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RAPPORT

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Comparison of Smoke Release Rate from Building Products

Paper presented at the International Conference 'Control the Heat - Reduce the Hazard', London, October 24-25, 1988

Trätek

INSTITUTET FÖR TRÄTEKNISK FORSKNING

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SAMMANFATTNING - Swedish summary

Rökalstringen från 13 olika byggnadsmaterial har bestämts i en småskalig metod, den s k konkalorimetern. Metoden är ursprungligen utvecklad för att mäta frigiven värmeeffekt vid brand, men ger också möjlighet att mäta andra parametrar som tid till antändning, massförlust, rök- och gasutveckling samtidigt, vilket framstår som alltmer angeläget i det internationella standardiseringsarbetet.

Andra småskaliga metoder för rökmätning är i allmänhet baserade på statiska mätningar av uppsamlad rök i en box. För jämförelse med bränder i full skala och för användning av matematiska modeller behövs emellertid data från dynamiska flödesförhållanden, t ex från konkalorimetern.

Röken har mätts med två olika optiska system, dels ett med laserljus som föreslås i konkalorimetern, dels ett med vitt ljus och en detektor som efterliknar det mänskliga ögat. En jämförelse ansågs angelägen eftersom den slutliga avsikten är att underlätta utrymning vid brand. Resultaten med de båda optiska systemen är, något oväntat, praktiskt taget identiska.

Rökutvecklingen för de olika materialen varierar ganska kraftigt. Träbaserade, syntetiska och mer "obrännbara" material samt kombinationer ingår i studien. Gasutvecklingen, huvudsakligen mätt som kolmonoxid, CO, varierar också kraftigt.

Resultaten har på ett preliminärt sätt jämförts med data från Statens provningsanstalt, där exakt samma material provats vid rumsbrand i full skala. Överensstämmelsen är förvånansvärt god, men sambanden måste studeras betydligt mer.

Rapporten ger en översikt som presenterats vid en internationell konferens. Fullständiga resultat redovisas separat.

COMPARISON OF SMOKE RELEASE RATE FROM BUILDING PRODUCTS

Birgit A-L. Östman*

Abstract

The smoke productions rates for 13 different surface lining materials have been determined in the cone calorimeter at three irradiance levels: 25, 50 and 75 kW/m^2. Two light systems have been used simultaneously, a helium-neon laser and a white light source, showing equal results. The smoke potentials obtained in the cone calorimeter have been compared with smoke potentials calculated from fullscale room fire tests. There seems to be a reasonable agreement which must be further studied.

Introduction

Measurements of smoke production from different materials has so far mainly been carried out in static boxes, of which the NBS Somke density chamber is best known (2). This test has several disadvantages: the rate of smoke production is hard to follow accurately, the vertical orientation of the specimen excludes relevant testing of thermoplastics, it has no measurements of mass loss and a limited range of irradiance levels. Some of these disadvantages have been overcome in later modifications, but the main problems with a static, accumulative test method still remain.

A dynamic, flow-through system has therefore been proposed (5, 15) and expected to have a better predictive capacity for full-scale and real fires. Such an instrument for small-scale testing is now available in the cone calorimeter (3). It was originally developed for rate of heat release measurements but enables also the determination of smoke release, time to ignition etc. However, some researchers have pointed out the importance of measuring matured or aged smoke (15, 16), which might not be the case in a flow-through system. Only limited comparisons between static and dynamic conditions have been carried out in small scale (9) showing less smoke production during dynamic conditions.

The relation of smoke production in small scale to full-scale fires is of main interest, even if the progress so far is limited (15, 17). The use of a mass loss related smoke parameter as smoke potential (16) or smoke extinction area (4) has recently shown promising results (5, 13) in some cases but has so far been applied to only a few surface linings (10). The cone calorimeter for smoke measurements includes the determination of mass loss and makes such comparisons easier.

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Smoke measurements in the cone calorimeter are performed by a laser beam (3) in contrast to most earlier measurements. The laser has several advantages such as simple design, high level of beam collimation and simplified theoretical relevance (5, 12). A laser system may, however, create some problems with signal stability and relation to visibility, which is important for escape in real fire situation. The signal stability has been improved by a second controling photometer in the cone calorimeter application. But the relation to visibility has not yet been proved. Only one direct comparison between a laser beam and a white light source has been published and was performed under static conditions (8).

This study compares directly the laser with a white light source in the cone calorimeter under dynamic conditions. It also presents smoke production data and smoke potentials for a set of different surface linings and makes a first attempt to relate them to a full-scale room fire test.

Experimental

The experiments have been performed in a cone calorimeter, Figure 1, which is in accordance with the standard version (3). It is a further development of an earlier version (14) used to test the effect of specimen size. New main items are the cone heater, the spark igniter, the hood and the exhaust duct. It is also equipped with two light systems to measure smoke production.

The cone heater and the spark igniter with motor has been delivered from the University of Ghent, Belgium. A square hood and a circular exhaust duct with 110 mm inner diameter is connected to the earlier constant volume radial fan, which is situated about 10 m away from the cone heater. This position of the fan is a real advantage which does not require a high-temperature fan and will not influence the flow or gas measurements. The volume flow can be varied by different dampers. The orifice plate is placed about 650 mm from the curve of the exhaust duct and the straight free section after it is about 650 mm long.

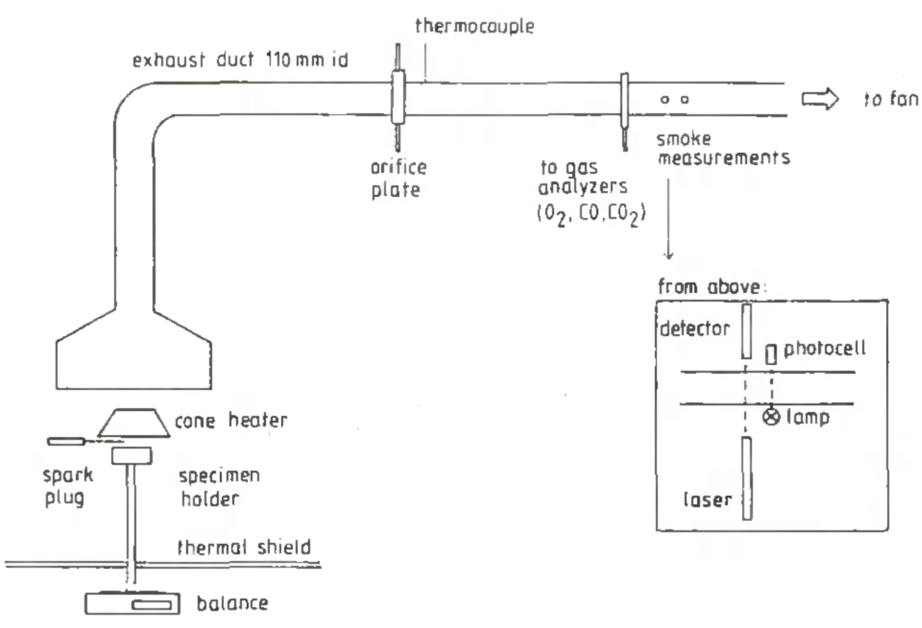

Figure 1. The cone calorimeter.

The oxygen concentration is measured by a paramagnetic cell (H&B Magnos 4G) and the concentrations of carbon monoxide and carbon dioxide by IR (Siemens Ultramat 22 P). The gas sample is taken from a ring sampler placed about 650 mm after the orifice plate. The gas sample passes a cold trap where moisture is removed, then a filter of loosely packed glass wool and a tube with water-free $CaSO_4$ for extra drying. The gas then goes through a pump and finally passes a 2.7 um glass fiber filter. In order to minimize the transient time, a major part of the flow is wasted after the pump.

The smoke is measured by two different light systems placed close together at about 50 mm distance and about 100 mm after the gas sampler. At first, there is a helium-neon laser with silicon photodiodes as main beam and reference detectors (3) delivered from Ghent University. Then there is a white light source from a 10 W tungsten filament lamp for which the beam is made parallel by a lens system. The detector has a spectrally distributed respons that duplicates the human eye (United Detector Techn. USA). In both cases the smoke release is expressed as smoke production rate in $ob \cdot m^3/s$ and smoke potential in $ob \cdot m^3/g$ according to Rasbach (16). The latter parameter is directly proportional to the specific extinction area in m^2/g (3).

The basic parameter is a quantity called obscura (ob). One ob is the smoke concentration giving a light absorption of 1 dB/m, which is equivalent to a visibility of about 10 m. Obscura, D_L, is defined as: $D_L = (10/L) \cdot \log (I_0/I)$ where L is path length in m, I_0 light intensity in absence of smoke and I light intensity in presence of smoke.

The smoke production rate, D_{sp}, is defined as: $D_{sp} = D_L \cdot \dot{V}_T$ $(ob \cdot m^3/s)$ where V_T is the volume flow of gases in the exhaust duct at the actual temperature in m^3/s.

The smoke potential, D_o, is defined as: $D_o = D_{sp} / \dot{m}$ $(ob \cdot m^3/g)$ where $\dot{m}$ is the mass loss rate in g/s.

The test materials used are listed in Table 1. All of them originate from the same lot which was initially selected and used for several studies on reaction to fire within Scandinavian fire laboratories (e.g. 1, 10, 11, 14, 19, 21, 22).

TABLE 1. Tested lining 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

Light systems for smoke

All smoke measurements were made simultaneously with two light systems, a helium-neon laser and a white light system. In most cases they showed an excellent agreement. In only some cases very narrow peaks had somewhat different heights. This can probably be overcome by a more frequent data sampling (5 s used here). Representative data are given in Figure 2.

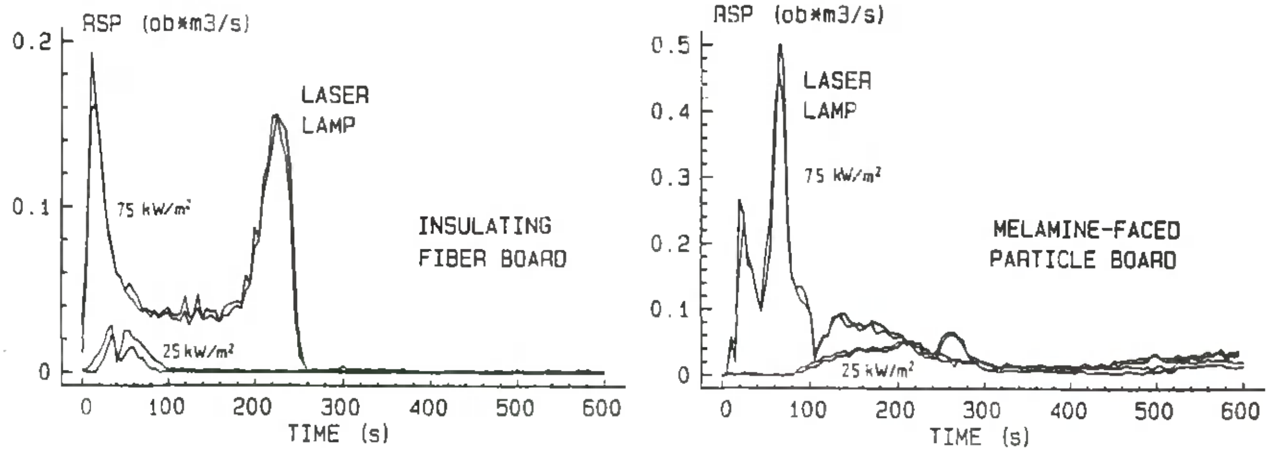

Figure 2. Comparison of a laser and white light system for measuring rate of smoke production (RSP).

Repeatability

Most data presented here are from single tests. This may be justified since the repeatability seems to be acceptable. Figure 3 gives an example for a material with quite low smoke production.

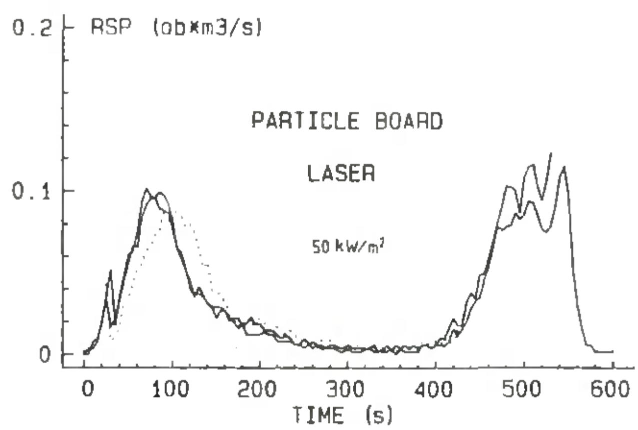

Figure 3. Repeatability in smoke measurements. The figure shows laser data for particleboard at 50 kW/m^2 as an example.

Smoke production

The smoke production was measured at three irradiance levels from the cone heater 25, 50 and 75 kW/m^2 and with two light systems. As the light systems give equal data, see a preceding section, just the white light data are presented here.

Figure 4 shows smoke production rate in relation to rate of heat release for some typical materials. The smoke may be released somewhat earlier than the heat. The early smoke released before ignition is usually white and different from the smoke after ignition which is more dark. In some cases they appear as distinct peaks.

Maximum production rates for all materials tested are given at 50 kW/m^2 in Table 2. Such peak data are less accurate (especially for materials with narrow peaks) but may still be of interest for a general comparison.

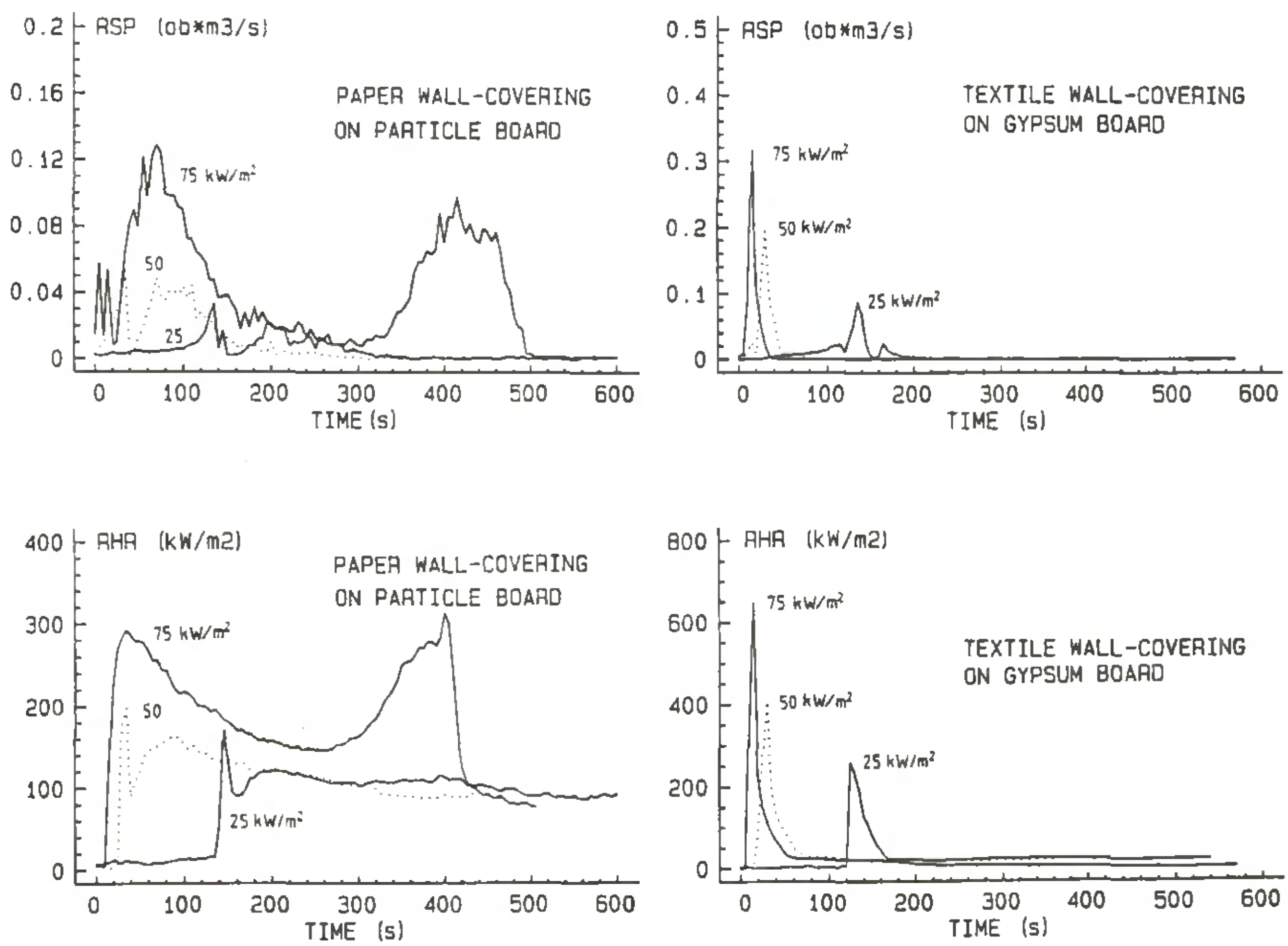

Figure 4. Rate of smoke production (RSP) and rate of heat release (RHR) for some lining materials. (Note the different scales in both cases.)

The smoke release may also be given in relation to mass loss which is expressed in ob m^3/g and called smoke potential according to Rasbach (16). A proportional parameter is smoke extinction area expressed in m^2/g according to (3). The general appearance of the smoke potential curves is similar to those for smoke production rate, since the mass loss rate is constant during major parts of the fire test for many materials. Data are given in Figure 5 and Table 2.

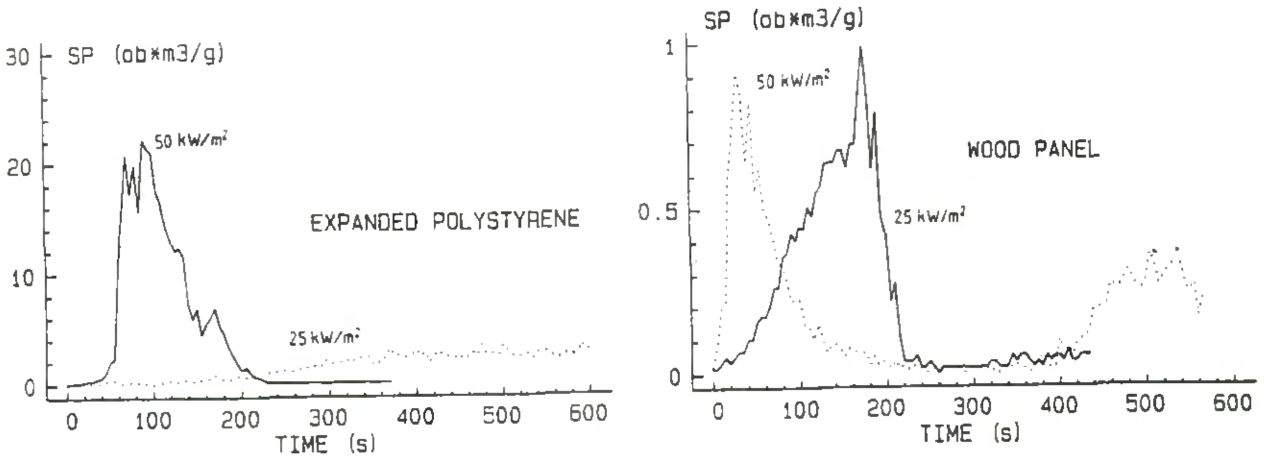

Figure 5. Smoke potentials (SP) for some materials. (Note the different scales.)

TABLE 2. Smoke and gas production data at 50 kW/m^2. Peak values.

Material	Smoke production rate $ob \cdot m^3/s$	Smoke potential $ob \cdot m^3/g$	CO production rate ml/s
Rigid polyurethane foam	0.86 (5 s)*	12.6	14.7 (10 s)*
Textile wall-covering on rock-wool	0.40 (20 s)	3.4	3.8 (25 s)
Insulating fiber board	0.10 (20 s)	1.37	0.6 (30 s)
Expended polystyrene	0.97 (90 s)	22.2	7.5 (85 s)
Medium density fiber board	0.13 (110 s)	1.21	0.8 (75 s)
Wood panel (spruce)	0.07 (30 s)	0.92	0.6 (45 s)
Paper wall-covering on particle board	0.05 (70 s)	0.47	0.6 (85 s)
Particle board	0.09 (90 s)	0.78	0.6 (115 s)
Melamine-faced particle board	0.34 (40 s)	4.05	3.7 (90 s)
Plastic wall-covering on gypsum board	0.70 (10 s)	7.8	2.2 (75 s)
Textile wall-covering on gypsum board	0.19 (30 s)	1.83	2.7 (80 s)
Paper wall-covering on gypsum board	0.11 (25 s)	1.55	2.5 (80 s)
Gypsum board	0.03 (30 s)	0.60	3.4 (75 s)

* Time for peak value.

Gas production

The production of carbon monoxide and carbon dioxide has also been detected. Some examples of CO production are given in relation to smoke production in Figure 6. Peak values at 50 kW/m^2 are given in Table 2. Generally, the peak in CO production seems to appear later than the peak in smoke production.

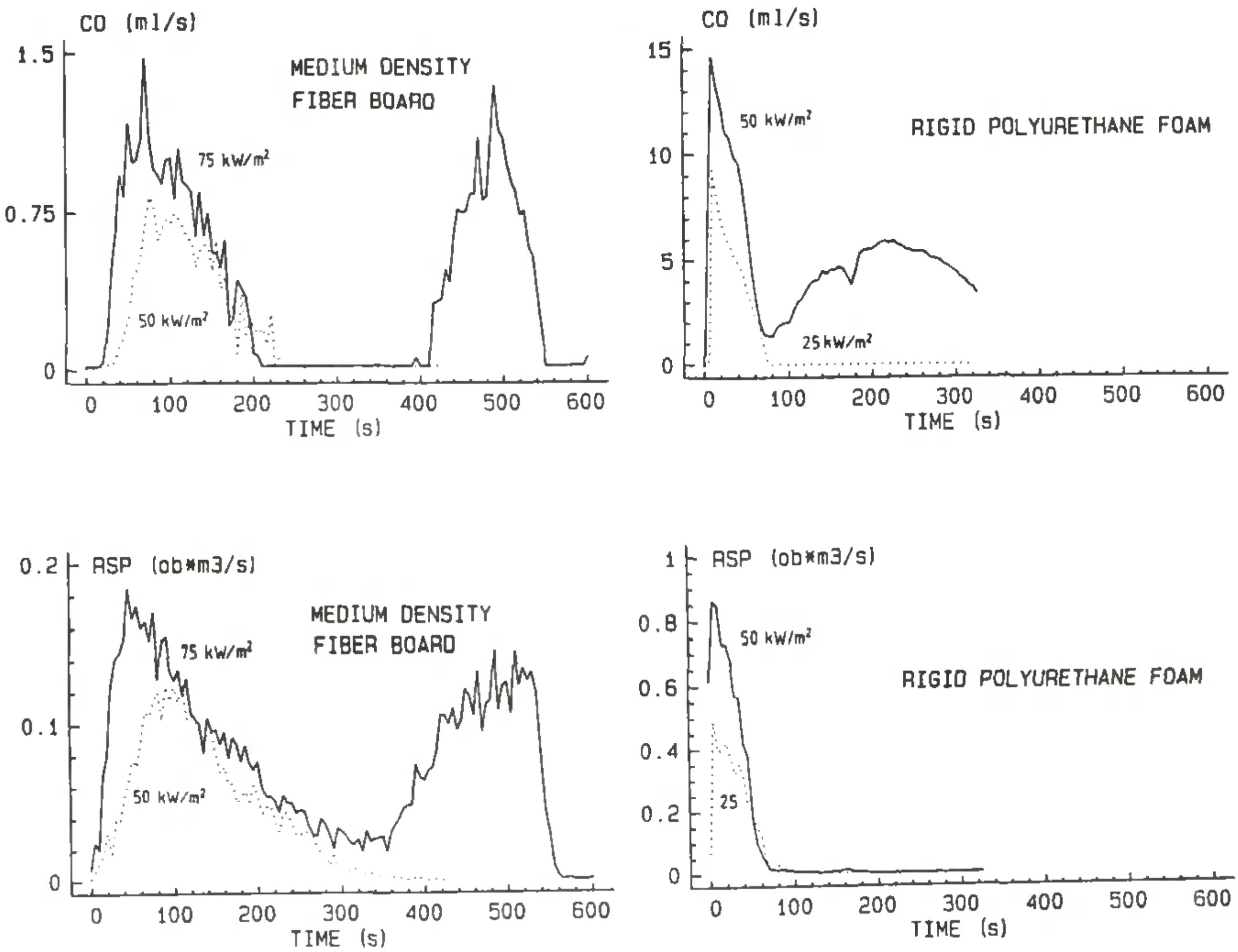

Figure 6. Production rate of carbon monoxide, CO, in relation to smoke production rate for some materials. (Note the different scales in both cases.)

Relation to full-scale fires

Smoke potential or the equivalent term smoke extinction area is probably the best parameter for comparing smoke production in small-scale and full-scale fire tests (5). In full-scale tests, however, the mass loss rate is usually not determined, but by using the effective heat release obtained in small scale, the full-scale smoke production data may be converted to smoke potential (10). Full-scale room fire data are available for exactly the same lining materials (19). They include smoke production per heat released (ob·m^3/MJ), which has been converted to smoke potential by multiplying with the average effective heat release (MJ/g) obtained at 50 kW/m^2 in the cone calorimeter. This effective heat release is constant during major parts of the fire test. The small-scale smoke potential used are peak values at 50 kW/m^2. Figure 7 shows a general agreement. Mean values in small scale seemed to give less agreement. However, more careful and comprehensive studies have to be made to find the best correlation. More lining materials have also to be incorporated. Still, the rough results so far are promising.

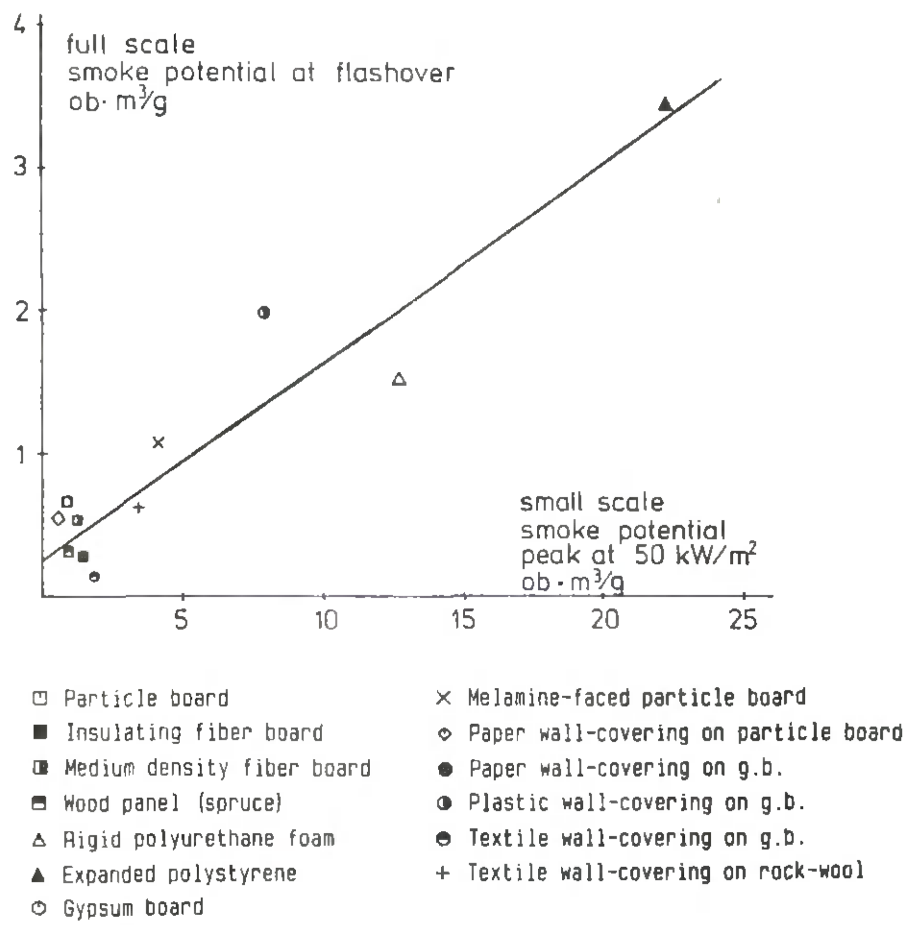

Figure 7. Relation between smoke potential obtained in the cone calorimeter at 50 kW/m^2 and calculated from a room fire test (19).

Conclusions

Smoke production can be measured with good accuracy in the cone calorimeter also for materials with low smoke release.

A helium-neon laser and a white light system give equal results.

There seems to be a general good agreement between smoke potentials obtained in the cone calorimeter and calculated from room-fire tests. This has to be further studied. More accurate means to obtain smoke potentials from room-fire tests have to be found.

Acknowledgement

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