials which do not fulfil the requirements are tested in a separate mild test for class B2. Both methods have been used here.

The Dutch contribution to flash-over test (NEN 3883) is a box method. The required energy supply for flash-over after 5 and 15 minutes is measured.

Materials are separated into four classes, class 1, 2, 3 and 4. For a definite classification, the materials have to be tested also according to a surface spread of flame test (5 classes) similar to the British standard. Classification is made on the basis of the least favourable classification of the two methods. Only the contribution to flash-over has been used here.

The Swedish box method (SS 02 48 23) separates tested materials into three classes, I, II and III, by classification curves for the exhaust gas temperature versus time. The optical smoke density is included in the classification, but it is not critical for many materials. Materials which do not fulfil the requirements for class III are considered outside the classification.

The test results are, however, not expressed on a continuous scale, which is necessary for a comparison with other test methods. The area under the time-temperature curve has been used in some cases (Wharton 1984, Östman 1981) but it mainly reflects the thermal properties, especially for fast burning materials (Holmstedt 1984), and does not give an acceptable measure of the heat release rate (Vandevelde 1980). Another drawback with using the area under the curve is the difficulty to relate it to the classification limits in a proper way. Therefore, another parameter, the relative peak height, has been used in this study. The relative peak height is the ratio between the temperature peak and the limiting curve III at the peak. The class limits are expressed as the ratios between the limiting curves at different points all over the time scale. Average ratios for each class are used in order to get constant limits, since the limiting curves are not parallel. The parameter "relative peak height" is similar to the "area under the curve" and preferable just because it is more easy to relate to the class limits. It is not suggested as a new type of test evaluation.

The ISO ignitability test (ISO DIS 5657) is a new draft international standard test and has been included for comparison. It determines the time to ignition at a number of constant radiation intensities from 10 to 50 kW/m^2. Classification limits have not yet been suggested.

The British, French, German and Dutch tests have been conducted on contract by Warrington Research Center, Mr Deakin, U.K.; Centre Scientifique et Technique du Bâtiment, M. Touchais, France; Institut für Holzforschung, Dr Topf, West Germany; and Institute TNO for building materials and structures, Mr Zorgman, Holland. The Swedish box test and the ISO ignitability tests were performed at the National Testing Institute in Sweden (Holmstedt and Wetterlund, 1984; Magnusson and Andersson, 1987).

Full-scale test

The full-scale room fire test for surface products has been developed within the ISO/TC92/SC1 (1986). It has been standardized by Nordtest (1986) and is similar to the ASTM version. The dimensions of the room are 3.6 m x x 2.4 m x 2.4 m (l x w x h). To allow ventilation into the room there is a doorway (0.8 m x 2.0 m). Walls and ceiling are covered with the surface lining materials being tested. An ignition source of 100 kW is placed in one of the corners. If flash-over does not occur within 10 minutes the ignition source is raised to 300 kW. The rate of heat release, the smoke density and gas components are also measured. In this comparison, only the time to flash-over has been used for characterizing the fire behaviour of the tested materials.

The full-scale tests were performed at the Swedish National Testing Institute (Sundström, 1986).

Test materials

A list and description of the materials tested are given in Table 1. All the test samples originate from the same lot which initially was selected for studies on reaction to fire within Scandinavian fire laboratories. All material was in moisture equilibrium with the climate specified in each test.

Table 1. Test materials.

Material	Thickness mm	Density kg/m^3
Rigid polyurethane foam	30	32
Textile wall-covering on rock-wool	42 + 0.5	150
Insulating fiber board	13	250
Expanded polystyrene	49	18
Medium density fiber board	12	655
Wood panel (spruce)	11	450
Paper wall-covering on particle board	10 + 0.5	670
Particle board	10	670
Melamine-faced particle board	13	870
Plastic wall-covering on gypsum board	13 + 0.7	725
Textile wall-covering on gypsum board	13 + 0.5	725
Paper wall-covering on gypsum board	13 + 0.5	725
Gypsum board	13	725

FIRE CLASSIFICATION

Fire classification of the 13 tested materials according to each national method is listed in Table 2. The ISO ignitability test is not represented since no classification rules yet exist.

Table 2. Classification according to full-scale room test and small-scale national standard fire tests.

	Full-scale time to flash-over min:s	Britain		France	Germany	Holland	Sweden
		Fire prop	Flame spread			Flash-over	
Rigid polyurethane foam	0:14	Unclass	4	M4	B3	4	Unclass
Textile wall-covering on rock-wool	0:55	Unclass	4	M3	B2	4	Unclass
Insulating fiber board	1:07	Unclass	4	M4	B2	4	Unclass
Expanded polystyrene	2:12	Unclass	4	- 2)	B1	1	I
Medium density fiber board	2:14	Unclass	3	M4	B2	4	III
Wood panel (spruce)	2:18	Unclass	4	M4	B2	3	III
Paper wall-covering on particle board	2:22	Unclass	3	M4	B2	3	III
Particle board	2:30	Unclass	3	M4	B2	3	III
Melamine-faced particle board	7:45	0	1	M3	B2	2	II
Plastic wall-covering on gypsum board	10:15 1)	Unclass	3	M3	B1	2	III
Textile wall-covering on gypsum board	10:37 1)	Unclass	4	M3	B2	2	III
Paper wall-covering on gypsum board	No	0	2	M2	B2	2	III
Gypsum board	No	0	2	M1	B1	1	I

1) Flash-over was reached after increase of burner heat output at 10:00 min.

2) Not classified since supplemenary tests were required.

Relation to full-scale test

The results from the different small-scale tests have been related to the full-scale corner test to get a better interpretation.

In full-scale, flash-over occurred before three minutes for eight materials, all wood based or synthetic polymers, except a textile wall-covering on rock-wool. Melamine-faced particle board reached flash-over after about eight minutes. Gypsum board, uncovered or with different wall-coverings, did either not reach flash-over at all or just after the increase of the ignition source to 300 kW after 10 minutes (Sundström, 1986).

A graphical comparison between the small-scale tests and the full-scale corner test is given in Figures 1-6. In all the diagrams, materials with slow fire development will appear in the upper right corner and materials with rapid fire development in the lower left corner. Below some comments are given.

The British fire propagation test in Figure 1 seems to distinguish between materials with rapid fire development, but not so well between materials with slower development. Peculiar and unexpected behavior is observed for expanded polystyrene which is close to class 0 and for melamine-faced particle board which gets the best classification of all materials tested.

The British spread of flame test, also in Figure 1, gives after 1.5 minutes a similar relation to full-scale as the fire propagation test (except for polystyrene, which melts). The final spread of flame gives less separation between the materials. Only melamine-faced particle board is in class 1.

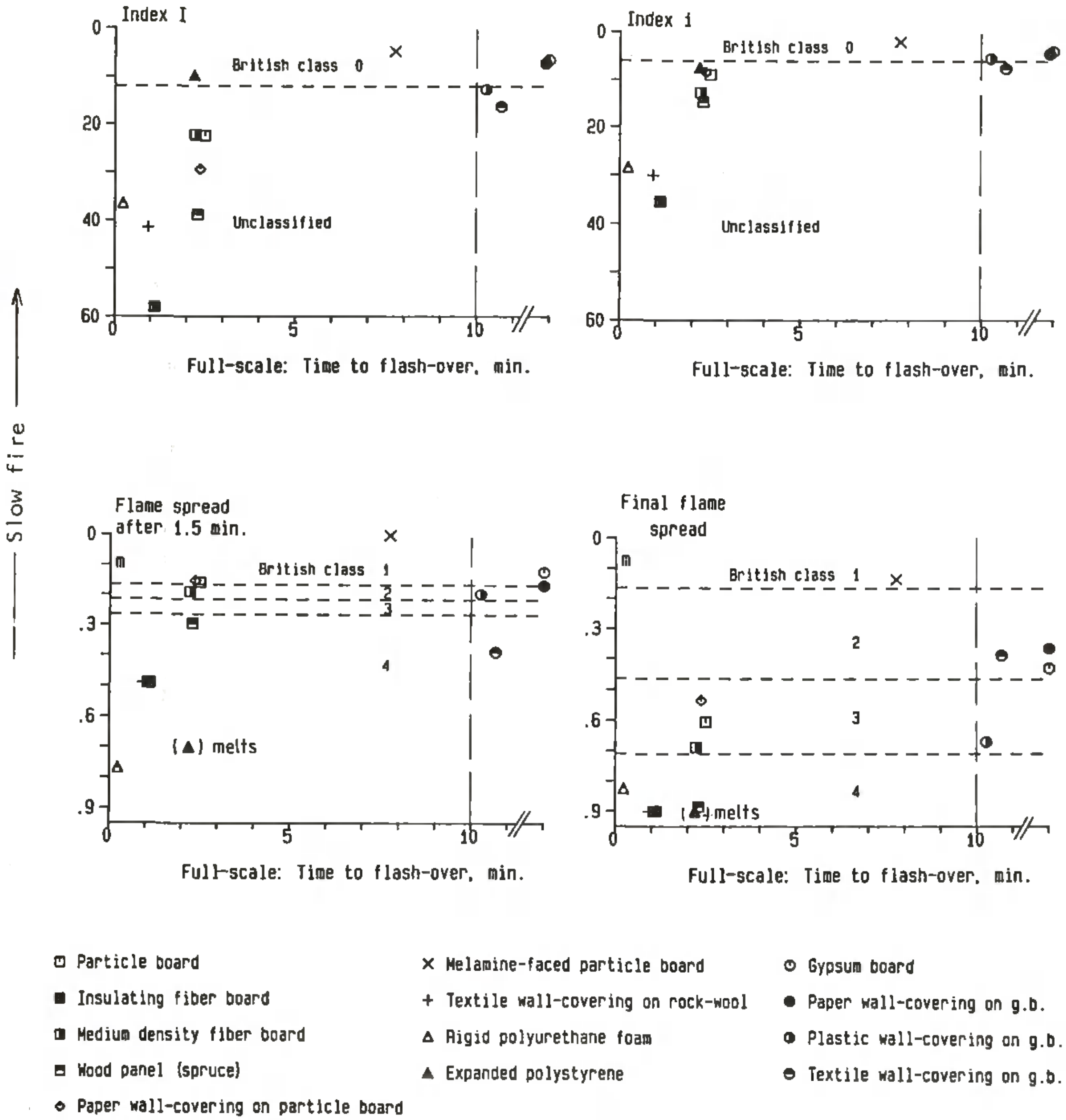


Figure 1. British classifications in relation to the full-scale room test. Above: Fire propagation. Both index i and index I should be fulfilled for class 0. Below: Surface spread of flame after 1.5 minutes and final spread after 10 minutes. Both criteria should be fulfilled. The vertical lines at 10 minutes mark the raise of the ignition source from 100 to 300 kW at full-scale testing.

The French radiation test requires criteria according to four different indices which should be fulfilled simultaneously, see Figure 2. For some of the indices there are alternative criteria. Only gypsum board without wall-covering fulfils class M1. Expanded polystyrene is not classified, since it melted during testing. Additional tests were then required but not performed. The rapid flash-over in full-scale for textile wall-covering on rock-wool is not detected by the test.

The German chimney test measures primarily the undamaged length which has no relation to full-scale flash-over, see Figure 3. Only three materials are in class B1, two gypsum boards and expanded polystyrene, which has the longest undamaged length of all materials tested. Other parameters measured in the chimney test were not critical for the B1 classification.

Materials which do not reach German class B1 are tested in a separate vertical spread of flame test. The results from that test, also in Figure 3, distinguish well between materials with a relatively short time to flash-over, but not so well between those with longer times. Only rigid polyurethane foam is in class B3, the others are in class B2.

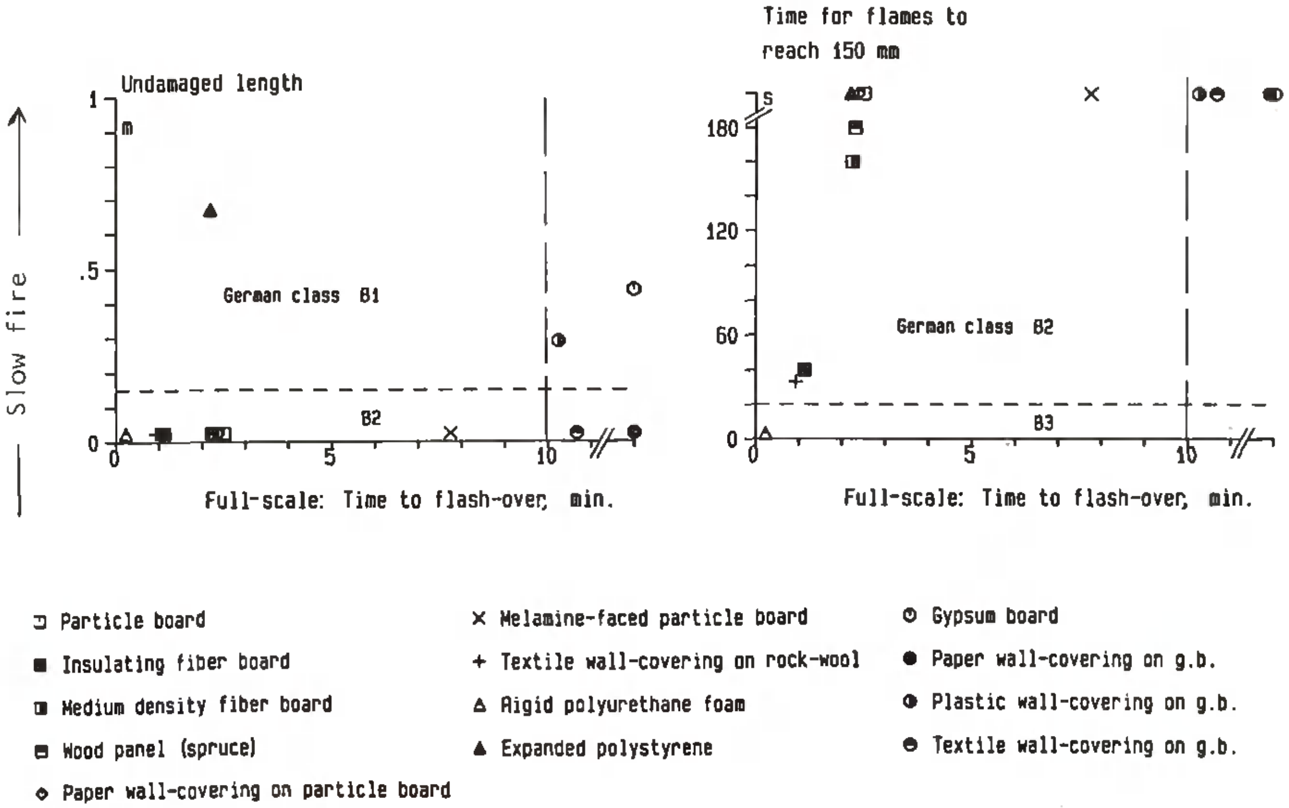


Figure 3. The German chimney test for class B1 (left) and the German test for class B2 (right). The vertical lines at 10 minutes mark the raise of the ignition source from 100 to 300 kW at full-scale testing.

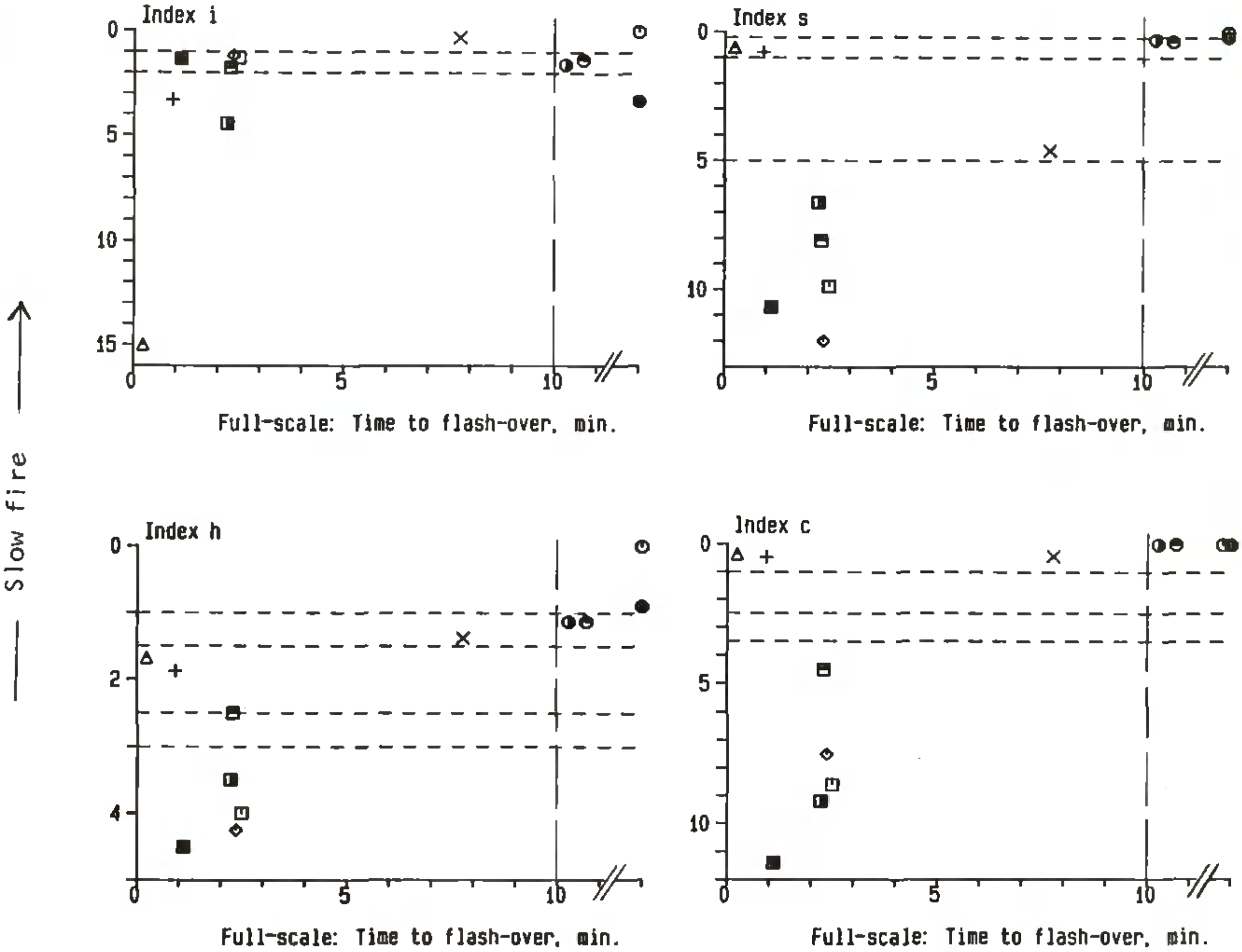
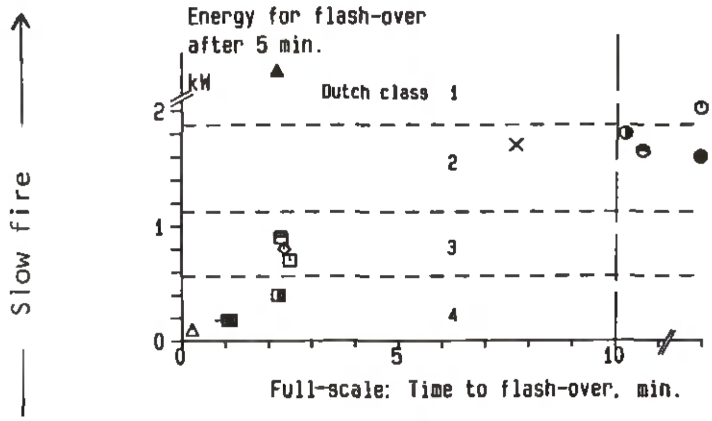


Figure 2. The French radiation test. The criteria according to all indices should be fulfilled simultaneously. Since there are alternative criteria, see table below, only the class limits are given in the diagrams. No data are given for polystyrene because of melting. Additional tests were then required.

Class	i ignition	s fire development	h flame length	c combustion
M0*	0	0	0	< 1
M1	0	0	0	< 1
M2	anything	< 0.20	< 1	< 1
	or < 1	0.20 ≤ s < 1	< 1	< 1
M3	anything	0.20 ≤ s < 1	< 1.5	< 1
	or < 2	1 < s < 5	< 2.5	< 2.5
M4		≥ 5 or	≥ 3 or	≥ 3.5
M5**		≥ 5 or	≥ 3 or	≥ 3.5

* + total heat of combustion ≤ 2.5 kJ/g.
** if flame spread according to separate method > 2 mm/s.

The Dutch contribution to flash-over test ranks the materials in a similar way as the full-scale room test except for expanded polystyrene which gets a much more favorable ranking in the small-scale test, see Figure 4. However, a surface spread of flame test, similar to the British test, is required for the final classification in Holland. In that way, the classification will probably be changed for polystyrene (compare with Figure 1). Some other materials may also change classification slightly.



- Particle board
- Insulating fiber board
- Medium density fiber board
- Wood panel (spruce)
- Paper wall-covering on particle board
- Melamine-faced particle board
- Textile wall-covering on rock-wool
- Rigid polyurethane foam
- Expanded polystyrene
- Gypsum board
- Paper wall-covering on g.b.
- Plastic wall-covering on g.b.
- Textile wall-covering on g.b.

Figure 4. Dutch test for contribution to flash-over. For a final classification, a separate test is required, similar to the British spread of flame test. The vertical line at 10 minutes marks the raise of the ignition source from 100 to 300 kW at full-scale testing.

The Swedish box method (as evaluated by the parameter "relative peak height" just to get a continuous measuring value) distinguishes fairly well between materials with short times to flash-over, except for expanded polystyrene which is in class I, see Figure 5. Materials with longer times to flash-over, e.g. gypsum board with different wall-coverings, are not so well detected.

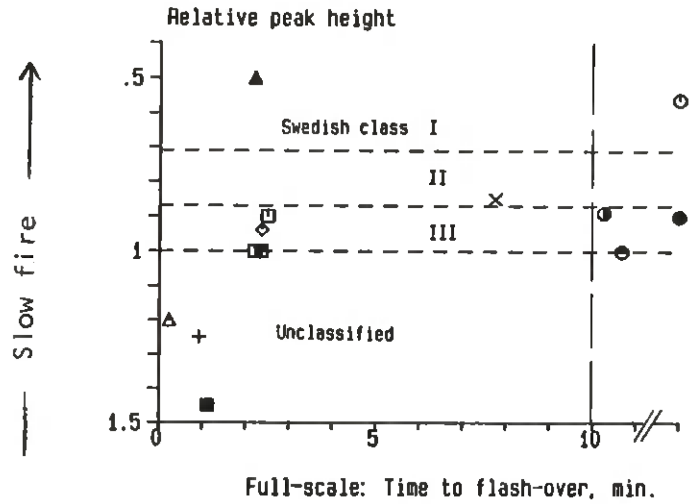


Figure 5. *Swedish box test.* A special parameter "relative peak height" is used in order to get a continuous measuring value. The class limits are mean values during the test time. The vertical line at 10 minutes marks the raise of the ignition source from 100 to 300 kW at full-scale testing.

ISO ignitability, here expressed as time to ignition at a radiation intensity of 30 kW/m^2, has a certain correlation with the full-scale test for most materials with short times to flash-over, but no correlation for materials which require longer times, see Figure 6. It is worth noting that polystyrene has the longest time to ignition (in spite of horizontal specimen at testing which reduces the effect of melting). A similar pattern is obtained at a radiation intensity of 50 kW/m^2 (no figure) except for polystyrene which then gets the shortest time to ignition.

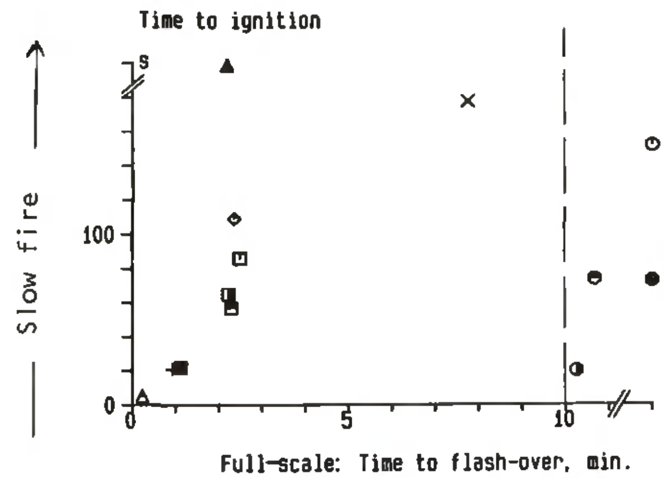


Figure 6.

ISO ignitability at 30 kW/m^2.

Stepwise ranking order

The test results have also been evaluated as a simple stepwise ranking order from 1 to 13 according to full-scale and to different small-scale tests. The different criteria for each test have then been considered together and only one diagram per test is given in order to simplify and get a better overview, see Figure 7.

Test information outside from what is given in Figures 1 to 5 have been used in some cases to distinguish between materials with very similar test results. The stepwise ranking in Figure 7 and the preceding figures may therefore be slightly different. For the British fire propagation test the stepwise ranking is based on the two indexes I and i; for the British spread of flame test on the spread of flame after 1.5 minutes and final spread of flame and for the French épiradiateur on the sum of the different indices within the same class. In the German chimney test, materials with the same classification (B2) were distinguished with the test parameter time for flames to reach 100 cm. In the Swedish box test the distances to the limiting curves have been evaluated as the classification system prescribes.

For a final classification (and ranking order) according to the small-scale tests, additional testing is needed in some cases: in France for melting materials, in Holland a supplementary test for spread of flame and in Sweden a full-scale test for materials with peculiar behaviour in the small-scale test.

It should also be noted that materials with a slow fire development will appear in the lower left corner in Figure 7 in contrast to figures 1 to 6.

A stepwise ranking order will of course overemphasize some small differences and conceal larger ones. However, the general agreement between small-scale and large-scale tests is surprisingly good. Only one material, expanded polystyrene, exhibits a peculiar behavior throughout all the tests, while others are different from test to test.

◘ Particle board	× Melamine-faced particle board	○ Gypsum board
■ Insulating fiber board	+ Textile wall-covering on rock-wool	● Paper wall-covering on g.b.
◧ Medium density fiber board	△ Rigid polyurethane foam	◑ Plastic wall-covering on g.b.
⊟ Wood panel (spruce)	▲ Expanded polystyrene	⊖ Textile wall-covering on g.b.
◇ Paper wall-covering on particle board		

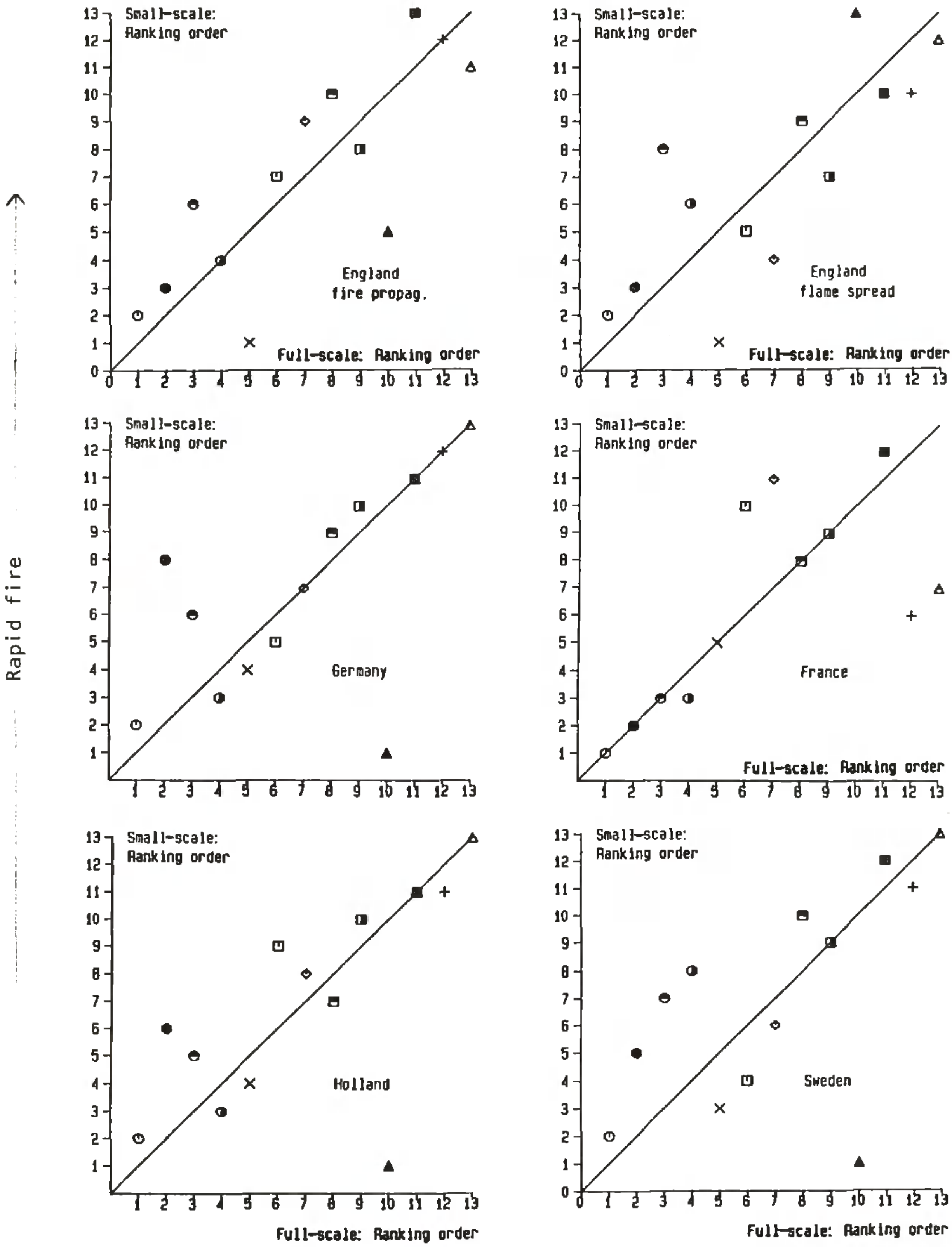


Figure 7. Stepwise ranking order from 1 to 13 according to full-scale and small-scale tests. Additional tests are needed for final classification in some cases: in France for melting materials, in Holland a supplementary test for spread of flame and in Sweden a full-scale test for materials with peculiar behavior in the small-scale test.

DISCUSSION AND CONCLUSIONS

Several of the small-scale tests are able to distinguish between the materials with less than three minutes to flash-over in the full-scale test, i.e. for eight of the thirteen materials tested, but the relative ranking is not exactly the same, especially not for the materials with very short times to flash-over. Generally all these materials show a wider range of fire behavior in the small-scale tests than in the full-scale test. Expanded polystyrene exhibits a peculiar behavior in many small-scale test and gets a better classification than would be expected from full-scale. In several cases it gets the best classification of all materials tested. Melamine-faced particle board is also somewhat peculiar, since it gets a better ranking in several small-scale tests than expected from full-scale.

Few of the small-scale tests can predict the longer times to flash-over for gypsum board with different wall-coverings, but in most cases gypsum without any covering gets the best classification.

It deserves to be noted how well all the small-scale methods (and the full-scale test) can distinguish between textile wall-paper on gypsum board and on rock-wool, i.e. the importance of the thermal properties of the backing material on the fire behavior of very thin materials.

The general relation between small-scale and large-scale tests indicates that most of the small-scale tests simulate a fire scenario with a less rapid fire development than the full-scale test. Materials with short time to flash-over might have been better distinguished in full-scale by a smaller ignition source. On the other hand, materials with longer time to flash-over in the full-scale fire scenario used here might need another type of small-scale test to predict the time to flash-over. A new small-scale test with a range of different fire exposures, e.g. the cone calorimeter (Babrauskas, 1984), might be helpful, but a range of full-scale fire scenarios is probably also necessary. However, if just one full-scale fire scenario should be used, the one used here seems to be appropriate.

Simple stepwise ranking orders according to small- and full-scale tests provide a reasonable agreement for many materials but also large deviations for certain others.

New small-scale tests are thus needed and in development. The most promising of these tests is the cone calorimeter which measures the rate of heat release as a function of time at different radiation intensities up to about 100 kW/m^2. Other parameters as time to ignition, mass loss and smoke density may be measured simultaneously. Rate of heat release determined by oxygen consumption as in the cone calorimeter is a basic fire parameter which is fairly independent of test apparatus (Östman et al, 1985). The cone calorimeter has been proposed as a new standard test within both the ISO and ASTM. No means of how to use the test results for classification of materials has yet been proposed, but should have a high priority in future work.

Mathematical models are also needed to link small- and full-scale fire behavior together. Two new approaches have been presented recently (Magnusson and Sundström, 1985; Wickström and Göransson, 1986). Both make use of rate of heat release data from new small-scale tests.

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