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RAPPORT

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Smoke, Gas and Heat Release Data for Building Products in the Cone Calorimeter

Trätek
INSTITUTET FÖR TRÄTEKNISK FORSKNING

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SMOKE, GAS AND HEAT RELEASE DATA FOR BUILDING PRODUCTS IN THE CONE CALORIMETER

TräteknikCentrum, Rapport I 8903013

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building products
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C O N T E N T S

SAMMANFATTNING - Swedish summary

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

Röken har mätts med två olika optiska system, dels ett med helium-neonlaser 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. Mätningarna visar att de båda optiska systemen ger praktiskt taget identiska resultat.

Rökutvecklingen för de olika provade materialen varierar ganska kraftigt. Gasutvecklingen, huvudsakligen mätt som kolmonoxid, CO, varierar också kraftigt.

Rapporten visar fullständiga resultat för träbaserade, syntetiska och mer "obrännbara" material.

ABSTRACT

The smoke production rates for 13 different building products have been determined in the cone calorimeter at three heat flux levels: 25, 50 and 75 kW/m^2. Also the rate of heat release, the gas production, the mass loss rate and the effective heat of combustion have been calculated.

The smoke production rates have been measured with two light systems simultaneously, a helium-neon laser and a white light source, which showed almost identical results. The smoke production rate can be measured with good accuracy for products with both high and low smoke release.

The results showed that the cone calorimeter can be used for smoke measurements as well as for rate of heat release measurements.

INTRODUCTION

The early fire behaviour of products is important for many aspects of fire safety. One of the basic parameters describing the fire behaviour of building products is the rate of heat release. The aim of a new ISO fire test /1/ is to determine and characterize that parameter.

Another basic parameter is to measure the smoke produced in fires. Measurements of smoke production from different products has so far been done in static boxes, of which the NBS Smoke density chamber /2/ is best known. A dynamic, flow-through system for small-scale testing is now available in the cone calorimeter /3/.

Smoke measurements in the cone calorimeter are performed by a laser beam /3/. The laser has several advantages such as simple design, high level of beam collimation and simplified theoretical relevance /4, 5/. A laser system may, however, create some problems with signal stability and relation to visibility. The signal stability has been improved by a second controlling photometer. But the relation to visibility, which is important for escape in real fire situations, 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 /6/.

This study presents complete results of smoke, gas and heat release for a set of different building products. It also compares directly the laser beam with a white light source for smoke measurements in the cone calorimeter.

Comparisons with full-scale room fire tests and some further analysis are given elsewhere /9, 10/.

EXPERIMENTAL

Test equipment

The cone calorimeter used is shown in Figure 1. It is a further development of an earlier version /7/ used to test the effect of specimen size. New items are the cone heater, the spark igniter, the hood, the exhaust duct and the paramagnetic oxygen cell. It is also equipped with two light systems to measure smoke production.

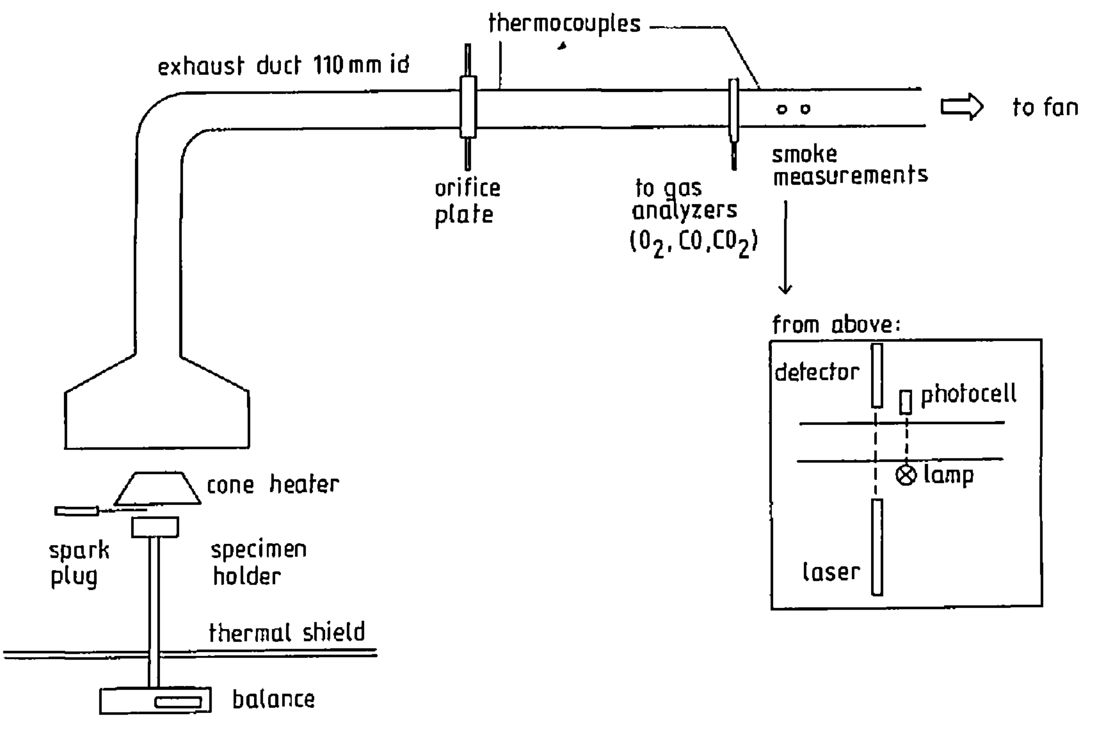


Figure 1. Cone Calorimeter.

The cone heater and spark igniter with motor has been delivered from the University of Ghent (Belgium). In order to characterize the radiation from the cone heater a water cooled heat flux meter of the Schmidt-Boelter type was used (Medtherm). It was recently calibrated in the ISO Cone Calorimeter round robin test program.

The hood is formed as a square (with 400 mm side and 140 mm height). The circular exhaust duct has an inner diameter of 110 mm and is connected with an exhaust system which has a constant volume radial fan (Bahco, Sweden). The volume flow can be varied by different dampers. The orifice plate is placed 825 mm from the curve of the exhaust duct and the straight free section after it is 1200 mm long.

To determine the gas density in the exhaust duct, the temperature is measured with two Chromel Alumel thermocouples, one located 90 mm after the orifice plate and the other 55 mm before the laser beam.

The oxygen concentration is measured by a paramagnetic cell (H&B, Magnos 4G) and the concentration of carbon monoxide and carbon dioxide by IR (Siemens Ultramat 22 P). The gas sample is taken from a ring sampler placed 675 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 µm glass fiber filter. In order to minimize the transient time, part of the flow is wasted after the pump.

The smoke is measured by two different light systems placed closely together at a 50 mm distance and 100 mm after the gas sampler. First, there is a helium-neon-laser, $\lambda = 633$ nm, with two silicon photodiodes as main beam and reference detectors delivered from the University of Ghent. 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 response that duplicates the human eye (United Detector Techn., USA).

Products

The 13 building products listed in Table 1 have been tested as 100 x 100 mm specimens. The specimens were conditioned at 65 % relative humidity and 20 °C before being tested.

Table 1. Building products tested.

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

Test procedure

The horizontal specimen holder consists of a specimen pan and a 60 mm deep retainer frame, all made of stainless steel. The specimen were wrapped in aluminium foil and non-combustible boards (Promatek, 450 kg/m^3) were used to fill up the depth of the retaining frame.

Single or double tests were performed at three different heat flux levels: 25, 50 and 75 kW/m^2. For a few products with rapid fire behaviour only the two lower levels were used.

Calculations

In both laser and white light systems the smoke release is expressed as rate of smoke production in ob·m^3/s and smoke potential in ob·m^3/g according to Rasbash /8/. The latter parameter is directly proportional to the specific extinction area in m^2/kg /3/.

The basic parameter is a quantity called obscura (ob) which expresses the smoke intensity. One ob is the smoke concentration giving a light absorption of 1 dB/m, which is equivalent to a visibility of about 10 m.

The smoke intensity is defined as:

$$D = (10/L)\cdot\log (I_0/I) \qquad \text{(ob)} \qquad (1)$$

where
L path length in m
I_0 light intensity in absence of smoke
I light intensity in presence of smoke.

The rate of smoke production is defined as:

$$RSP = D\cdot\dot{V} \qquad (\text{ob}\cdot\text{m}^3/\text{s}) \qquad (2)$$

where
$\dot{V}$ volume flow of gases in the exhaust duct at atmospheric pressure and ambient temperature in m^3/s.

The smoke potential is defined as:

$$SP = RSP/\dot{m}_l \qquad (\text{ob}\cdot\text{m}^3/\text{g}) \qquad (3)$$

where
$\dot{m}_l$ mass loss rate in g/s.

The specific extinction area is defined as:

$$SEA = k\cdot\dot{V}/\dot{m} \qquad (\text{m}^2/\text{kg}) \qquad (4)$$

where
k extinction coefficient in 1/m
$\dot{V}$ volume flow of gases in the exhaust duct at atmospheric pressure and ambient temperature in m^3/s
$\dot{m}$ mass loss rate in kg/s.

Equations (3) and (4) show that the specific extinction area and the smoke potential are proportional parameters with SEA = 230·SP.

RESULTS AND DISCUSSION

Smoke, gas and heat release

Smoke, gas and heat release curves at different heat flux levels for the 13 building products are shown in Figures 2 to 14.

A characteristic peak in the rate of heat release, RHR, is obtained just after ignition, as shown before /7/. When the fire penetrates the product, the RHR decreases and when the rear and edges of the specimen then become involved there is a new rise in RHR. If a specimen consists of layers of different products, more than one RHR peak is usually obtained.

The rate of smoke production has the same behaviour as RHR but the smoke is released somewhat earlier than the heat. The early smoke, released before ignition, is usually white and different from the smoke that is released after ignition which is darker. In some cases they appear as distinct peaks. The rate of smoke production is higher for plastic products than for other tested products. The two smoke measurement systems, the He-Ne laser and the white light, showed good agreement in most cases. Only for products with high peak values in a short period of time, minor differences may appear.

The smoke release, expressed as rate of smoke production ($ob \cdot m^3/s$), differs between the heat flux levels as the rate of heat release does. But expressed as specific extinction area (m^2/kg) or smoke potential ($ob \cdot m^3/g$) it is similar, regardless of the heat flux levels. However, peaks may occur at different times related to the times to ignition at different heat fluxes. Peaks may also occur at a lower heat flux but not at higher heat fluxes.

The gas production is given as volume flow in the exhaust duct at atmospheric pressure and ambient temperature. The curves for the production of carbon dioxide are almost identical in shape when compared with the RHR-curves, while the carbon monoxide curves are dissimilar, partly depending on the low CO production during the test. Generally, the peak in CO production seems to appear later than the peak in smoke production and in heat release.

In order to facilitate a comparison of the products, some smoke and gas release data are summerized in Table 2.

Table 2. Average smoke potential, rate of smoke production (RSP) during peak period, average production of carbon monoxide and carbon dioxide per mass loss rate at 50 kW/m^2.

Product	Average smoke potential ($ob \cdot m^3/g$)	RSP during peak period ($ob \cdot m^3$)	Average CO_2 (kg/kg)	Average CO (g/kg)
Particle board	0.4	6.7	1.2	4
Insulating fiber board	0.4	3.5	1.4	15
Medium density fiber board	0.4	14.1	1.2	2
Wood panel (spruce)	0.4	3.5	1.2	2
Melamine-faced particle board	1.3	21.9	0.8	25
Gypsum board	0.4	0.5	0.3	27
Paper wall-covering on gypsum board	0.5	1.0	0.4	28
Plastic wall-covering on gypsum board	2.8	4.5	0.4	28
Textile wall-covering on gypsum board	1.0	2.2	0.4	25
Textile wall-covering on rock-wool	2.9	2.7	1.8	91
Paper wall-covering on particle board	0.3	3.1	1.2	3
Rigid polyurethane foam	3.8	28.5	1.1	200
Expanded polystyrene	5.5	57.3	1.9	54

Mass loss rate and effective heat of combustion

The mass loss rate curves, shown in Figures 2 to 14, have an appearance similar to the RHR curves, which means that the mass is lost when the heat is released. (The time intervals for the calculation of mass loss rate is 10 s according to /3/.)

The effective heat of combustion is the heat released per gram of mass lost. It has a constant value for each product after the ignition and is quite independent of the heat flux levels. Table 3 shows average values for the constant period. All these values are lower than the total heat of combustion, which is natural since the combustion is not complete.

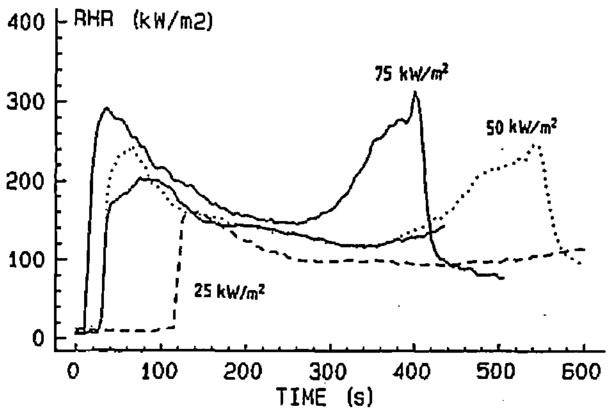
Table 3. Average effective heat of combustion at three heat fluxes.

Product	Average effective heat of combustion (kJ/g)		
	Heat flux, kW/m^2		
	25	50[a]	75
Particle board	14	14	13
Insulating fiber board	14	14	14
Medium density fiber board	13	14	15
Wood panel (spruce)	15	15	15
Melamine-faced particle board	9	11	12
Gypsum board	-	-	-
Paper wall-covering on gypsum board	-	-	-
Plastic wall-covering on gypsum board	17	13	13
Textile wall-covering on gypsum board	13	12	14
Textile wall-covering on rock-wool	-	25	-
Paper wall-covering on particle board	13	12	13
Rigid polyurethane foam	13	13	NT
Expanded polystyrene	NI	28	NT

[a] Mean values from double tests at 50 kW/m^2.
\- Not possible to calculate because of irregularities.

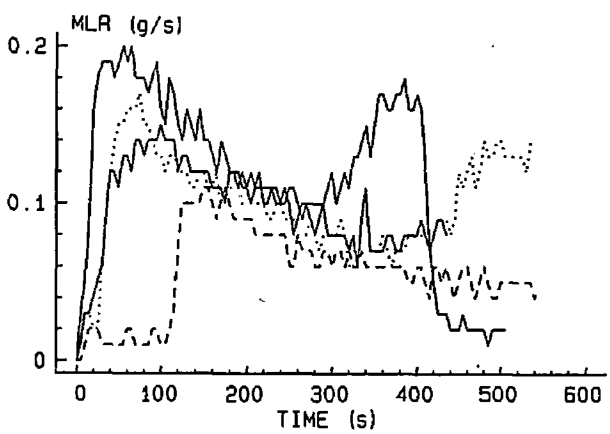
NI = No ignition.
NT = Not tested.

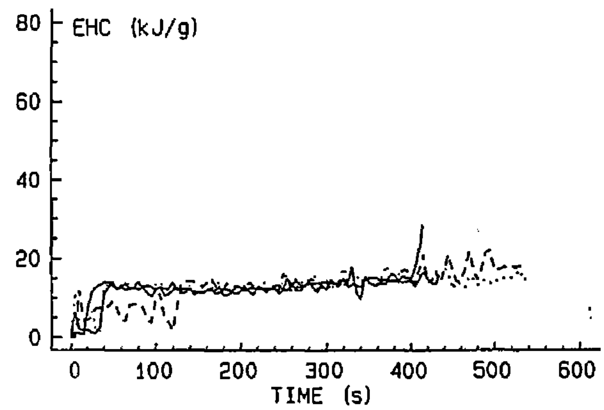
PARTICLE BOARD

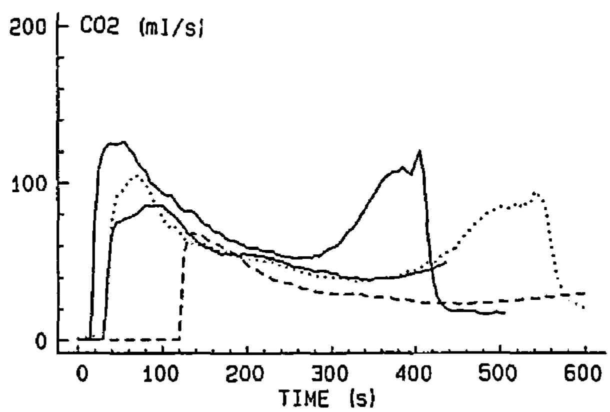


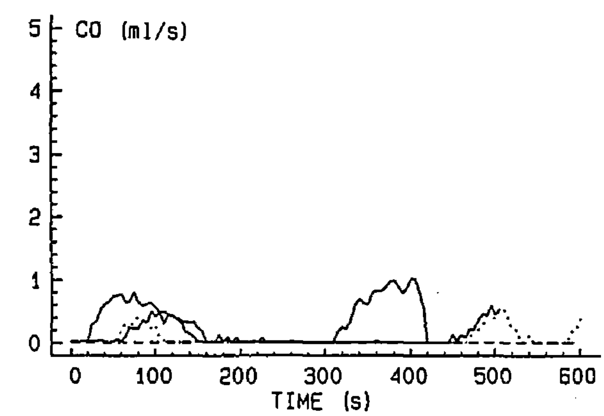
RHR = Rate of heat release
MLR = Mass loss rate
EHC = Effective heat of combustion
CO2 = Carbon dioxide
CO = Carbon monoxide

RSP = Rate of smoke production
SEA = Specific extinction area
SP = Smoke potential









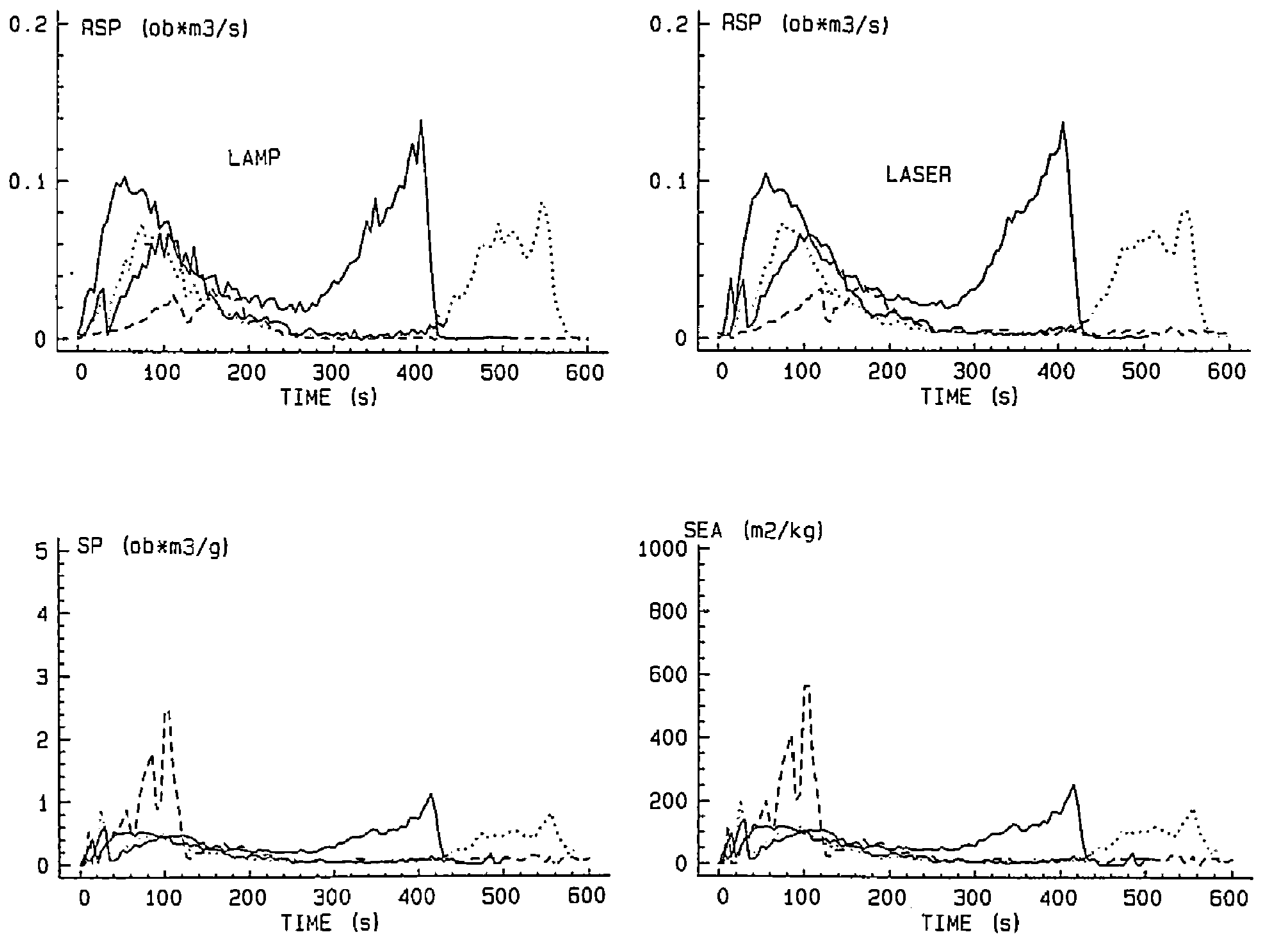
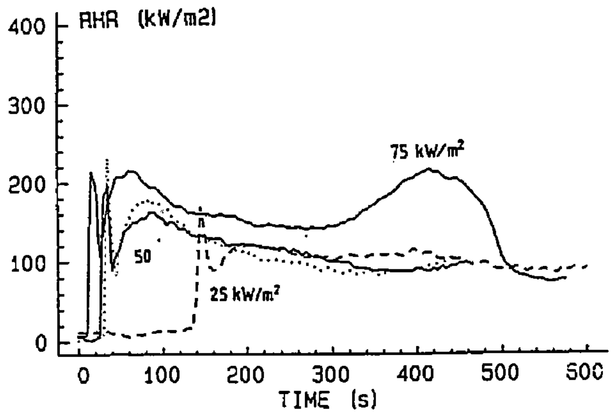


Figure 2. Particle board
Smoke, gas and heat release data at three heat flux levels. Double tests at 50 kW/m². Mass loss rate and effective heat of combustion are also presented.

PAPER WALL-COVERING ON PARTICLE BOARD



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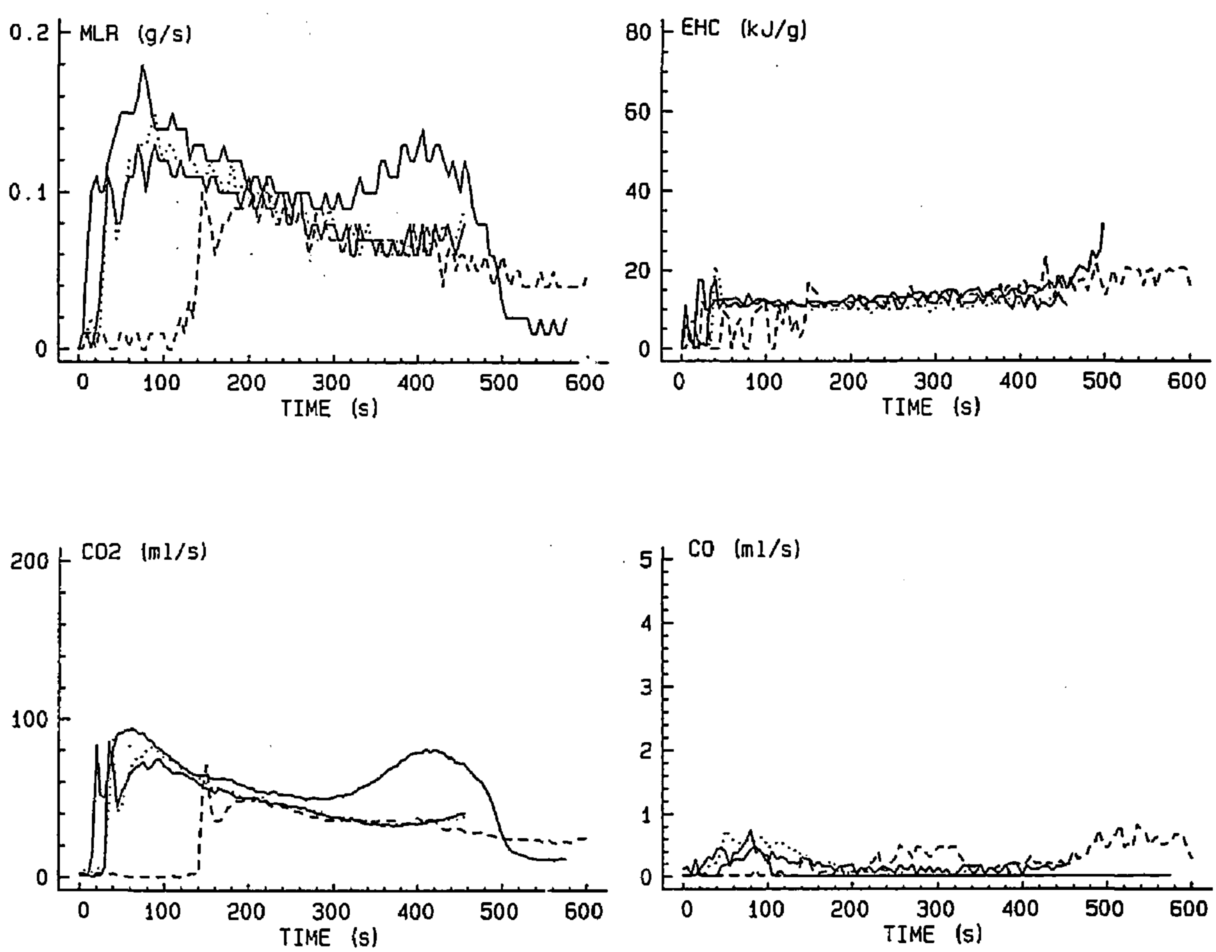


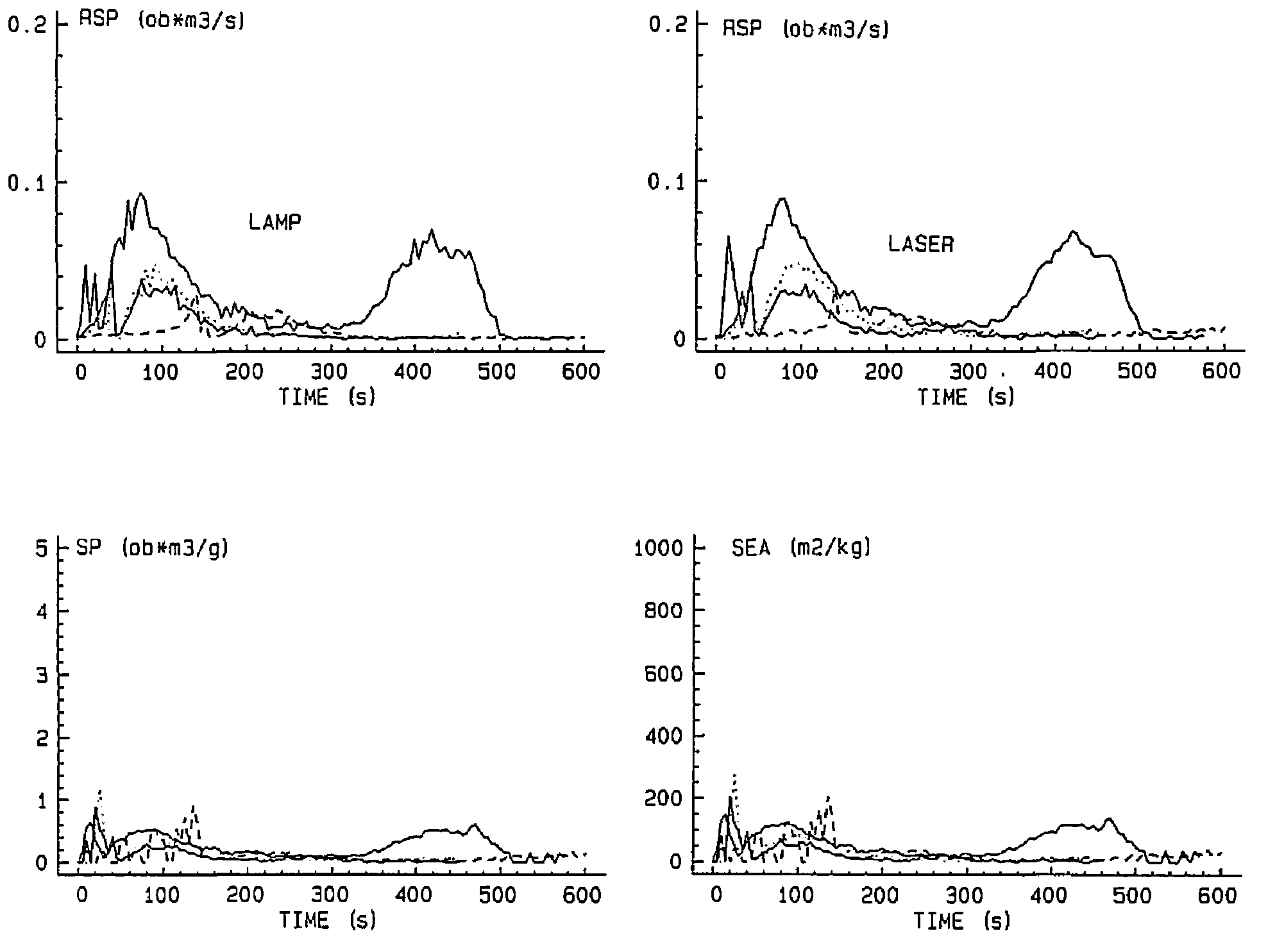
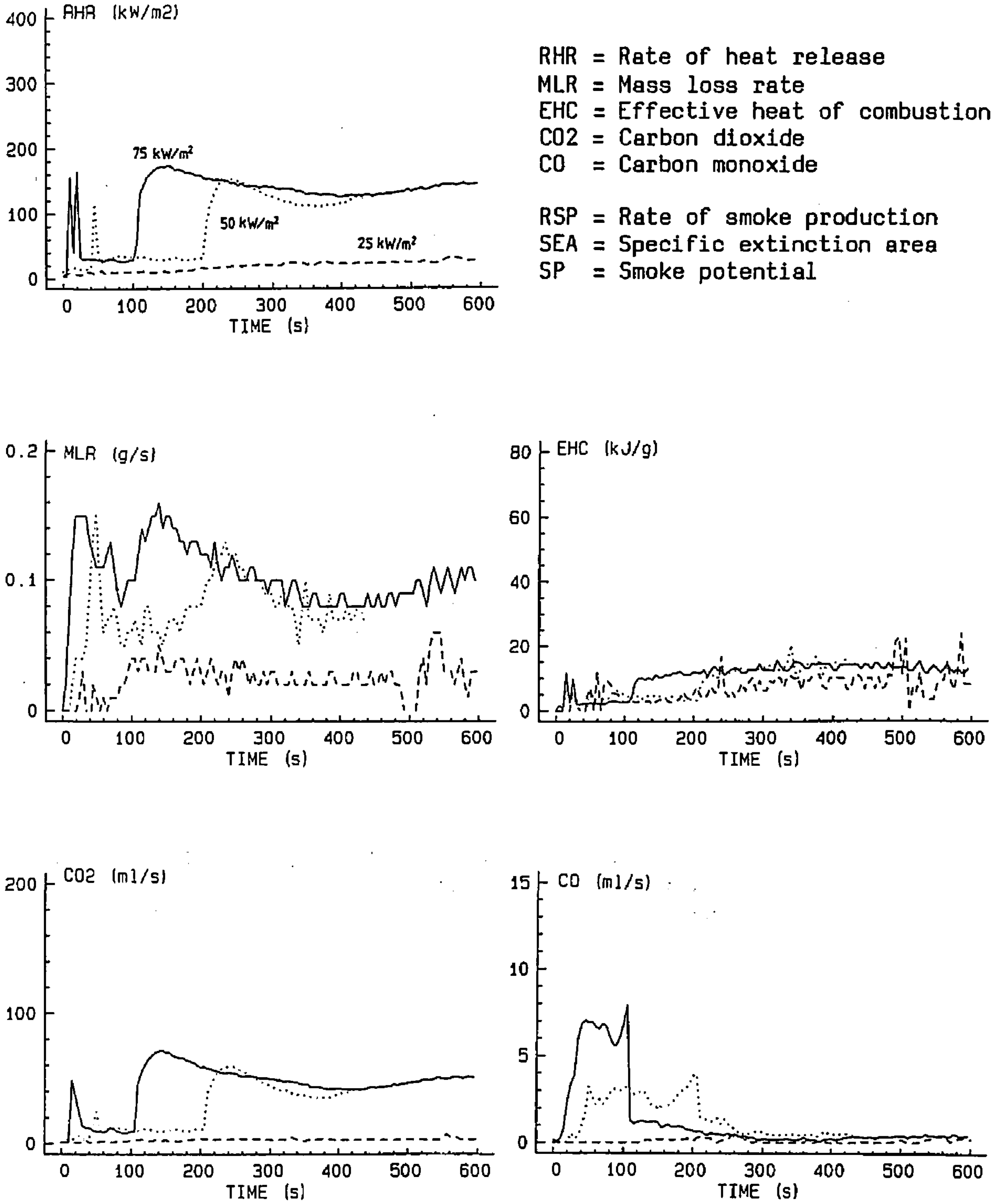


Figure 3. Paper wall-covering on particle board
Smoke, gas and heat release data at three heat flux levels. Double tests at 50 kW/m^2. Mass loss rate and effective heat of combustion are also presented.

MELAMINE-FACED PARTICLE BOARD



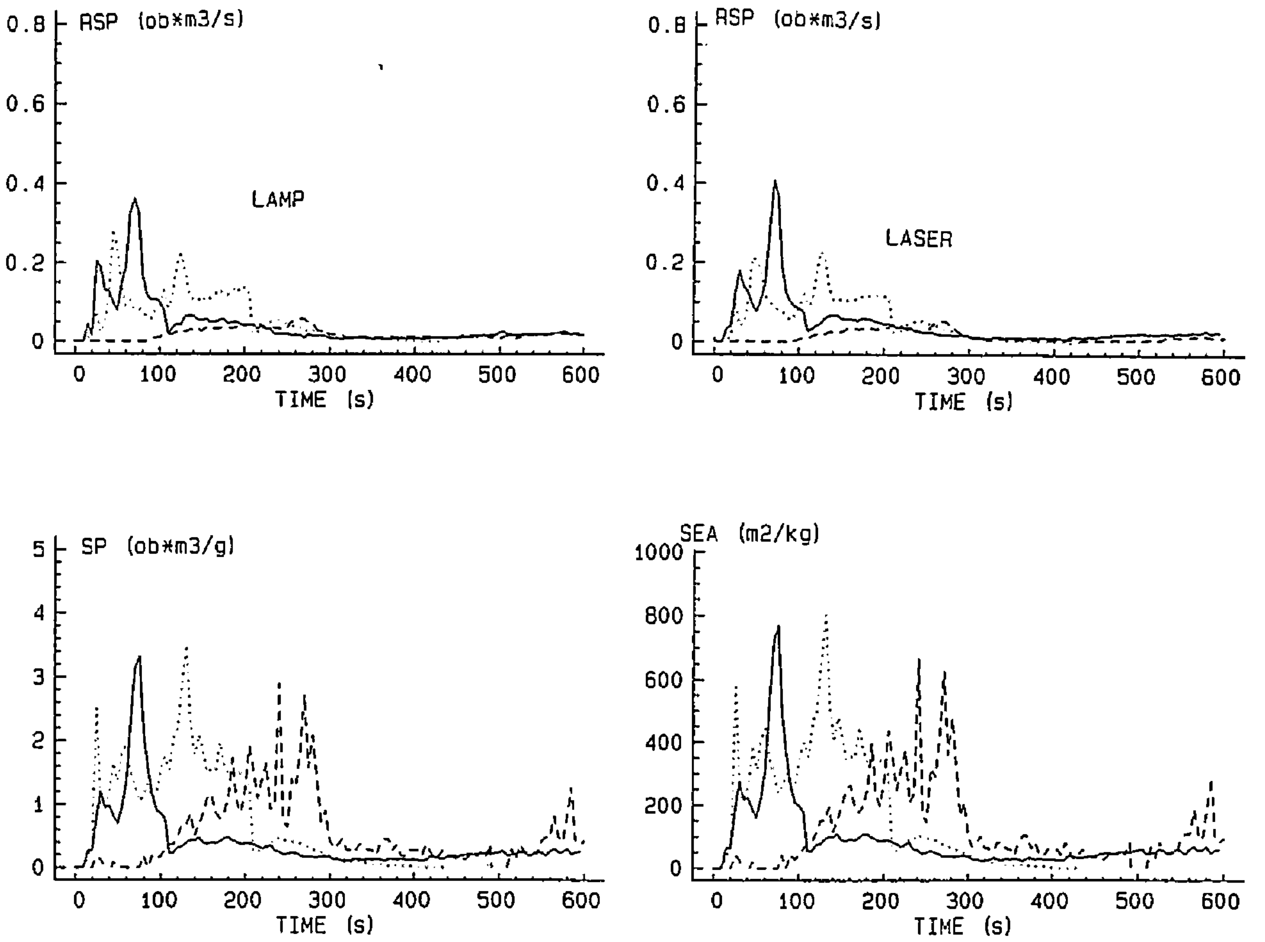
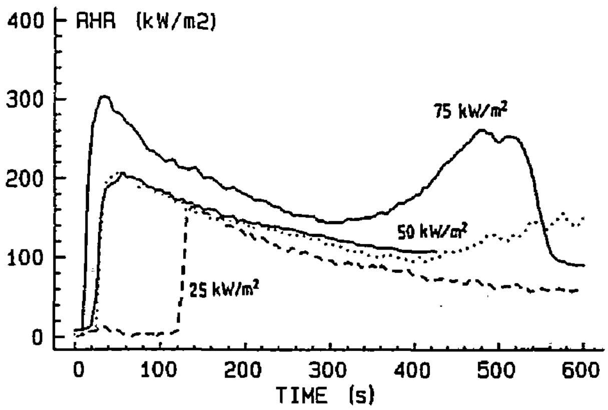


Figure 4. Melamine-faced particle board
Smoke, gas and heat release data at three heat flux levels. Mass loss rate and effective heat of combustion are also presented. Note the different scales in CO production and in RSP.

MEDIUM DENSITY FIBER BOARD



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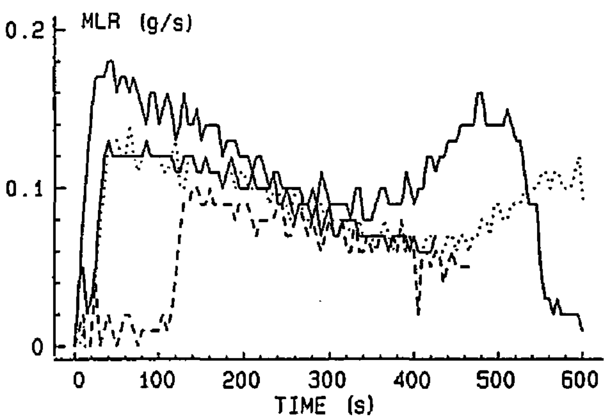
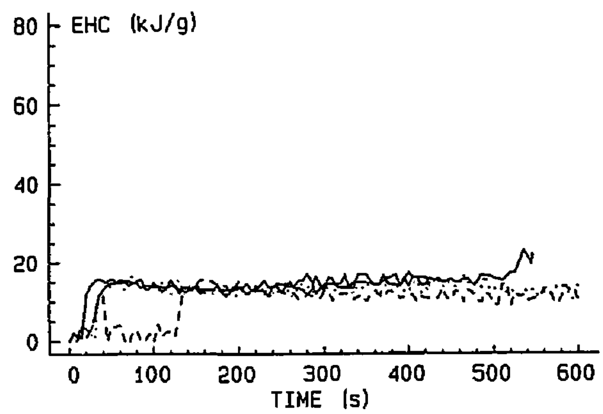
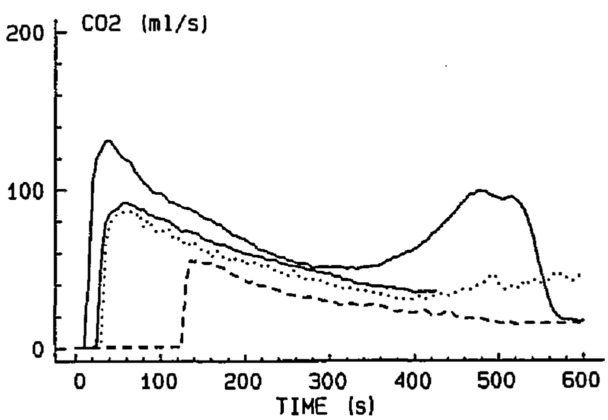
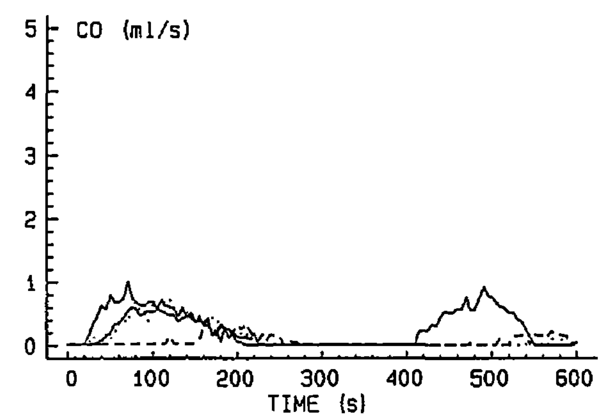








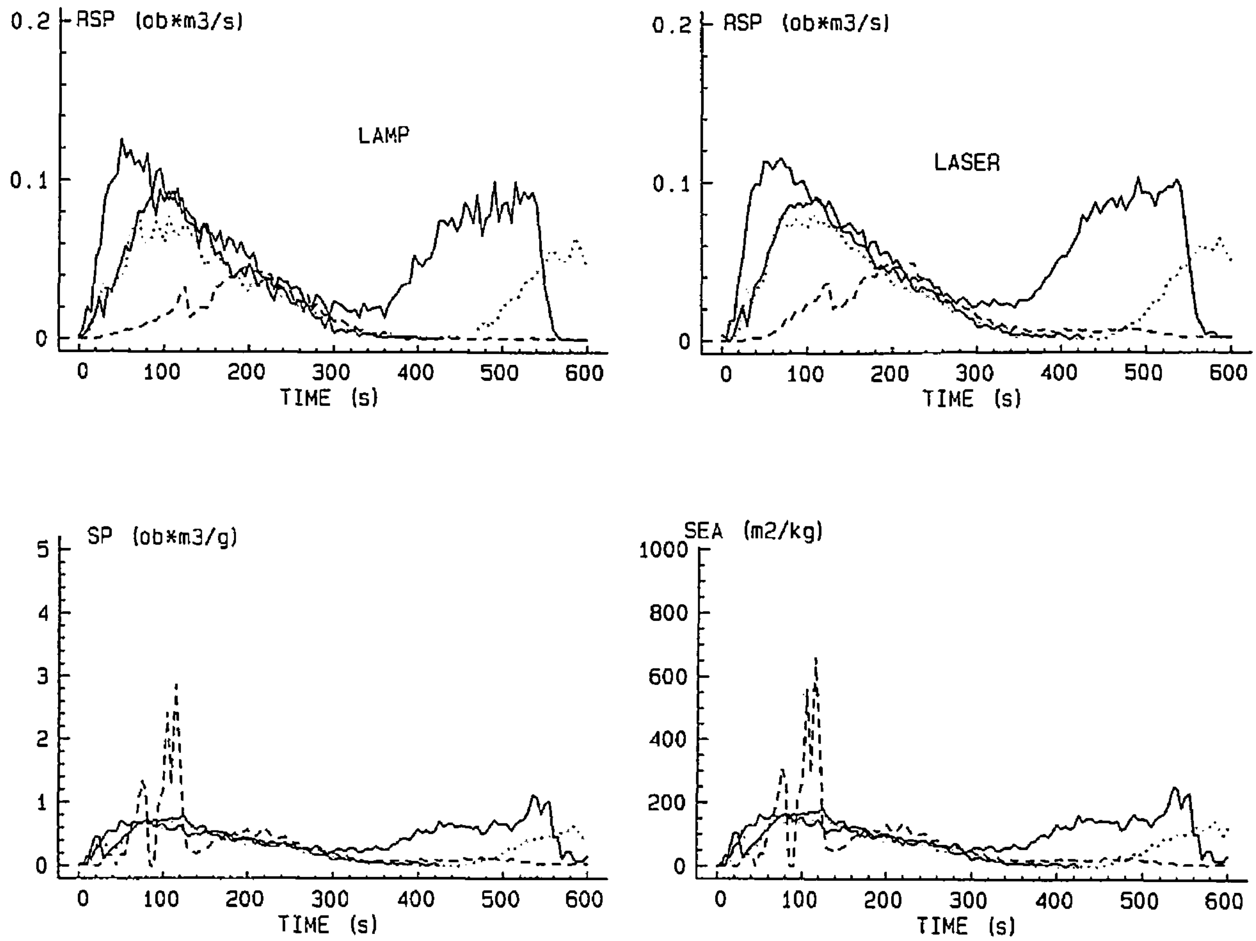
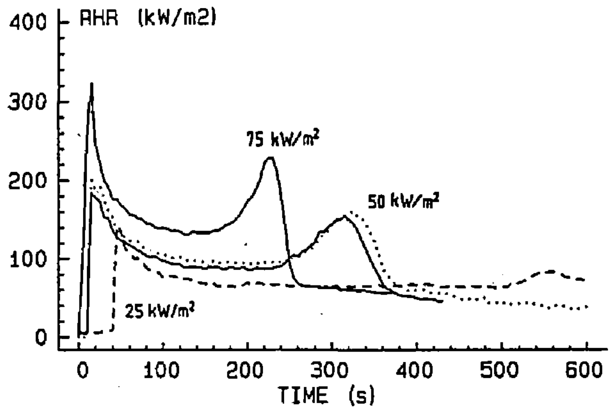


Figure 5. <u>Medium density fiber board</u>
Smoke, gas and heat release data at three heat flux levels. Double tests at 50 kW/m^2. Mass loss rate and effective heat of combustion are also presented.

INSULATING FIBER BOARD



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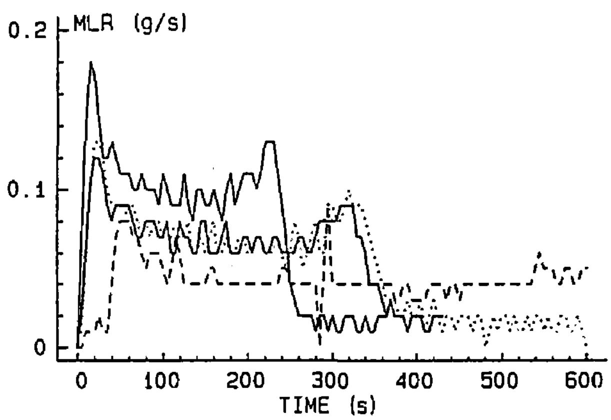
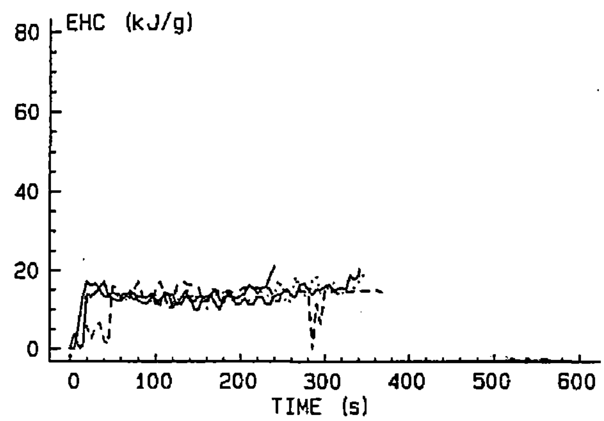
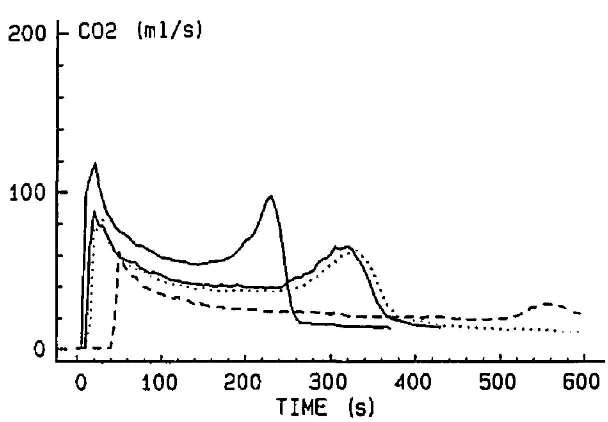
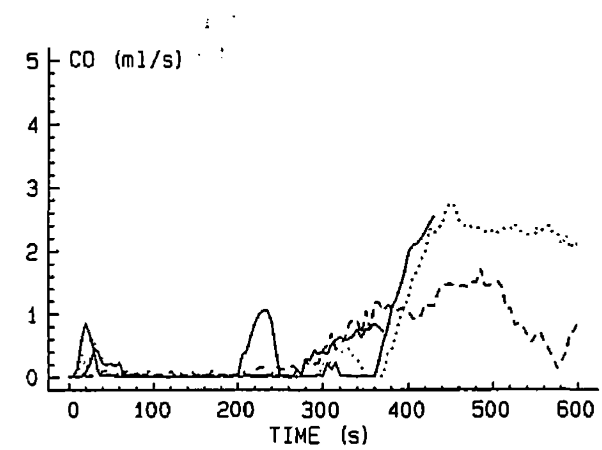








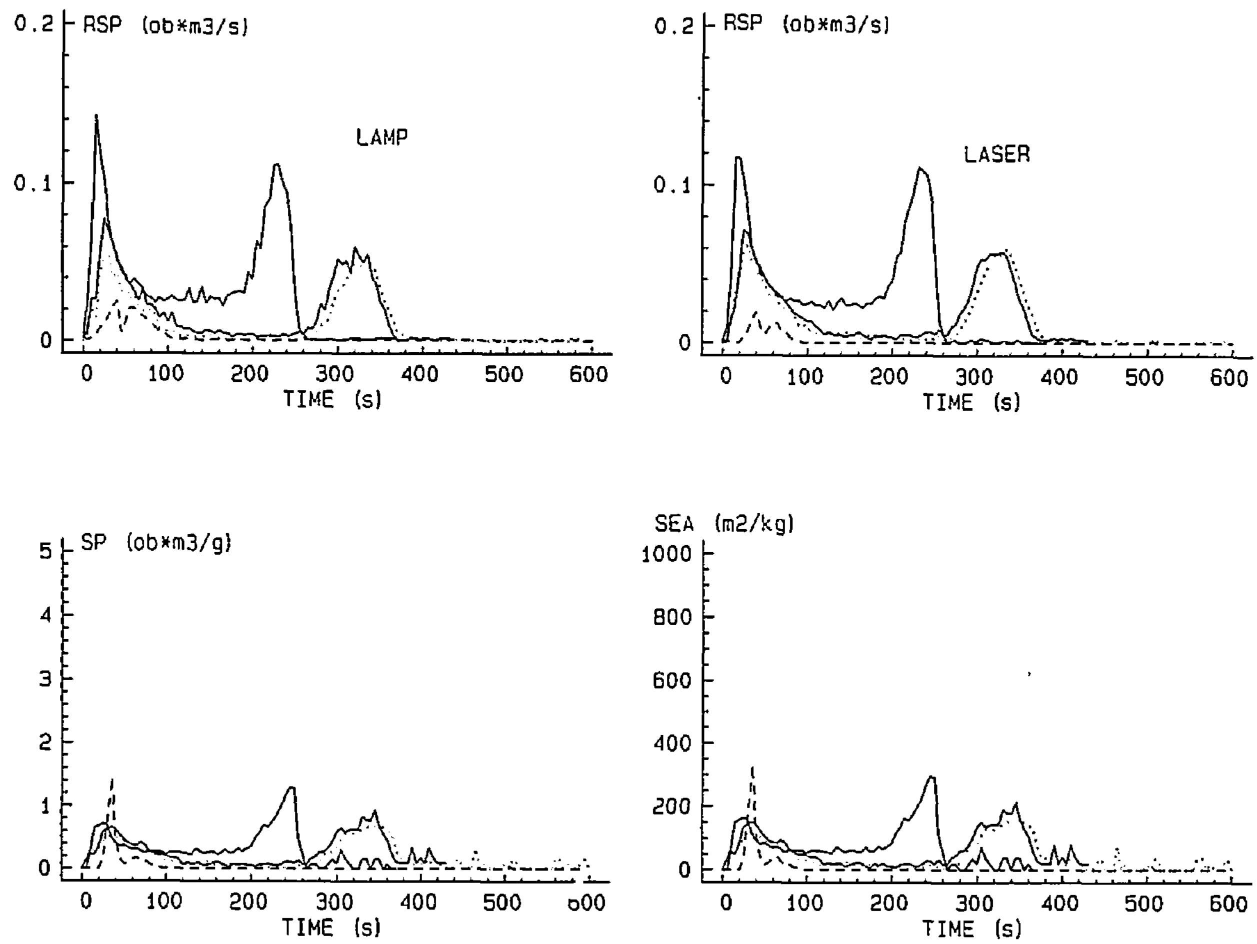
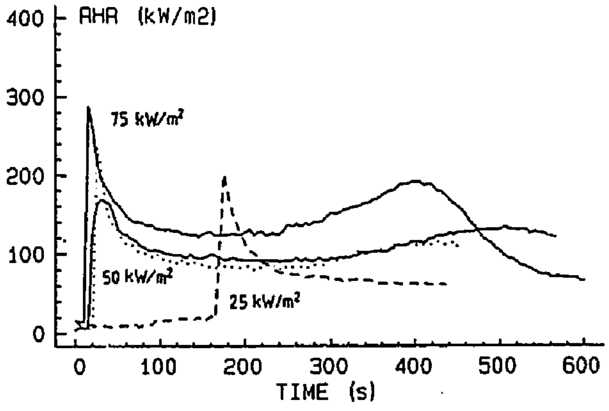


Figure 6. Insulating fiber board
Smoke, gas and heat release data at three heat flux levels. Double tests at 50 kW/m^2. Mass loss rate and effective heat of combustion are also presented.

WOOD PANEL (SPRUCE)



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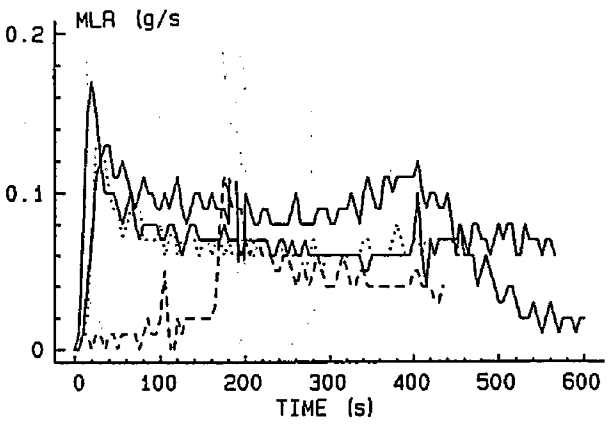
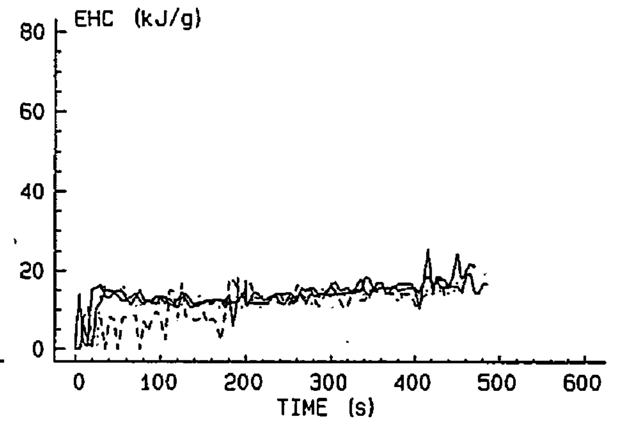
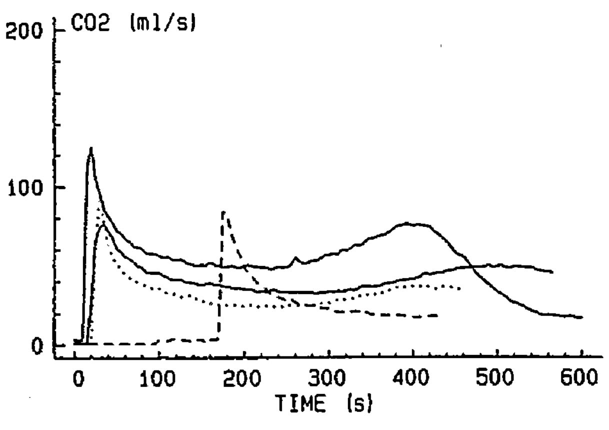
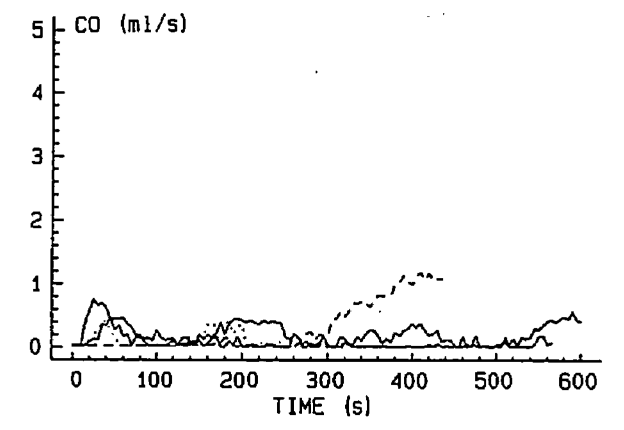








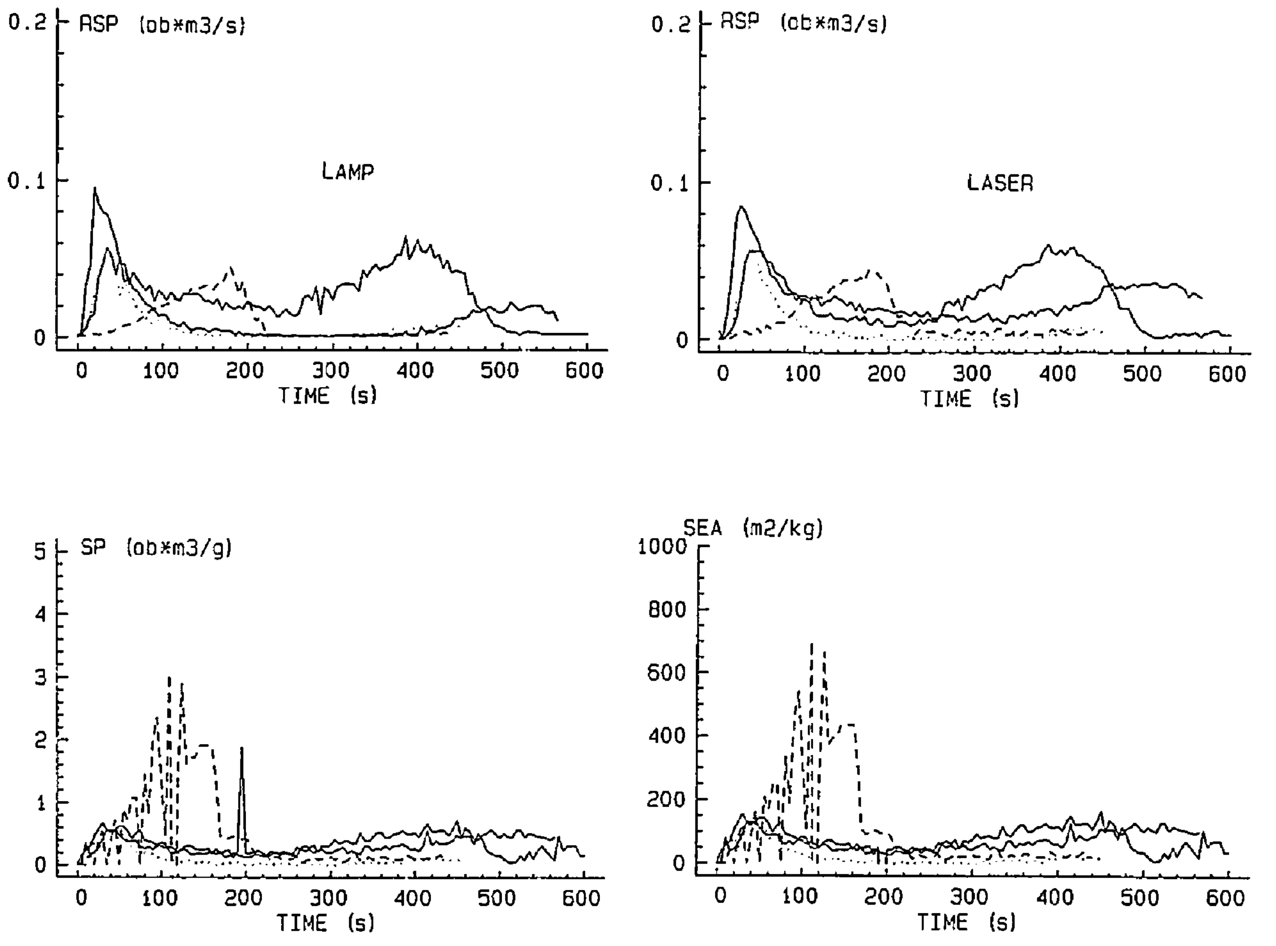
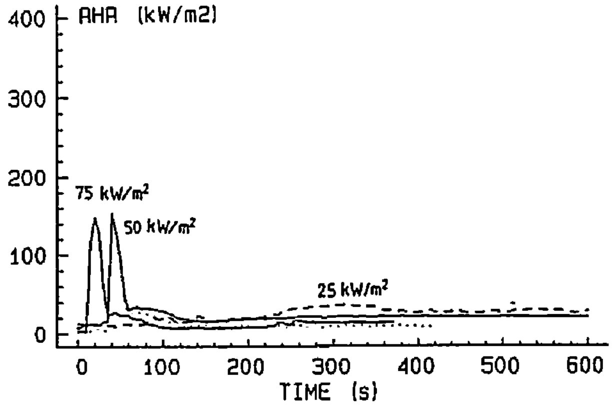


Figure 7. <u>Wood panel (spruce)</u>
Smoke, gas and heat release data at three heat flux levels. Double tests at 50 kW/m^2. Mass loss rate and effective heat of combustion are also presented.

GYPSUM BOARD



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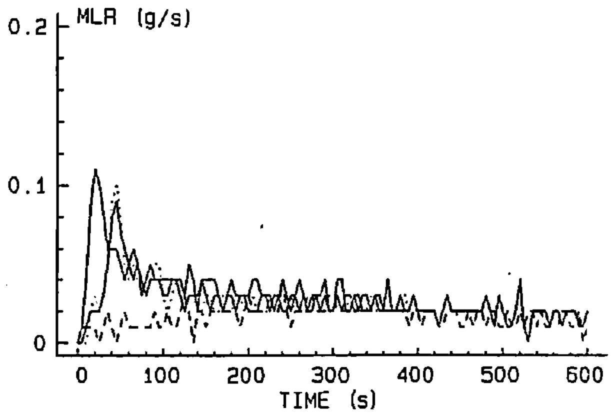
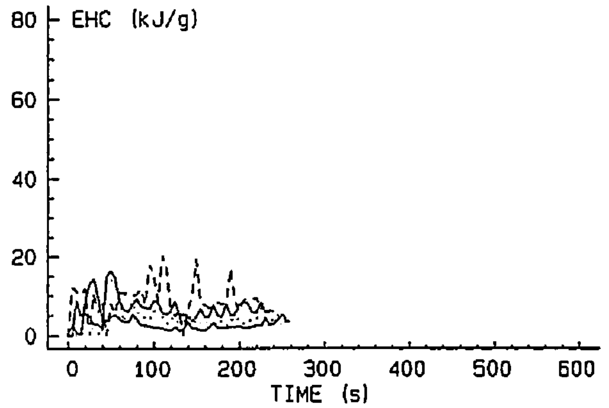
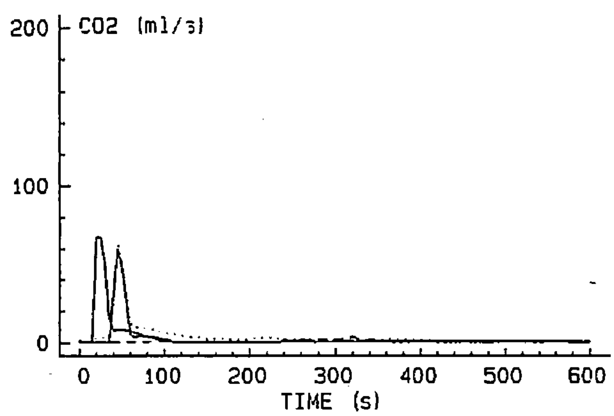
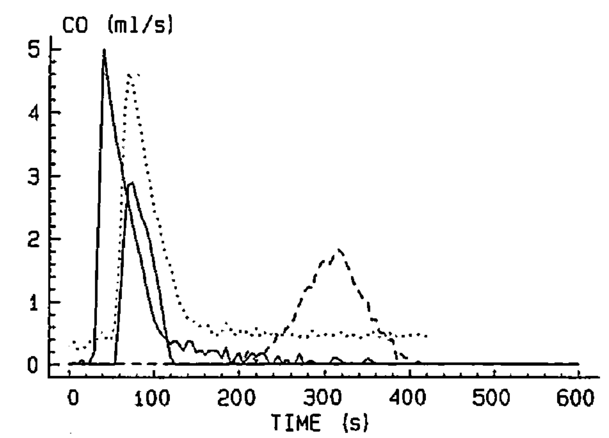








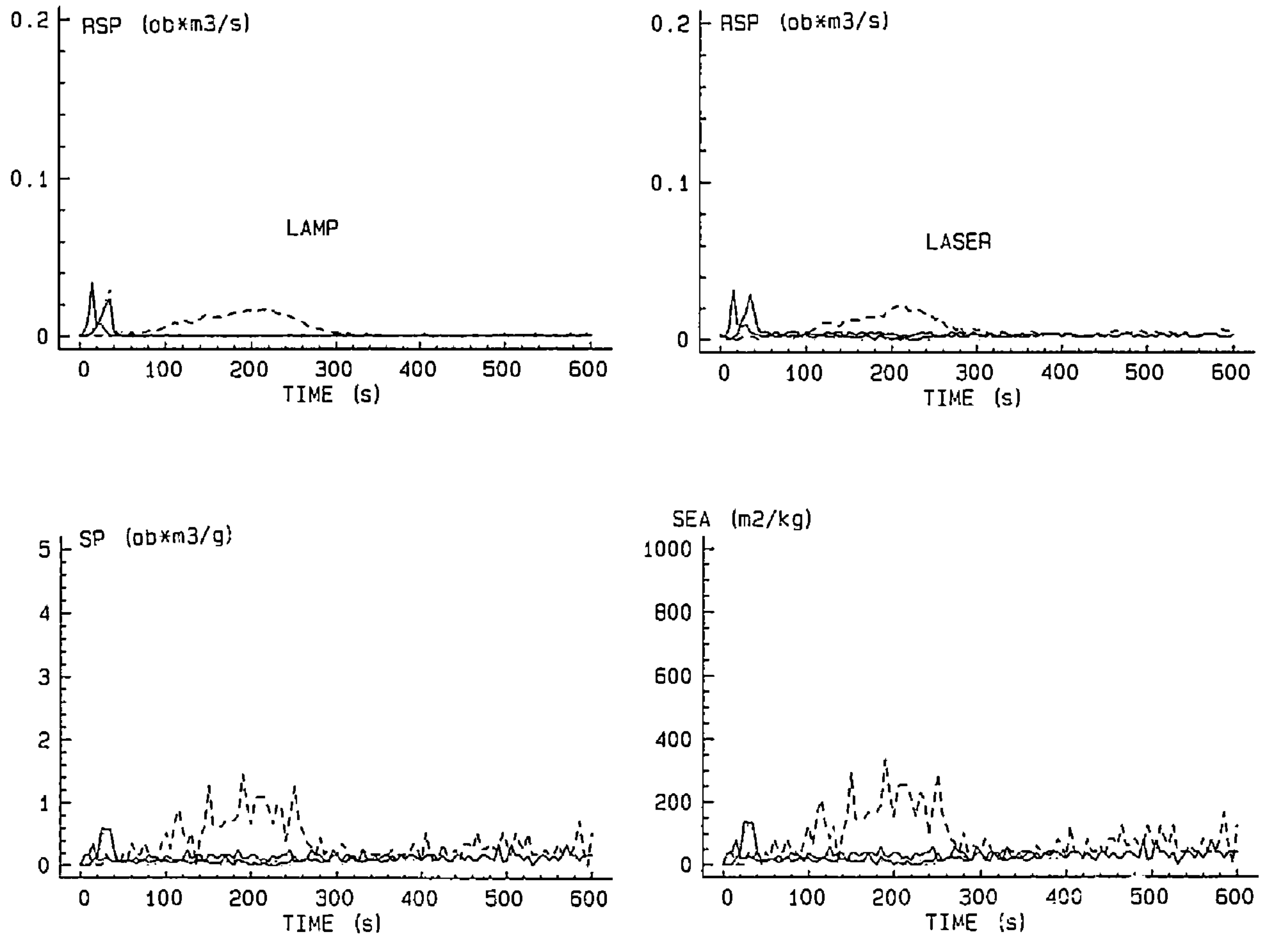
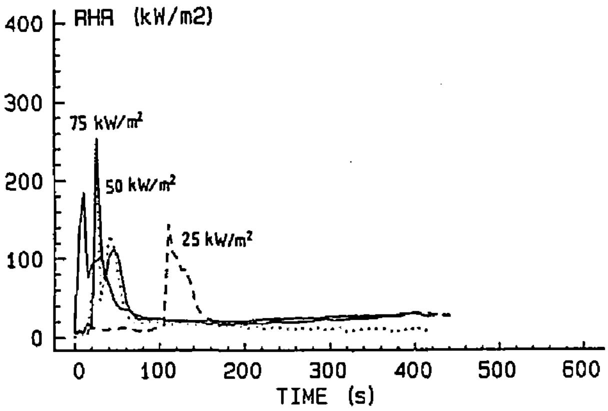


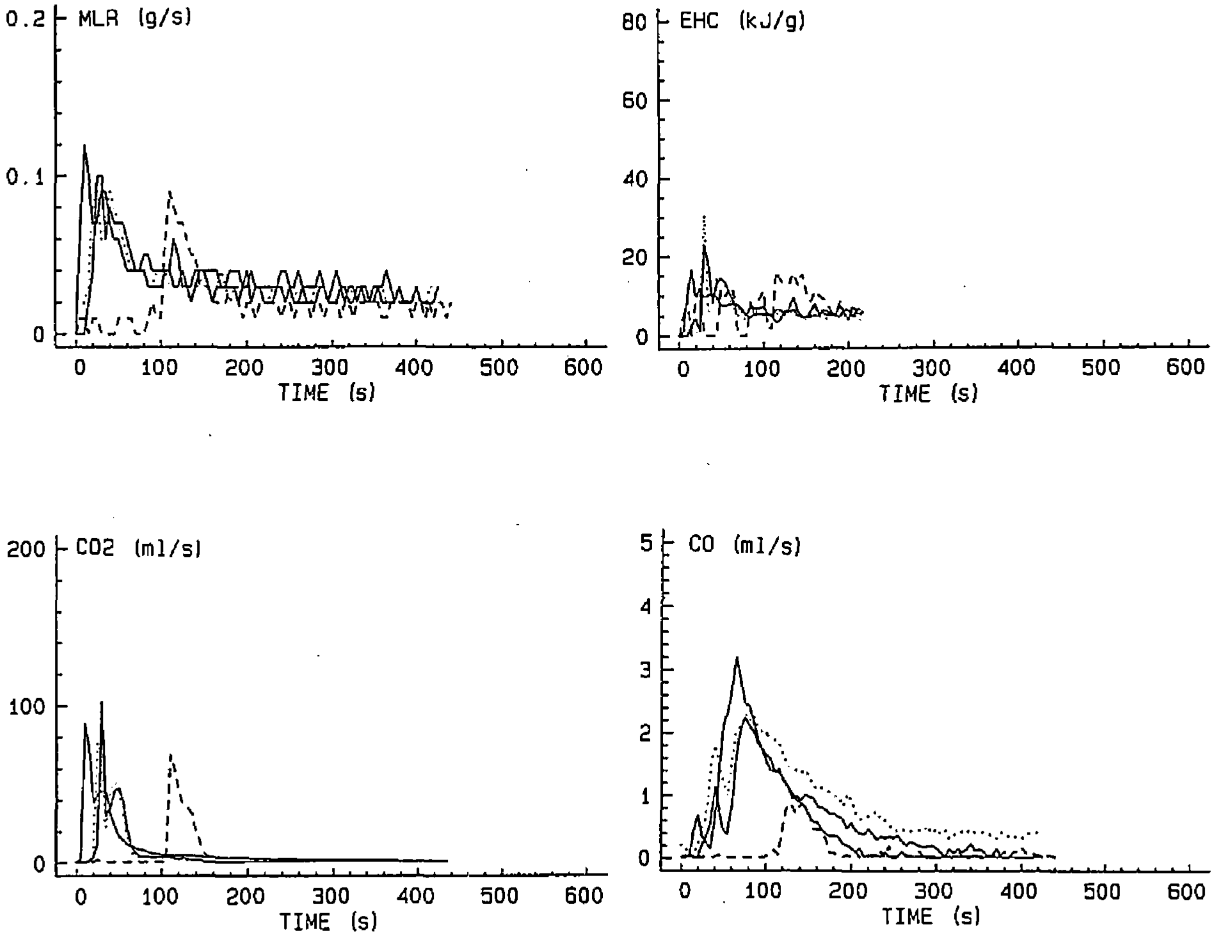
Figure 8. Gypsum board
Smoke, gas and heat release data at three heat flux levels. Double tests at 50 kW/m^2. Mass loss rate and effective heat of combustion are also presented.

PAPER WALL-COVERING ON GYPSUM BOARD



RHR = Rate of heat release
MLR = Mass loss rate
EHC = Effective heat of combustion
CO2 = Carbon dioxide
CO = Carbon monoxide

RSP = Rate of smoke production
SEA = Specific extinction area
SP = Smoke potential



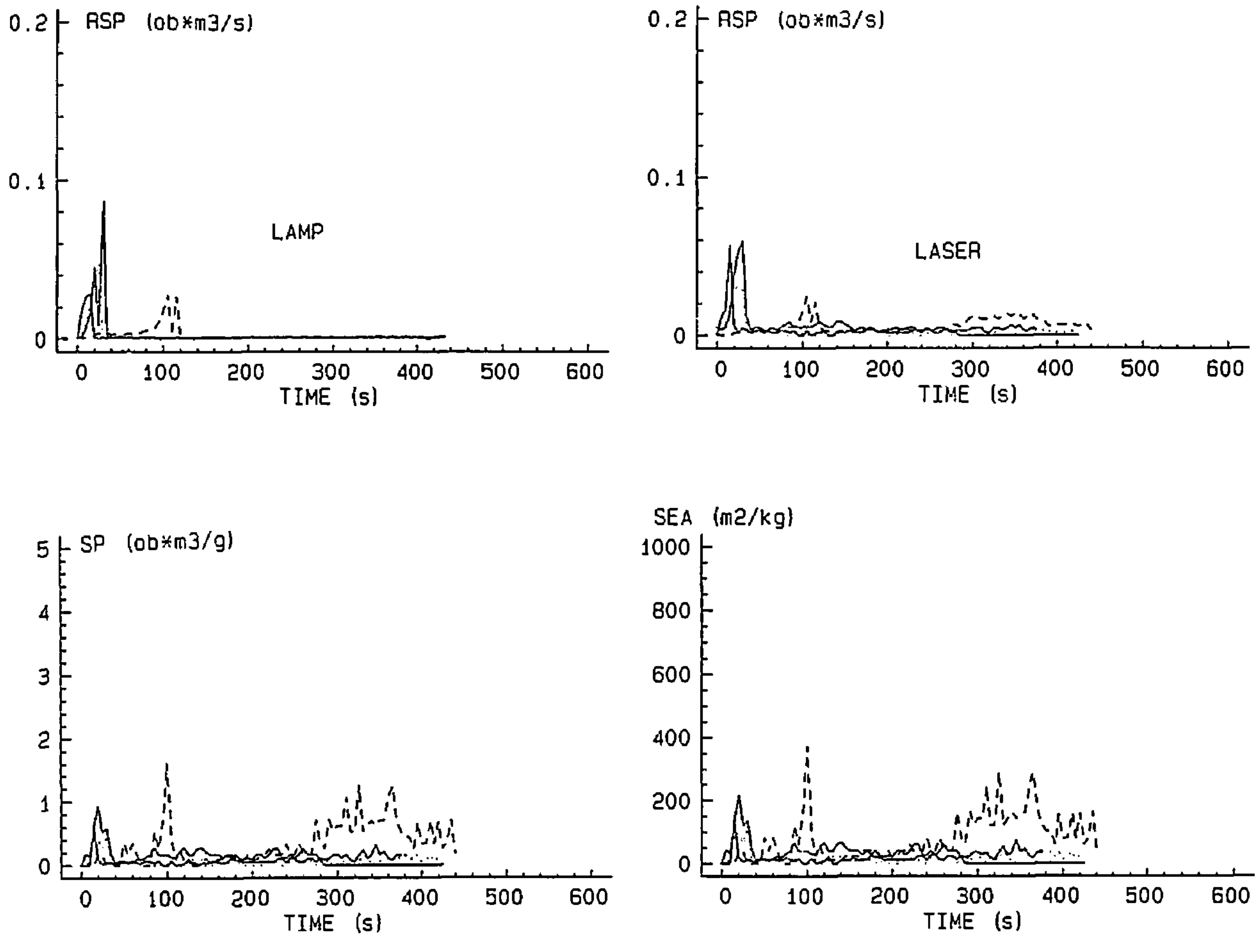
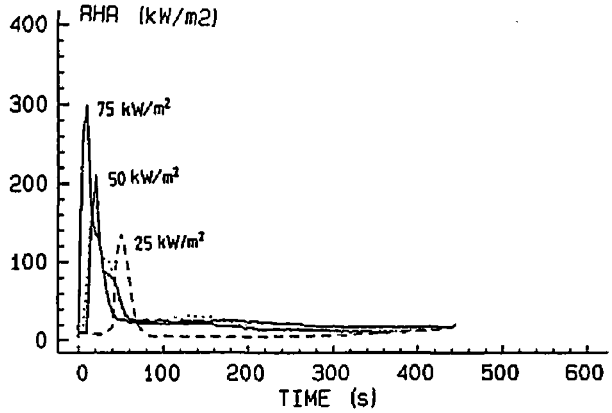
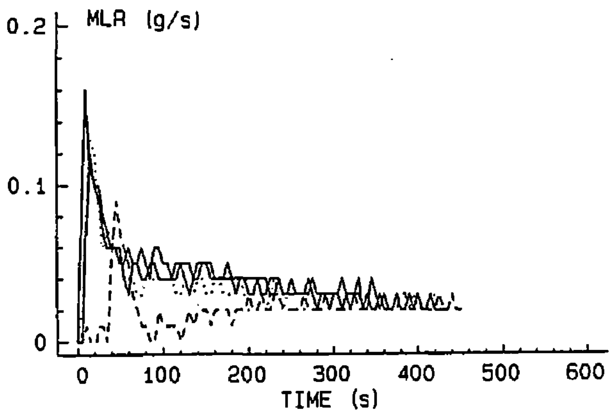


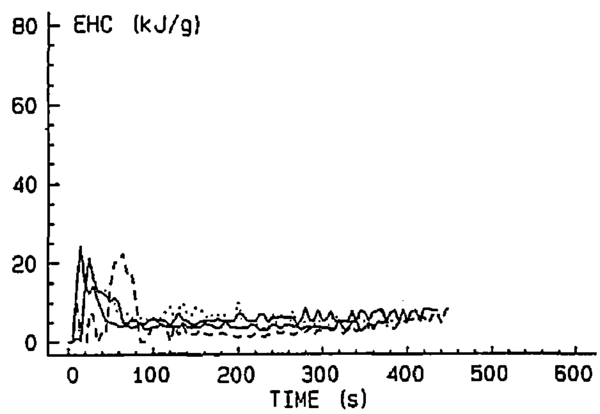
Figure 9. <u>Paper wall-covering on gypsum board</u>
Smoke, gas and heat release data at three heat flux levels. Double tests at 50 kW/m^2. Mass loss rate and effective heat of combustion are also presented.

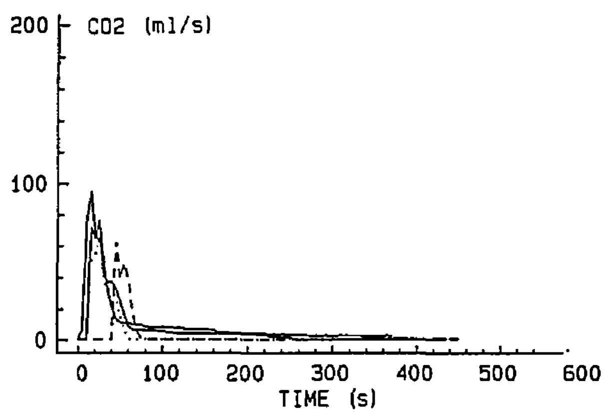


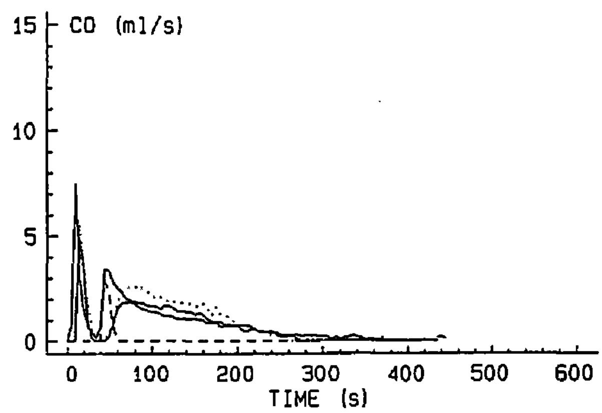
RHR = Rate of heat release
MLR = Mass loss rate
EHC = Effective heat of combustion
CO2 = Carbon dioxide
CO = Carbon monoxide

RSP = Rate of smoke production
SEA = Specific extinction area
SP = Smoke potential









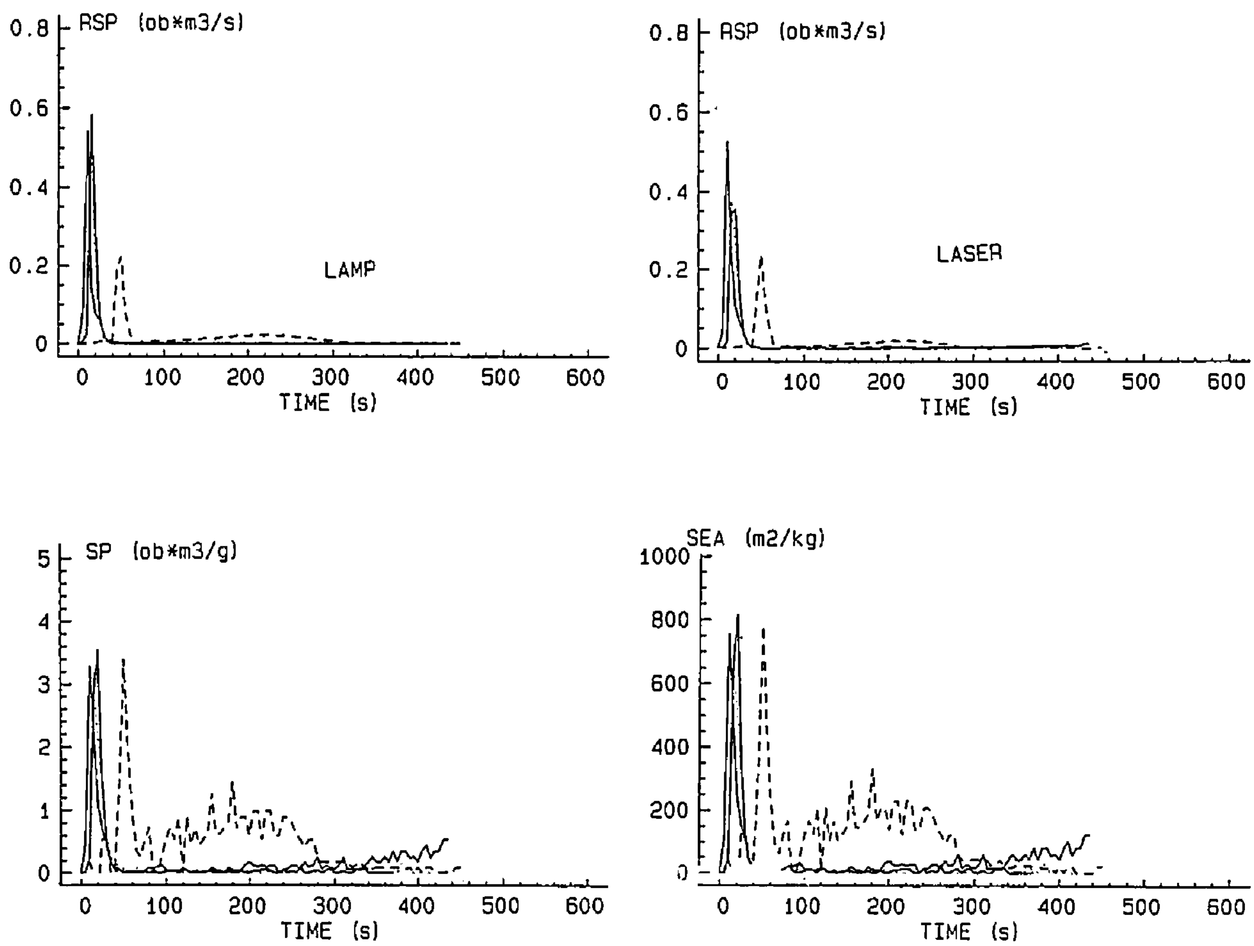
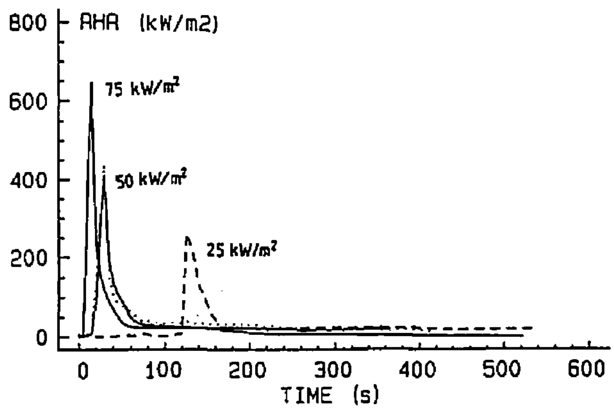


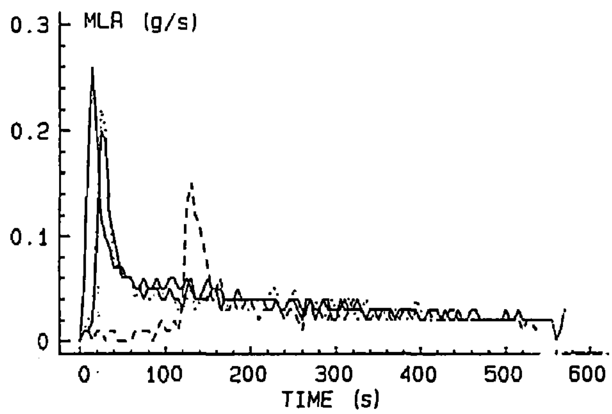
Figure 10. Plastic wall-covering on gypsum board
Smoke, gas and heat release data at three heat flux levels. Double tests at 50 kW/m^2. Mass loss rate and effective heat of combustion are also presented.
Note the different scales in CO production and in RSP.

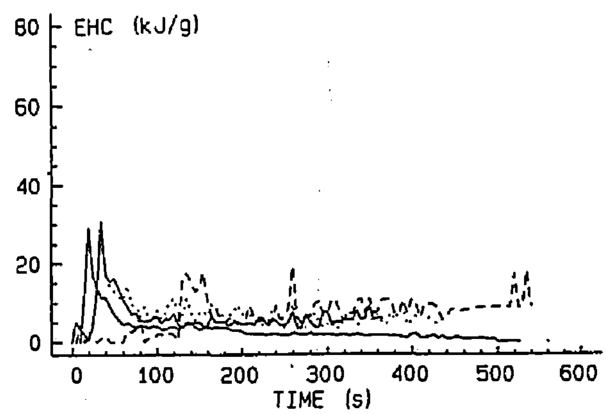
TEXTILE WALL-COVERING ON GYPSUM BOARD

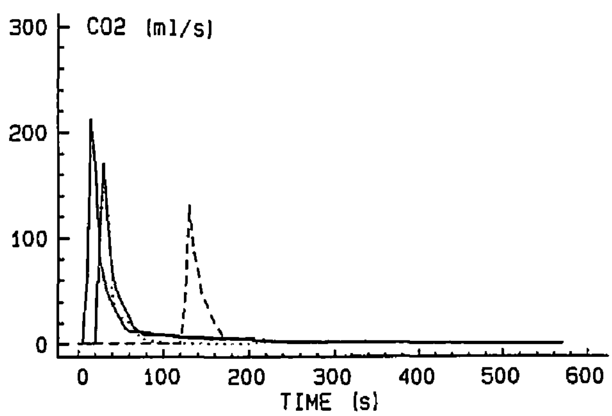


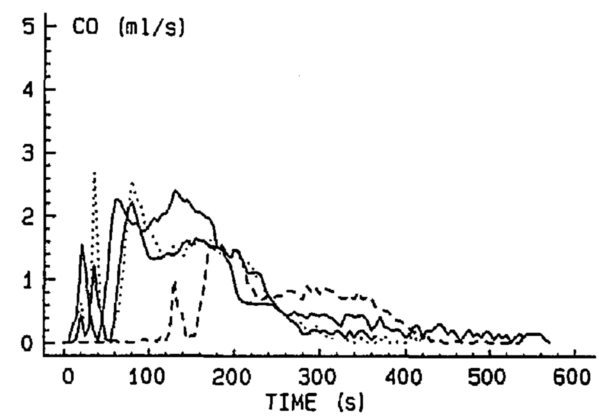
RHR = Rate of heat release
MLR = Mass loss rate
EHC = Effective heat of combustion
CO2 = Carbon dioxide
CO = Carbon monoxide

RSP = Rate of smoke production
SEA = Specific extinction area
SP = Smoke potential









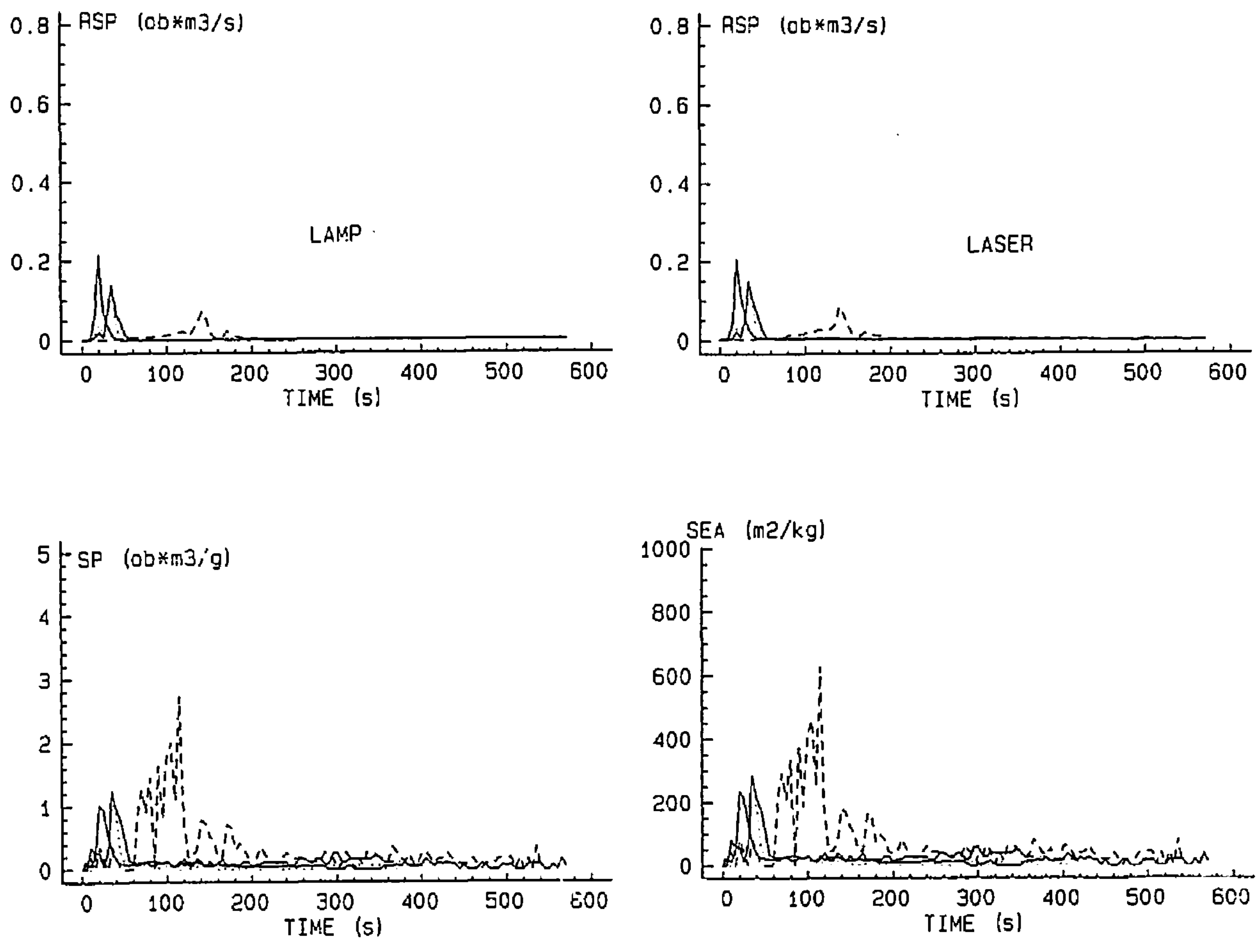
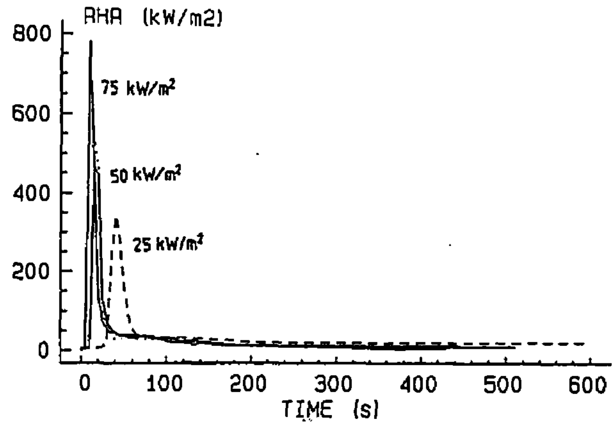


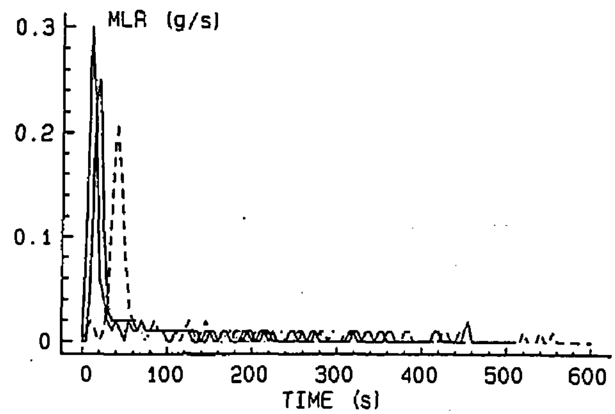
Figure 11. Textile wall-covering on gypsum board
Smoke, gas and heat release data at three heat flux levels. Double tests at 50 kW/m^2. Mass loss rate and effective heat of combustion are also presented.
Note the different scales in RHR, MLR, CO2 production and in RSP.

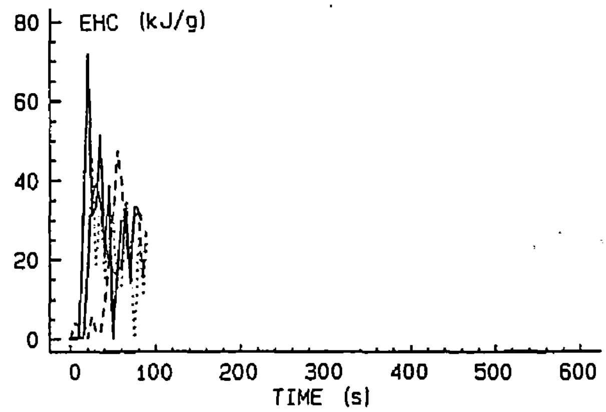
TEXTILE WALL-COVERING ON ROCK-WOOL

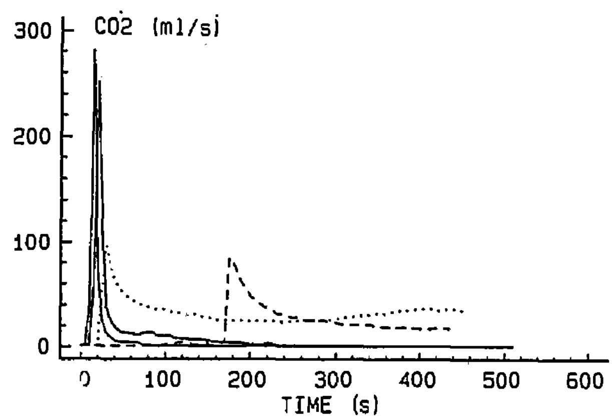


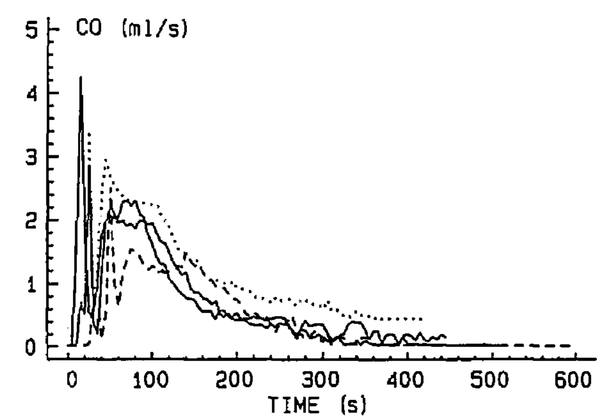
RHR = Rate of heat release
MLR = Mass loss rate
EHC = Effective heat of combustion
CO2 = Carbon dioxide
CO = Carbon monoxide

RSP = Rate of smoke production
SEA = Specific extinction area
SP = Smoke potential









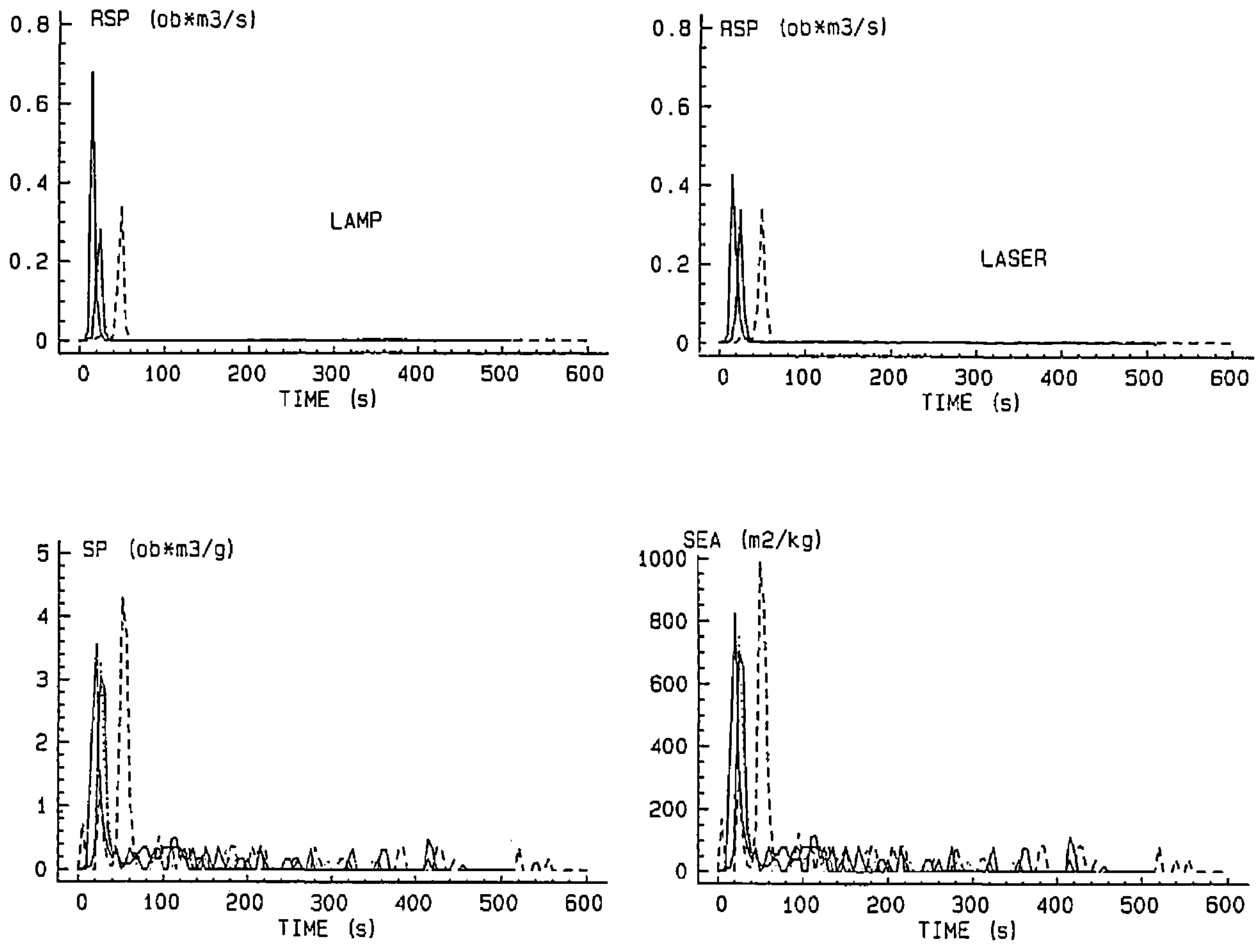
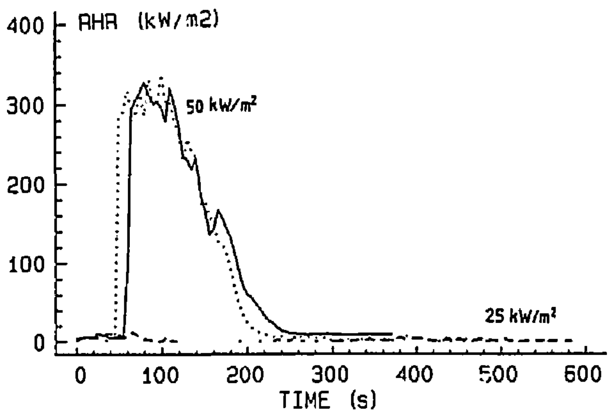


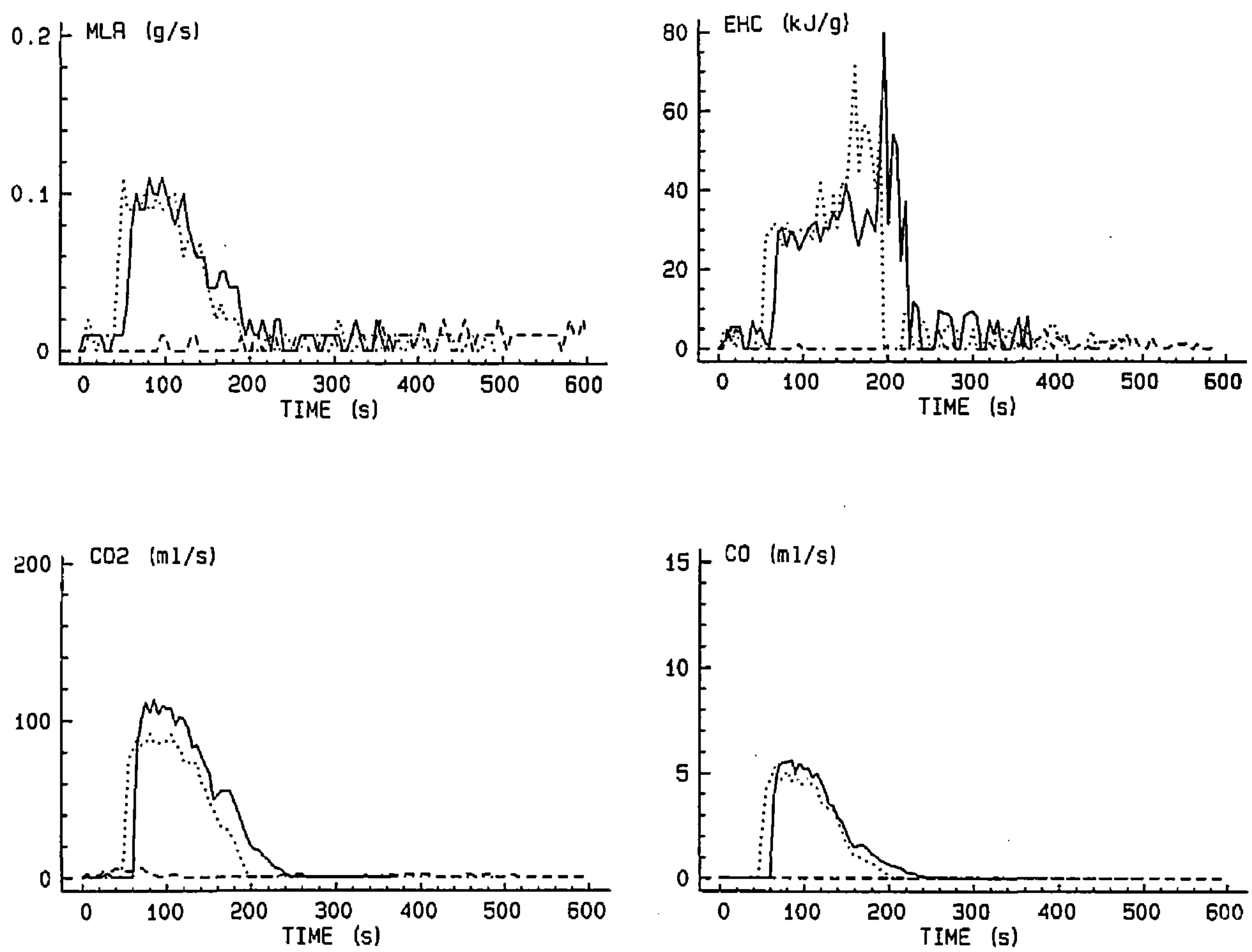
Figure 12. <u>Textile wall-covering on rock-wool</u>
Smoke, gas and heat release data at three heat flux levels. Double tests at 50 kW/m^2. Mass loss rate and effective heat of combustion are also presented.
Note the different scales in RHR, MLR, CO2 production and in RSP.

EXPANDED POLYSTYRENE



RHR = Rate of heat release
MLR = Mass loss rate
EHC = Effective heat of combustion
CO2 = Carbon dioxide
CO = Carbon monoxide

RSP = Rate of smoke production
SEA = Specific extinction area
SP = Smoke potential



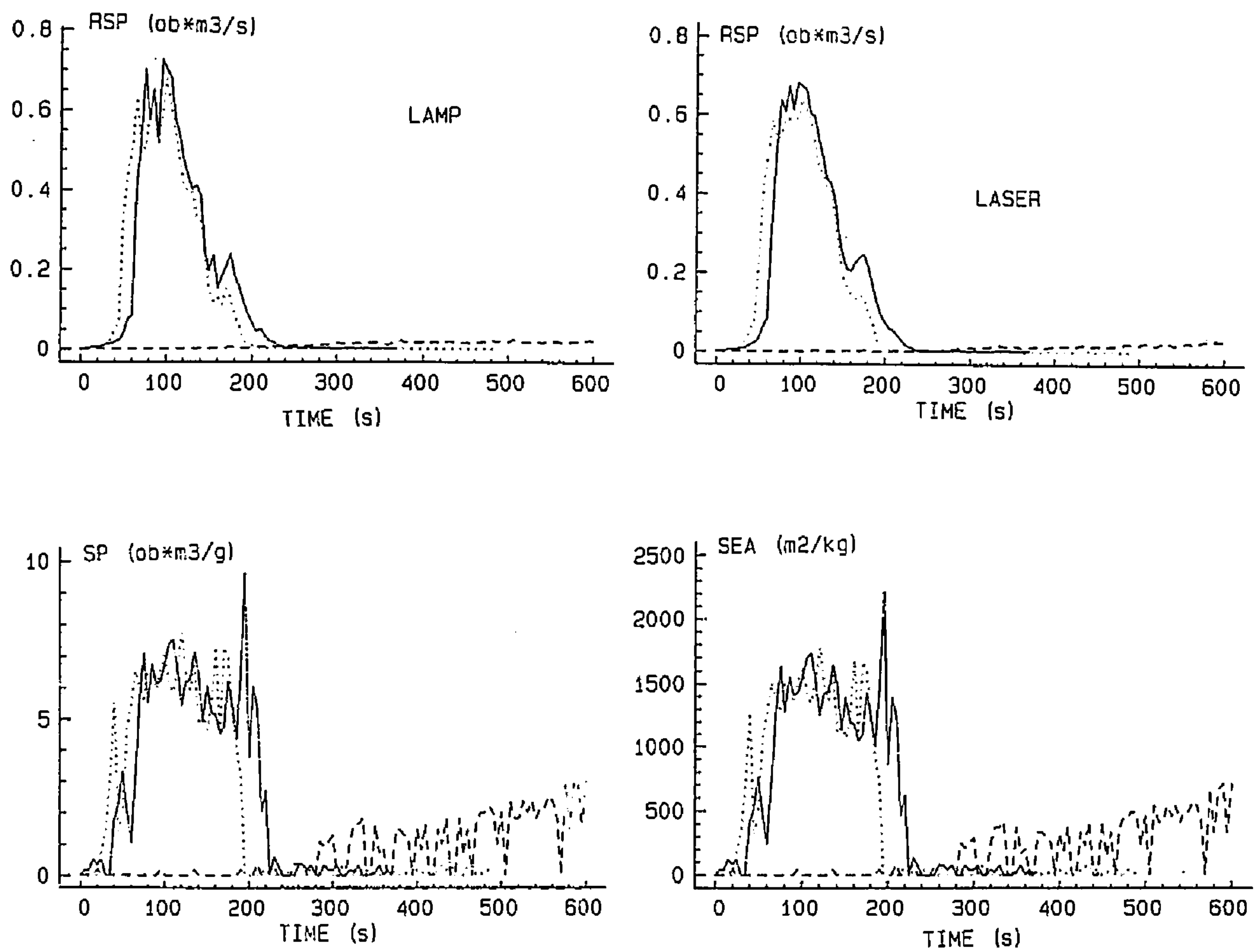
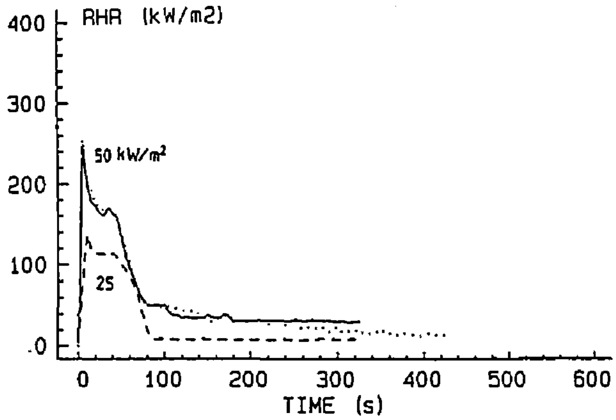


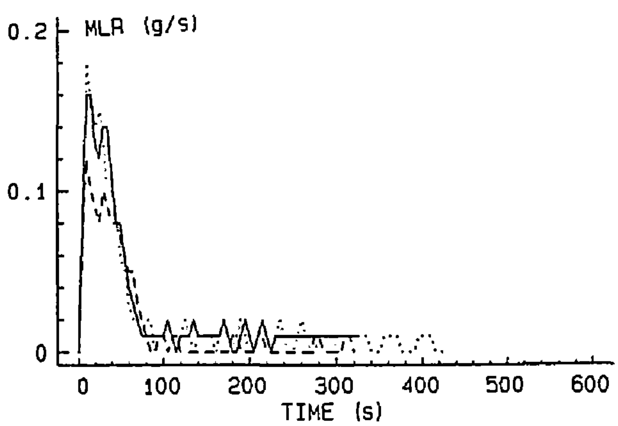
Figure 13. Expanded polystyrene
Smoke, gas and heat release data at two heat flux levels. Double tests at 50 kW/m^2. Mass loss rate and effective heat of combustion are also presented.
Note the different scales in CO production, RSP, SP and in SEA.

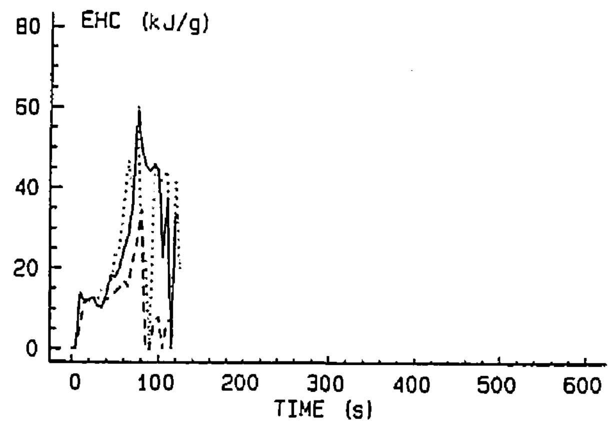
RIGID POLYURETHANE FOAM

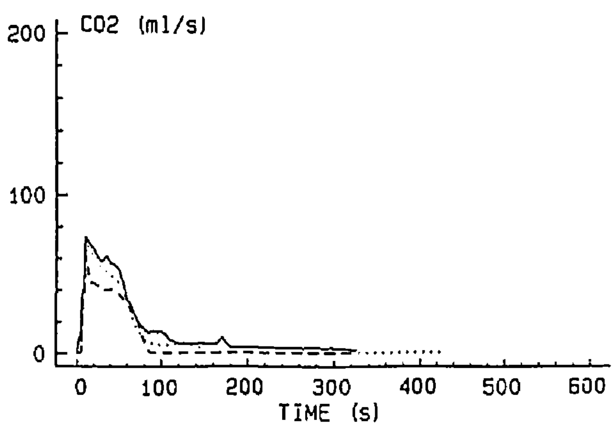


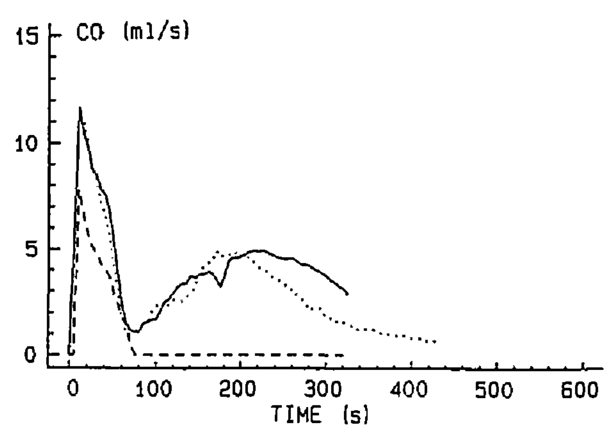
RHR = Rate of heat release
MLR = Mass loss rate
EHC = Effective heat of combustion
CO2 = Carbon dioxide
CO = Carbon monoxide

RSP = Rate of smoke production
SEA = Specific extinction area
SP = Smoke potential









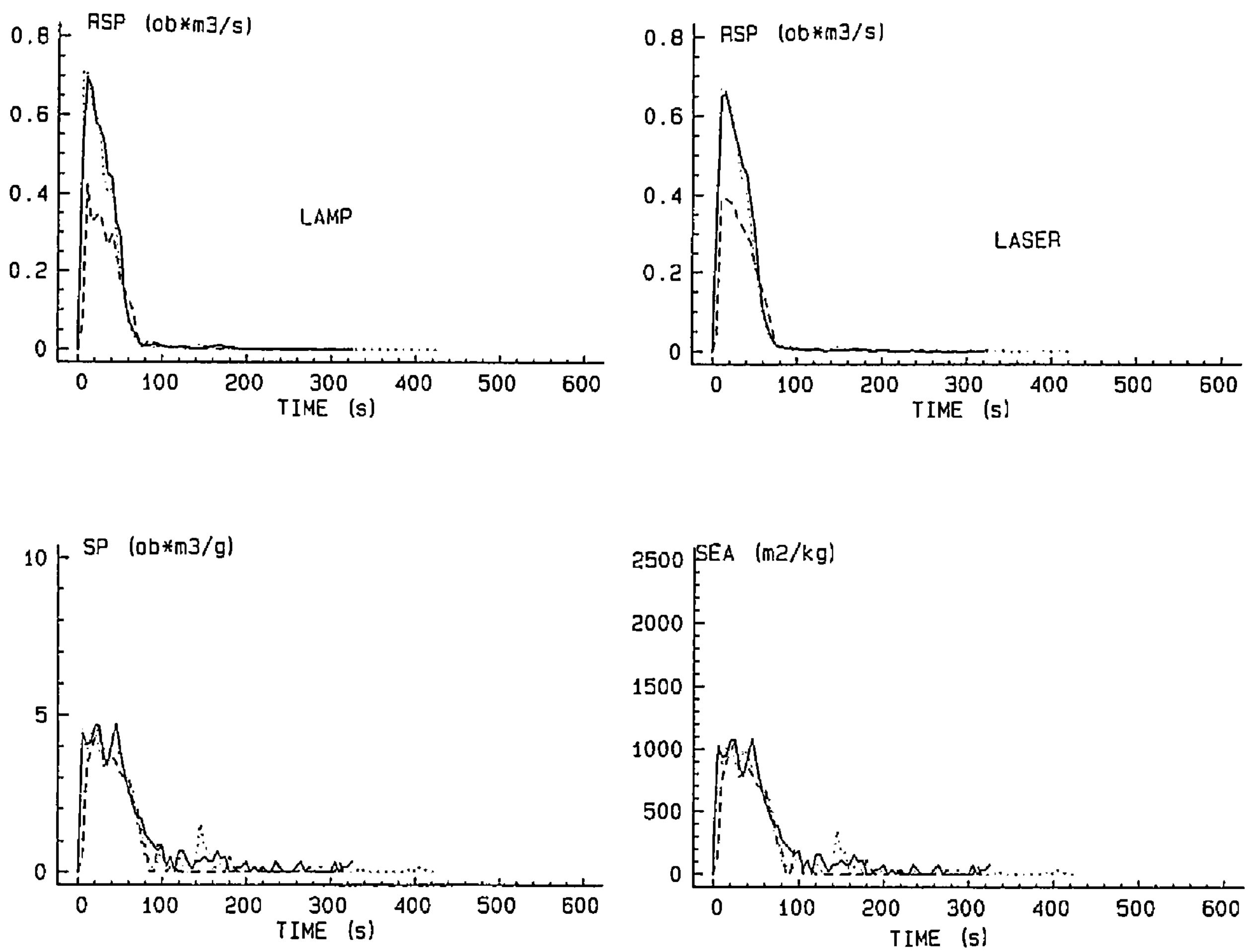
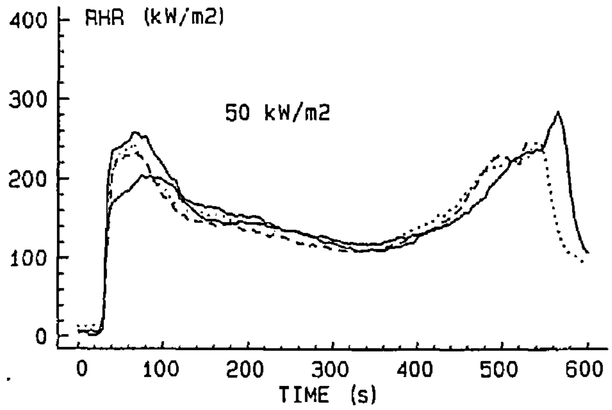


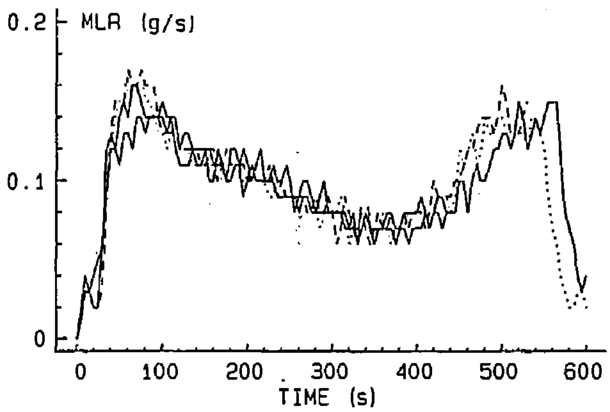
Figure 14. <u>Rigid polyurethane foam</u>
Smoke, gas and heat release data at two heat flux levels. Double tests at 50 kW/m^2. Mass loss rate and effective heat of combustion are also presented.
Note the different scales in CO production, RSP, SP and in SEA.

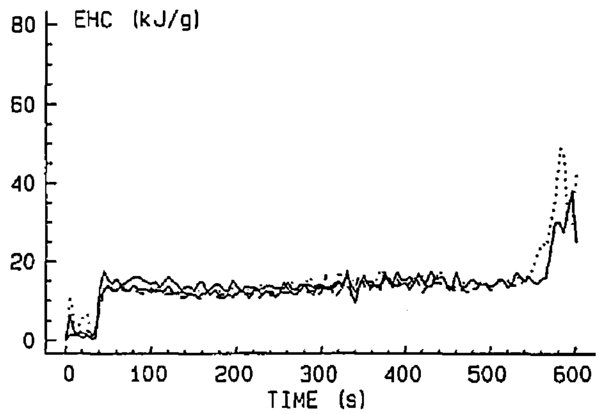
PARTICLE BOARD

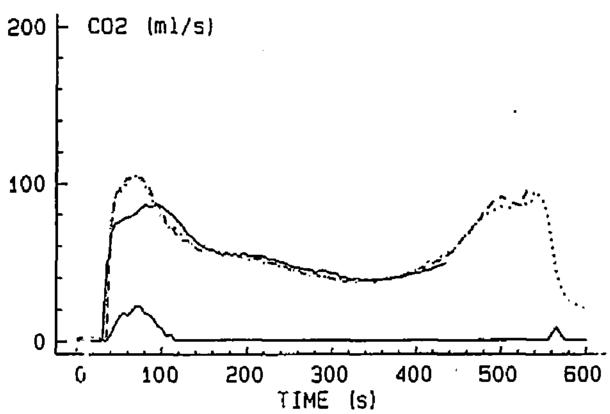


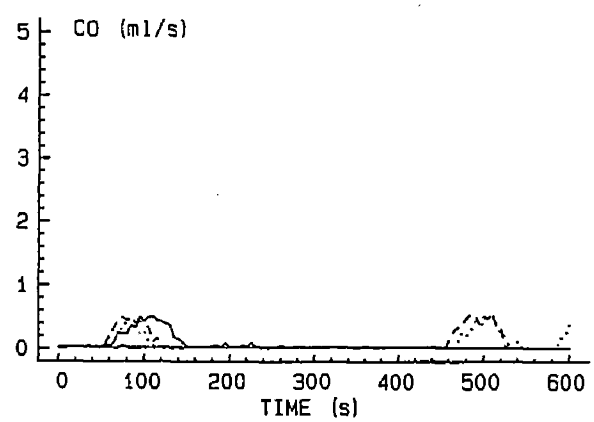
RHR = Rate of heat release
MLR = Mass loss rate
EHC = Effective heat of combustion
CO2 = Carbon dioxide
CO = Carbon monoxide

RSP = Rate of smoke production
SEA = Specific extinction area
SP = Smoke potential









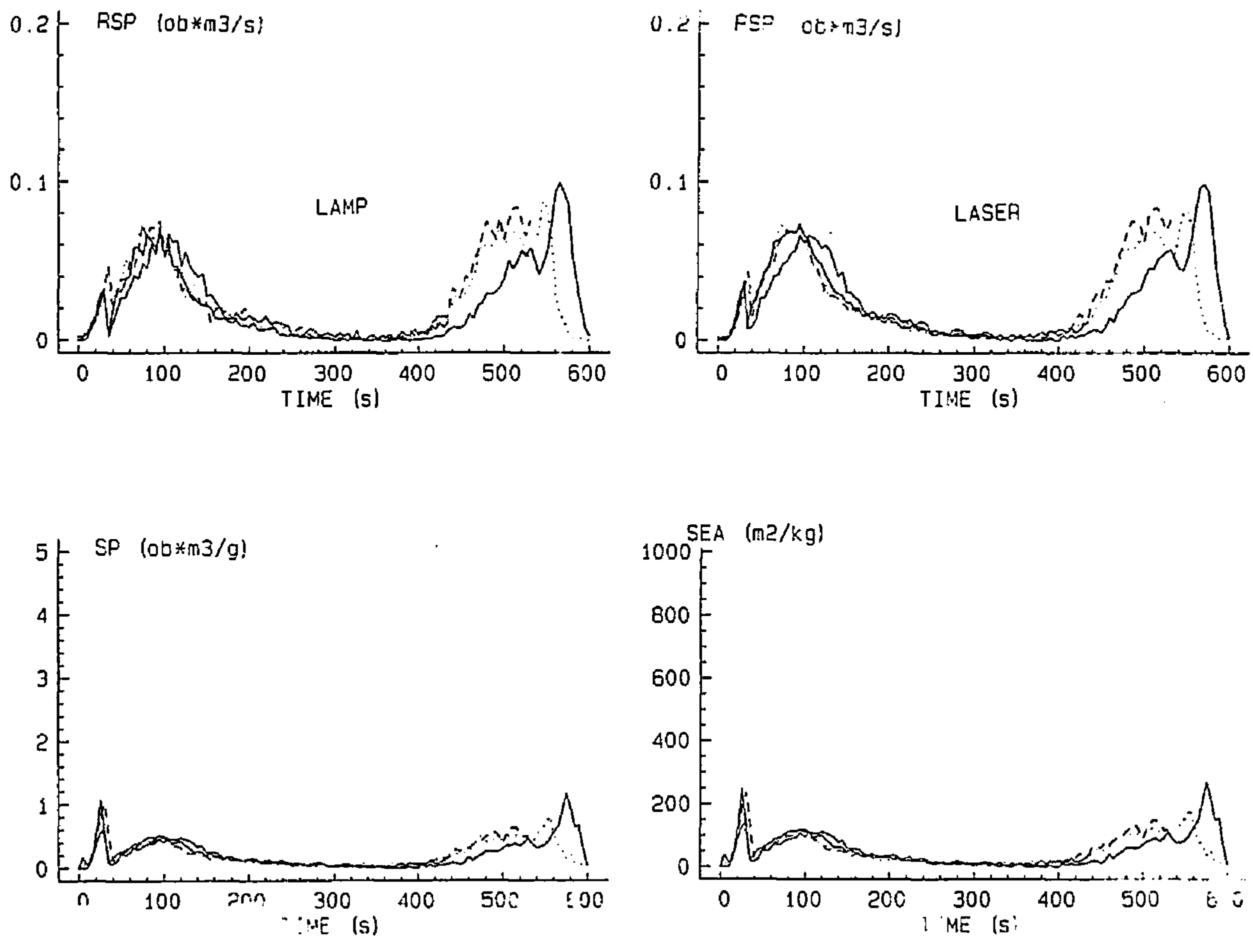


Figure 15. Repeatability for particle board
Smoke, gas and heat release data at 50 kW/m^2. Four tests performed on different days. Mass loss rate and effective heat of combustion are also presented.

Repeatability

The repeatability is good for most of the products. When some minor differences appear in rate of heat release, differences also appear in rate of smoke and gas production. Particle board in Figure 15 is one illustrative example of such differences.

Double tests at 50 kW/m^2 for all tested products are also shown in Figures 2 to 14. In spite of the generally good repeatability, at least double tests are recommended.

Smoke production in relation to different parameters

It may be of interest to study how the smoke production is related to other fire parameters measured in the cone calorimeter a bit further. Three examples are given below.

The rate of smoke production divided by the rate of heat release as shown in Figure 16 have a characteristic peak just before ignition. Then the curves have an almost plane appearance. The smoke is released just before ignition and the heat just after ignition. This explains the peak. Table 4 shows average RSP/RHR values after the characteristic peak at 50 kW/m^2 heat flux. This ratio is in the order of 15 to 35 for most products except those containing mainly synthetic polymers, which have ratios 100 to 200. A higher ratio indicates a higher smoke release in relation to the heat release.

Figure 17 presents the rate of smoke production divided by the carbon monoxide production. The RSP/CO curves have a peak, like the RSP/RHR curves, for some products but for others the curves have a more irregular appearance. The smoke is usually released before the release of carbon monoxide. This explains the peak before ignition for some products. For the other products the peak after ignition appears when the CO decreases to near zero. An average RSP/CO ratio in the order of 0.1 to 2 is obtained for most products. A lower average ratio is obtained only for rigid polyurethane foam, indicating a high CO release in relation to smoke release for this product.

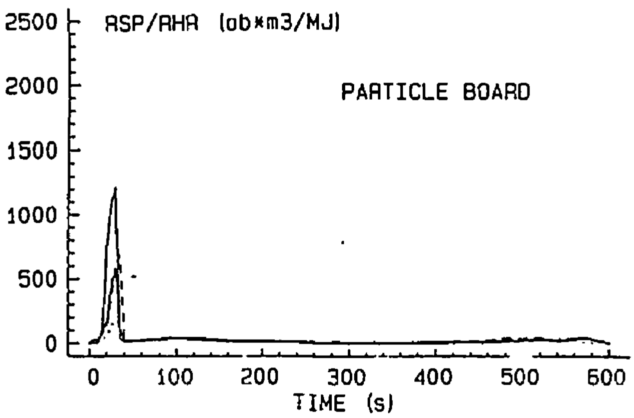
Finally, the carbon dioxide production divided by the carbon monoxide production curves shown in Figure 18 have a similar appearance as the RSP/CO curves. The average ratio is in this case usually in the order of 100 to 2000, again with the exception of rigid polyurethane foam which has a ratio of less than 10, indicating a high release of CO also in relation to CO_2.

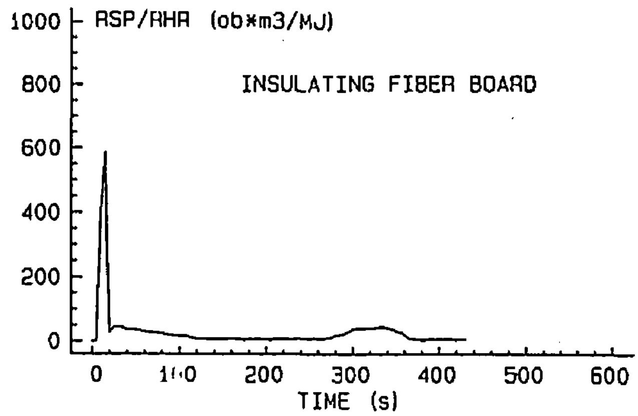
Table 4. Time to ignition at three heat fluxes and average RSP/RHR after peak near ignition.

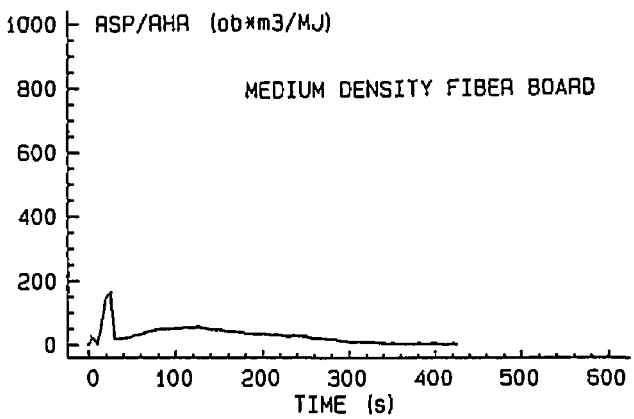
Product	Time to ignition (s)			Average RSP/RHR after peak near ignition ($ob \cdot m^3/MJ$)
	Heat flux, kW/m^2			
	25	50[a]	75	50
Particle board	123	34	16	21
Insulating fiber board	43	12	6	26
Medium density fiber board	123	28	14	34
Wood panel (spruce)	169	21	11	22
Melamine-faced particle board	NI	42	12	201
Gypsum board	NI	34	13	16
Paper wall-covering on gypsum board	106	21	6	26
Plastic wall-covering on gypsum board	41	10	4	29
Textile wall-covering on gypsum board	115	20	7	26
Textile wall-covering on rock-wool	30	11	9	26
Paper wall-covering on particle board	139	27	12	16
Rigid polyurethane foam	4	2	NT	139
Expanded polystyrene	NI	52	NT	111

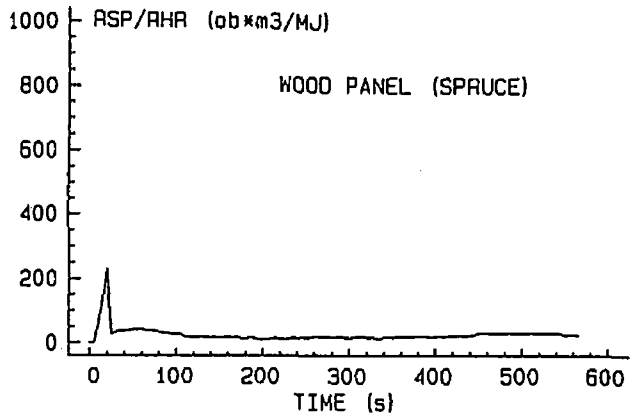
a) Time to ignition is mean value from double tests at 50 kW/m^2.

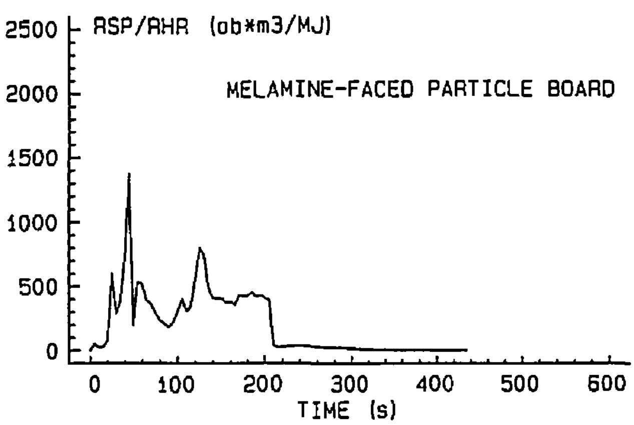
NI = No ignition.
NT = Not tested.

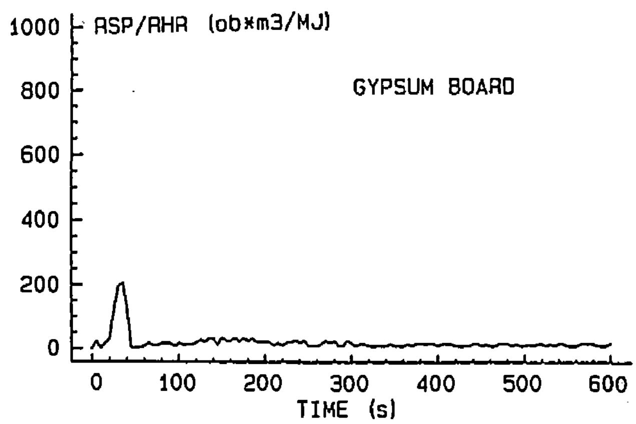

RSP/RHR (ob*m3/MJ)
PARTICLE BOARD
TIME (s)

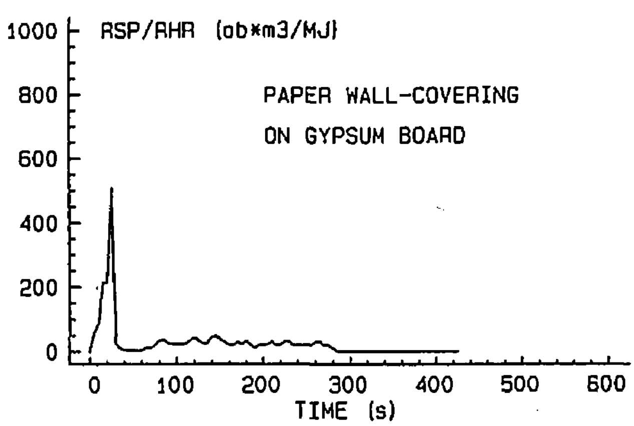

RSP/RHR (ob*m3/MJ)
INSULATING FIBER BOARD
TIME (s)


RSP/RHR (ob*m3/MJ)
MEDIUM DENSITY FIBER BOARD
TIME (s)


RSP/RHR (ob*m3/MJ)
WOOD PANEL (SPRUCE)
TIME (s)


RSP/RHR (ob*m3/MJ)
MELAMINE-FACED PARTICLE BOARD
TIME (s)


RSP/RHR (ob*m3/MJ)
GYPSUM BOARD
TIME (s)


RSP/RHR (ob*m3/MJ)
PAPER WALL-COVERING
ON GYPSUM BOARD
TIME (s)

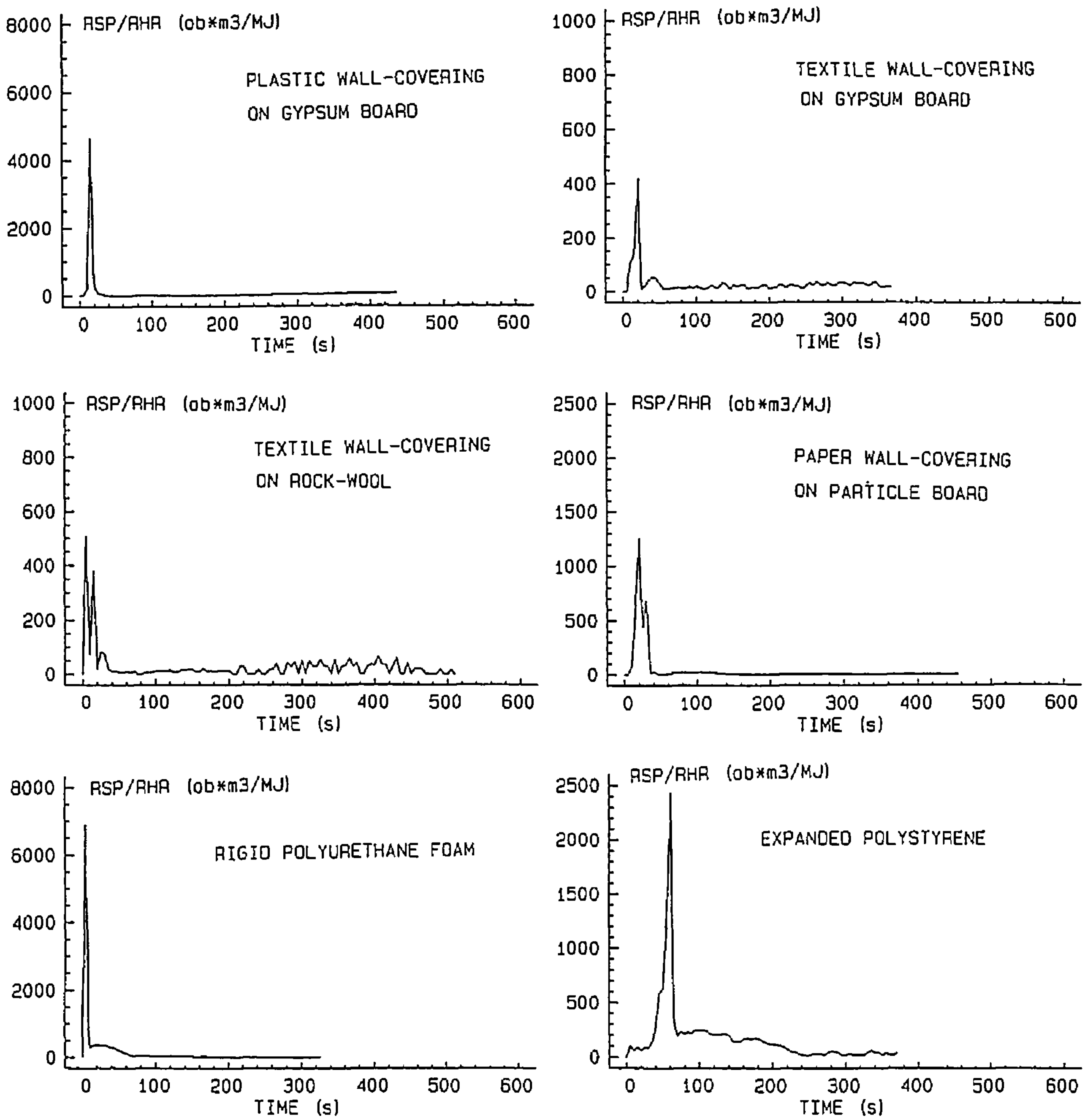
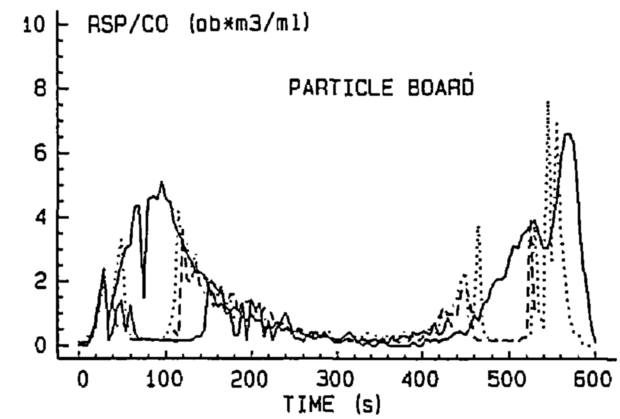
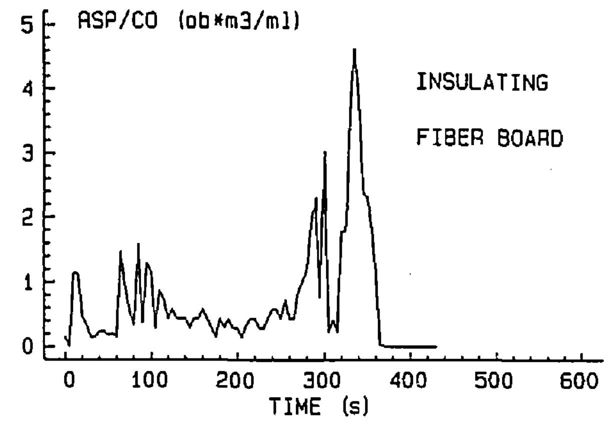
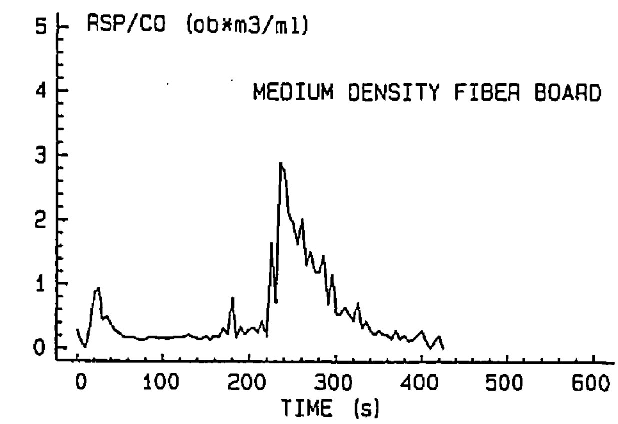
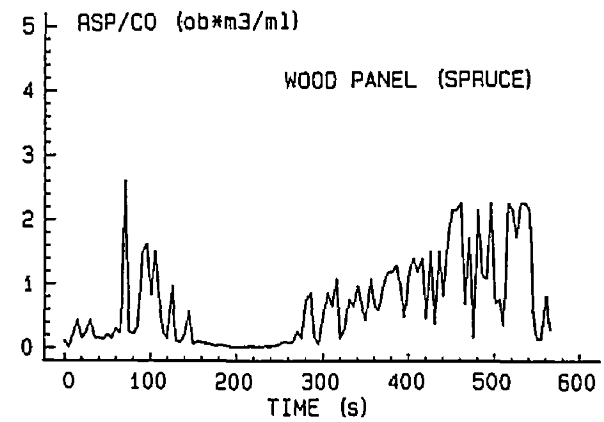


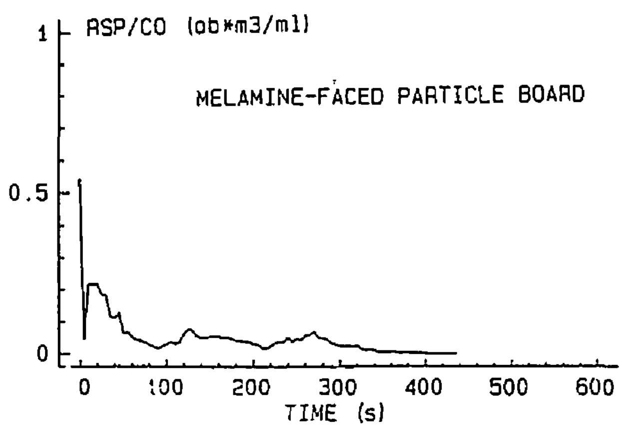
Figure 16. The rate of smoke production (RSP) divided by the rate of heat release (RHR) at 50 kW/m^2 for the 13 building products. Note the different scales.

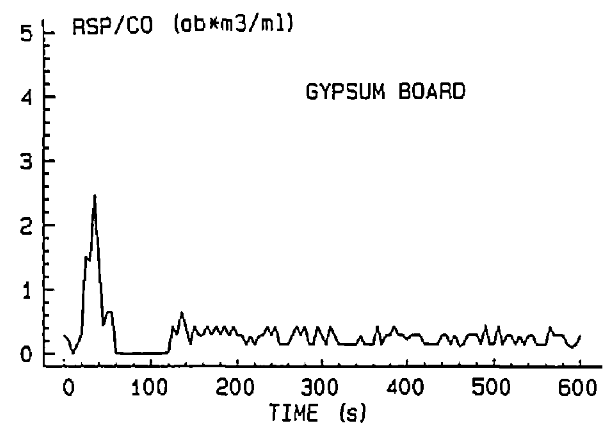

RSP/CO (ob*m3/ml)
PARTICLE BOARD
TIME (s)

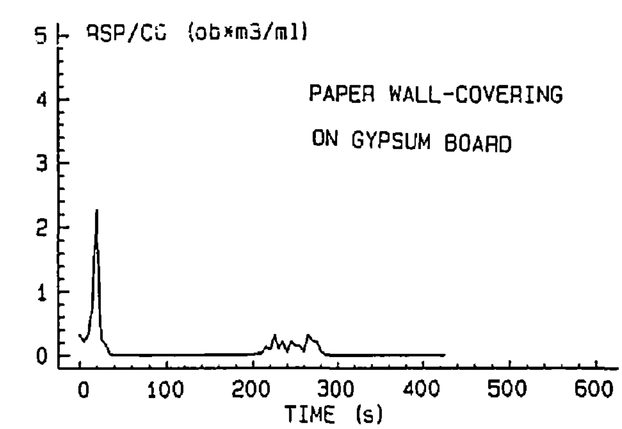

RSP/CO (ob*m3/ml)
INSULATING
FIBER BOARD
TIME (s)


RSP/CO (ob*m3/ml)
MEDIUM DENSITY FIBER BOARD
TIME (s)


RSP/CO (ob*m3/ml)
WOOD PANEL (SPRUCE)
TIME (s)


RSP/CO (ob*m3/ml)
MELAMINE-FACED PARTICLE BOARD
TIME (s)


RSP/CO (ob*m3/ml)
GYPSUM BOARD
TIME (s)


RSP/CO (ob*m3/ml)
PAPER WALL-COVERING
ON GYPSUM BOARD
TIME (s)

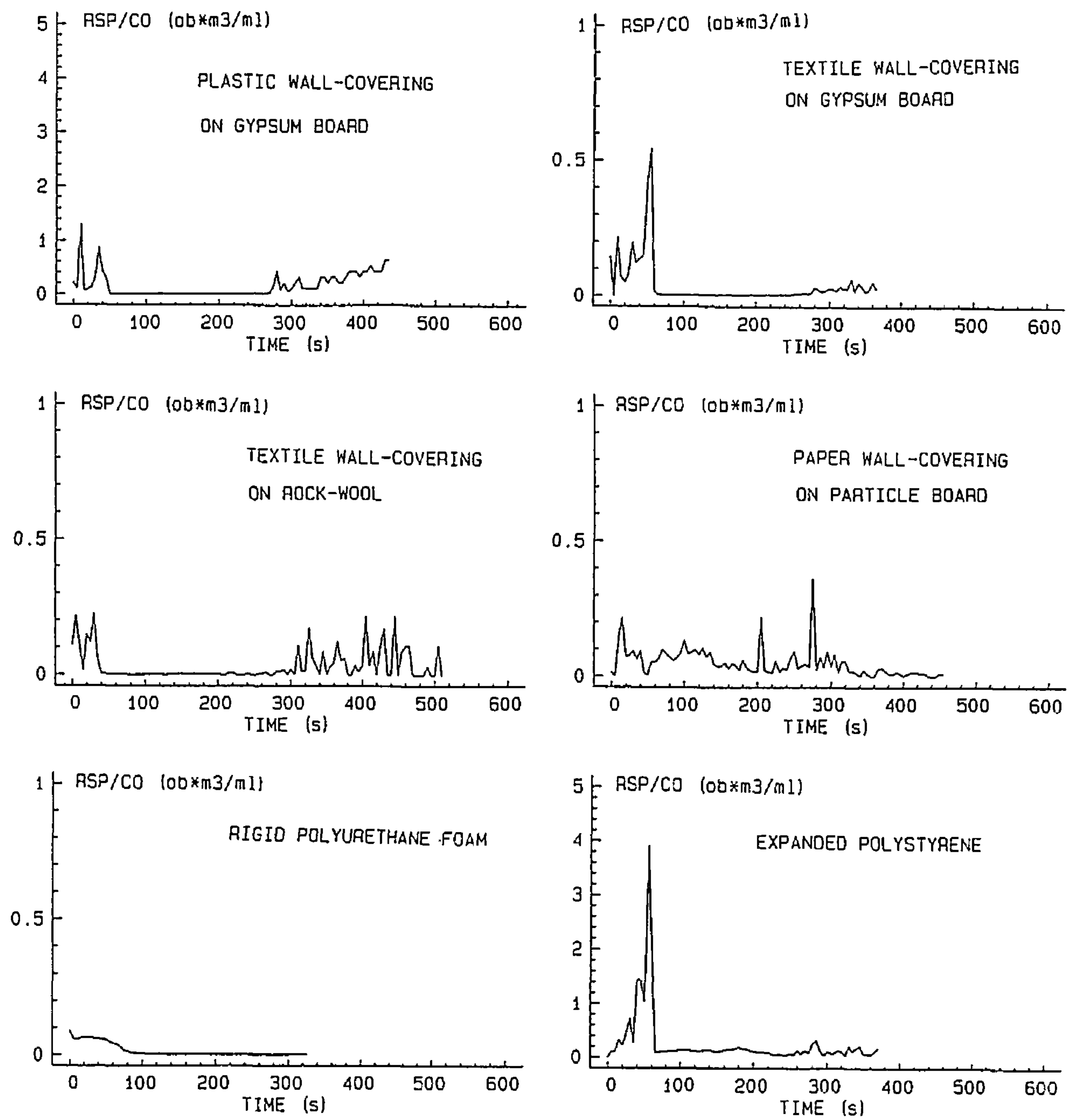
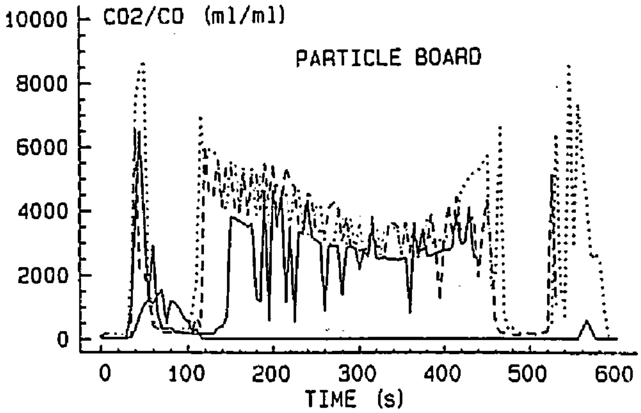
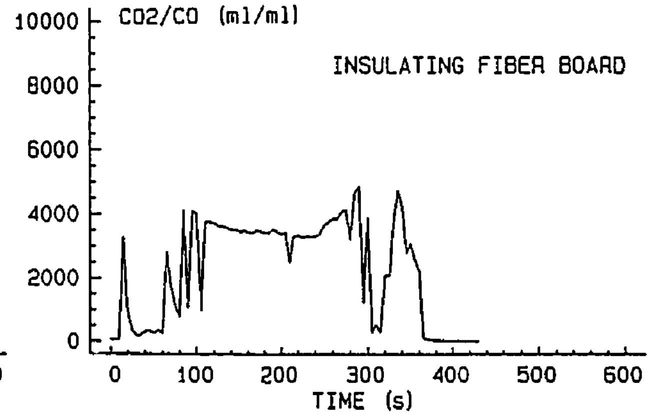
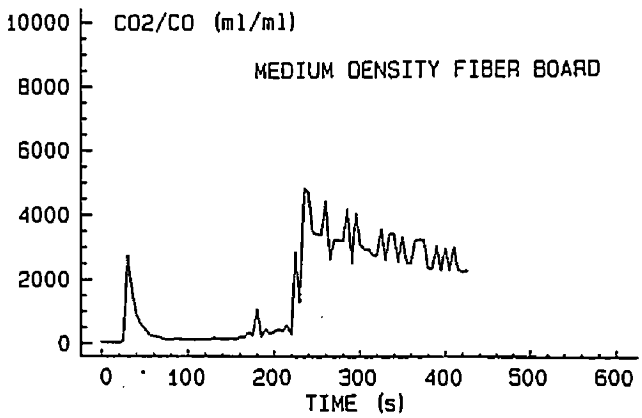
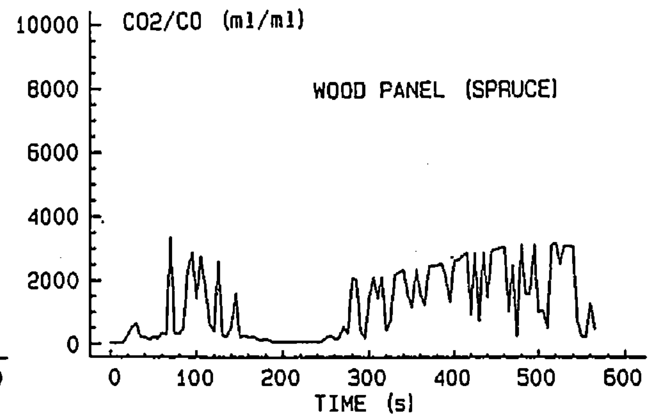


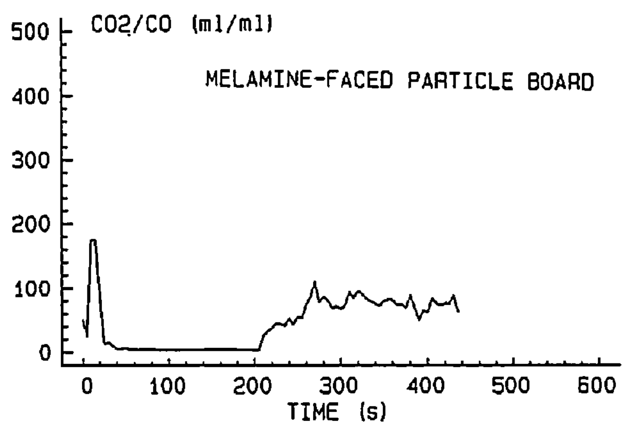
Figure 17. The rate of smoke production (RSP) divided by the carbon monoxide production (CO) at 50 kW/m^2 for the 13 building products. Note the different scales.

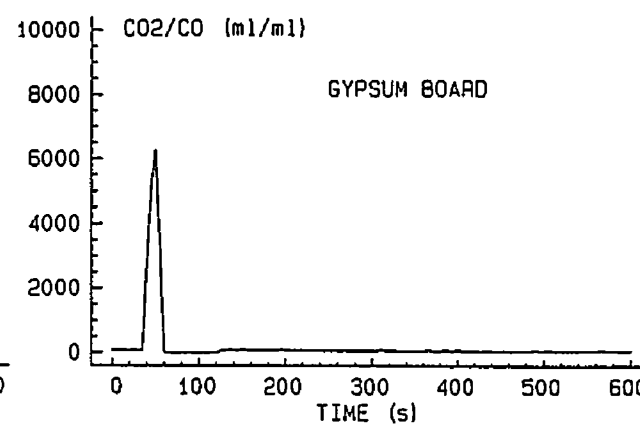

CO2/CO (ml/ml)
PARTICLE BOARD
TIME (s)

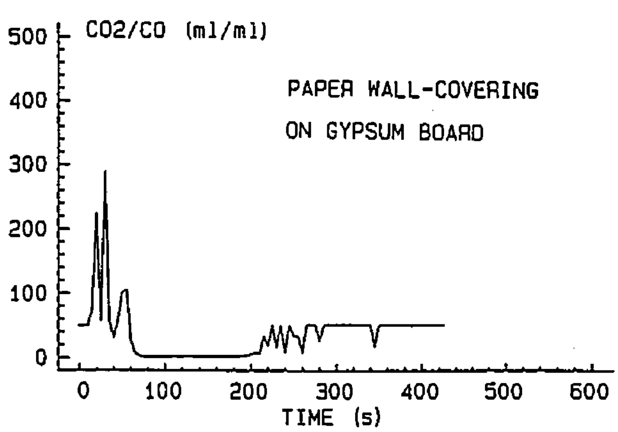

CO2/CO (ml/ml)
INSULATING FIBER BOARD
TIME (s)


CO2/CO (ml/ml)
MEDIUM DENSITY FIBER BOARD
TIME (s)


CO2/CO (ml/ml)
WOOD PANEL (SPRUCE)
TIME (s)


CO2/CO (ml/ml)
MELAMINE-FACED PARTICLE BOARD
TIME (s)


CO2/CO (ml/ml)
GYPSUM BOARD
TIME (s)


CO2/CO (ml/ml)
PAPER WALL-COVERING
ON GYPSUM BOARD
TIME (s)

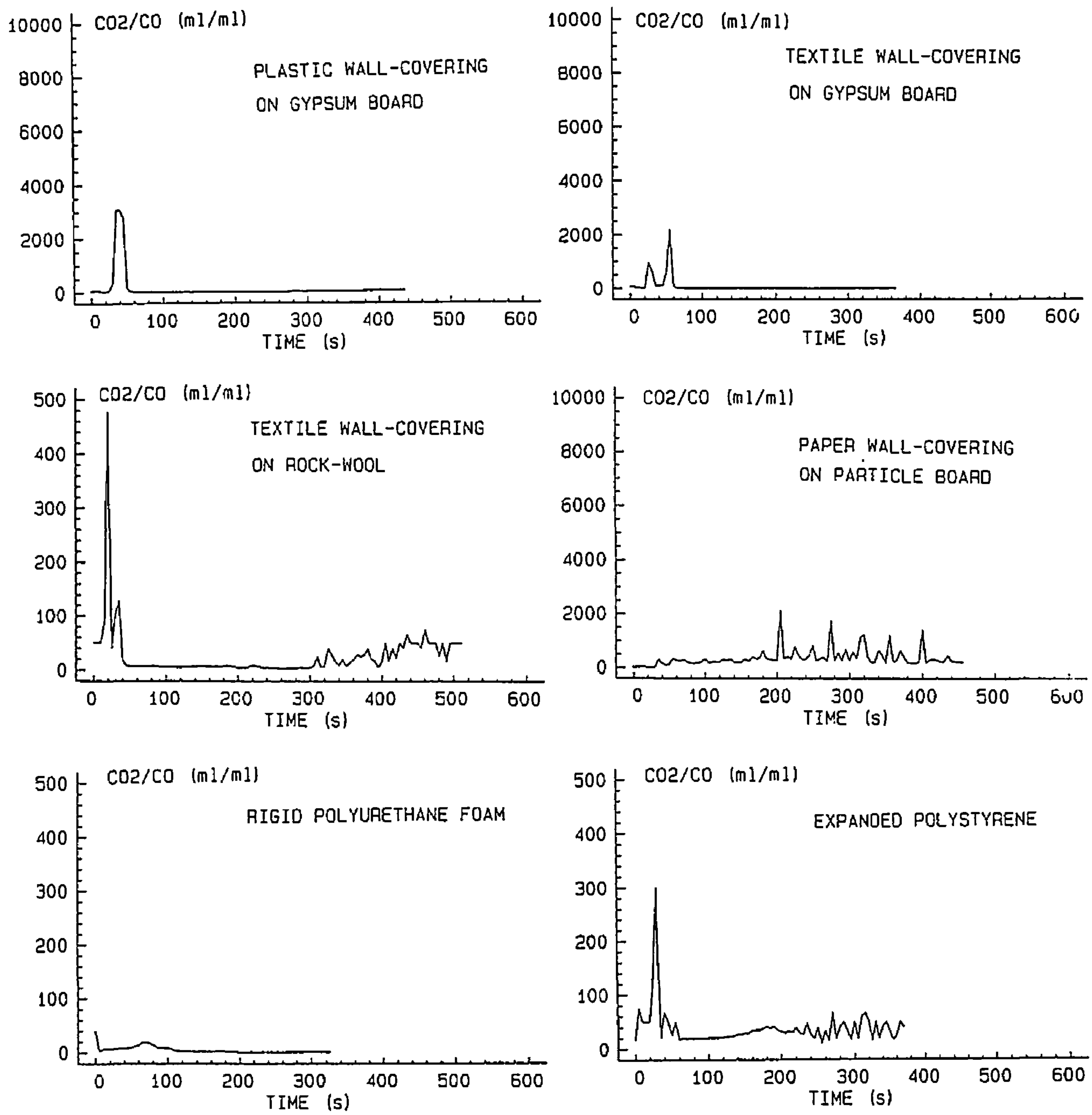


Figure 18. The carbon dioxide production (CO_2) divided by the carbon monoxide production (CO) at 50 kW/m^2 for the 13 building products. Note the different scales.

CONCLUSIONS

Smoke production can be measured with good accuracy and repeatability in the cone calorimeter for products that have a high smoke release such as rigid polyurethane foam and also for products that have a low smoke release such as gypsum board.

The two smoke measurement systems, the helium-neon laser and the white light, give almost identical results for all tested products at all heat flux levels.

The production of carbon dioxide and carbon monoxide can also be measured accurately.

The wood products have a lower production of smoke and carbon monoxide than the synthetic polymers. Gypsum board products have a surprisingly high release of carbon monoxide in relation to other products.

The production of smoke is more or less proportional to the rate of heat release, but not so closely related to the gas production for most products.

The data obtained also include mass loss rate and effective heat of combustion. They are all well suited for inclusion in models predicting larger fires, e.g. room fires.

REFERENCES

/1/ ISO DP 5660: Fire tests - Reaction to fire - Rate of heat release from building products. ISO/TC 92/SC 1/WG 5 - Doc. No. 96 (1988).

/2/ ASTM E 662-83: Standard test method for specific optical density of smoke generated by solid materials. Annual Book of ASTM Standards Vol. 04.07 (1987).

/3/ ASTM E-5 Proposal P 190: Proposed test method for heat and visible smoke rates for materials and products using an oxygen consumption calorimeter. Annual Book of ASTM Standards Vol. 04.07 (1987).

/4/ Babrauskas, V. and Mulholland, G.: Smoke and soot data determinations in the cone calorimeter. Mathematical Modelling of Fires. ASTM STP 983, Am. Society for Testing Materials, p 83-104 (1987).

/5/ Mulholland, G.V.: How well are we measuring smoke? Fire and Materials 6 (2), p 65-67 (1982).

/6/ Clark, F.R.S: Assessment of smoke density with a helium-neon laser. Fire and Materials 9 (1), p 30-35 (1985).

/7/ Nussbaum, R.M. and Östman, B.A-L.: Larger specimens for determining rate of heat release in the cone calorimeter. Fire and Materials 10, p 151-160 (1986).

/8/ Rasbash, D.J. and Pratt, B.T.: Estimation of the smoke produced in fires. Fire Safety J. 2, p 23-37 (1979/80).

/9/ Östman, B.A-L.: Comparison of smoke release rate from building products. Paper presented at the International Conference "Control the Heat - Reduce the Hazard", London, October 1988. TräteknikCentrum, Report P 8811075 (1988).

/10/ Östman, B.A-L. and Tsantaridis, L.D.: Smoke release rates for building products in the cone calorimeter. In preparation for Fire Safety J. (1989).

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