Initial Fires. RHR, Smoke Production and CO Generation from Single Items and Room Fire Tests

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SUMMARY

This report is to be used as a guide in determining what an initial fire will look like. It is a summary of a large number of full scale tests on different items and under various conditions performed at different laboratories. The results shown are primarily the rate of heat release (RHR), as well as the production of smoke and generation of carbon monoxide. The results are shown as curves in this report, but are also digitally available in a database.

NOMENCLATURE

CO	[l/s]	Carbon monoxide generation at NTP
D	[m^2/g]	Smoke potential (logarithm to base 10) [alt. unit: Bel m^2/g]
D_0	[obm^3/g]	Smoke potential (logarithm to base 10) [alt. unit: dB m^2/g]
e_C	[m^2/g]	Specific extinction coefficient (natural logarithm base)
H_C	[MJ/kg]	Heat of combustion
H_{eff}	[MJ/kg]	Effective heat of combustion
I_0/I	[-]	Intensity of a light ray / Intensity of the light ray after passing the distance L through the smoke
L	[m]	Distance the light passes through the smoke
m	[kg/s]	Mass loss rate
m_{C0} / m_{CO2}	[-]	CO/CO_2 fraction
m_{O2}	[g]	Consumed oxygen mass
M(x)	[g/mole]	Molecular weight for the substance x
n_{CO} / n_{CO2}	[-]	CO/CO_2 ratio
n_x	[mole/s]	Production/consumption of the substance x
POD	[obm^3/kg]	Particulate optical density. 33 000 in flaming mode and 19 000 in non-flaming mode
RHR	[kW]	Rate of heat release, including the ignition source
S	[obm^3/s]	Smoke production
V	[m^3/s]	Flow in the exhaust tube at exhaust gas temperature
X	[-]	Fraction of m that is converted into obscuring particles
	[-]	Combustion efficiency factor
$\bar{z}$	[-]	Carbon/Hydrogen ratio of the fuel

INTRODUCTION

There are always difficulties in choosing the right data to put into a smoke filling or fire spread model. This report is to be used as a guide in estimating what an initial fire will look like and how fast it will grow. It may also be of some help in determining the rate of production of smoke and toxic gases, such as carbon monoxide. The report is based on results from burning tests at several laboratories, with a large number of different items and under various conditions. The samples cover a wide range of items, from lining materials and pallet systems to chairs, curtains and coffee makers. Most of the results have been published earlier, but quite a few have, until now, been unpublished.

The criterion for the selection of test results in this report is primarily that the rate of heat release is given, as measured by oxygen consumption. This is believed to be the single most important parameter in describing a fire. Furthermore it is necessary to know the burning conditions, for example if the tested item is burning freely or in a room. Other aspects that might be of interest are naturally given when available, such as the smoke production, the generation of carbon monoxide or the effective heat of combustion.

Each test is reprinted with a description of the item or sample, with materials, size, mass, application etc. There is also a brief description of the test procedure, whether the sample burned freely or in a room and a description of the ignition source used. The rate of heat release, the production of smoke and the generation of carbon monoxide are all given in diagrams against the time and other measurements are given as an average value. An example is the effective heat of combustion. In some cases there are also measurements from gases such as CO_2 and NO_X. The reference to the original report can be useful as there is a note of which other measurements were taken, usually the heat flux, the gas temperatures, the mass loss or the burning area.

ACKNOWLEDGEMENTS

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THE BSAB SYSTEM

The tested items are arranged into different groups and subgroups according to their function. A refrigerator will be classified as a technical fitting, and will therefore be placed into subgroup Y1. However, if the refrigerator is stored with others in a pallet system, the classification will be for the pallet system, that is in subgroup Y3.3. The system is called BSAB and is developed by 'Svensk Byggtjänst' to make possible the classification of different construction components /1/. Naturally the system is used with permission. Using a system like this, it is possible to add new test results to the list.

The main groups in the BSAB system are as follows:

A	Marking, testing, documentation etc.
B	Preparatory work, auxiliary work, excavation etc.
C	Filling, reinforcement, piling etc.
D	Earthworks, fixtures above ground etc.
E	'In situ' concrete structures
F	Brickwork and blockwork
G	Carcassing of precast units
H	Structural elements of miscellaneous materials
I	Pipes and tubes, ducts etc.
J	Electrical conduits and wiring
K	Thermal insulation etc.
L	Building felt, fabric, foil etc. for waterproofing
M	Flat sheet products for roof and facade cladding
N	Tiles, profiled materials etc. for roof and facade cladding
O	Lining etc. of board and sheet materials
P	Plaster, rendering, protective treatment
Q	Covering and cladding products - buildings
R	Apparatus in heating and cooling systems etc.
S	Sanitary fittings etc. in piped and ducted systems
T	Apparatus, ducts, equipment etc. in air handling systems
U	Control and monitoring equipment in technical systems
V	Apparatus, machinery etc. in electrical systems
W	Apparatus, machinery etc. in materials and passenger handling systems
X	Individual objects as secondary elements
Y	Fittings and furnishings etc.
Z	Building sundries of miscellaneous bulk and continous materials and individual objects

As the list is made to suit the entire building sector, most of the headings are not suitable for this report. With its subgroups, the headings used in the report are:

J4	Wiring, cables etc.
K4	Thermal insulation of building services
O1	Lining etc. of cement and plaster based board
O2	Lining etc. of metal panels
O3	Lining etc. of boards of wood laminates
O4	Lining etc. of boards of organic fibres, wood chips etc.
O5	Lining etc. of boards of inorganic fibres, expanded stone etc.
O6	Lining etc. of sheets of plastics, plastics laminates et.c
Y0	Fittings and furnishings of composite function
Y1	Technical fittings
Y3.1	Closed storage units
Y3.3	Storage units with shelves, pallet systems etc.
Y3.4	Holders, hangers, hooks, containers etc.
Y5.0	Seating units of composed function
Y5.2	Chairs etc.
Y5.3	Easy chairs etc.
Y5.4	Sofas etc.
Y6	Beds etc.
Y7	Textile units etc.
Y8	Miscellaneous fittings and furnishings
Z1	Building sundries of miscellaneous bulk materials
Z3	Building sundries of miscellaneous individual objects

In some cases there are difficulties in choosing the right group for a tested item. One example is mineral wool with wall covering. The mineral wool may be classified as thermal insulation in group K, and the wall covering as a protective treatment in group P. However, one could see the mineral wool with wall covering as a board construction, and as it consists mainly of expanded stone it will be put into the group O5.

There are also cases where one may doubt if the item suits any group at all. A tram car is one. It is to be found in the group Z3 with other large individual objects.

To avoid mixing the results in each subgroup, every item has also been given a two-figure number, starting with 10. In the subgroups with different types of objects, each type starts with a different multiple of ten.

Thus, the code Y5.2/11 means that the sample is a piece of furniture (Y), that it may be used to sit on (5), that it is a chair or an armchair (2) and that it has the identity number 11.

DEFINITIONS AND GUIDELINES

The criterion for selection of test results for the report is that the rate of heat release is given, measured by the oxygen consumption. It is believed to be the single most important parameter describing a fire.

In the report, the following abbreviations are used:

FR	Fire retardant / Fire retardant treated
GPB	Gypsum plaster board
PS	Polystyrene
PP	Polypropene
PU	Polyurethane
PVA	Polyvinyl acetate
PVC	Polyvinyl chloride
NA	Data is not available

The furniture dimensions throughout the report are written in the order:
Widht x Length x Height

Under the heading 'Also available' there is a note of which measurements are shown in diagrams in the original report.

Unfortunately there are a great variety of terms that are used to describe the same phenomena. The fire growth may be described by either the rate of heat release in kW or by the mass loss rate in kg/s. There are also examples where the same variable is determined, but different units used. The most remarkable one is the smoke production, where one can use the optical units dBm^2/s, obm^3/s or m^2/s. As if that were not enough, the last one can be used with both the base 10-logarithm and the natural logarithm. They differ by a factor of 2.3. There are also some units based on weight, such as g/s. The generation of carbon monoxide can be measured in either l/s, g/s, g/g_{fuel} or g/g_{CO2}. To avoid misunderstandings, some of the test results have been recalculated in this report so that the same units and logarithm bases are used throughout.

Used in the report are:

RHR	[kW]	Rate of heat release, including the ignition source $RHR = 13.1 \times m_{O2}$
S	[obm^3/s]	Smoke production $S = 1 / L \times 10 \log_{10} (I_0 / I) \times V$
CO	[l/s]	Carbon monoxide generation at NTP
H_{eff}	[MJ/kg]	Effective heat of combustion $H_{eff} = H_C \times$ _

In the report RHR, S and CO are plotted against the time in diagrams and H_{eff} is given as a constant. Since the heat release varies within a large range depending on the size of the samples, it is not possible to use the same maxima on the scales. However the same scales are used in each subgroup of samples. Unfortunately it has the effect of making some of the curves very tiny, almost invisible, but in spite of that, they indicate the magnitude of the heat release rate. The scale maxima that are used are, for time 1200, 2400 and 4800 s and for RHR 100, 500, 1000, 2000, 4000 and 8000 kW. The scales of smoke production are always 1/10 of the RHR scale and the CO production 1/100 of the RHR scale. One scale mark always represents 60 s, 100 kW, 10 obm^3/s or 1 l/s, respectively.

THE DATABASE

In addition to the report, there is also a database, with all the data files containing rates of heat release, smoke production and generation of carbon monoxide.

The data base is built up using the same system as in the report, using the same codes. This means that the sofa Y5.4/11 corresponds to data file Y54-11.FIR. The format used is the ASCII text format, within each file four columns; for time, rate of heat release, smoke production and CO generation, respectively. The first row is used for the sample identity code and the second for the column headings. The data is tab separated, and to indicate the end of data, the figure -9 is used in each column. In the event that S or CO is not available, the columns are left empty.

The following example shows the format that is used:

Y1/40

T (s)	RHR (kW)	S (obm3/s)	CO (l/s)
0	0	0	0
30	10	0.5	0
60	50	3	0.5
90	100	9	1
...	...	...	...
-9	-9	-9	-9

TEST METHODS

All the RHR measurements in the report are made in calorimeters. There are three types of full scale calorimeters, namely: the room calorimeter, the furniture calorimeter and the industry calorimeter.

They are all based on the assumption that when a material is burning, for every gram of oxygen that is consumed, about 13.1 MJ of energy is released. 13.1 is an empirical constant, which is used for most substances. However, the constant differs slightly for different materials. If the sample is of a known material, it is possible to adjust the constant. Otherwise the error may be as large as +/- 15% depending on the material burning. In addition to this, there is the inaccuracy of the instruments, up to +/- 10% depending on how well the equipment has been calibrated. Thus, the error may be as large as +/- 25%.

It is worth noting that the phase of pyrolysis shows a great variation depending on the ignition source. It varies from when the ignition source is so small so that the sample is not ignited, to the ones that give a very rapid increase in the rate of heat release. A middle form is when the sample is smouldering for some time before the heat release increases. There are four main aspects to consider about the ignition sources; the rate of heat release, the maximum temperature, the time of application to the target and the area of contact. This is important, as the ignition sources used vary from ordinary matches to 1000 kW gas burners.

The test equipment is based on an exhaust hood with a fan, an oxygen meter, a photocell measuring the smoke obscuration, and in some cases there is also equipment analyzing the amounts of CO, CO_2, NO_X etc. in the gases. It is the fan that sets the limits of how large the samples are that may be tested, since it is necessary that all the smoke is exhausted through the hood.

In the room calorimeter, the sample is burned in a room, usually with the size 2.4 x 3.6 x 2.4 m^3, with an opening of 0.8 x 2.0 m^2. The hood is located outside the opening, collecting all the smoke. The room is usually built of lightweight concrete. According to Thomas' flashover correlation, the energy release needed to cause flashover in the room is 1300 kW. The stoichiometric post flashover rate of heat release is 3400 kW. The two correlations are to be found in *The SFPE Handbook of Fire Safety Engineering* /2/. Other room geometries are used as well. The beds Y6/13-21 were burned in a room of a size 3.40 x 3.50 x 2.44 m^3, with an opening 0.91 x 2.13 m^2.

In the furniture calorimeter, the same hood is used as in the room calorimeter. It is usually of the size 2 x 2 m^2. The sample is placed directly under the hood, in some cases on a weighing platform to make possible measurement of the mass loss.

The industry calorimeter is very similar to the furnitiure calorimeter, but on a much larger scale. It can easily handle a heat release up to about 10 MW, which is needed, for example for the rack storages.

CONVERSIONS

There are a large number of different computer and paper-and-pencil models that can be used to calculate a smoke filling, fire spread or detector activation process. Almost every model has its own set of data to make possible the calculation. To get the right set of data to put into the models one often needs conversions. The most common ones are as follows:

Burning rate conversions

Conversion to mass loss rate:

$$m = RHR / (H_{eff} \times 10^3) = RHR / (H_C \times 10^3 \times \_)$$

It is worth noting that if the model is doing a plume calculation, one has to know the fraction of radiation. It is usually in the order 15 - 50 % of the RHR, with the lowest values for substances with a low smoke production and the highest for those producing a large amount of smoke. *The SFPE Handbook of Fire Protection Engineering* /2/ and *Heat transfer in Flames* /3/ discusses this subject in greater detail.

Smoke conversions

Conversion to smoke potentials and specific extinction coefficient:

$$D_0 \times 10^{-3} = 1 / L \times 10 \log_{10} (I_0 / I) \times V / m = S / m$$
$$D \times 10^{-3} = 1 / L \times \log_{10} (I_0 / I) \times V / m = 0.1 \times S / m$$
$$e_C \times 10^{-3} = 1 / L \times \ln (I_0 / I) \times V / m = 0.23 \times S / m$$

Calculation of S when m (or RHR) is given:

$$S = POD \times m \times X$$

The POD has been shown to be 33 000 obm^3/kg for flaming combustion and 19 000 obm^3/kg for non-flaming combustion.

CO conversions

Conversion to CO/CO_2 fraction and ratio - approximation when the CO generation is relatively low:

The oxygen consumption can be calculated from the RHR:

$$n_{O2} = RHR / (13.1 \text{ kJ/g} \times 32 \text{ g/mole}) = RHR / 419 \text{ mole/s}$$

The burning process can be approximated to ($\_ = 1$):

$$\text{Fuel} + n_{O2} O_2 \Rightarrow n_{CO2} CO_2 + n_{H2O} H_2O$$

The oxygen balance gives the generation of CO_2:

$$2 n_{O2} = 2 n_{CO2} + n_{H2O} = 2 n_{CO2} + n_{CO2} / 2 z$$
$$n_{CO2} = n_{O2} / (1 + 1/4z)$$
$$n_{CO2} = RHR / 419 (1 + 1/4z)$$

The CO generation is needed:

$$n_{CO} = CO / 24 \text{ l/mole}$$

CO/CO_2 fraction:

$$n_{CO} / n_{CO2} = (CO / 24 \text{ l/mole}) / (RHR / 419 (1 + 1/4z))$$
$$= 17.5 (1 + 1/4z) \ CO / RHR$$

The approximation is acceptable when $n_{CO} / n_{CO2} < 0.2$

CO/CO_2 ratio:

$$m_{CO} / m_{CO2} =$$
$$= (n_{C0} / n_{CO2}) (M(CO) / M(CO_2)) = (17.5 (1 + 1/4z) \ CO / RHR)(28/44)$$
$$= 11 (1 + 1/4z) \ CO / RHR$$

The approximation is acceptable when $m_{CO} / m_{CO2} < 0.1$

DISCUSSION

Tests to be conducted

In writing this report it became quite obvious that some areas of test objects are covered very well, and others hardly at all. Chairs are popular samples, and they are tested in a large number and variety of ways. There are tests performed on both commercial chairs and standardized mock-up chairs with different paddings and covers. In the results you can also find some curiosities, such as the stuffed fox or the christmas trees. Other items appear rarely in the test records. These may be clothes, ordinary cars or stored goods, such as bookcases, all of them known to burn under the right, or shall we say wrong, circumstances.

This means that there is a need for additional tests to be conducted. Some areas to be covered are:
industrial machinery,
vehicles, such as cars, buses, trucks and railroad cars,
storage units up to the size of pallet systems, with different goods and
wardrobes, especially larger open wardrobes with clothes.

Choosing a rate of heat release

There are several factors that affect the rate of heat release. One of them is ventilation and how the item is located with respect to walls etc. It may differ by more than a factor of two on the rate of heat release if the item is standing in the corner of a room or is burning with free acess to air. Another factor is the ignition source. It is quite obvious that the strength of the ignition source necessary to cause ignition of the item differs greatly between items. An example is lining materials, where one can easily see the time when the burner output is increased. How the ignition source affects the target can be described with four parameters: the maximum temperature, the rate of heat release, the time of application to the target and the area in contact with the ignition source.

One may also find examples of tests that are made with similar objects, under apparently similar conditions, which in spite of that give slightly different results. This means that it is impossible to predict an exact result even if there is a sample that fits most of the conditions.

The conclusion is that it is necessary to see to both the environment and the item itself when assuming a fire progress. Furthermore the user of a computer or paper-and-pencil model has to think for himself and not just use the data as written. In fact, the test method itself is a source of inaccuracy, with its constant 13.1 MJ released energy per gram consumed oxygen. The error of up to +/- 25% is far too much to be neglected. This shows that it is necessary to make an analysis of the sensitivity of the calculations, that is, to assume one rate of heat release that is lower and slower and one that is higher and faster than the proposed, to see if it makes any difference to the results. A number of 20 to 30 different simulations in each scenario is not at all unrealistic.

Warnings

The user of a model is always responsible for how the results are used.

It is necessary to know the limitations of the models used, to avoid using a two-zone-model when clearly not applicable.

In making a simulation, there also has to be an analysis of the sensitivity of the calculations.

When assuming fire progress, the following has to be taken into consideration:

- the access of air
- the location of walls and ceiling
- the ignition source ("strength", application and time)
- the configuration of the sample
- the materials and size of the sample
- and all the other factors that affect the heat release rate.

Which can be summed up by:

- the environment, the ignition source and the sample itself.

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Electric cable with 5 copper wires
Thickness: Wire: 1.63 mm, insulated wire: 3.30 mm, complete cabel: 12.7 mm

Z-configuration: 35 cables (single layer, 0.43 x 2.44 m^2) on Z-shaped ladder rack (0.53 m horizontal, 1.37 m vertical and 0.53 m horizontal)
Vertical configuration: 25 cables (single layer, 0.30 x 2.18 m^2) on vertical ladder rack

10: Z-configuration
Wire insulation: Crosslinked ethylene vinyl acetate copolymer with clay (18.9%), antioxidant (2%), processing aid (1%), and catalyst (1.5%)
Jacket: Chlorosulfonated polyethylene containing Sb_2O_3.
Elemental content: Cl (12.2%), Sb (2%)
Mass: 17.5 kg
Sample D, test 5,

11: Vertical configuration
Cable identical to sample 10.
Mass: 11.4 kg
Test 19

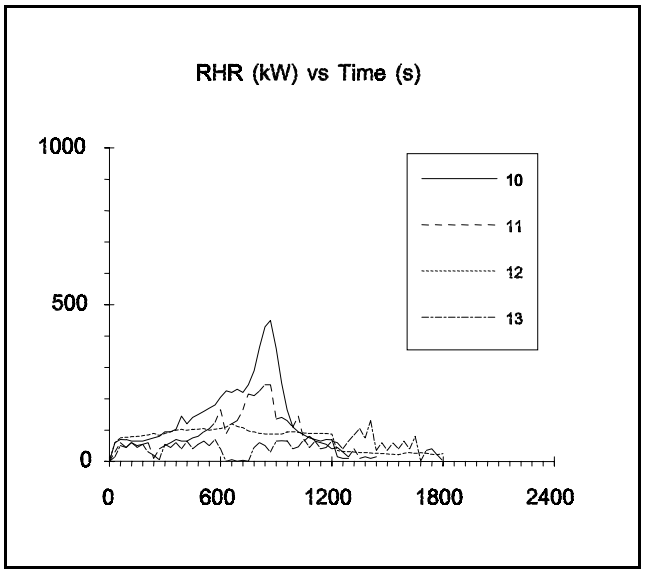
12: FR, Z-configuration
Wire insulation: Polyethylene crosslinked with ethylene vinyl acetate, with clay (28%), chlorinated cycloaliphatic fire retardant (38%), Sb_2O_3 (18.9%), antioxidant (2%), processing aid (1%), and catalyst (1.5%)
Jacket: Identical to sample 10
Mass: 18.2 kg
Sample K, test 6

13: FR, Vertical configuration
Cable identical to sample 12.
Mass: 11.5 kg
Test 20

Test procedure:
Method: Freeburning in furniture calorimeter
Ignition source: Gas burner, 50 kW at 0-200, 240-600 and 730-1380 s (sample 10 and 12) or at 0-1200 s (sample 11 and 13)

Sample:	11	13
H_{eff} (MJ/kg):	41	NA
Smoke (obm^3/kg):	2800	2400
CO (kg/kg):	0.12	0.10
CO_2 (kg/kg):	1.61	1.04
HCl (kg/kg):	0.12	0.13

Reference:
Babrauskas, V. et al.
Fire Hazard Comparison of Fire-Retarded and Non-Fire-Retarded Products
NBS Special Publication 749
National Bureau of Standards
U.S.A. 1988



10: Phenol
Glass fibre reinforced
L-shaped
Volume of mat. per ceiling surface area: 0.028 m^3/m^2
Density: 115 kg/m^3

11: Amino plastic
Inner diameter: 15 mm
Thickness: 28 mm
Volume of mat. per ceiling surface area: 0.053 m^3/m^2
Density: 12 kg/m^3

Material of similar kind in sample 12-14

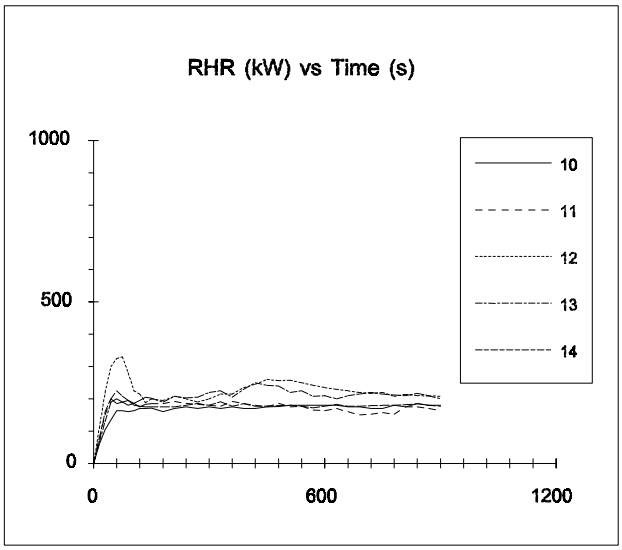
12: PVC
Inner diameter: 22 mm
Thickness: 13 mm
Volume of mat. per ceiling surface area: 0.030 m^3/m^2
Density: 95 kg/m^3

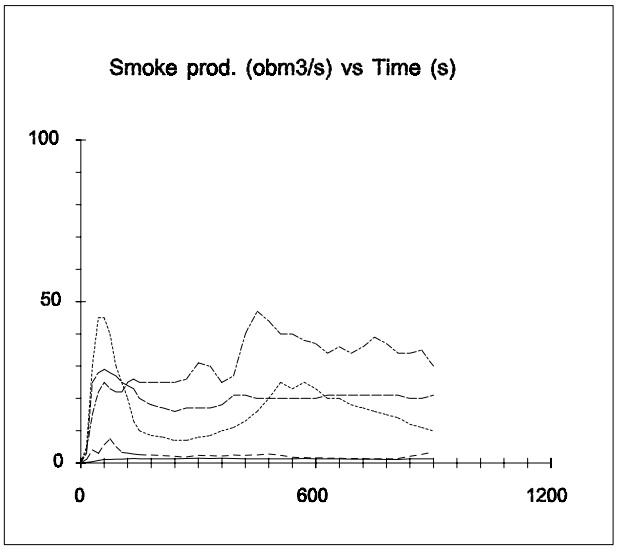
13: PVC/nitrile rubber
Inner diameter: 15 mm
Thickness: 25 mm
Volume of mat. per ceiling surface area: 0.048 m^3/m^2
Density: 100kg/m^3

14: Vinyl rubber
Inner diameter: 22 mm
Thickness: 13 mm
Volume of mat. per ceiling surface area: 0.030 m^3/m^2
Density: 60 kg/m^3

Test procedure:
Method: Room calorimeter. The insulation was mounted on 10 mm diameter steel bars at the distance 0.15 m from underside of the insulation to the ceiling. The insulation covered the entire ceiling.
Ignition source: 150 kW gas burner 1 m above the floor.

Reference:
Wetterlund, I. & Göransson, U.
New Method for Fire Testing of Pipe Insulation in Full Scale
Fire Technology
SP Report 1986:33, ISSN 0280-2503
Borås, Sweden 1986





15: Polyisocyanurate
With glass fibre reinforced aluminium foil
Inner diameter: 34 mm
Thickness: 20 mm
Volume of mat. per ceiling surface area: 0.046 m^3/m^2
Density: 35 kg/m^3
Only 1/3 of the ceiling was covered.
Ignition source: 90 kW gas burner

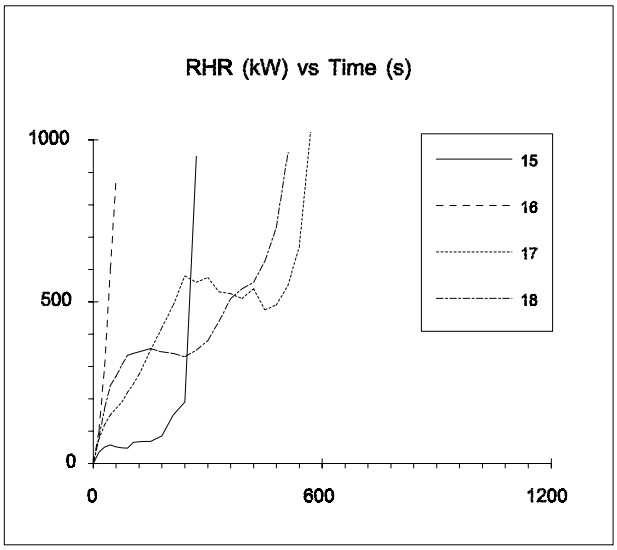
16: PU with paper surface
L-shaped
Volume of mat. per ceiling surface area: 0.028 m^3/m^2
Density: 80 kg/m^3

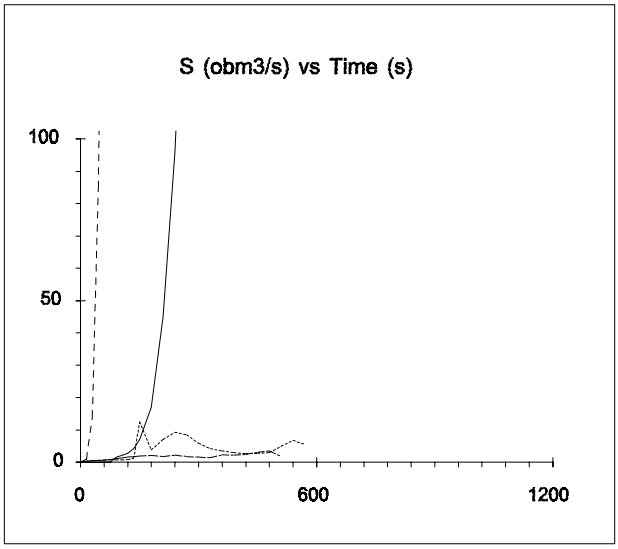
17: Particle board
Thickness: 10 mm
Volume of mat. per ceiling surface area: 0.010 m^3/m^2
Density: 700 kg/m^3

18: Insulating fibre board
Thickness: 12.5 mm
Volume of mat. per ceiling surface area: 0.013 m^3/m^2
Density: 250 kg/m^3

Test procedure:
See page K4/10

Reference:
See page K4/10





10: Gypsum plaster board (GPB)
Thickness: 13 mm
Density: 700 kg/m^3
Test 4

11: PVC wallcovering on GPB
Thickness: 0.7 mm
Surface weight: 240 g/m^2
Application: Glued
Test 5

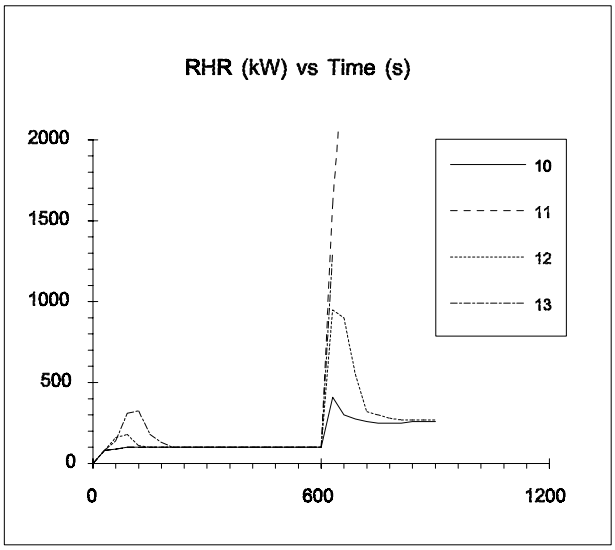
12: Paper wallcovering on GPB
Thickness: 0.7 mm
Surface weight: 240 g/m^2
Application: Glued
Test 6

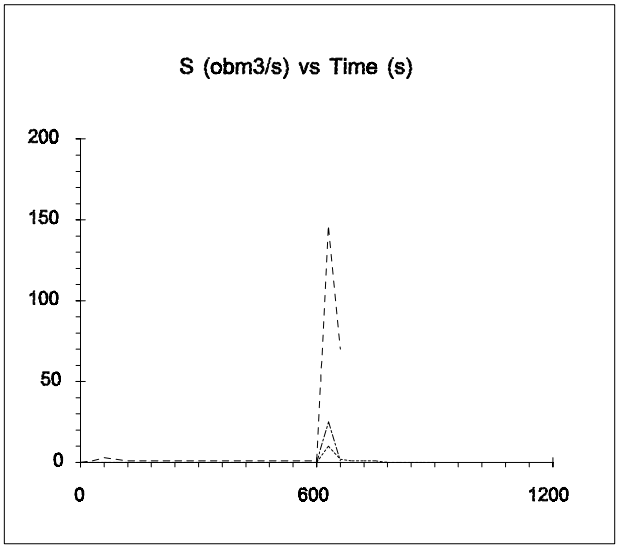
13: Textile wallcovering on GPB
Thickness: 0.6 mm
Surface weight: 240 g/m^2
Application: Glued
Test 7

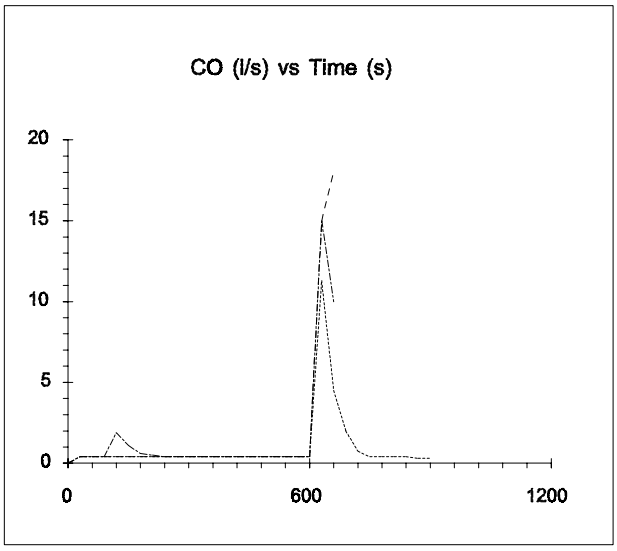
Test procedure:
Method: Room/corner test. 3 walls and ceiling covered with material
Ignition source: Gas burner, 100 kW in 600 s, thereafter 300 kW in 600 s.

Also available:
Gas temp., surface temp., heat flux, mass flow, burning area, and production of CO_2 and hydrocarbons.

Reference:
Sundström, B
Full Scale Fire Testing of Surface Materials
Fire Technology
Technical report 1986:45, ISSN 0280-2503
Borås, Sweden 1986







Gypsum plaster board

Gypsum plaster board
Thickness: 12 mm

14: PVA latex paint on GPB
Surface weight: approx. 100 g/m^2
Test 1, PAINT

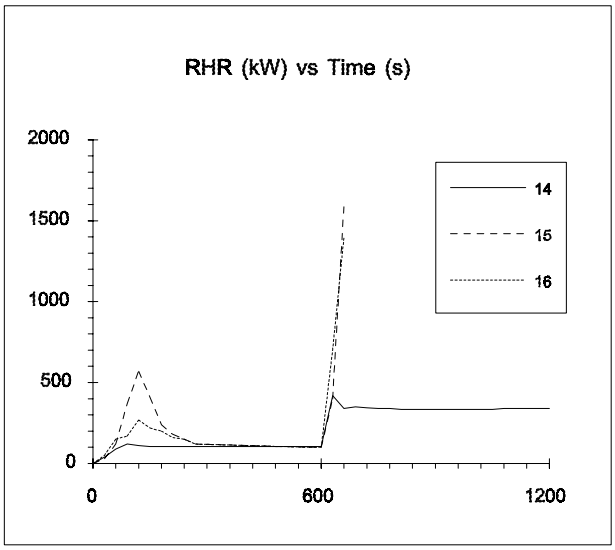
15: Textile wallcovering on GPB
Thickness: approx. 1 mm
Surface weight: approx. 505 g/m^2
Application: Glued
Test 3, TEXT

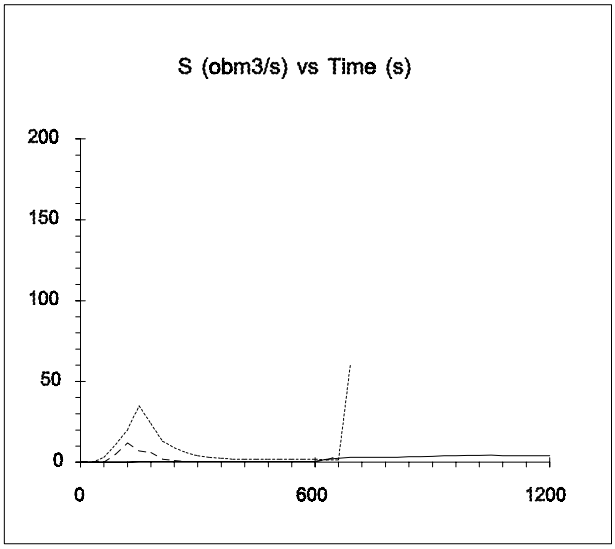
16: PVC wallcarpet on GPB
Thickness: 0.9 mm
Surface weight: approx. 1250 g/m^2
Application: Glued
Test 10, PVC WALL

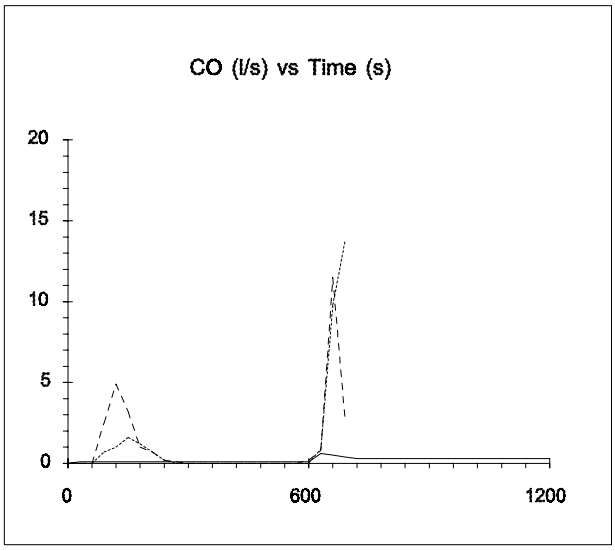
Test procedure:
Method: Room/corner test. 3 walls and ceiling covered with material
Ignition source: Gas burner, 100 kW in 600 s, thereafter 300 kW in 600 s.

Also available:
Heat flux, gas temp. and flame spread.

Reference:
Söderbom, J
EURIFIC - Large Scale Tests according to ISO DIS 9705
Fire Technology
SP REPORT 1991:27, ISSN 0248-5127
Borås, Sweden 1991







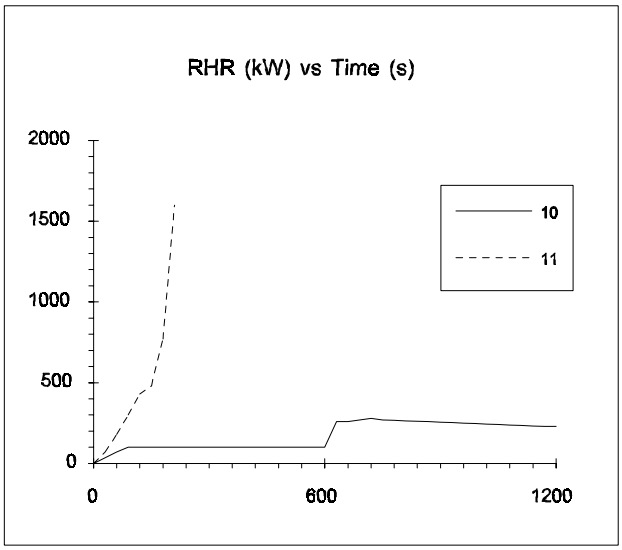
10: Plastic faced steel sheets on mineral wool
Thickness: 0.15 + 0.7 + 23 mm
Density: 640 kg/m^3 (total)
The panels mineral wool was completely enclosed by steel
Test 5, PL.FAC

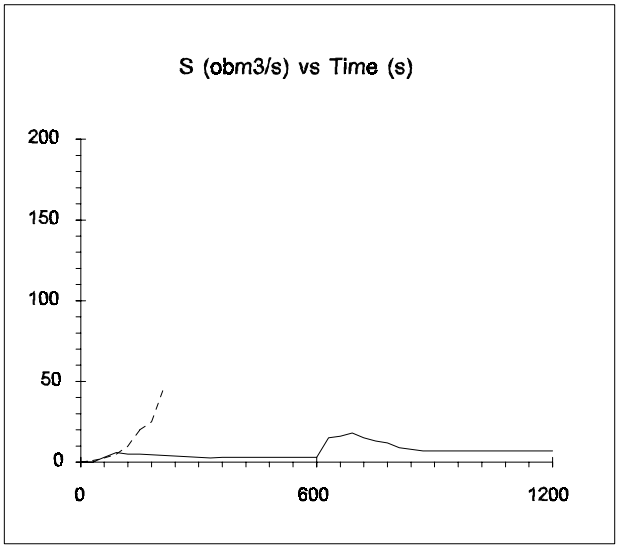
11: Plastic faced steel sheets on PU foam
Thickness: approx 1 + 80 mm
Density: 160 kg/m^3 (total)
Test 9, PU.FOAM

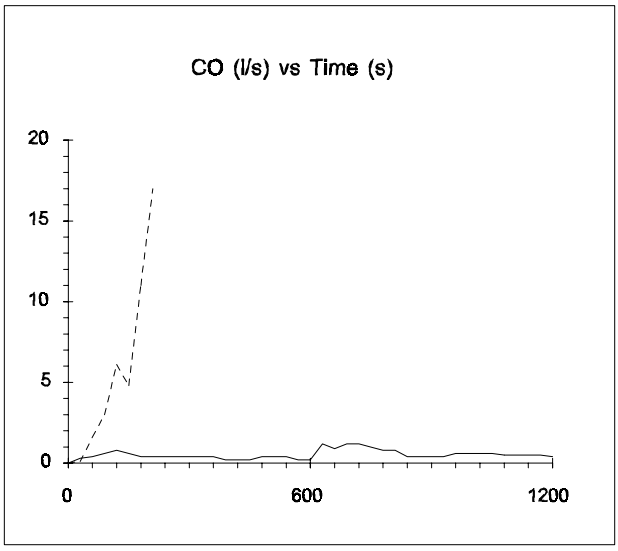
Test procedure:
Method: Room/corner test. 3 walls and ceiling covered with material
Ignition source: Gas burner, 100 kW in 600 s, thereafter 300 kW in 600 s.

Also available:
Heat flux, gas temp. and flame spread.

Reference:
Söderbom, J
EURIFIC - Large Scale Tests according to ISO DIS 9705
Fire Technology
SP REPORT 1991:27, ISSN 0248-5127
Borås, Sweden 1991





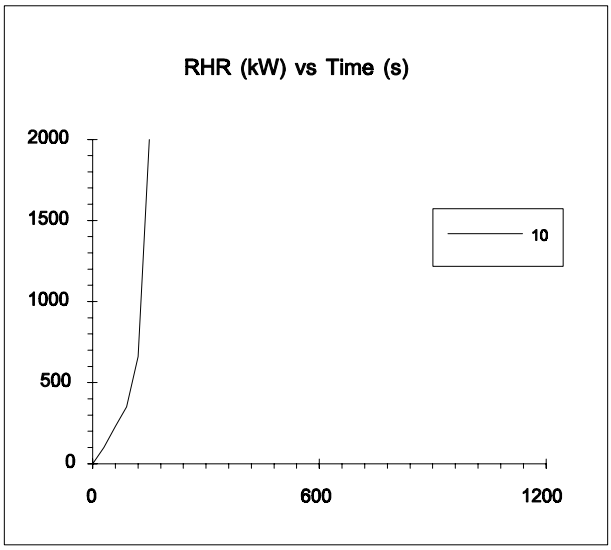


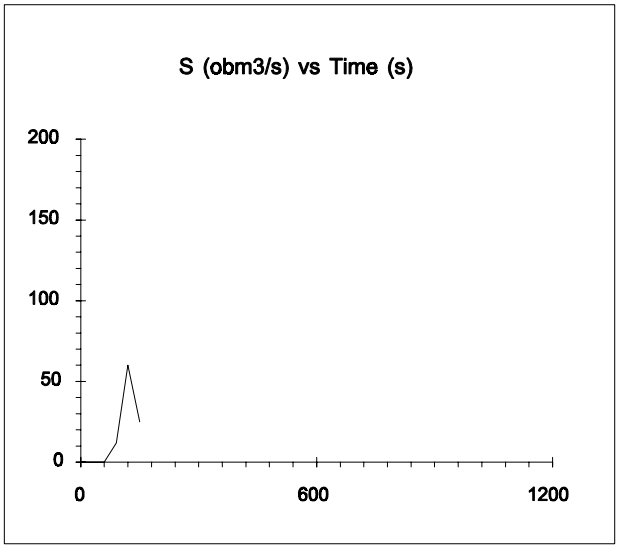
10: Wood panel, spruce
Tickness: 11 mm
Density: 530 kg/m^3
Moisture content: 10.0%
Test 12

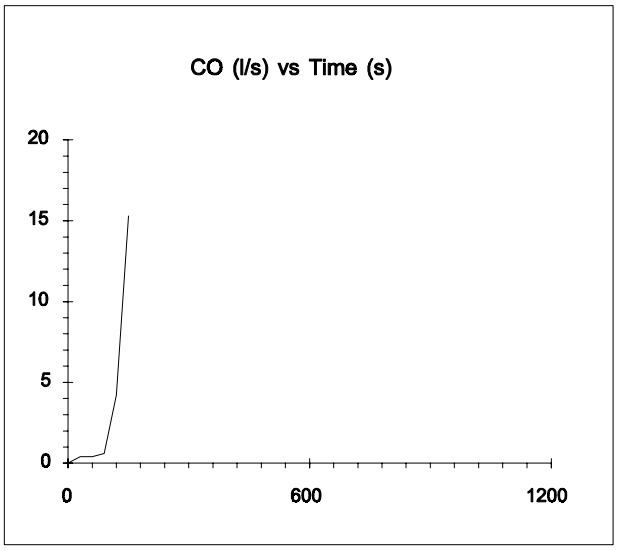
Test procedure:
Method: Room/corner test. 3 walls and ceiling covered with material
Ignition source: Gas burner, 100 kW.

Also available:
Gas and surface temp., heat flux, mass flow, burning area and production of CO_2 and hydrocarbons.

Reference:
Sundström, B
Full Scale Fire Testing of Surface Materials
Fire Technology
Technical report 1986:45, ISSN 0280-2503
Borås, Sweden 1986





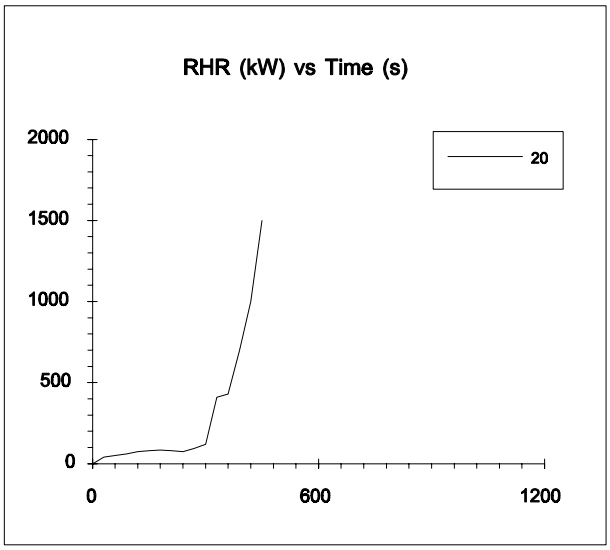


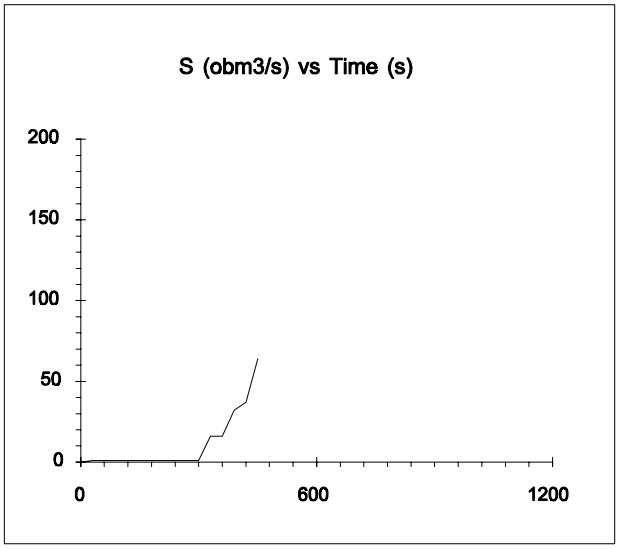
20: Ordinary plywood
Tickness: 12 mm
Density: 600 kg/m^3

Test procedure:
Method: Room/corner test. 3 walls covered with material
Ignition source: Gas burner, at first 40 kW, thereafter 160 kW

Also available:
Heat flux and gas temp.

Reference:
Söderbom, J
Swedish Results from Interlaboratory Calibration Tests
According to ISO/ASTM Room Fire Test Method
SP-AR 1991:27
Fire Technology
Borås, Sweden 1991



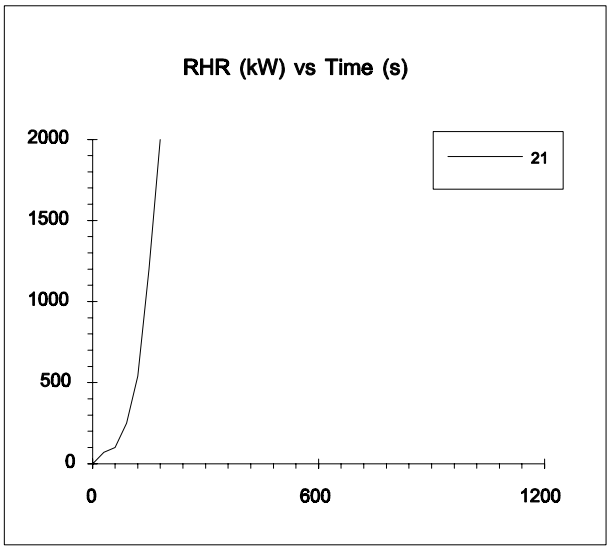


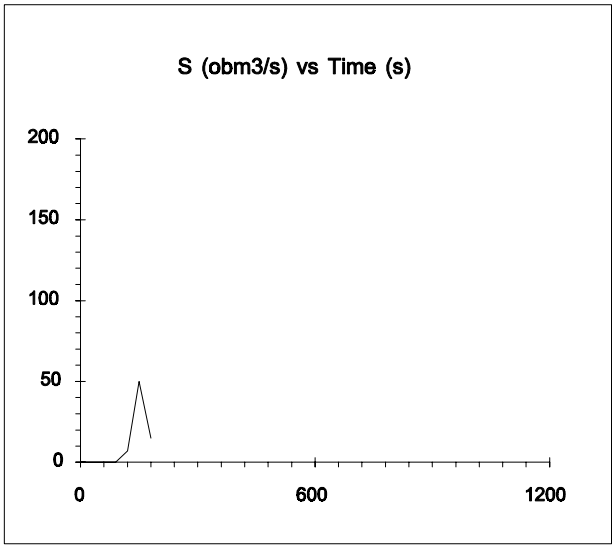
21: Ordinary birch plywood
Tickness: 12 mm
Density: 600 kg/m^3
Test 2, PLYWOOD

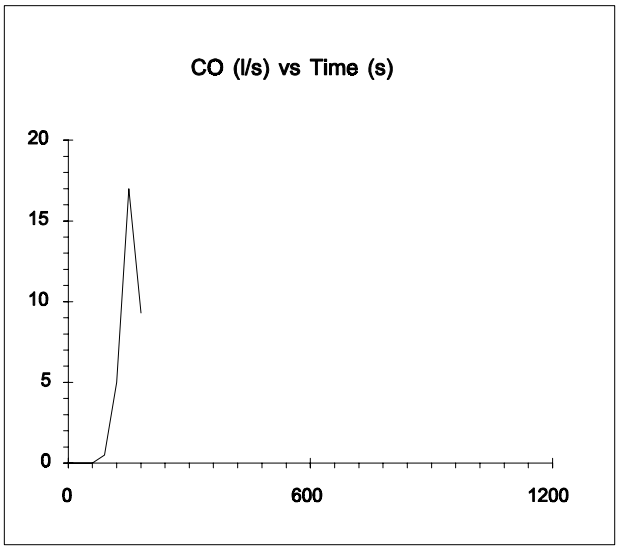
Test procedure:
Method: Room/corner test. 3 walls and ceiling covered with material
Ignition source: Gas burner, 100 kW.

Also available:
Heat flux, gas temp. and flame spread.

Reference:
Söderbom, J
EURIFIC - Large Scale Tests according to ISO DIS 9705
Fire Technology
SP REPORT 1991:27, ISSN 0248-5127
Borås, Sweden 1991







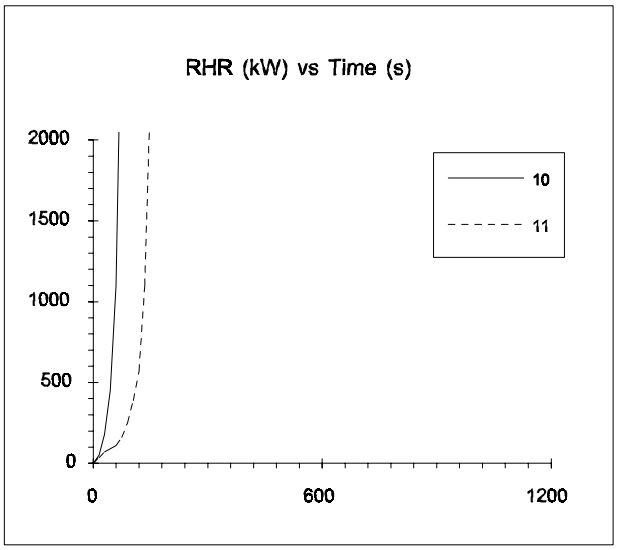
10: Insulating fibre board
Thickness: 13 mm
Density: 250 kg/m^3
Moisture content: 7.0%
Test 1

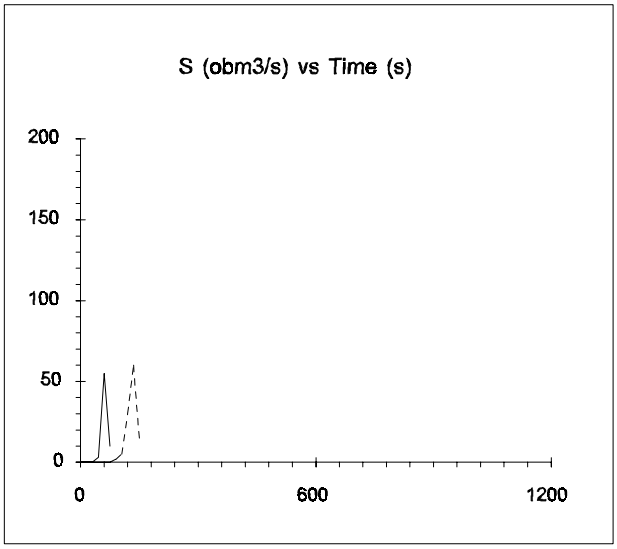
11: Medium density fibre board
Thickness: 12 mm
Density: 600 kg/m^3
Moisture content: 5.9%
Test 2

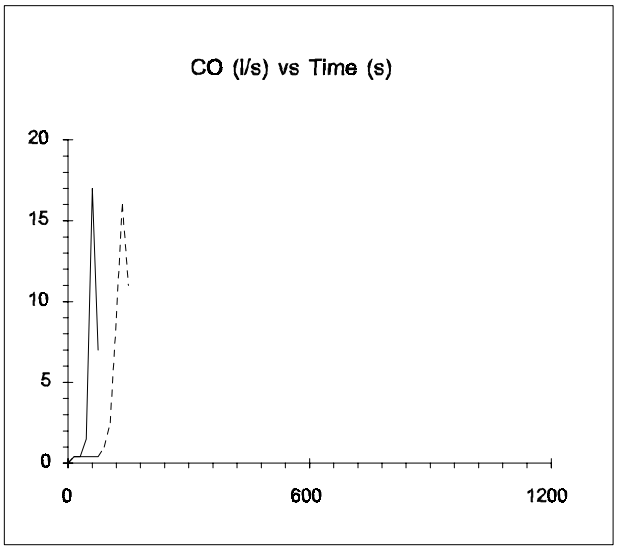
Test procedure:
Method: Room/corner test. 3 walls and ceiling covered with material
Ignition source: Gas burner, 100 kW.

Also available:
Gas and surface temp., heat flux, mass flow, burning area and production of CO_2 and hydrocarbons.

Reference:
Sundström, B
Full Scale Fire Testing of Surface Materials
Fire Technology
Technical report 1986:45, ISSN 0280-2503
Borås, Sweden 1986







Particle boards

Particle board in sample 20-24:
Thickness: 10 mm
Density: 750 kg/m^3
Moisture content: 7.1%

20:
Test 3

21:
Ignition source: 40 kW gas burner
Moisture content: 5.0%
Test 15

22:
Only walls covered with material
Test 16

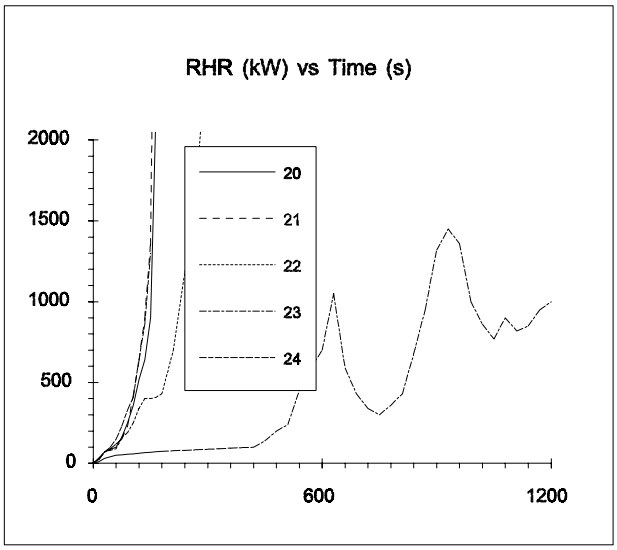
23:
Only ceiling covered with material
Test 17

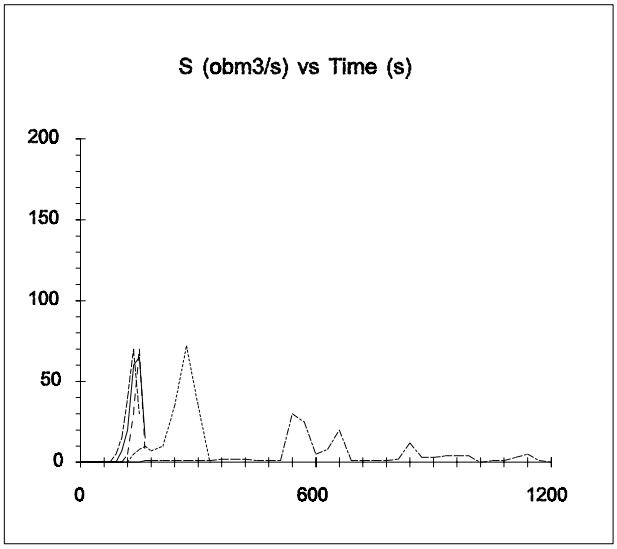
24: Paper wallcovering on particle board
Thickness: 0.6 mm
Density: 200 g/m^2
Application: Glued
Test 13

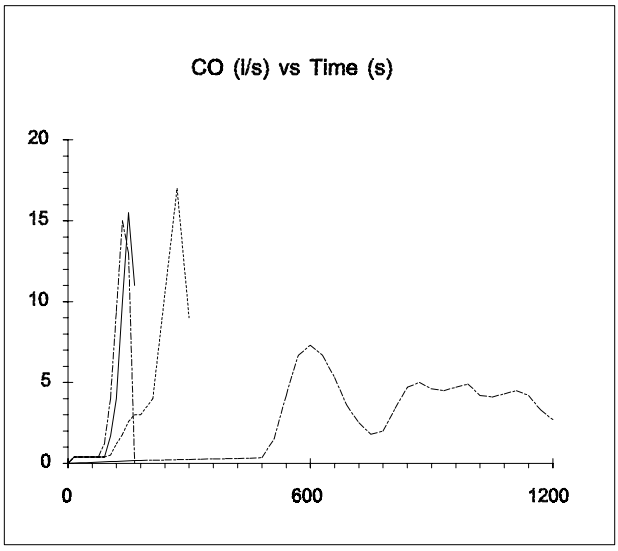
Test procedure:
Method: Room/corner test. 3 walls and ceiling covered with material
Ignition source: Gas burner, 100 kW.

Also available:
Gas and surface temp., heat flux, mass flow, convective heat flow, burning area and production of CO_2 and hydrocarbons.

Reference:
Sundström, B
Full Scale Fire Testing of Surface Materials
Fire Technology
Technical report 1986:45, ISSN 0280-2503
Borås, Sweden 1986







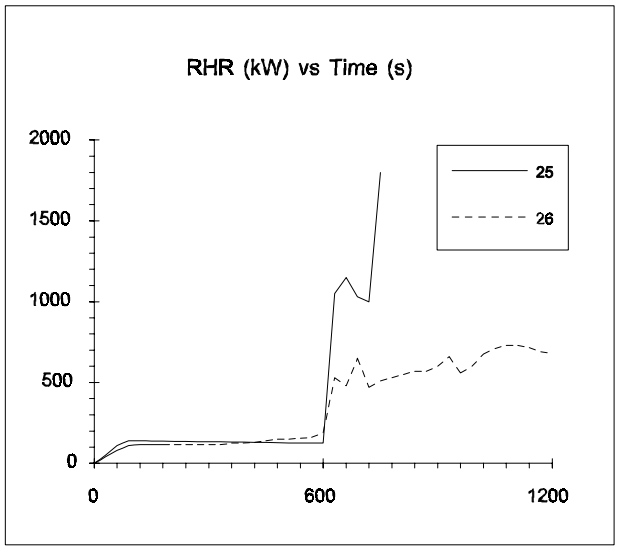
25: FR Particle board
Thickness: 16 mm
Density: 630 kg/m^3
Test 6, PART.B1

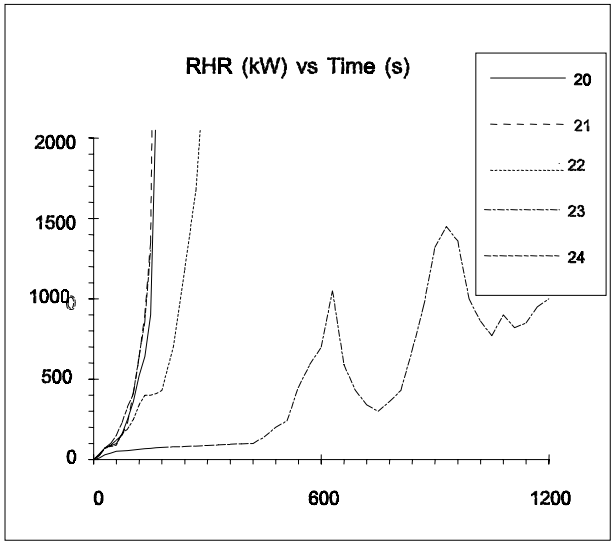
26: FR Particle board
Thickness: 12 mm
Density: 750 kg/m^3
Test 8, FR.PARTB

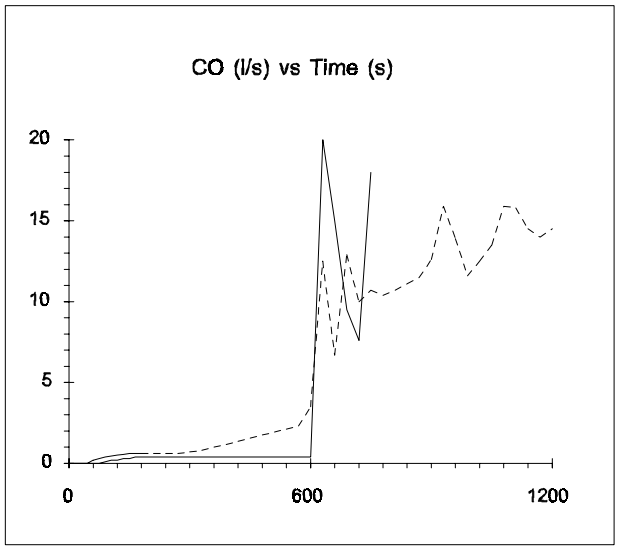
Test procedure:
Method: Room/corner test. 3 walls and ceiling covered with material
Ignition source: Gas burner, 100 kW in 600 s, thereafter 300 kW in 600 s.

Also available:
Heat flux, gas temp. and flame spread.

Reference:
Söderbom, J
EURIFIC - Large Scale Tests according to ISO DIS 9705
Fire Technology
SP REPORT 1991:27, ISSN 0248-5127
Borås, Sweden 1991





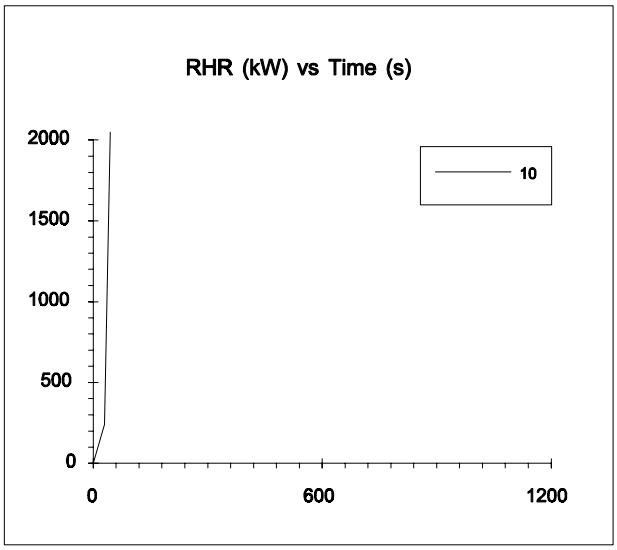


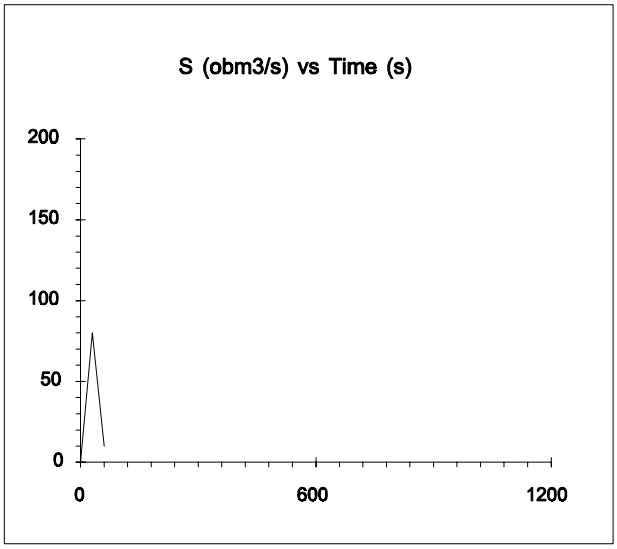
10: Textile wallcovering on mineral wool
Mineral wool:
Thickness: 50 mm
Density: 100 kg/m^3
Textile wallcovering:
Thickness: 0.7 mm
Surface weight: 370 g/m^2
Application: Glued
Test 8

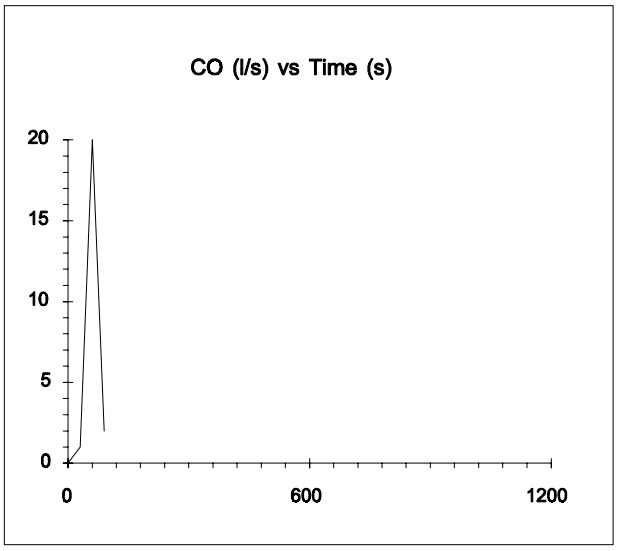
Test procedure:
Method: Room/corner test. 3 walls and ceiling covered with material
Ignition source: Gas burner, 100 kW.

Also available:
Gas and surface temp., heat flux, mass flow, burning area and production of CO_2 and hydrocarbons.

Reference:
Sundström, B
Full Scale Fire Testing of Surface Materials
Fire Technology
Technical report 1986:45, ISSN 0280-2503
Borås, Sweden 1986





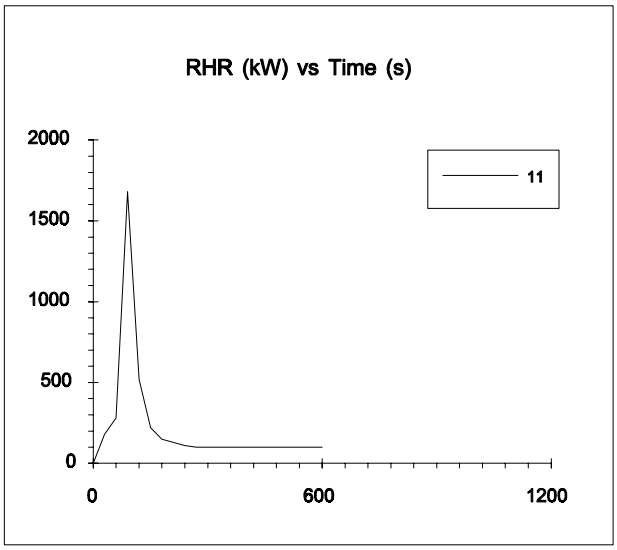


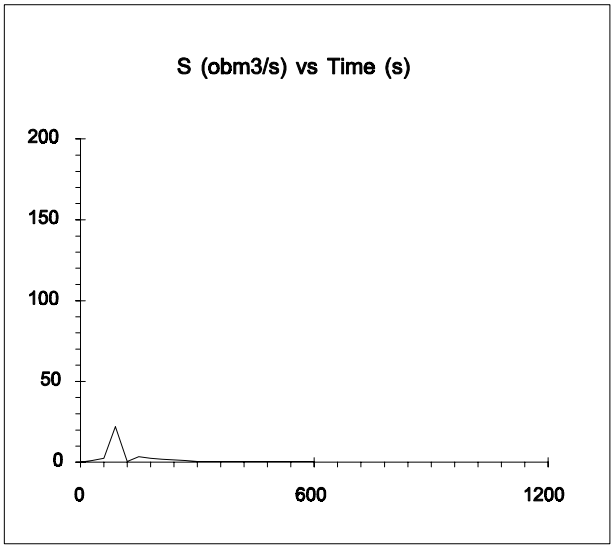
11: Combustible faced mineral wool
Thickness: 30 mm
Density: 87 kg/m^3 (total)
Test 7, FACED MW

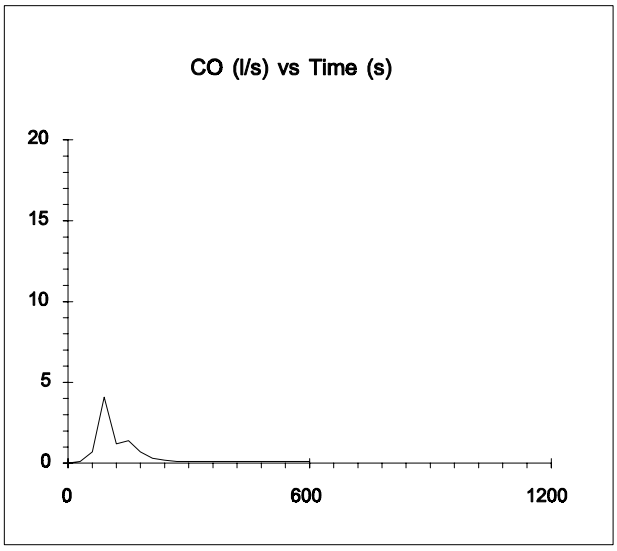
Test procedure:
Method: Room/corner test. 3 walls and ceiling covered with material
Ignition source: Gas burner, 100 kW in 600 s.

Also available:
Heat flux, gas temp. and flame spread

Reference:
Söderbom, J
EURIFIC - Large Scale Tests according to ISO DIS 9705
Fire Technology
SP REPORT 1991:27, ISSN 0248-5127
Borås, Sweden 1991





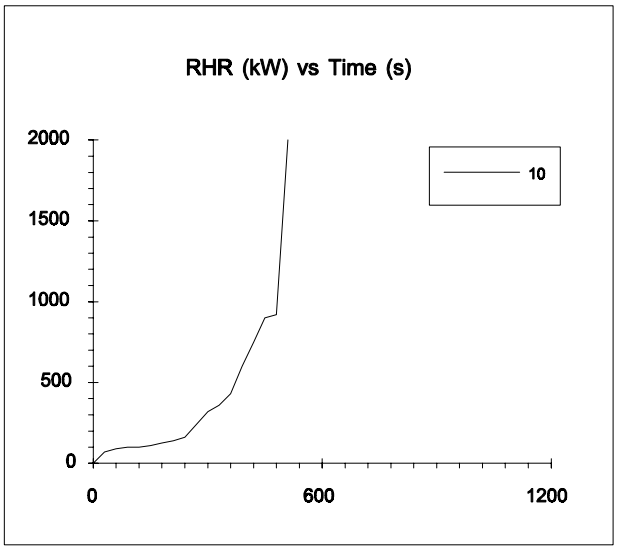


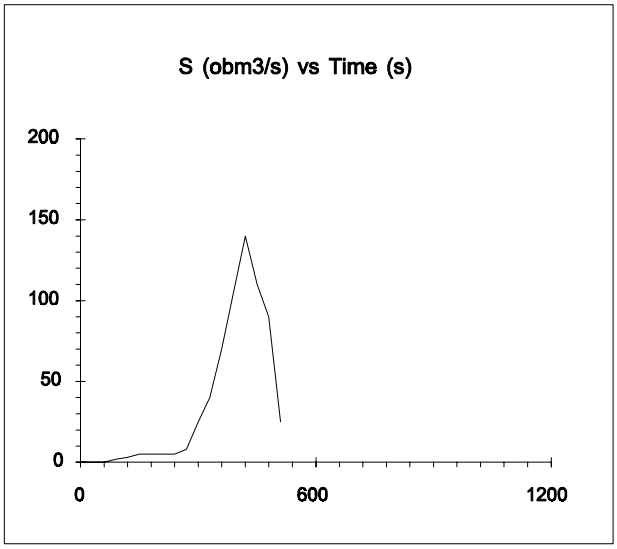
10: Melamine faced particle board
Thickness: 13 mm (Laminate 1.2 mm)
Density: 810 g/m^3
Moisture content: 6.7%
Application: Laminate glued on both sides of board
Test 9

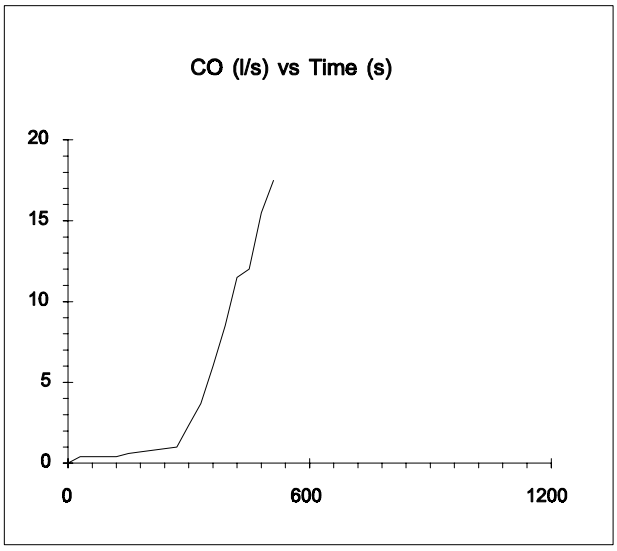
Test procedure:
Method: Room/corner test. 3 walls and ceiling covered with material
Ignition source: Gas burner, 100 kW.

Also available:
Gas and surface temp., heat flux, mass flow, burning area and production of CO_2 and hydrocarbons.

Reference:
Sundström, B
Full Scale Fire Testing of Surface Materials
Fire Technology
Technical report 1986:45, ISSN 0280-2503
Borås, Sweden 1986







Laminate faced panels

Laminate faced particle board
Front surface lined with decorative laminate and back of panel lined with protective laminate
Tickness: 11 mm
Density: 760 kg/m^3 (particle board)

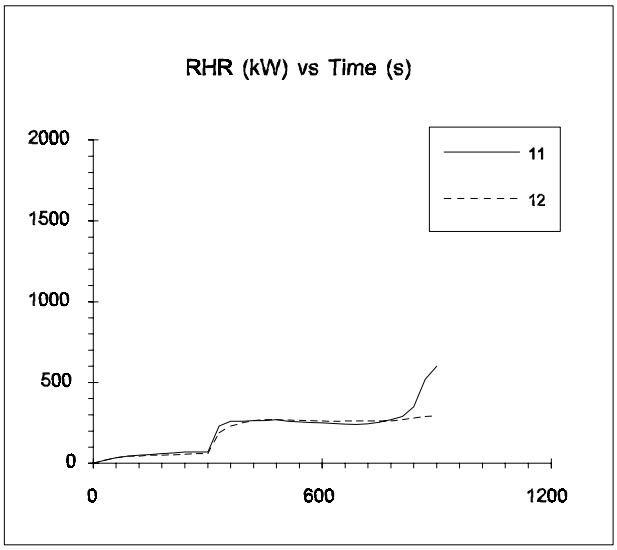
11:
Mounting: Horizontal furring strips making a 25 mm space between panel and wall gypsum board.
Test: Composite wall panel 210

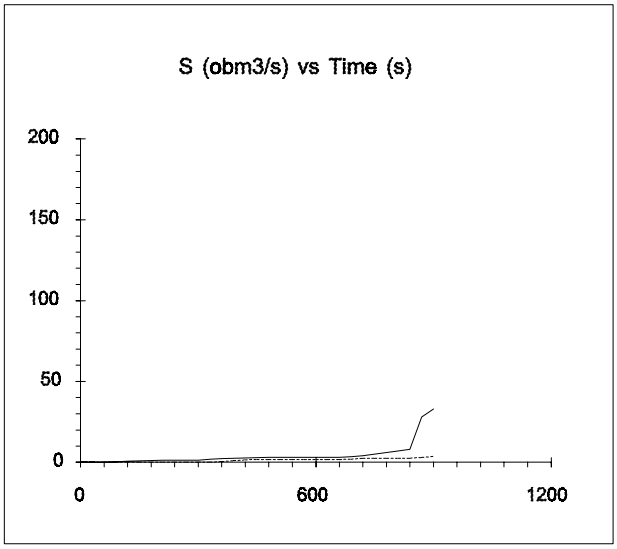
12:
Mounting: Directly on wall gypsum board.
Test: Composite wall panel 310

Test procedure:
Method: Room/corner test. 3 walls covered with material
Ignition source: Gas burner, 40 kW, thereafter 160 kW.

Also available:
Heat flux and gas temp.

Reference:
Söderbom, J
Swedish results from interlaboratory calibration tests according to ISO/ASTM room fire test method
Fire Technology
SP-AR 1991:27
Borås, Sweden 1991



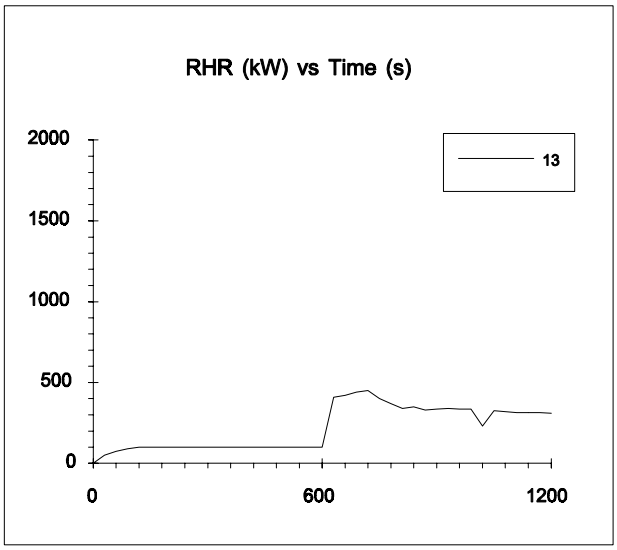


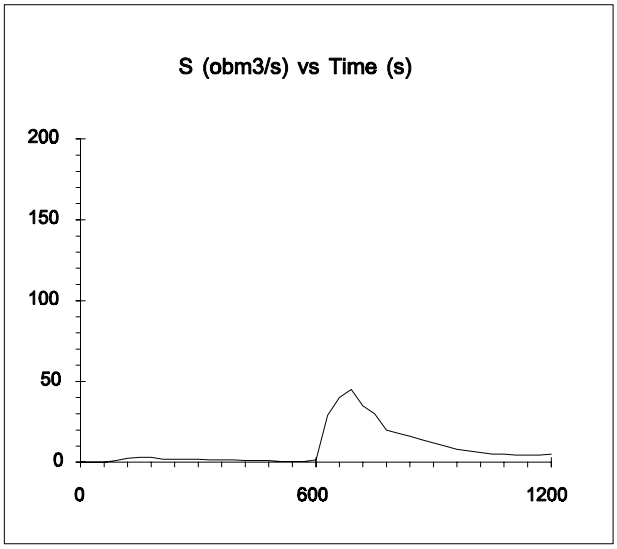
13: Melamine faced high density non comb. board
The boards were faced on both sides
Tickness: 1.5 + 12 mm
Density: 1055 kg/m^3 (total)
Test: 4, MEL FAC

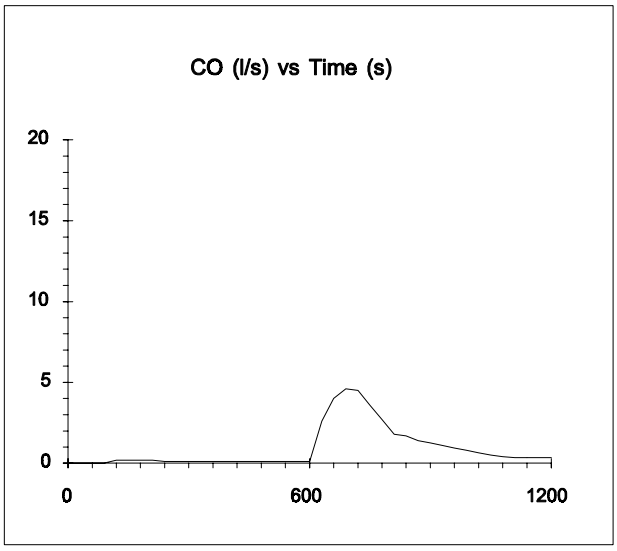
Test procedure:
Method: Room/corner test. 3 walls and ceiling covered with material
Ignition source: Gas burner, 100 kW in 600 s, thereafter 300 kW in 600 s.

Also available:
Heat flux, gas temp. and flame spread

Reference:
Söderbom, J
EURIFIC - Large Scale Tests according to ISO DIS 9705
Fire Technology
SP REPORT 1991:27, ISSN 0248-5127
Borås, Sweden 1991







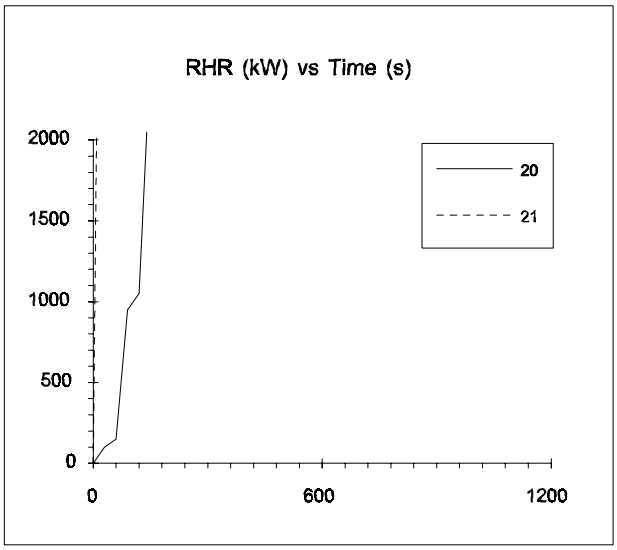
20: Expanded PS
Thickness: 50 mm
Density: 20 g/m^3
Application: Glued to non-combustible silicate board
Test 10

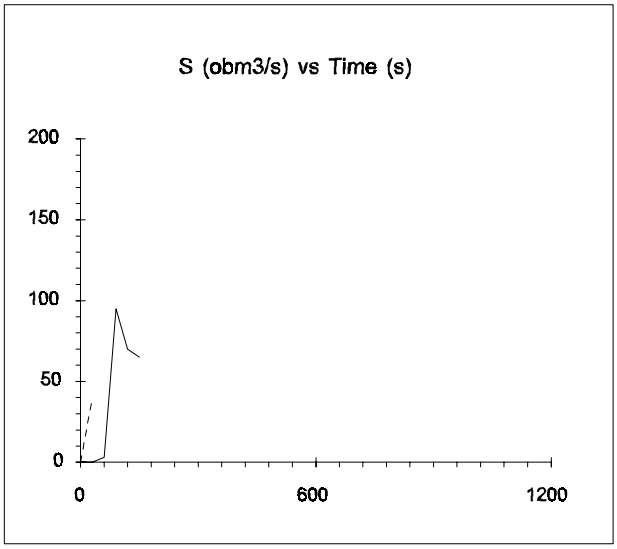
21: Rigid PU foam
Thickness: 30 mm
Density: 30 g/m^3
Test 11

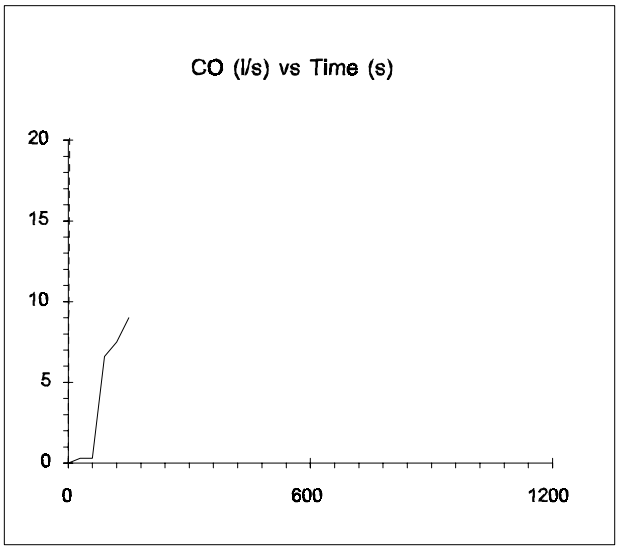
Test procedure:
Method: Room/corner test. 3 walls and ceiling covered with material
Ignition source: Gas burner, 100 kW.

Also available:
Gas and surface temp., heat flux, mass flow, burning area and production of CO_2 and hydrocarbons.

Reference:
Sundström, B
Full Scale Fire Testing of Surface Materials
Fire Technology
Technical report 1986:45, ISSN 0280-2503
Borås, Sweden 1986





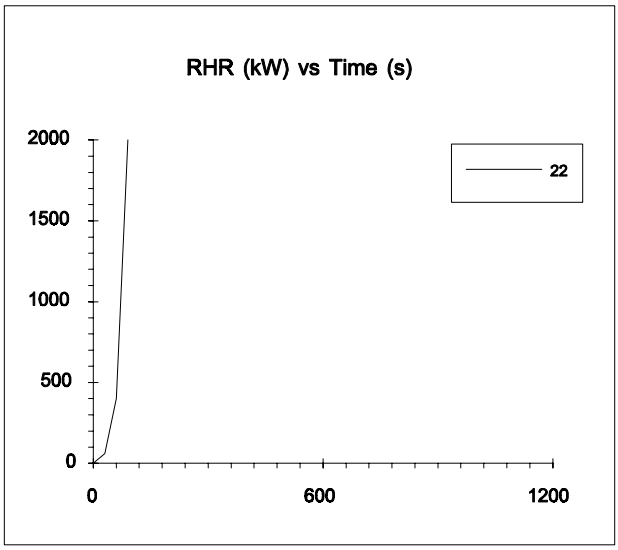


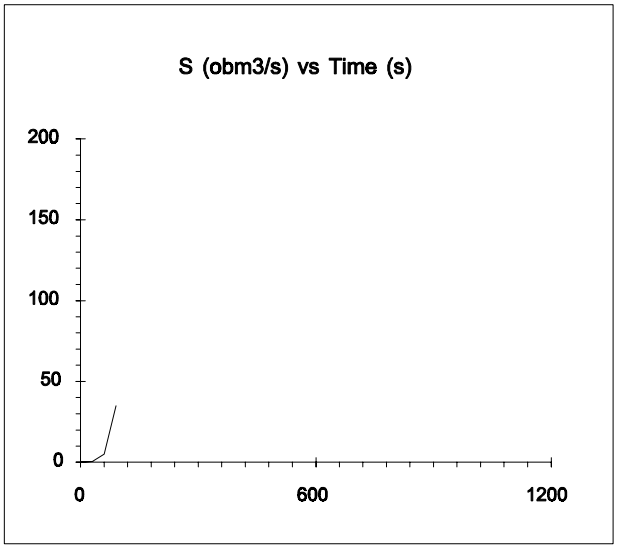
22: FR expanded PS
Thickness: 25 mm (foam)
Density: 37 g/m^3
Glued to non combustible board
Test 11, EX.POLYS

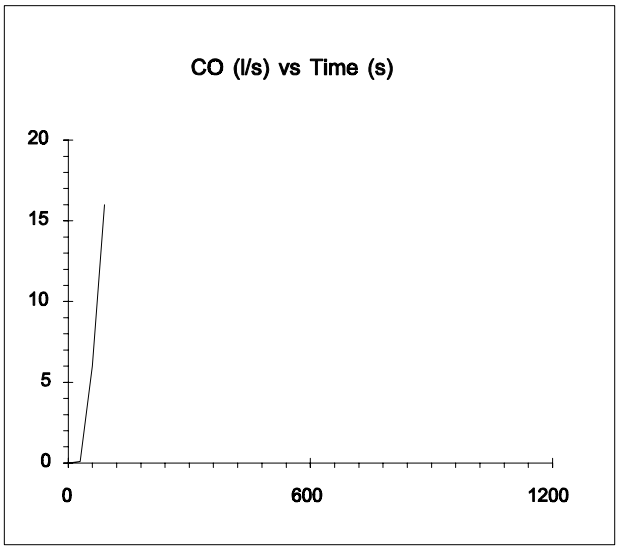
Test procedure:
Method: Room/corner test. 3 walls and ceiling covered with material
Ignition source: Gas burner, 100 kW.

Also available:
Heat flux, gas temp. and flame spread

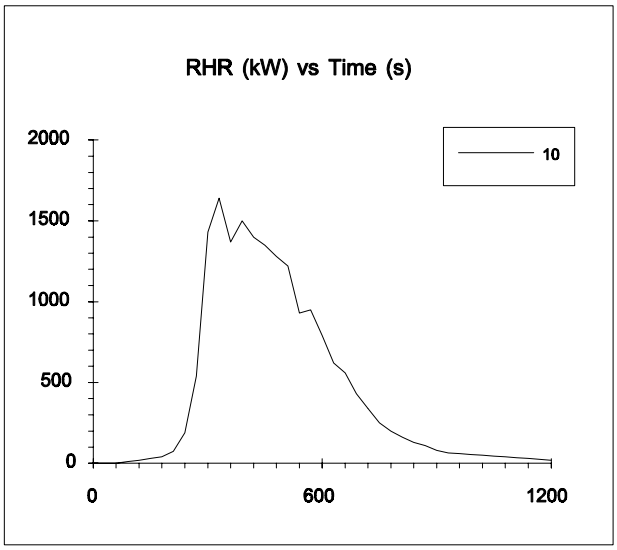
Reference:
Söderbom, J
EURIFIC - Large Scale Tests according to ISO DIS 9705
Fire Technology
SP REPORT 1991:27, ISSN 0248-5127
Borås, Sweden 1991







10: Simulated navy cabin
Furnishing: Two two-storey beds.
Beds: 0.80 x 2.00 x 0.12 m^3 PU foam mattress with a cotton cover, and one pillow. The bottom beds had an additional mattress as a back cushion.
(Total: 6 mattresses)
Walls and ceiling: Non combustible
Room size: 4 x 3 x 2.4 m^3
Door opening: 0.8 x 2.1 m^2
Room ventilation: 0.060 m^3/s
The door was located in the middle of a 12 m corridor with the hood in the open end.



Test procedure:
Method: Room calorimeter
Ignition source: Fibre insulating board, 75 mm in diameter and 75 mm long, soaked in with 120 ml of heptane and wrapped in a polyethylene bag, placed on bottom bed next to the pillow.

Note:
The room was completely burned out after the test.

Reference:
Dahlberg, M
Fartygshytt
Fire Technology
Borås, Sweden
Not published

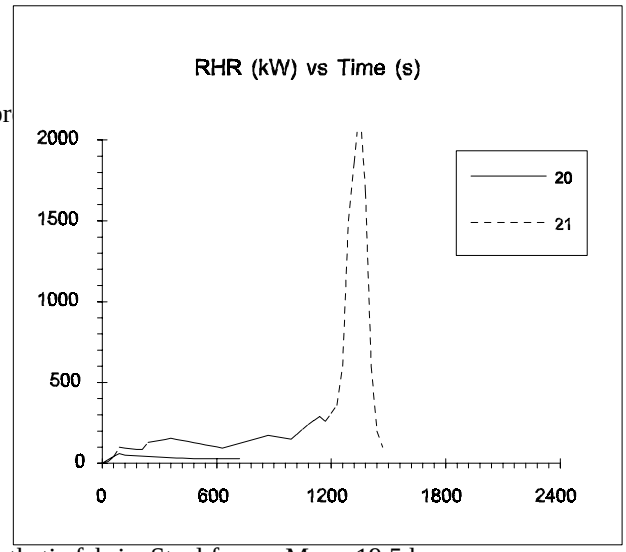
Offices

Room furnished with an office module. The partitions were forming a U, with a desk on one side and a file cabinet on the other.

Partitions: Steel framed hardboard panel covered with fibr
Width: 1.8 + 2.1 + 1.8 m
Height: 1.7 m
Thickness: 41 mm

Desk: Steel frame with plastic top
Size: 1.8 x 0.6 x 0.76 m^3
Mass: 59 kg
Paper load: 14 kg
Shelve: Steel shelve 0.56 m above the desk
Size: 1.8 x 0.3 m^2
Paper load: 32 kg (open top file boxes)
Drawers: Conventional two drawer steel file cabinet
Paper load: 6 + 6 kg
Chair: Molded plastic, lightly padded and covered with synthetic fabric. Steel frame. Mass: 19.5 kg

File cabinet: 5 shelf steel construction
Paper load: 20 + 20 kg on the two top shelves.



20:
Test 320

21: Similar to sample 20, with a rearrangement of the papers on the desk
Test 321

Test procedure:
Method: Room calorimeter
Ignition source: Steel trash can with 1.7 kg paper, in the corner between the desk and the back partition.

Also available:
Total heat release, gas temp, and O_2, CO_2 and CO concentrations.

Note:
In sample 20, the fire did not spread from the trash can. Similar tests were performed using different types of water sprinkler.

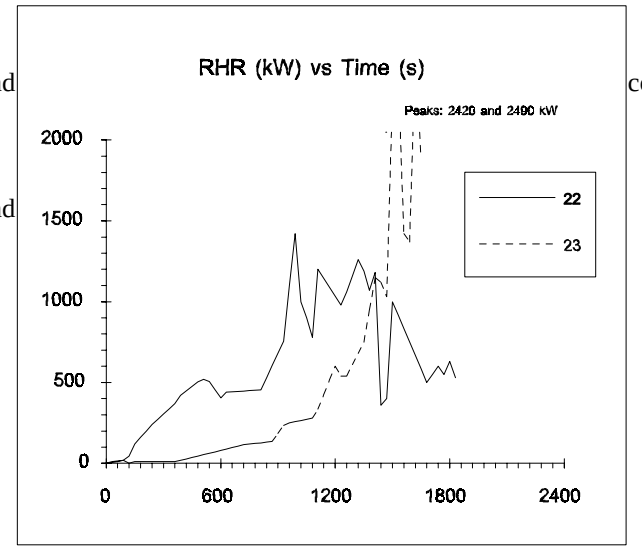
Reference:
Walton, W. D. & Budnick, E. K.
Quick response Sprinkler in Office Configurations: Fire Test Results
NISTIR 88-3695
U.S.A 1988

Offices

Computer work station with a computer desk and a bookcase at right angels to each other.

Computer desk: The desk had a set of 4 shelves above and covered
Plastic laminate covered 16 mm hardboard
Size: 0.60 / 0.24 x 1.24 x 1.52 m^3
Mass: 58.1 kg
Paper load: 44.9 kg distributed on the 4 shelves

Book case: 5 shelf construction and
Plastic laminate covered 16 mm hardboard
Size: 0.3 x 0.91 x 1.83 m^2
Mass: 46.3 kg
Paper load: 72.6 kg distributed on the 5 shelves.



22:
Freeburning
Test 101

23:
In room
Test 102

Y0/22-23

Test procedure:
Methods:
Sample 22: Freeburning in calorimeter
Sample 23: Room calorimeter
Ignition sources: In the corner between the desk and the book case.
Sample 22: 50 kW gas burner.
Sample 23: Steel trash can with 1.7 kg paper,

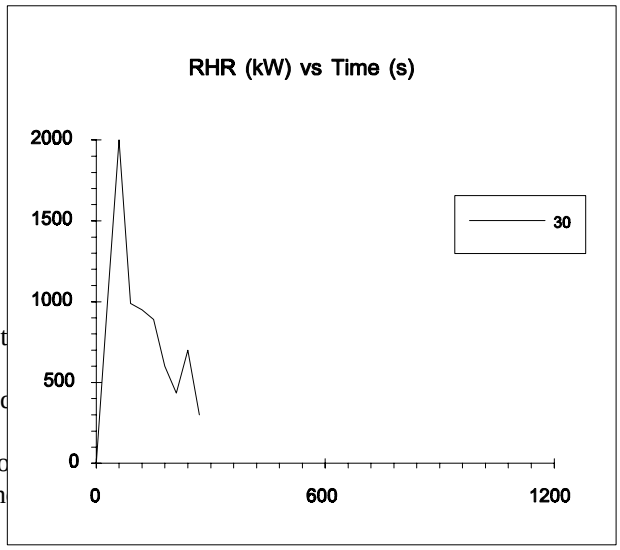
Also available:
Total heat release, gas temp, O_2, CO_2 and CO concentrations.

Note:
Similar tests were performed using different types of water sprinkler.

Reference:
Walton, W. D. & Budnick, E. K.
Quick response Sprinkler in Office Configurations: Fire Test ResultsNISTIR 88-3695
U.S.A 1988

30: Acetone spill in laboratory
Steel laboratory bench with closed drawers and stone bench top. Above the bench there was an open wooden shelving unit.

Bench:
Size: 1.23 x 0.56 x 0.94 m^3
Mass: 134 kg
Shelves:
Size: 0.94 x 0.30 x 0.99 m^3
Mass: 24.0 kg
Load: Computer paper, folders, notebooks et c. ditributed
Mass: 50.8 kg
In the floor pan there was placed a glass disposal
Acetone:
3 l of acetone in a 1.23 x 0.76 m^2 steel pan on the
1 l of acetone in a 0.61 x 0.46 m^2 steel pan on the



Test procedure:
Method: Freeburning in calorimeter
Ignition source: Acetone in floor pan ignited

Also available:
Total heat released

Note:
Tests using sprinklers were also performed.

Reference:
Walton, W. D.
Quick Response Sprinkler in Chemical Laboratories: Fire Test Results
NISTIR 89-4200
U.S.A 1989

Coffee makers

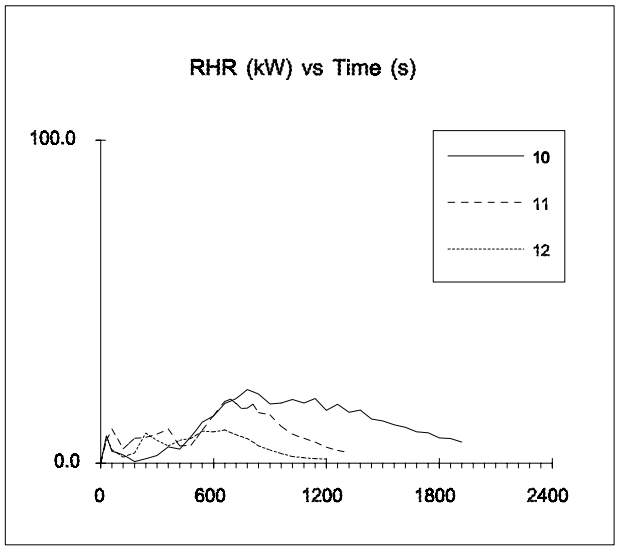
10: Melitta
Mass: 1117 g

11: Philips
Mass: 820 g

12: Melitta
Mass: 1290 g

Test procedure:
Method: Freeburning in furniture calorimeter

Reference:
Andersson, Berit
Kaffebryggare
Departement of Fire Safety Engineering
Lund Institute of Technology, Lund University
Not published



Television sets

The recievers were manufactured in the early 1960's
Frame: Wood
Back cover and components: Plastics
The components were covered with dust from twenty years of use.

20: Luxor Carina, 24"
Mass: 32.7 kg
Expt.no. 1

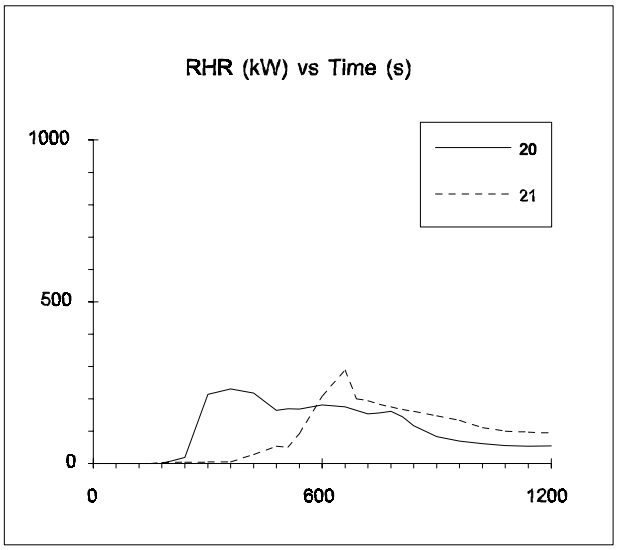
21: Luxor Continental, 26"
Mass: 39.8 kg
Expt.no. 3

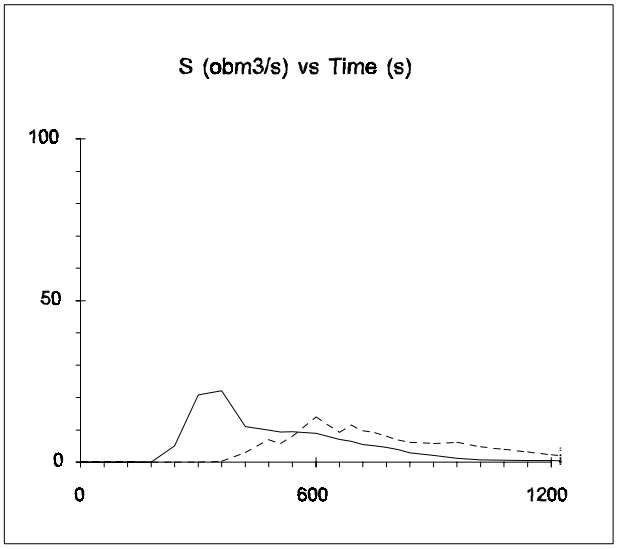
Test procedure:
Method: Room calorimeter, in the corner.
Ignition source: 100 ml isopropanol in tray, about 4 kW, inside the TV sets.

Sample:	20	21
H_{eff} (MJ/kg):	14	15

Also available:
Radiation and gas temp.

Reference:
Ahonen, A, Kokkala, M & Weckman, H.
Burning Characteristics of potential ignition sources of room fires
Technical Research Center of Finland
Research reports 285, ISSN 0358-5077
Espoo, Finland 1985



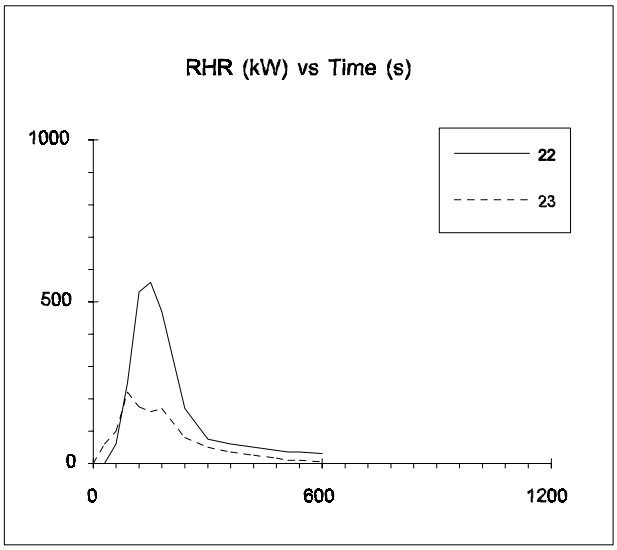


Television sets

Two cabinets with the spacing 0.025 m.
The TV cabinets were moldings of an external cabinet only. The opening was closed with a steel cover. No internal working parts were used.
Size: 0.36 x 0.33 x 0.25 m^3
Thickness: 3.0 mm

22:
High impact polystyrene base formulation.
Mass: 3.7 kg
Sample H.

23: FR
High impact polystyrene bas formulation with decabromodiphenyl oxide (12% by mass) and antimony oxide (4% by mass).
Mass: 3.7 kg
Sample G.



Test procedure:
Method: Freeburning in furniture calorimeter
Ignition source: 50 kW gas burner in 200 s, positioned between the cabinets.

Sample:	22	23
H_{eff} (MJ/kg):	23	20
Smoke (obm^3/kg):	13200	28000
CO (kg/kg):	0.12	0.37
CO_2 (kg/kg):	1.39	0.74
HBr (kg/kg):	NA	0.08

Reference:
Babrauskas, V et al.
Fire Hazard Comparison of Fire-Retarded and Non-Fire-Retarded Products
National Bureau of Standards
NBS Special Publication 749
U.S.A. 1988

Business machines

Two Business machine cabinets with the spacing 0.025 m.
The cabinets were moldings of an external cabinet only.
No internal working parts were used.
Thickness: 3.0 mm.

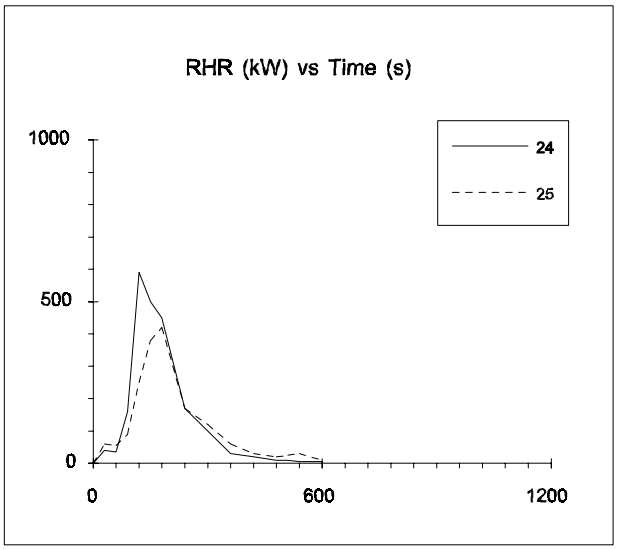
25:
Poly(2,6-dimethyl 1,4-phenylene)oxid, also including polystyrene, polybutadiene, polyethylene, mineral oil and stabilizer additives.
Mass: 3.5 kg
Sample F

26: FR
The same base formulation as sample 25 with a triaryl phosphate ester based flame retardant (1% by mass).
Mass: 3.5 kg
Sample A.

Test procedure:
Method: Freeburning in furniture calorimeter
Ignition source: 50 kW gas burner in 200 s, positioned between the cabinets.

Sample:	25	26
H_{eff} (MJ/kg):	24	28
Smoke (obm^3/kg):	11500	12800
CO (kg/kg):	0.13	0.29
CO_2 (kg/kg):	1.61	1.45

Reference:
Babrauskas, V et al.
Fire Hazard Comparison of Fire-Retarded and Non-Fire-Retarded Products
National Bureau of Standards
NBS Special Publication 749
U.S.A. 1988



Wardrobes

Simulated clothing:
Four different fabrics placed into the wardrobes on 16 clothes hangers. 53% cotton, 47% polyester.
Mass: 0.87 kg,

10: Steel wardrobe
Size: 0.47 x 1.22 x 1.6 m^3
Thickness:0.69 mm
Painted
Test 21

11: Plywood wardrobe
Size: 0.61 x 1.22 x 1.78 m^3
Thickness: 12.7 mm
Unfinished
Test 43

12: Particle board wardrobe with drawers and shelves
Back covered with 3.2 mm hardboard
Shelves covered with plastic laminate
Size: 0.4 x (0.42 wardrobe + 0.81 drawers and shelves) x 1.6 m^3
Thickness: 19.1 mm
Test 61

Test procedure:
Method: Freeburning in furniture calorimeter. The wardrobe door next to the ignition box was closed and the other door was opened 178 mm.
Ignition source: Cardboard box filled with 10 sheets of crumpled newspaper placed in the corner of the wardrobe under the fabrics. Total mass 0.90 kg.

Sample:	10	11	12
H_{eff} (MJ/kg):	18.8	14.9	17.5
CO (g/s), peak:	0.3	2.3	1.2

Also available:
Mass loss, target irradiance and smoke particulate conversion

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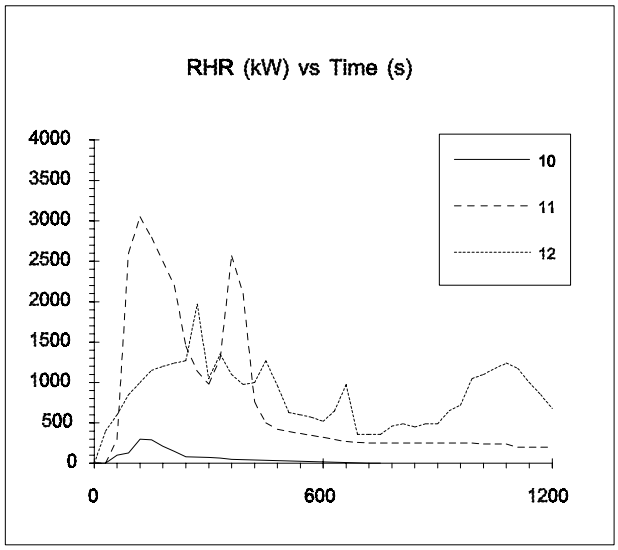
Reference:
Lawson, J.R et al
Fire Performance of Furnishings As Measured in the NBS Furniture Calorimeter. Part I
National Bureau of Standards
NBSIR 83-2787
U.S.A. 1983



Wardrobes

Simulated clothing:
See page Y3.1/10

Plywood wardrobe
Size: 0.62 x 1.22 x 1.82 m^3
Thickness: 3.2 mm
Rolling doors

13:
Unfinished
Test 41

14:
1 coat FR latex paint on the inside
Test 42

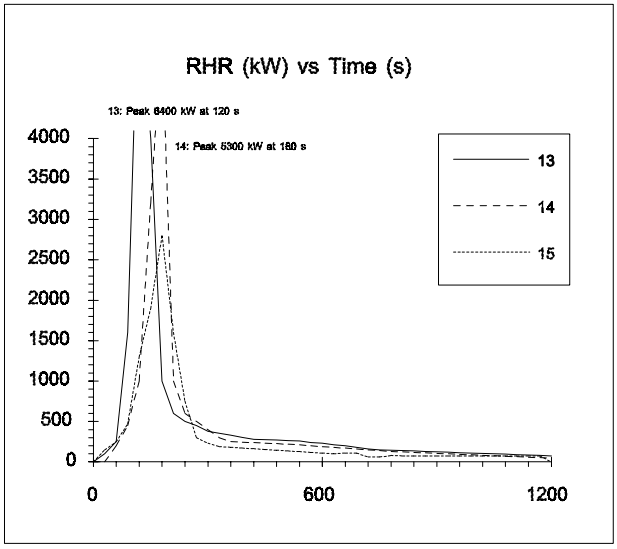
15:
2 coats FR latex paint inside and out
Test 44

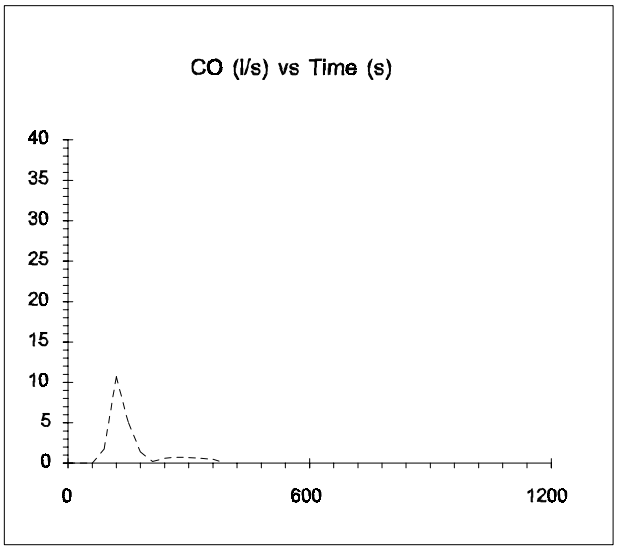
Test procedure:
See page Y3.1/10

Sample:	13	14	15
H_{eff} (MJ/kg):	16.9	15.9	14.2
CO (g/s), peak: 3.1	12.6	7.7	

Also available:
See page Y3.1/10

Reference:
See page Y3.1/10





Office storage

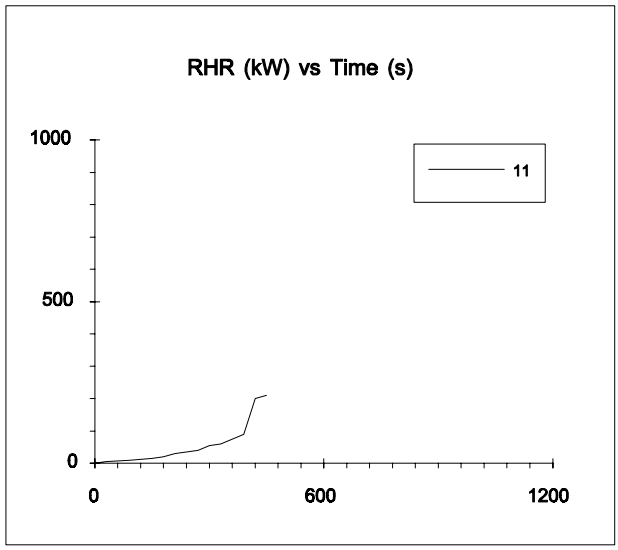
Hospital records closely packed in a set of 3 metal shelves.

10: Hospital records
Paper envelopes containing paper. Not even a tray with 2 dl ethanole was sufficiant to get a fast fire growth. No data available.

11: X-ray records
Paper envelopes containing paper and plastic X-ray plates. At 450 s one metal shelve collapsed and the journals fell inwards. Melted plastics dripped on the bottom shelf but did not ignite the journals.

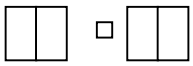
Test procedure:
Method: Freeburning in furniture calorimeter
Ignition source: Match on journal at the middle shelf

Reference:
Malmquist, P-O
Riskanalys, Helsingborgs lasarett - arkivet
Helsingborgs brandförsvar
Helsingborg, Sweden 1988



Office storage

Four open shelving units placed as in the figure:



Each unit consisted of:
5 steel shelves with vertical steel support at the corners.
Size: 0.91 x 0.46 x 1.80 m^3
Shelf loads:
1(bottom) and 2: 37 kg horiz. stacked paper each.
3 and 4: 14 kg paper in open top vert. file holders each.
5 (top): 19 kg paper in closed cardboard boxes.

12: Open shelving unit with paper
Distance between the units: 0.7 m
Test 201

13: Open shelving unit with paper
Two boxes with paper products were placed in the aisle between the units. Total mass: 3 kg
Distance between the units: 0.61 m
Test 202

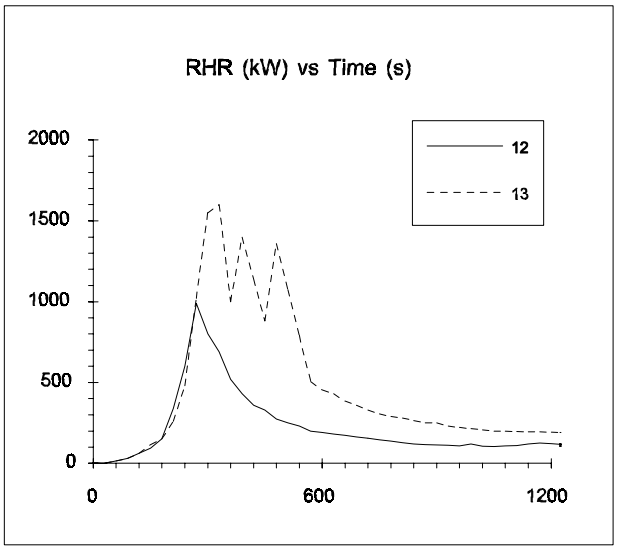
Test procedure:
Method: Freeburning in calorimeter
Ignition source: 50 kW gas burner located as shown in the figure, 0.37 m above the floor

---

Also available:
Total heat release

Note:
In sample 13 all the units were involved in the fire.
In sample 12 only the two units next to the burner were involved.

Reference:
Walton, W. D. & Budnick, E. K.
Quick response Sprinkler in Office Configurations: Fire Test Results
NISTIR 88-3695
U.S.A 1988

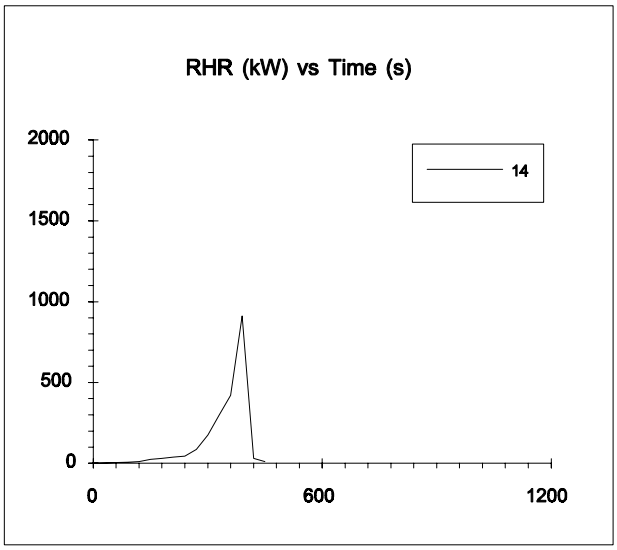


14: Book case with file holders
3 shelve book case
Frame: Fibre board and hard board (back)
Size: 0.64 x 0.38 x 1.22 m^3
Mass: 19.1 kg
Load: Paper in 15 open top PS file holders
Mass: 3.8 kg (PS) + 7.0 kg (paper) distr. on 3 shelves

Test procedure:
Method: Freeburning in furniture calorimeter
Ignition source: Cigarette lighter

Note:
The plastic were melting, making a liquid pool fire on the floor under the book case

Reference:
Andersson, L et al.
Universitetsbiblioteket. Risker och brister vid utrymning
Brandingenjörslinjen, Lunds Tekniska Högskola
Lund, Sweden 1988



Single pallet freeburn tests

50: FMRC standard plastic commodity
125 PS cups packaged in compartmented, singlewall corrugated cartons on wood pallet.
Size 530 x 530 x 510 mm^3
Weight: 6850 g (4125 g PS and 2725 g carton)
Pallet load: 8 cartons in a 2 x 2 x 2 array

51: CEA Standard commodity
PS chips packaged in singlewall corrugated cartons (completely filled) on wood pallet.
Size 450 x 550 x 370 mm^3
Weight: 1145 g (340 g PS and 805 g carton)
Pallet load: 12 cartons in a 2 x 2 x 3 array

52: SCEA Swedish standard commodity
PS chips packaged in singlewall corrugated cartons (completely filled) on wood pallet. Not the same shape as the CEA-chips
Size 380 x 570 x 380 mm^3
Weight: 1120 g (420 g PS and 700 g carton)
Pallet load: 12 cartons in a 2 x 2 x 3 array

53: Large SCEA Swedish standard commodity
PS chips packaged in cartons filled to 75-80% on wood pallet. Quality of chips and cartons identically to the SCEA goods.
Size 600 x 800 x 500 mm^3
Weight: 2690 g (1220 g PS and 1470 g carton)
Pallet load: 4 cartons in a 1 x 2 x 2 array

Test procedure:
Method: Freeburning in industry calorimeter
Ignition source: Fibre insulating board, 75 mm in diameter and 75 mm long, soaked in with 120 ml of heptane and wrapped in a polyethylene bag

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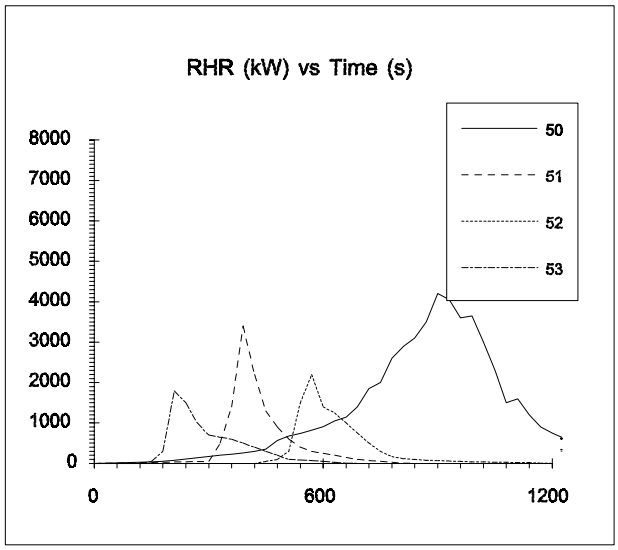
Sample:	50	51	53	54
H_{eff} (MJ/kg):	21.0	13.7	12.6	10.9

Reference:
Persson, H
Evaluation of the RDD-measuring technique
Swedish National Testing and Research Institute
SP Report 1991:04, ISSN 0284-5172
Borås, Sweden 1991



Pallet storage with water sprinkler

54: CEA Standard commodity
Same as sample Y3.3/51
Post pallet system
Fuel array: 12 pallets in a 2 x 2 x 3 array
Flue spaces: 450 mm (short side) and 150 mm (long side)

55:
Same as sample Y3.3/54
Fuel array: 8 pallets in a 2 x 2 x 2 array

56: SCEA Swedish standard commodity
Same as sample Y3.3/52
Post pallet system
Fuel array: 12 pallets in a 2 x 2 x 3 array
Flue spaces: 335 mm (short side) and 270 mm (long side)

57:
Same as sample Y3.3/56
Fuel array: 8 pallets in a 2 x 2 x 2 array

58: Large SCEA Swedish standard commodity
Same as sample Y3.3/53
Post pallet system
Fuel array: 8 pallets in a 2 x 2 x 2 array

Test procedure:
Method: Freeburning in industry calorimeter
Ignition source: Fibre insulating board, 75 mm in diameter and 75 mm long, soaked in with 120 ml of heptane and wrapped in a polyethylene bag, placed in the center of the flue space at the bottom of the pallet loads of the lowest tier.

Also available:
Required Delivered Density for the sprinkler system

Note:
In the tests, water sprinkler were used. The rate of heat release is given until the sprinkler was activated

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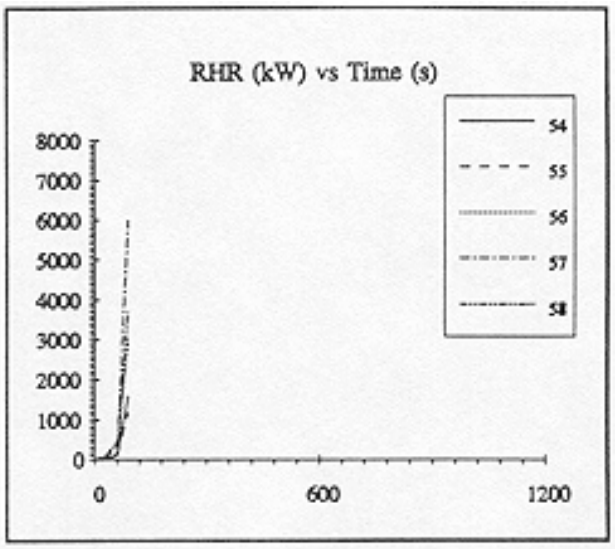
Reference:
Persson, H
Evaluation of the RDD-measuring technique
Swedish National Testing and Research Institute
SP Report 1991:04, ISSN 0284-5172
Borås, Sweden 1991



PET bottles in crates (Swedish standard bottle) on wood pallet
Bottles: Polyethene, volume 1.5 l, empty
Crates: Plastic, each containing 6 bottles
Crate size: 0.27 x 0.30 x 0.40 m^3
Pallet load: 36 crates in a 3 x 4 x 3 array
Pallet size: 0.81 x 1.21 x 1.34 m^3
Total mass: 83.2 kg

59:
Single pallet

60:
Double row steel rack
Fuel array: 8 pallets in a 2 x 2 x 2 array
Water sprinkler started at 330 s

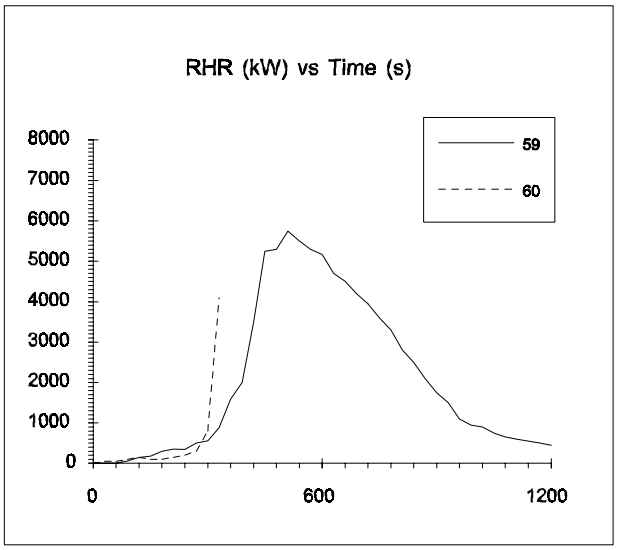
Test procedure:
Method: Freeburning in industry calorimeter
Ignition source: Fibre insulating board, 75 mm in diameter and 75 mm long, soaked in with 120 ml of heptane and wrapped in a polyethylene bag, placed in the center of the flue space at the bottom of the pallet loads of the lowest tier.

Also available:
Required Delivered Density for the sprinkler system

Note:
In sample 60, water sprinkler were used. The rate of heat release is given until the sprinkler was activated.

A test was performed with bottles filled with sparkling water that showed to be almost self-extinguishing. No data available.

Reference:
Arvidson, M. & Persson, H
Sprinkling av PETflaskor
Brand & Räddning, 3/93, pp 26-27, ISSN 0283-1155
Katrineholm, Sweden 1993



Waste baskets

Polyethylene paper baskets

10:
14 l basket with tight walls
Mass: 0.63 kg
Filling: Shredded paper, 0.20 kg
Expt.no. 4

11:
14 l basket with net walls
Mass: 0.53 kg
Filling: Shredded paper, 0.20 kg
Expt.no. 6

12:
14 l basket with net walls
Mass: 0.53 kg
Filling: Milk cans (parafinized cardboard), 0.41 kg
Expt.no. 7

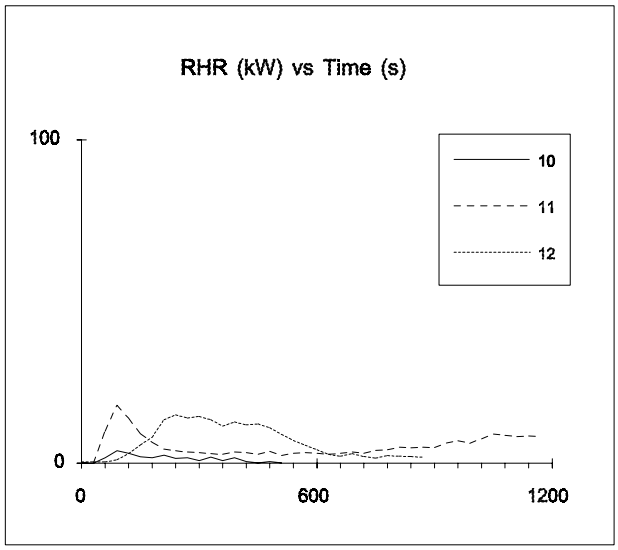
Test procedure:
Method: Room calorimeter, in the corner.
Ignition source: 20 cm cotton wire wetted in isopropanol. Sample 13 was ignited with 10 ml isopropanol on a 20 cm^2 tray, appr. 1 kW.

Sample: 10-12
Smoke prod: Hardly visible

Also available:
Gas temp.

Note:
Sample 10 only melted. The filling burned.

Reference:
Ahonen, A, Kokkala, M & Weckman, H.
Burning Characteristics of potential ignition sources of room fires
Technical Research Center of Finland
Research reports 285
Espoo, 1985



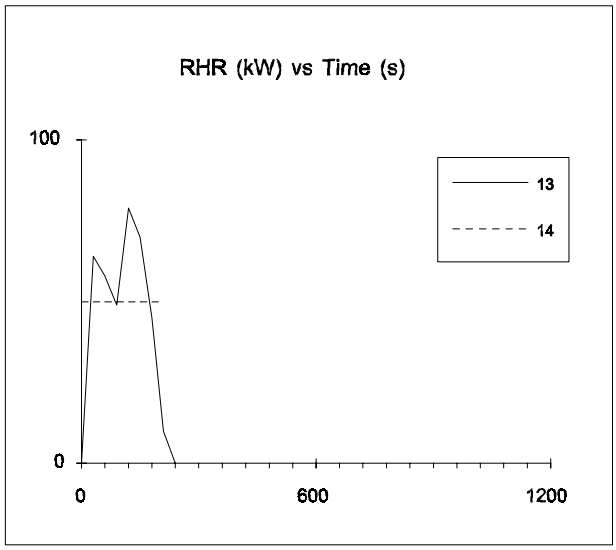
Waste baskets

Polyethylene waste baskets

13:
6.6 l basket
Filling: 12 milk cartons

14:
Simplified representation from 5 samples similar to sample 13

Test procedure:
Method: Freeburning in furniture calorimeter.



Reference:
Babrauskas, V.
Burning Rates
The SFPE Handbook of Fire Protection engineering, pp 2-1 to 2-15
U.S.A., 1988

Rubbish sacks

20: One sack
Filling: straw, grass and duff
Mass: 4.1 kg

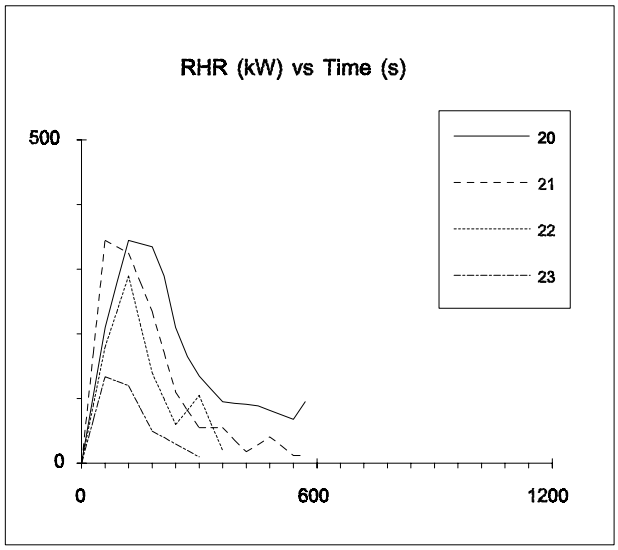
21: Three sacks
Filling: paper rubbish
Mass: 3.51 kg

22: Two sacks
Filling: paper rubbish
Mass: 2.34 kg

23: One sack
Filling: paper rubbish
Mass: 1.17 kg

Test procedure:
Method: Freeburning in furniture calorimeter

Reference:
Babrauskas, V.
Burning Rates
The SFPE Handbook of Fire Protection engineering, pp 2-1 to 2-15
U.S.A., 1988



Chairs, stackable

Stackable plastic chairs
Neither padding nor cushions
Seat and back: Polypropene (one piece)
Legs: Metal
Size: 0.50 x 0.55 x 0.70 m^3
Mass: 1.49 kg (combustible)

10: Single chair

11: 5 chairs in 1 row
Middle chair ignited

12: 8 chairs in 4 rows
Chair in second row ignited

13: 6 chairs in 1 stack
Top chair ignited

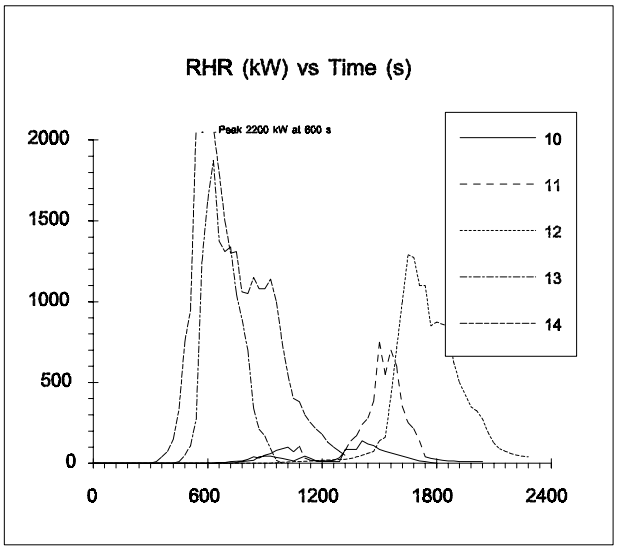
14: 12 chairs in 2 stacks
Top chair ignited

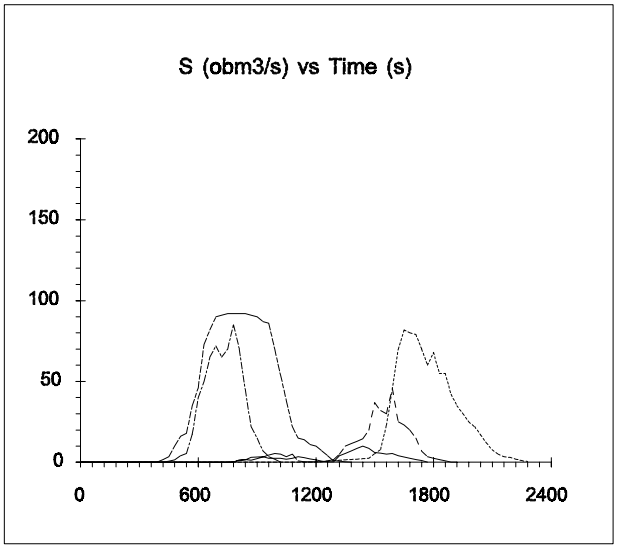
Test procedure:
Method: Freeburning in furniture calorimeter.
Ignition source: 17 g wooden cribs at the seat.

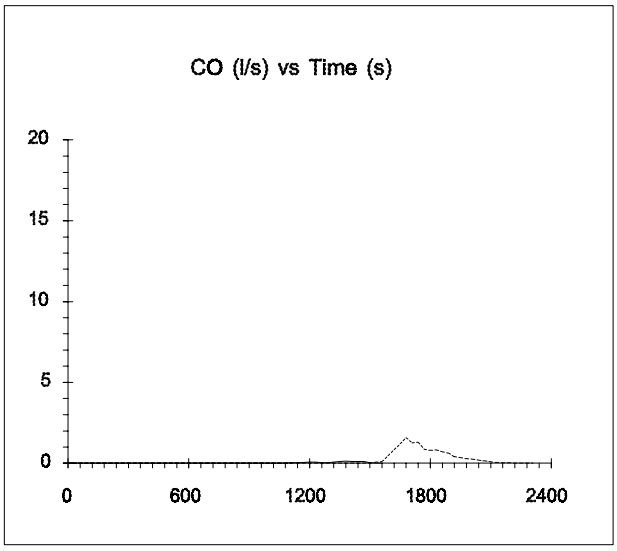
Also available:
Total mass loss, CO2-production and heat flux

Note:
The chairs were melting, making a liquid pool fire on the floor under the chairs.

Reference:
Irjala, B-L
Muovituolien palo-ominaisuuksien selvittäminen
VTT, 76/759/86
Espoo, Finland, 1986







Chairs, stackable

Metal framed chairs containing approx. 0.5 kg PU foam and 2 kg cellulosic materials

15: Single chair

16: 4 chairs in 1 stack

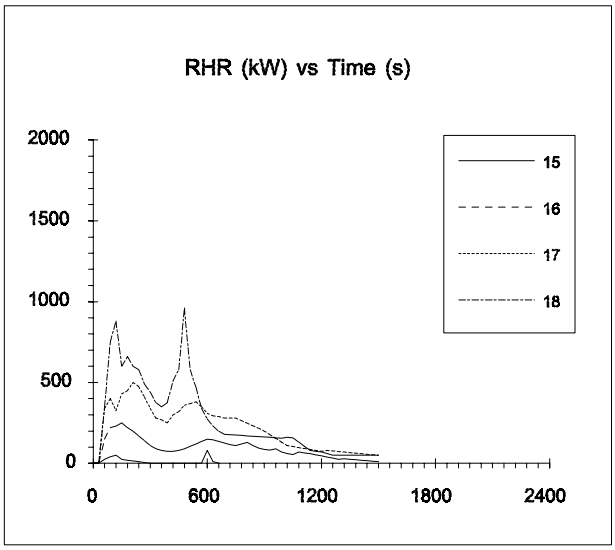
17: 8 chairs in 1 stack

18: 8 chairs in 1 stack
Burned in the corner of a standard room

Test procedure:
Method: Freeburning in furniture calorimeter.
Ignition source: NA

Sample:	17	18
H_{eff} (MJ/kg):	12	18

Reference:
Williamson, R. B., & Dembsey, N. A.
Advances in Assessment Methods for Fire Safety
Fire Safety Journal, Vol 20 No 1, pp 15-38
1993



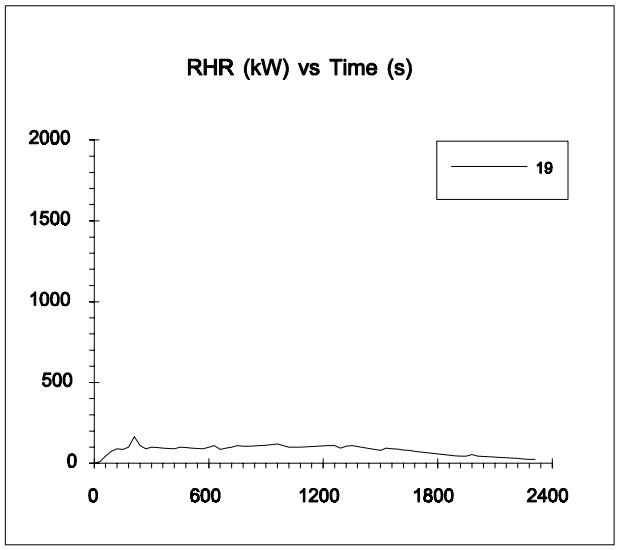
19: 4 chairs in 1 stack
Seat and back: Plywood with PU padding
Frame: Metal
Size: 0.56 x 0.44 x 0.81 m^3
Mass: 29.94 kg
Test 75

Test procedure:
Method: Freeburning in furniture calorimeter
Ignition source: Gas burner at the side of the stack, 50 kW in 200 s (subtracted from the RHR).

Sample:	19
H_{eff} (MJ/kg):	18.7
CO prod. (g/s), peak	0.3

Also available:
Mass loss, target irradiance and smoke particulate conversion

Reference:
Lawson, J.R. et al.
Fire Performance of Furnishings As Measured in the NBS Furniture Calorimeter. Part I
National Bureau of Standards
NBSIR 83-2787
U.S.A. 1983



10: One piece molded glassfibre
Neither padding nor cushions
Legs: Metal
Size: 0.61 x 0.64 x 0.74 m^3
Mass: 5.28 kg
Test 51

11: Group setting chair
Frame: Metal with plywood seat and back
Padding: Thin PU foam
Cover: Synthetic fibre fabric
Size: 0.46 x 0.51 x 0.76 m^3
Mass: 6.08 kg
Test 55

Test procedure:
Method: Freeburning in furniture calorimeter
Ignition source: Gas burner at the side of the chair, 50 kW in 200 s (subtracted from the RHR).

Sample:	10	11
H_{eff} (MJ/kg):	26.2	19.2
CO (g/s), peak:	0.3	0.0

Also available:
Mass loss, target irradiance and smoke particulate conversion

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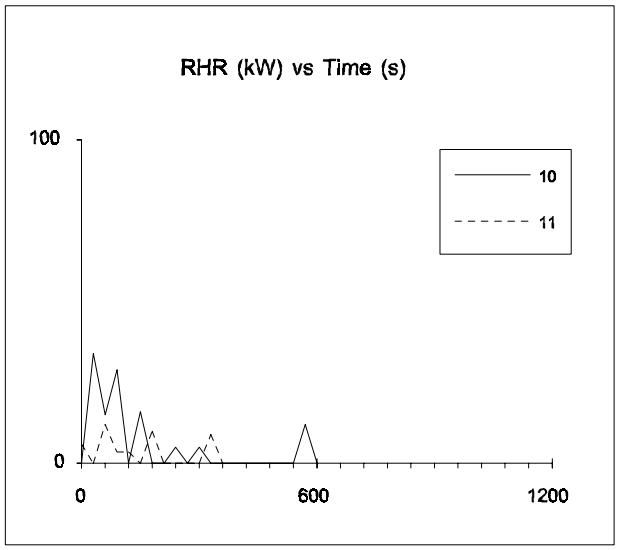
Reference:
Lawson, J.R. et al.
Fire Performance of Furnishings As Measured in the NBS Furniture Calorimeter. Part I
National Bureau of Standards
NBSIR 83-2787
U.S.A. 1983



50:
Frame: Metal
Padding: PU foam on 16 mm particle board
Cover: Polyester fibre
Size: 0.89 x 0.61 x 1.07 m^3
Mass: 20.82 kg
Test 47

51:
Frame: Metal
Padding: Vegetable fibre and cotton
Cover: Plastic coated fabric
Size: 0.76 x 0.56 x 0.86 m^3
Mass: 16.52 kg
Test 50

52:
Frame: Metal
Padding: PU foam on 12.7 mm plywood
Cover: Plastic coated fabric
Size: 0.81 x 0.66 x 0.79 m^3
Mass: 15.54 kg
Test 53

53:
Frame: Wood
Padding: Latex foam on 14 mm plywood. On the seat also 10% cotton felt
Cover: Plastic coated fabric
Size: 0.64 x 0.61 x 0.76 m^3
Mass: 11.20 kg
Test 56

Test procedure:
Method: Freeburning in furniture calorimeter
Ignition source: Gas burner at the side of the chair, 50 kW in 200 s (subtracted from the RHR).

Sample:	50	51	52	53
H_{eff} (MJ/kg):	21.8	NA	21.4	16.5
CO (g/s), peak:	0.4	0.0	1.1	0.3

Also available:
Mass loss, target irradiance and smoke particulate conversion

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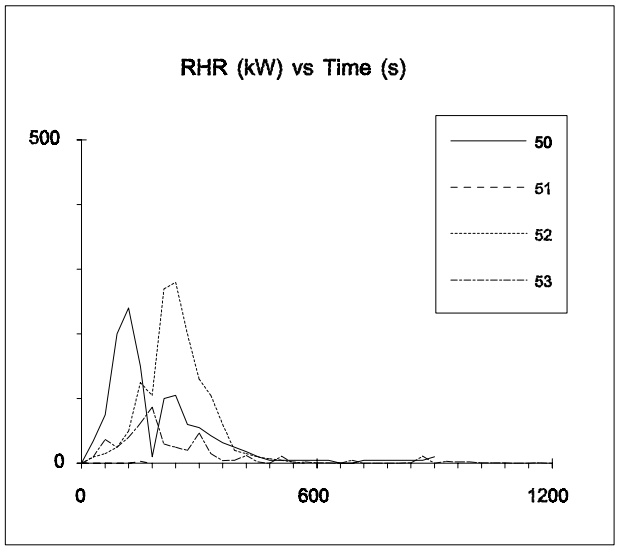
Reference:
Lawson, J.R. et al.
Fire Performance of Furnishings As Measured in the NBS Furniture Calorimeter. Part I
National Bureau of Standards
NBSIR 83-2787
U.S.A. 1983



2-cushion mock-up chairs

Built according to BS 5852
Pillow size (seat and back): 0.5 x 0.5 x 0.075 m^3
Filling: PU foam, 0.95 kg
Cover: 52% linen / 48% cotton fabric, 0.43 kg

54: Single chair
Ignited with 2 meteneamine tablets
Expt.no.12

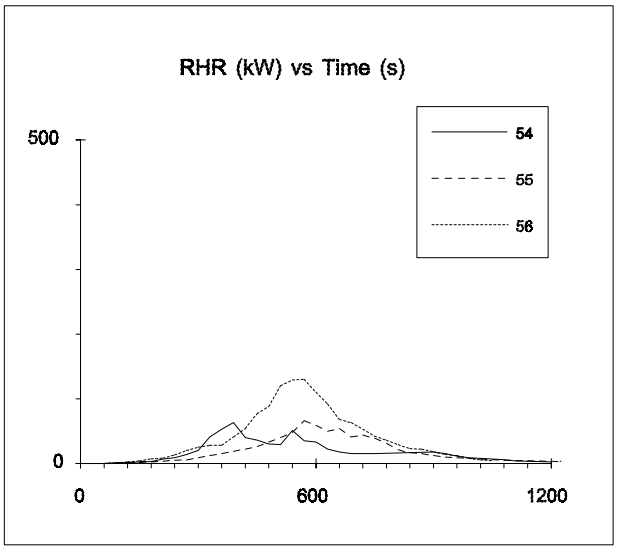
55: Single chair
Ignited with 1 meteneamine tablet
Expt.no.13

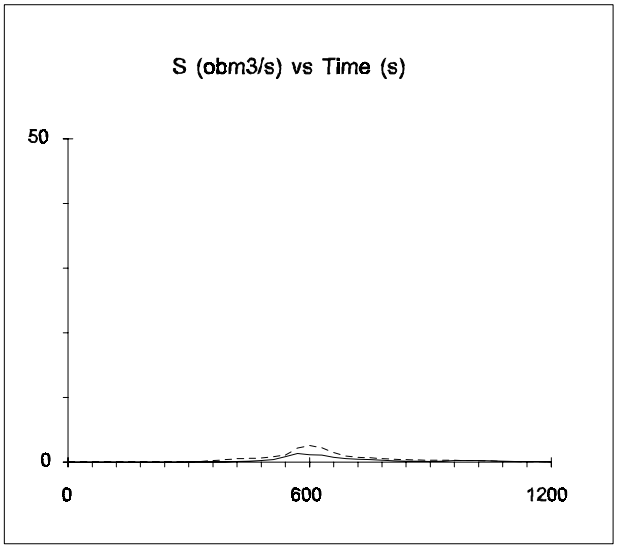
56: Doubled chair
Ignited with 2 meteneamine tablets
Expt.no.14

Test procedure:
Method: Room calorimeter, in the corner.
Ignition source: Metheneamine tablets located at the junction of the seat and the back at each pair of pillows.

Sample:	54	55	56
H_{eff} (MJ/kg):	15	16	17

Reference:
Ahonen, A, Kokkala, M & Weckman, H.
Burning Characteristics of Potential Ignition Sources of Room Fires
Technical Research Center of Finland
Research reports 285
Espoo, Finland 1985





2-cushion mock-up chairs

With plastic covers

Built according to BS 5852
Pillow size (seat and back): 0.5 x 0.5 x 0.075 m^3

57:
Filling: FR PU foam, 35 kg/m^3
Interliner: FR polyester wadding, 200 g/m^2
Cover: Imitation suede, 1.3 mm, 420 g/m^2
Test no II, 6A

58: Identical to 57 with
Filling: FR PU foam, 30 kg/m^3
Test no II, 6B

59:
Filling: FR PU foam, 33 kg/m^3
Cover: PVC furniture plastics, 670 g/m^2
Test no I, 17

60: Identical to 59 with
Interliner: FR cotton fabric, 150 g/m^2
Test no I, 10B
Heat release below 25 kW, no data available

61:
Filling: FR PU foam, 65 kg/m^3
Cover: PVA PVC fabric, 475 g/m^2
Test no I, 13

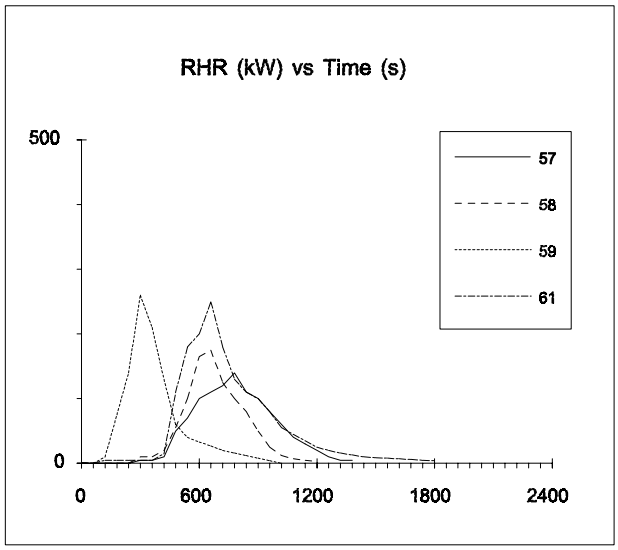
62: Identical to 62 with
Interliner: FR cotton fabric, 150 g/m^2
Test no I, 13B
Heat release below 25 kW, no data available

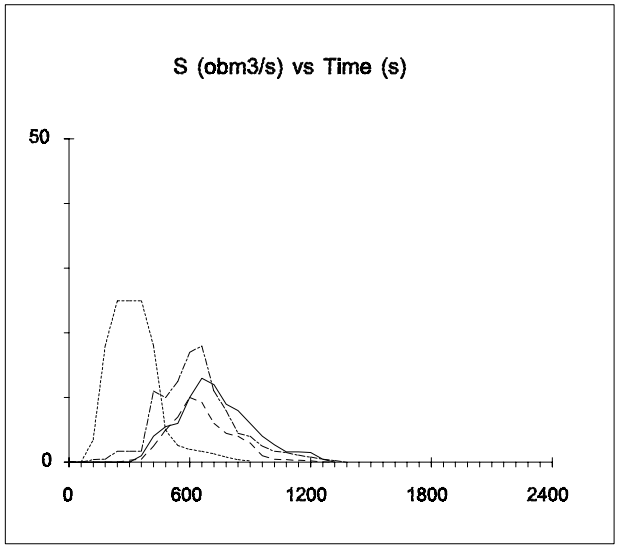
Test procedure:
Method: Room calorimeter, near back wall.
Ignition source: Wooden cribs (BS-7) on the seat in contact with the back.

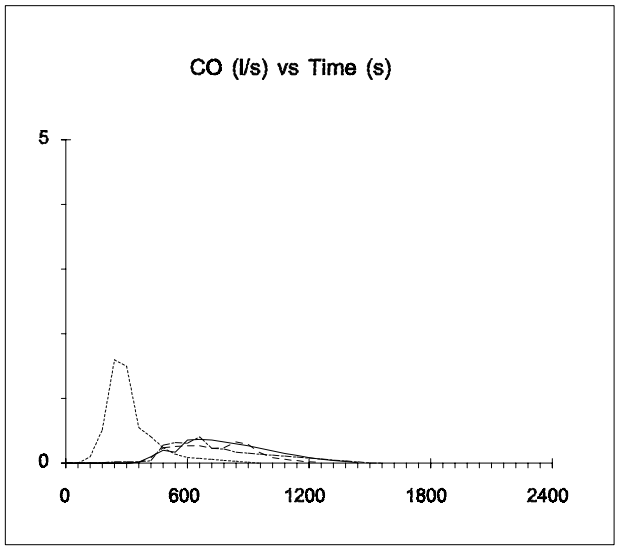
Also available:
Radiation, temp, CO_2 production and mass loss

Note:
Sample 59 had a peak S above 25 obm^3/s.

Reference:
See page Y5.2/63







With cotton velvet covers

Construction, see page Y5.2/57

63:
Filling: FR PU foam, 33 kg/m^3
Cover: FR cotton velvet, 380 g/m^2
Test no I, 1
Heat release below 25 kW, no data available.

64: Identical to 63 with
Interliner: FR PU foam, 20 mm, 35 kg/m^3
Ignition source: BS-5
Test no II, 1A
Heat release below 25 kW, no data available.

65: Identical to 64
Ignition source: BS-7
Test no II, 1AX

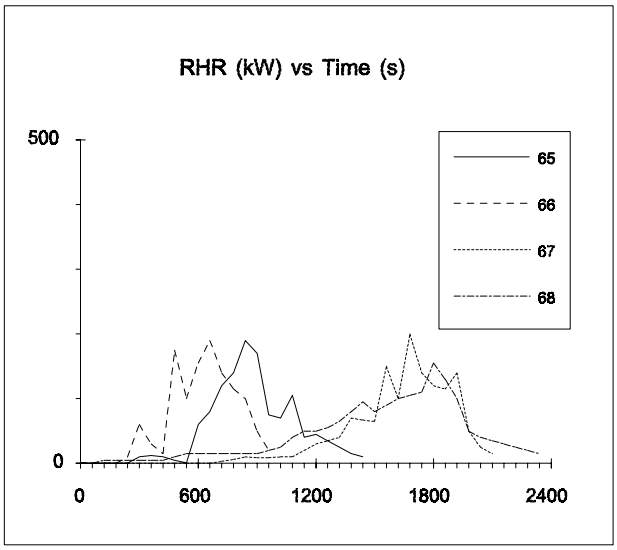
66: Identical to 64
Ignition source: Burning curtain
Test no II, 1B

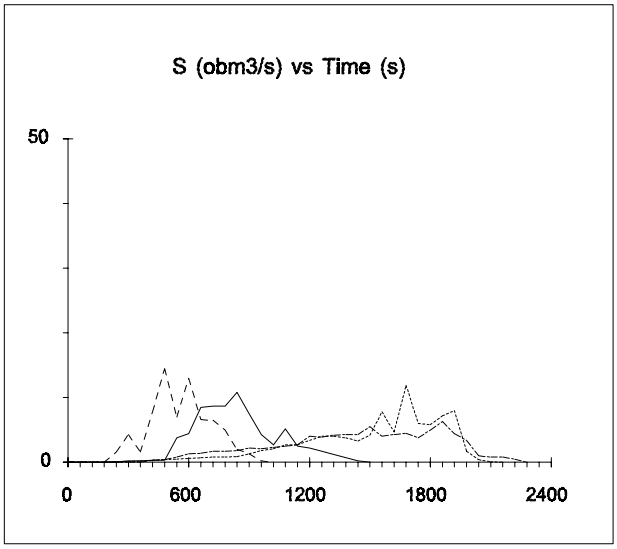
67: Identical to 63 with
Filling: FR PU foam, 65 kg/m^3
Test no I, 2

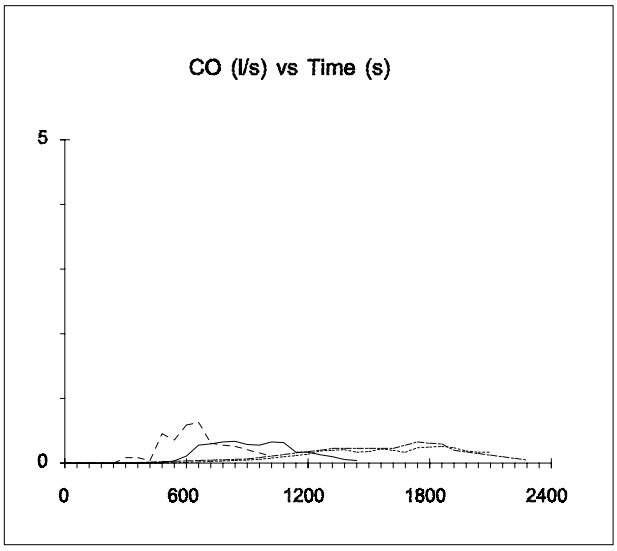
68: Identical to 63 with
Filling: FR PU foam, 50 kg/m^3
Test no I, 14

70:
Filling: FR PU foam, 65 kg/m^3
Interliner: FR PU foam, 1180 kg/m^3
Cover: cotton velvet, 380 g/m^2
Test no II, 9
Heat release below 25 kW, no data available

Test procedure:
See page Y5.2/57







References:
Pakkala, L. & Ryynänen
Täytteellisten huonekaljuen ja patjojen paloturvallisuuden parantaminen
VTT Research notes 750, ISSN 0358-5085
Espoo, Finland 1987

Pakkala, L. & Ryynänen
Improving the Fire Resistance Properties of Upholstered Furniture
VTT Research notes 1002, ISSN 0358-5085
Espoo, Finland 1989

With polyester fabric covers

Construction, see page Y5.2/57

71:
Filling: FR PU foam, 33 kg/m^3
Interliner: FR PU foam, 20 mm, 35 kg/m^3
Cover: FR polyester fabric, 190 g/m^2
Ignition source: BS-5
Test no II, 2A
Heat release below 25 kW, no data available.

72: Identical to 71
Ignition source: Burning curtain
Test no II, 2B

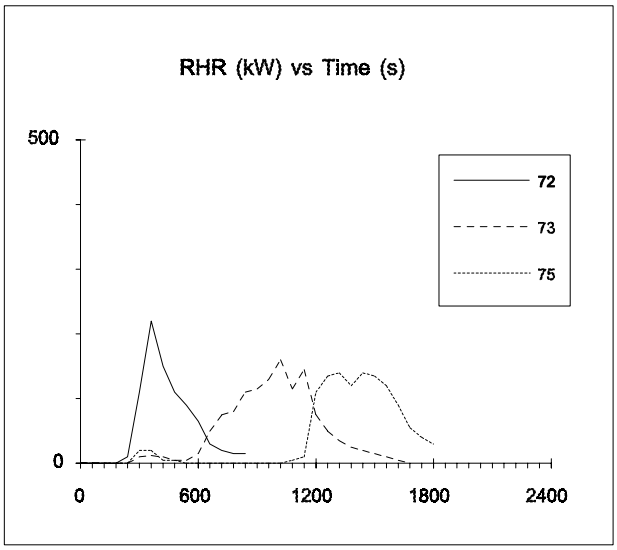
73:
Filling: FR PU foam, 35 kg/m^3
Interliner: FR cotton fabric, 230 g/m^2
Cover: FR polyester fabric, 340 g/m^2
Test no II, 7

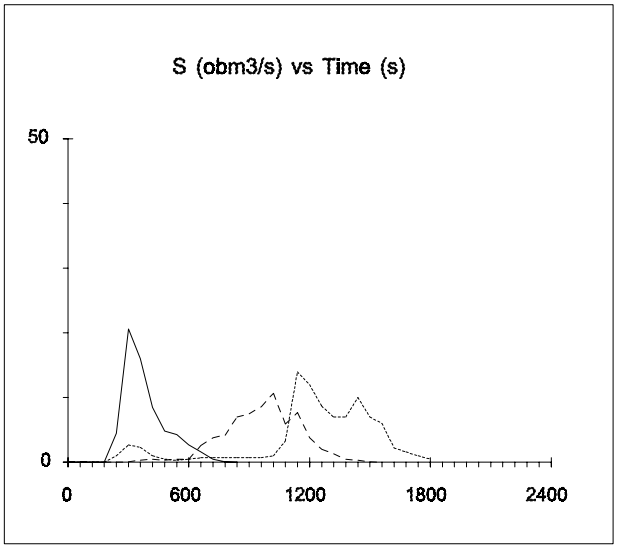
74:
Filling: FR PU foam, 35 kg/m^3
Interliner: FR PU foam, 10 mm, 1180 g/m^2
Cover: FR polyester fabric, 425 g/m^2
Test no II, 8
Heat release below 25 kW, no data available.

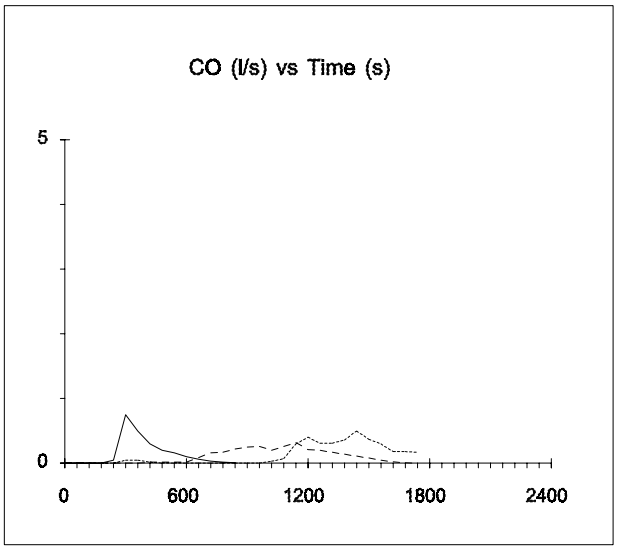
75:
Filling: FR PU foam, 33 kg/m^3
Interliner: FR PU foam, 10 mm, 1180 g/m^2
Cover: FR polyester fabric, 340 g/m^2
Ignition source: Burning curtain
Test no II, 11

Test procedure:
See page Y5.2/57

Reference:
See page Y5.2/63







2-cushion mock-up chairs

With polyester/cotton fabric covers

Construction, see page Y5.2/57

76:
Filling: PU foam, 30kg/m^3
Interliner: PU foam, 20 mm, 20 kg/m^3
Cover: Polyester/cotton fabric, 340 g/m^2
Ignition source: BS-5
Test no II, 3A

77: Identical to 76
Ignition source: Burning curtain
Test no II, 3B

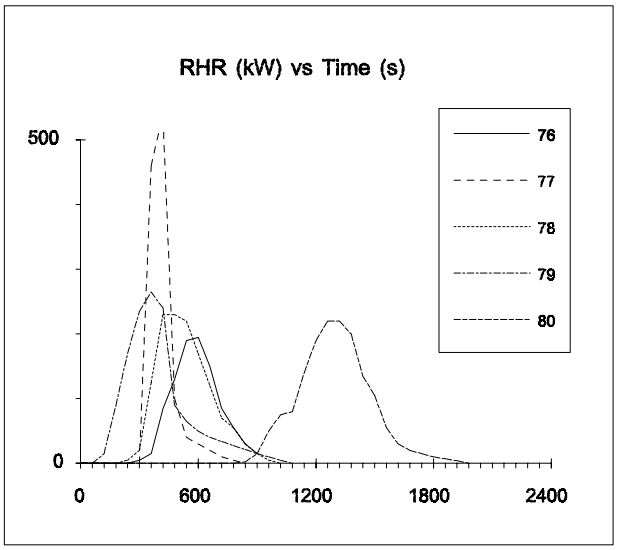
78:
Filling: PU foam 30 kg/m^3
Interliner: FR polyester wadding
Cover: Polyester/cotton fabric, 230 g/m^2
Test no II, 10

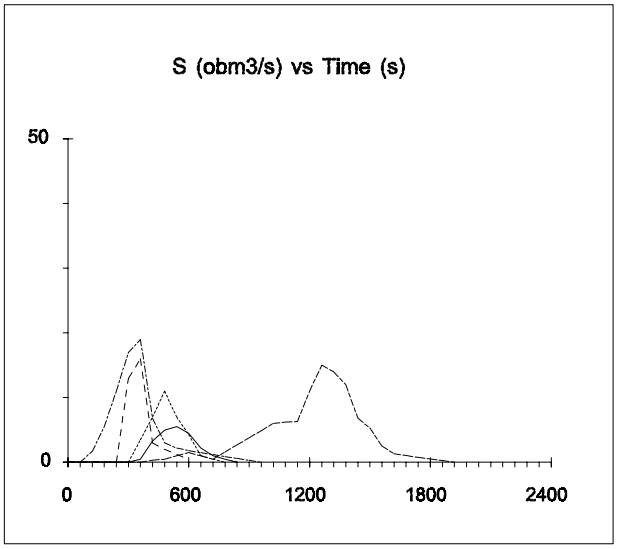
79:
Filling: FR PU foam, 65 kg/m^3
Cover: FR polyester fabric, 400 g/m^2
Test no I, 5

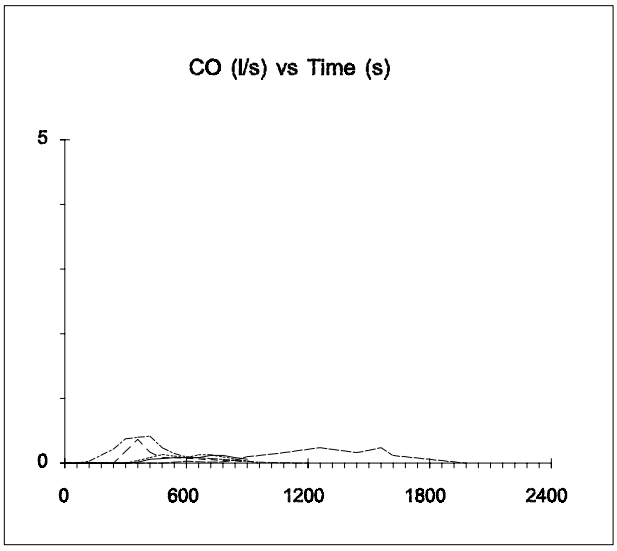
80: Identical to 79 with
Interliner: FR cotton fabric, 150 g/m^2
Test no I, 5B

Test procedure:
See page Y5.2/57

Reference:
See page Y5.2/63







2-cushion mock-up chairs

With polyester fabric covers

Construction, see page Y5.2/57

81:
Filling: FR PU foam, 33 kg/m^3
Cover: FR polyester fabric, 400 g/m^2
Test no I, 4

82: Identical to 81 with
Interliner: FR cotton fabric, 150 g/m^2
Test no I, 4B
Heat release below 25 kW, no data available

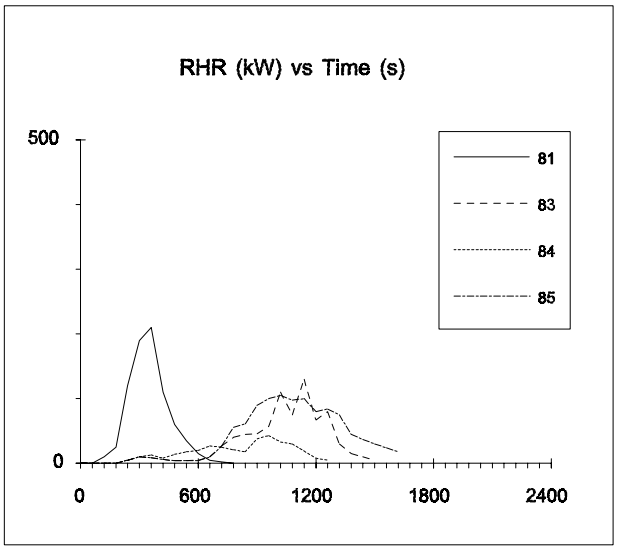
83: Identical to 81 with
Interliner: FR cotton fabric, 230 g/m^2
Test no II, 4B

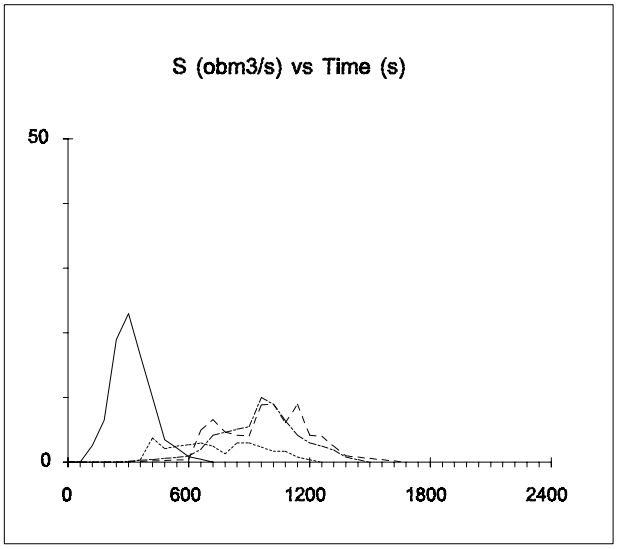
84: Identical to 81 with
Interliner: FR wool wadding, 10 mm, 710 g/m^2
Test no II, 4C

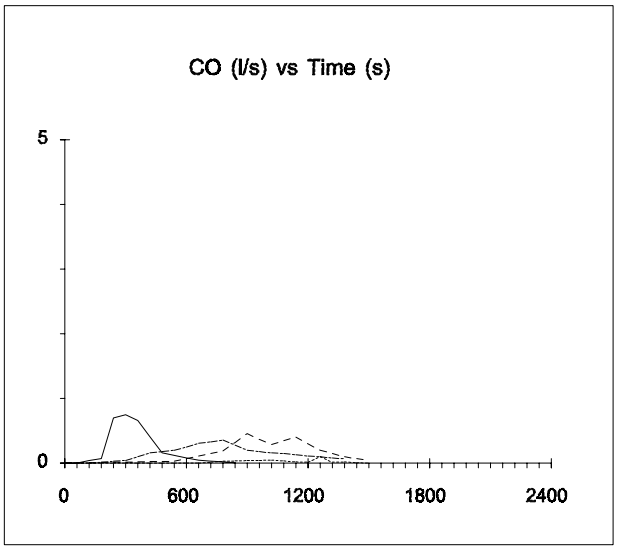
85: Identical to 81 with
Interliner: FR PU foam, 10 mm, 1180 g/m^2
Test no II, 4D

Test procedure:
See page Y5.2/57

Reference:
See page Y5.2/63







2-cushion mock-up chairs

With wool fabric covers

Construction, see page Y5.2/57

86:
Filling: FR PU foam, 33 kg/m^3
Cover: 56% wool fabric, 480 g/m^2
Test no I, 7

87: Identical to 86 with
Interliner: FR cotton fabric, 150 g/m^2
Test no I, 7B
Heat release below 25 kW, no data available

88:
Filling: FR PU foam, 65 kg/m^3
Interliner: FR PU foam, 20 mm, 25 kg/m^3
Cover: wool fabric, 1.8 mm, 488 g/m^2
Test no II, 5A

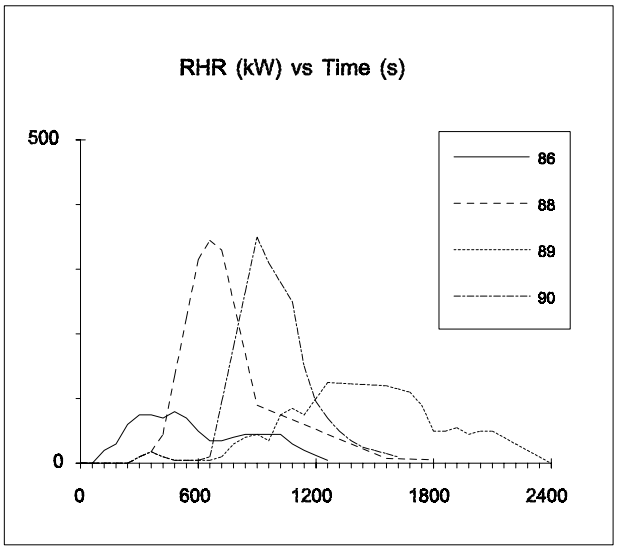
89: Identical to 88 with
Interliner: FR cotton fabric, 230 g/m^2
Test no II, 5B

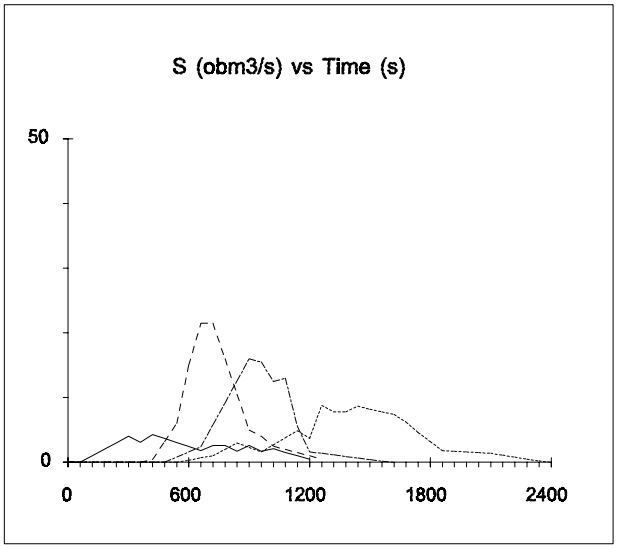
90: Identical to 88 with
Interliner: FR wool wadding, 10 mm, 710 g/m^2
Test no II, 5C

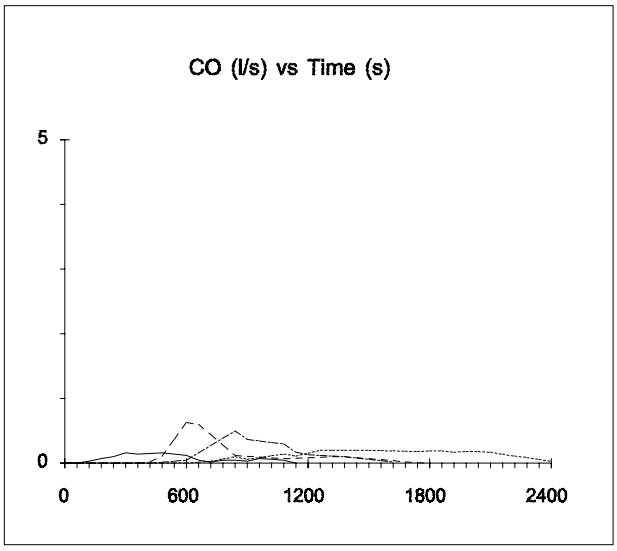
91: Identical to 88 with
Interliner: Carbon fibre fabric, 330 g/m^2
Test no II, 5D
Heat release below 25 kW, no data available

Test procedure:
See page Y5.2/57

Reference:
See page Y5.2/63







Easy chairs

10:
Frame: Wood
Padding: PU foam
Cover: Polyolefin fabric
Size and mass: 0.84 x 0.84 x 0.81 m^3, 28.34 kg
The armchair is of the same model as the sofa Y5.4/21
Test 45

11:
Frame: One-piece molded PS with plywood inserts
Padding: PU foam
Cover: PU foam with polyolefin fabric backing
Size and mass: 0.84 x 0.84 x 0.81 m^3, 11.52 kg
Test 48

12:
Frame: Wood
Padding: PU foam
Cover: Cotton fabric
Size and mass: 0.91 x 0.91 x 0.81 m^3, 15.68 kg
Test 49

13:
Frame: Wood reinforced PU foam
Padding: Metal springs with 25-50 mm polyester batting
Cover: PU foam imitation leather
Size and mass: 0.84 x 0.84 x 0.76 m^3, 15.98 kg
Test 64

14:
Frame: Wood
Padding: PU foam. Polyester filled cushions
Cover: Cotton fabric
Size and mass: 0.84 x 0.84 x 0.76 m^3, 23.02 kg
Test 66

Test procedure:
Method: Freeburning in furniture calorimeter
Ignition source: Gas burner at the side of the chair, 50 kW in 200 s (subtracted from the RHR). Sample 14 was ignited with smoldering cigarette

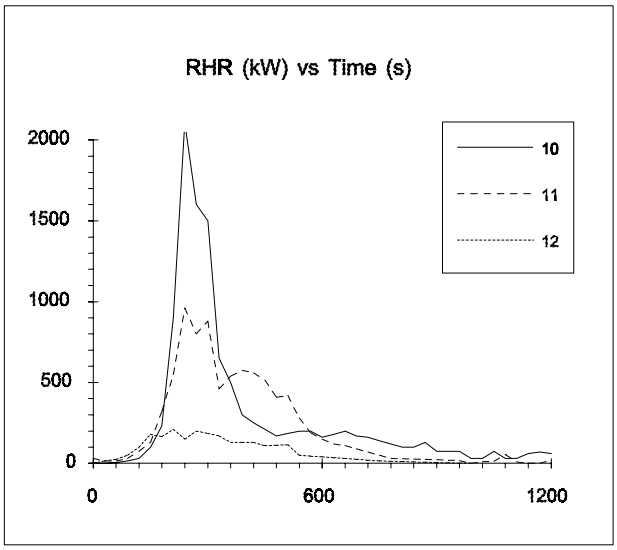
---

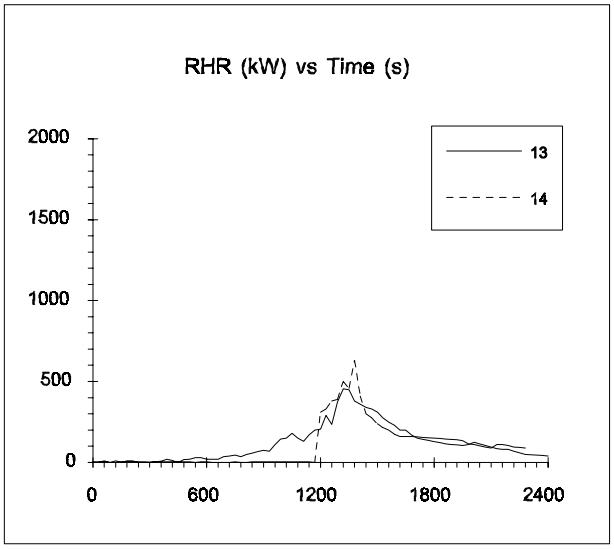
Sample:	10	11	12	13	14
H_{eff} (MJ/kg):	18.1	33.3	23.0	21.0	22.7
CO (g/s), peak:	1.3	3.1	0.5	0.6	1.0

Also available:
Mass loss, Target irradiance and particulate conversion

Note:
The RHR curve of sample 14 starts 2500 s after ignition.

Reference:
Lawson, J.R. et al.
Fire Performance of Furnishings As Measured in the NBS Furniture Calorimeter. Part I
National Bureau of Standards
NBSIR 83-2787, U.S.A. 1983





4-cushion mock-up chairs

Size and mass: NA

15:
Padding: PU foam
Cover: Light olefin fabric
Test 12, A1

16:
Padding: FR PU foam
Cover: Light olefin fabric
Test 07, A2

17:
Padding: FR PU foam
Cover: Heavy olefin fabric
Test 14, A3

18:
Padding: FR PU foam
Cover: Light cotton fabric
Test 21, A4

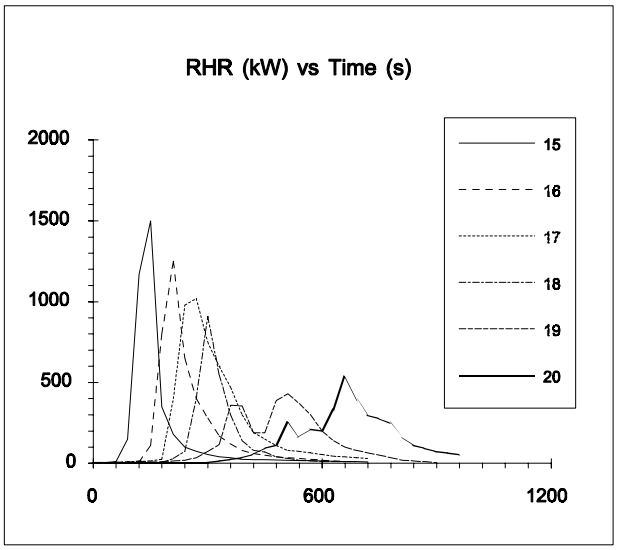
19:
Padding: PU foam
Cover: Heavy cotton fabric
Test 20, A5

20:
Padding: FR PU foam
Cover: Heavy cotton fabric
Test 17, A6

Test procedure:
Method: Freeburning in furniture calorimeter
Ignition source: Wooden cribs, at the seat 0.10 m from the back.

Also available:
Mass loss

Reference:
Dietenberger, M. A.
Modifications to Furniture Fire Model for Hazard System
University of Dayton
NIST-GCR-92-601
U.S.A. 1992

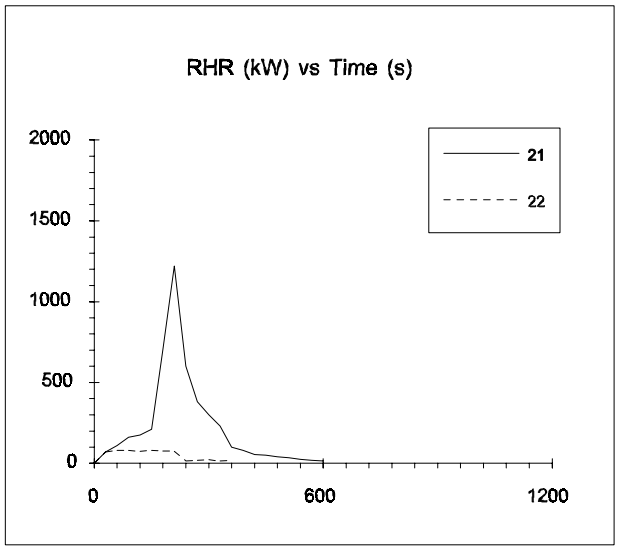


4-cushion mock-up chairs

Mock-up chair with 4 cushions
Frame: Steel mock-up
Cover: Nylon fabric, , 250 kg/m^2
Cushion size: 0.61 x 0.61 x 0.10 m^3

21:
PU foam, 25 kg/m^3
Mass: 5.5 kg
Chair T, test 16

22:
FR PU foam, 64 kg/m^3
Foam containing organic chlorinated phosphate, organic brominated retardant and alumina trihydrate (Elemental content: 10% Al, 4.75% Br, 2.6% Cl and 0.32% P).
Mass: 11.9 kg
Chair S, test 17



Test procedure:
Method: Freeburning in furniture calorimeter
Ignition source: 50 kW gas burner in 200 s at the side of the chair

Sample: 36
H_{eff}, (MJ/kg): 27
CO (kg/kg): 0.01
CO_2 (kg/kg): 1.89
HCN (kg/kg): 0.001 (Determined by ion cromathography)

Reference:
Babrauskas, B et al.
Fire Hazard Comparison of Fire-Retarded and Non-Fire-Retarded Products
NBS Special Publication 749
National Bureau of Standards
U.S.A. 1988

Commercial 3-seat sofas

10: Sofa-bed
Frame: Wood
Filling: Ordinary PU foam
Cover: 100% viscose fabric, 665 g/m^2
Mass: appr. 65 kg
Test 4

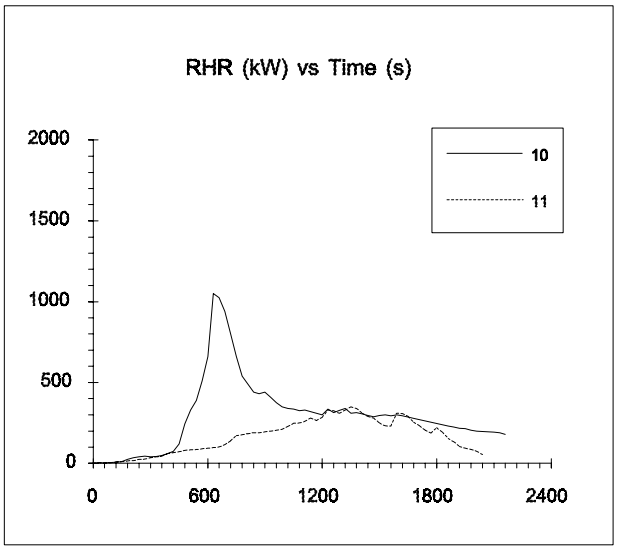
11: Old design sofa
Filling, seat cushions: Latex rubber foam
Filling, back cushions: Cotton felt
Cover: 100% wool fabric, 420 g/m^2
Mass: appr. 40 kg
Test 5

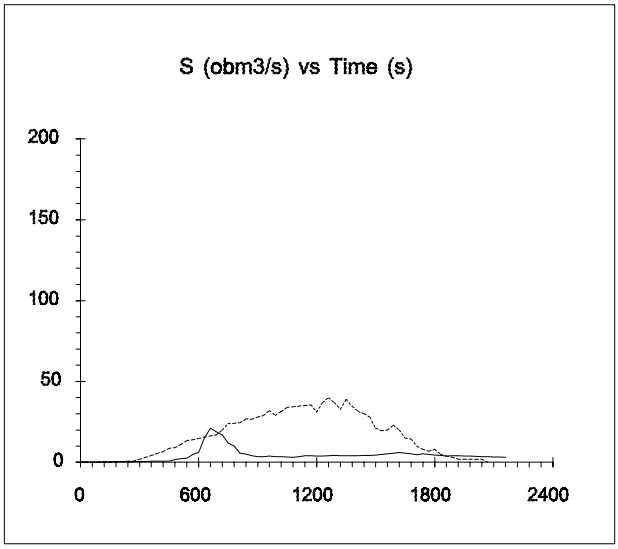
Test procedure:
Method: Freeburning in furniture calorimeter.
Ignition source: 126 g wooden cribs, positioned in the corner where seat, back and arm rest cushion meet.

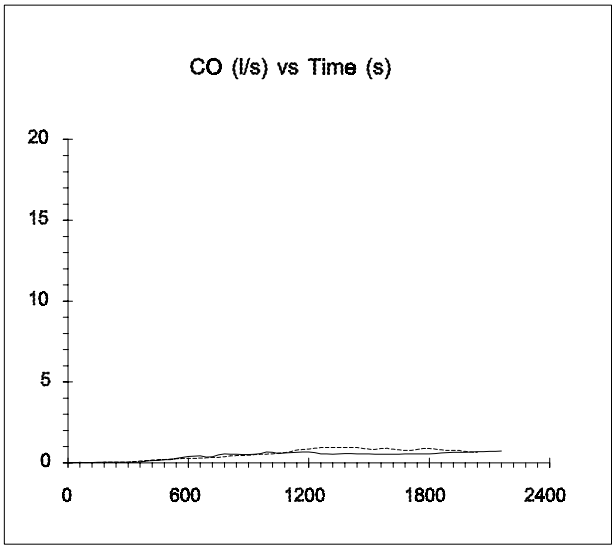
Sample:	10	11
H_{eff} (MJ/kg):	11.7	15.4

Also available:
CO/RHR, CO/mass loss, CO_2/RHR, CO_2/mass loss, S/RHR, S/mass loss and total energy, CO and smoke.

Reference:
Sundström, B. & Kaiser, I.
Full Scale Fire Testing of Upholstered Furniture
Technical Report
SP RAPP 1986:01, ISSN 0280-2503
Borås, Sweden 1986







Mock-up sofa
Frame: Steel with wire net
Size: 0.65 x 1.8 x 0.76 m
Frame mass is not included below.
Cushions, filling material covered with fabric:
Number: 3 seat-, 3 back-, and 2 arm rest cushions
Thickness: 0.10-0.14 m

12:
Filling: Ordinary PU foam, 25 kg/m^3
Cover: 100% acrylic velour fabric, 400 g/m^2
Mass: 8.80 kg
Test 1

13:
Filling: Ordinary PU foam, 25 kg/m^3
Cover: 100% cotton fabric, 480 g/m^2
Mass: 8.91 kg
Test 2

14: FR
Filling: Highly resilient FR PU foam, 37 kg/m^3
Cover: 100% PVA/PVC fabric, 500 g/m^2
Mass: 10.90 kg
Test 7

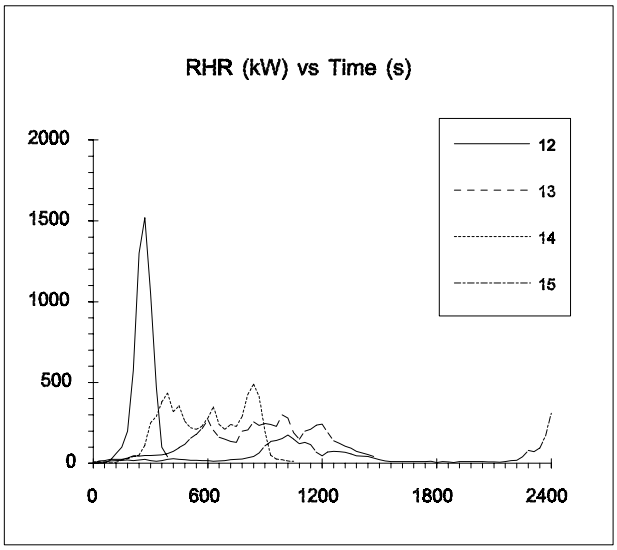
15: FR
Filling: Highly resilient FR PU foam, 37 kg/m^3
Cover: 65% wool / 35% viscose fabric, 500 g/m^2
Mass: 11.13 kg
Test 8

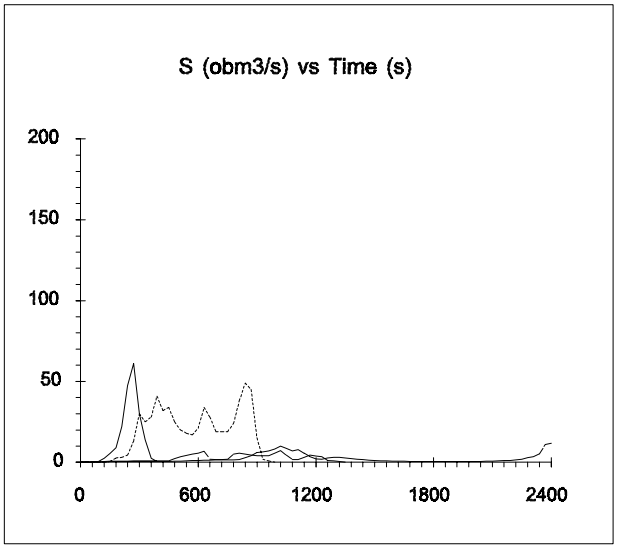
Test procedure:
See page Y5.4/10

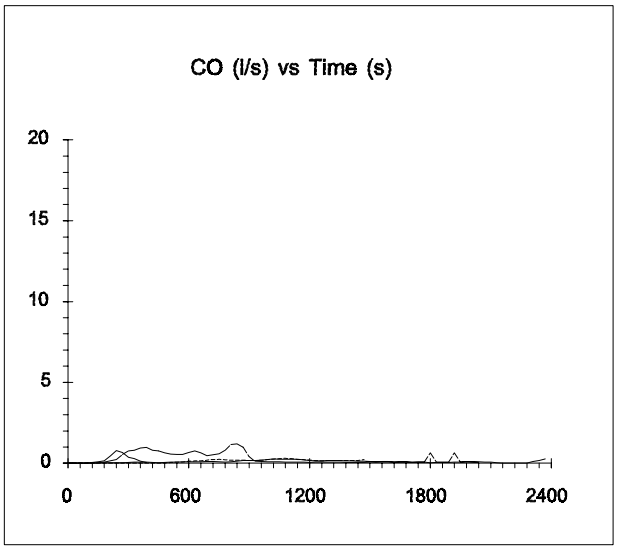
Sample:	12	13	14	15
H_{eff}(MJ/kg):	18.5	22.4	18.9	20.3

Also available:
See page Y5.4/10

Reference:
See page Y5.4/10







Mock-up sofa
Construction and size similar as to sample 12

16:
Filling: Standard PU foam, 30 kg/m^3
Cover: 100% acrylic fabric, 300 g/m^2
Mass: 8.2 kg
Test 5

17:
Filling: FR PU foam, 35 kg/m^3
Cover: 100% acrylic fabric, 300 g/m^2
Mass: 8.9 kg
Test 6

18:
Filling: Standard PU foam, 30 kg/m^3
Cover: 61% wool / 39 % viscose fabric, 540 g/m^2
Mass: 9.3 kg
Test 7

19:
Identical to sample 16.
Ventilation restricted (lower half of the door shutted off)
Test 10

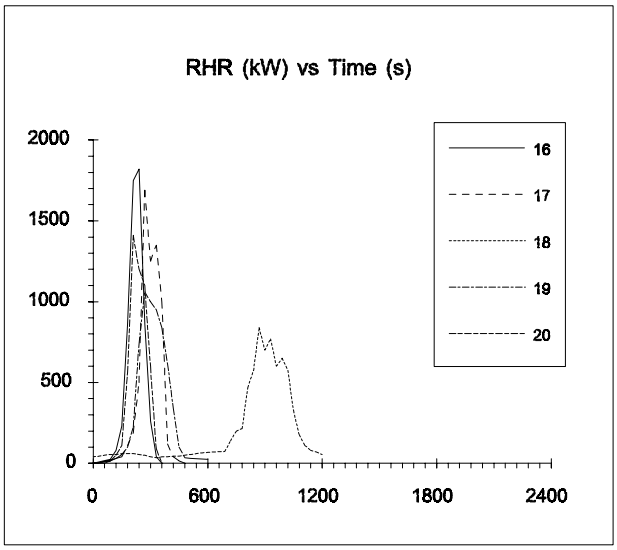
20:
Identical to sample 16.
Freeburning
Test 12

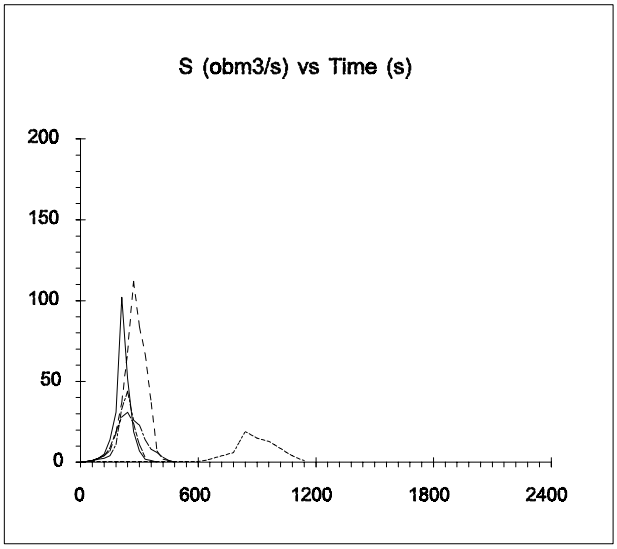
Test procedure:
Method: Room calorimeter
Ignition source: Liquid fuel burner with 0.1 l heptane positioned in front of the sofa at the side. Burner output: 20 kW for 150-180 s.

Sample: 16-21
H_{eff} (MJ/kg): 24.6

Also available:
Gas temp., heat flux, RHR calculated from mass loss and total prod. of smoke, CO, CO_2 and NO_X.

Reference:
Andersson, B
Fire Behaviour of Beds and Upholstered Furniture - an Experimental Study
REPORT LUTVDG/(TVBB-3023) ISSN 0282-3756
Lund, Sweden 1985





21: 3-seat sofa
Frame: Wood
Filling: PU foam
Cover: Polyolefin fabric
Size: 0.84 x 2.0 x 0.81 m^3
Mass: 51.50 kg
The sofa is of the same model as the armchair Y5.3/10
Test 38

22: Loveseat
Frame: Metal
Filling: PU foam
Cover: Plastic coated fabric
Size: 0.84 x 1.32 x 0.72 m^3
Mass: 27.26 kg
Test 54

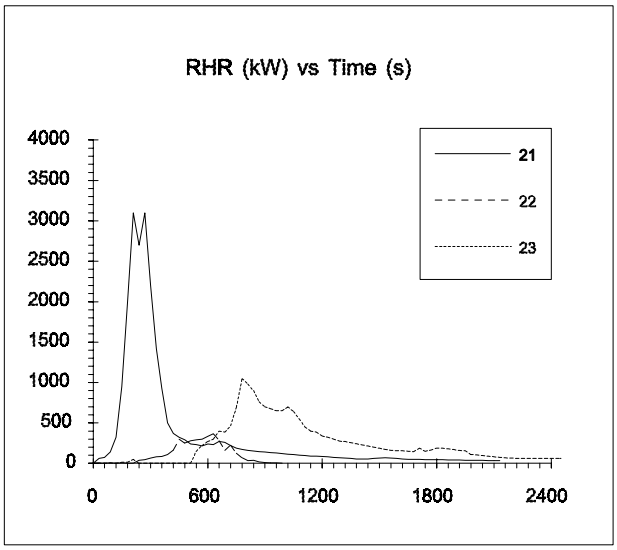
23: Loveseat
Frame: Oak wood
Filling: PU foam covered with a layer of cotton
Cover: Plastic coated fabric
End panels: 9.5 mm plywood with PU padding and plastic coated fabric cover
Size: 0.81 x 1.37 x 0.76 m^3
Mass: 54.60 kg
Test 57

Test procedure:
Method: Freeburning in furniture calorimeter
Ignition source: Gas burner at the side of the sofa, 50 kW in 200 s (subtracted from the RHR).

Sample:	21	22	23
H_{eff} (MJ/kg):	18.9	18.6	15.1
CO (g/s), peak:	4.5	2.3	4.0

Also available:
Mass loss, target irradiance and particulate conversion

Reference:
Lawson, J.R. et al.
Fire Performance of Furnishings As Measured in the NBS Furniture Calorimeter. Part I
National Bureau of Standards
NBSIR 83-2787
U.S.A. 1983



Beds

With foam mattresses. The beddings were all well laundred.

10: Hospital bed
Standard bed used in many Swedish hospitals
Mattress: polyether foam 27 kg/m^3, 0.10 m
Sheets: 7 layers, polyester/cotton/PVC
Blanket: cotton
Pillow: feather/cotton/polyester/PVC
Säng 1A

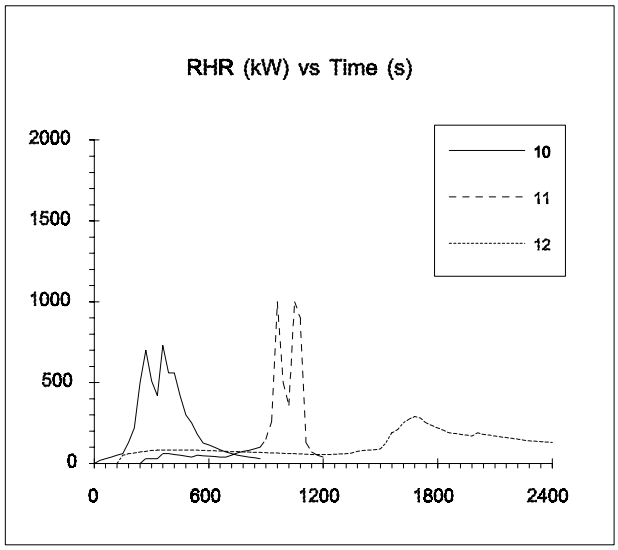
11: Improved hospital bed
Mattress: PU foam 35 kg/m^3, 0.10 m with polymeric surface
Sheets: 4 layers, 100% polyester, 140 g/m^2
Blanket: 100 % polyester
Pillow: 100% polyester
Säng 2A

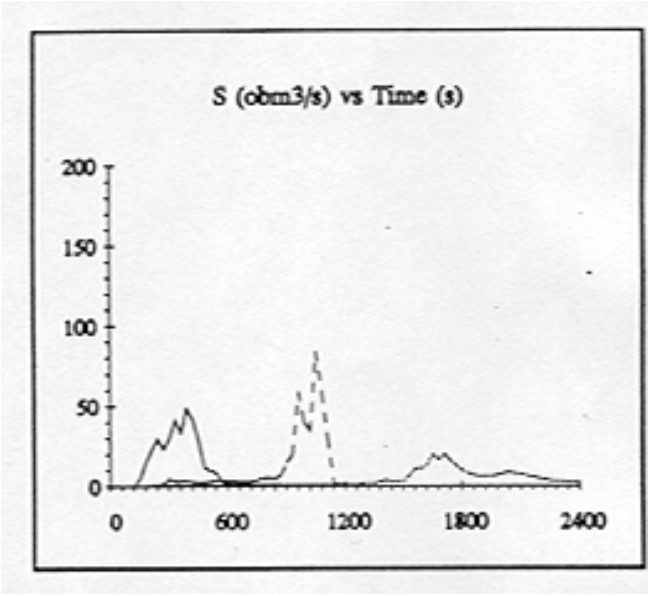
12: Prison bed
Mattress: PU foam 35 kg/m^3, 0.10 m. with interliner, 0.01 m polyester and polymeric surface
Sheets: 4 layers, polyester/viscose
Pillow: feather/cotton/polyester
Säng 3A

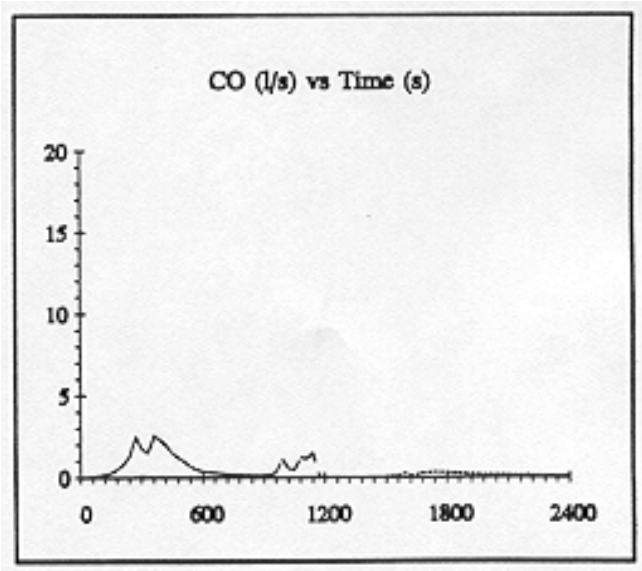
Test procedure:
Method: Room calorimeter
Ignition sources:
10: Meteneamine tablets (SIS 83 25 27), one in the center of the bed and one next to the pillow.
11: Wooden cribs in the center of the bed
12: Meteneamine tablet (SIS 83 25 27) next to the pillow

Also available:
Production of CO_2 and NO_X

Reference:
Holmstedt, G. & Kaiser, I.
Brand i vårdbäddar
SP-Rapp 1983:04, ISSN 0280-2503
Borås, Sweden 1983







With polychloroprene foam mattresses

Bedding: Similar in bed 13-21

Drawsheet: 1 layer, cotton, 108 g/m^2
Sheets: 2 layers, cotton/polyester, 125 g/m^2
Bedspread: 1 layer, cotton/polyester, 200 g/m^2
Pillow filling: shredded PU foam 670 g
Pillow cover: cotton, 230 g/m^2
Pillow protector: PVC, 108 g/m^2
Pillow case: cotton/polyester, 125 g/m^2
Total mass: 3,6 kg
The bedding was not retardant treated and was not laundered

13: Navy mattress
Core: FR Polychloroprene foam, 152 mm, 67 kg/m^3
Ticking: FR Cotton, 253 g/m^2
Size: 0.88 x 1.93 x 0.15 m^3
Mass: 18 kg
Test M08

14: Prison mattress
Core: FR Polychloroprene foam, 76.2 mm, 50 kg/m^3
Ticking: FR PVC with nylon fabric, 354 g/m^2
Size: 0.66 x 1.84 x 0.08 m^3
Mass: 6 kg
Test M10

Test procedure:
Method: Room calorimeter
Ignition source: Polyethylene wastebasket with mixed contents, located on the side of the bed. Mass: 725 g

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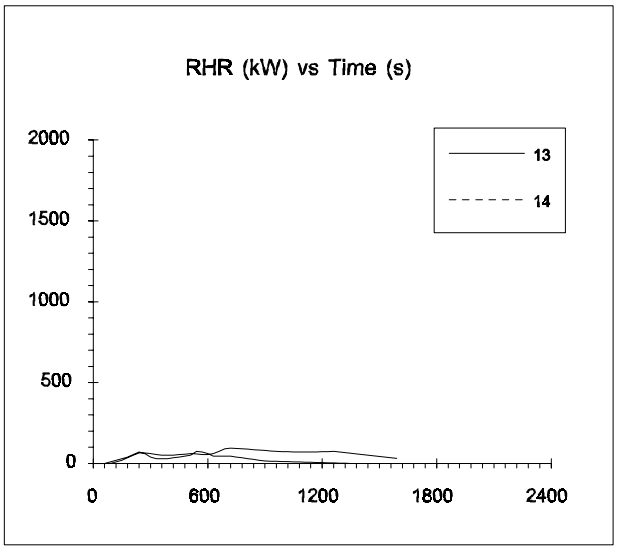
Also available:
Mass outflow

Reference:
Babrauskas, V.
Combustion of Matteresses Exposed to flaming Ignition Sources part II. Bench-Scale tests and Recommended Standard Test
National Bureau of Standards
NBSIR 80-2186
U.S.A. 1980



With PU foam or latex mattresses

Bedding:
See page Y6/13

15: Hospital mattress
Core: FR PU foam, 86.9 mm, 64 kg/m^3
Padding: PU foam, 36.8 mm, 25 kg/m^3
Ticking: FR PVC, 378 g/m^2
Size: 0.89 x 2.03 x 0.17 m^3
Mass: 14 kg
Test M01

16: Hospital mattress
Core: Latex (butadiene-styrene), 101.6 mm, 81 kg/m^3
Ticking: FR PVC with cotton backing, 410 g/m^2
Size: 0.92 x 2.11 x 0.11 m^3
Mass: 19 kg
Test M04

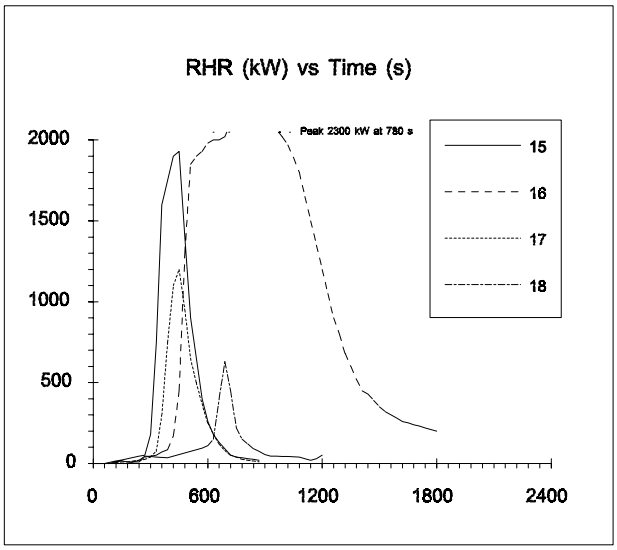
17: Commercial mattress
Core: PU foam, 127 mm, 20 kg/m^3
Padding: Rayon fabric, 20 g/m^2
Padding: PU, 78 g/m^2
Ticking: Rayon fabric, 154 g/m^2
Size: 0.95 x 1.88 x 0.13 m^3
Mass: 6 kg
Test M05

18: Prison mattress
Core: PU foam, 76,2 mm, 22 kg/m^3
Ticking: FR PVC with nylon fabric, 284 g/m^2
Size: 0.66 x 1.84 x 0.08 m^3
Mass: 3.2 kg
Test M09

Test procedure:
See page Y6/13

Also available:
See page Y6/13

Reference:
See page Y6/13



With innerspring mattresses

Bedding:
See page Y6/13

19: Hospital mattress with innersprings
Interfacing: PP fabric, 64 g/m^2
Padding: PU foam, 37.5 mm, 19 kg/m^3
Ticking: FR PVC, 385 g/m^2
Size: 0.89 x 2.03 x 0.17 m^3
Mass: 15 kg
Test M02

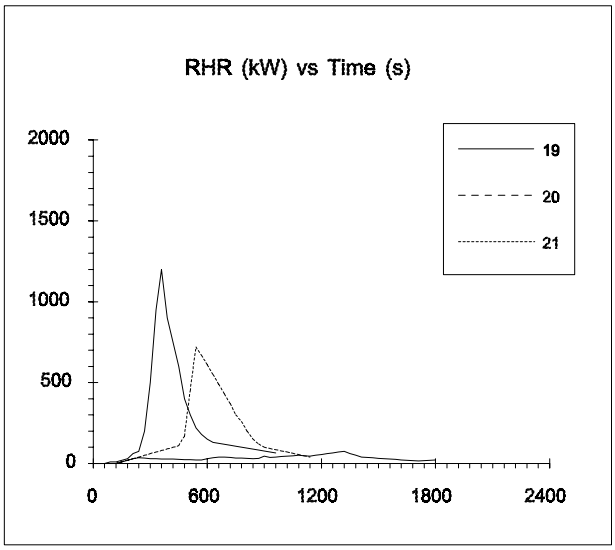
20: Hospital mattress with innersprings
Interfacing: PP fabric, 70 g/m^2
Padding: FR Cotton felt, 49.6 mm, 38 kg/m^3
Ticking: PVC, 379 g/m^2, FR
Size: 0.9 x 2.0 x 0.17 m^3
Mass: 20 kg
Test M03

21: Mattress with innersprings
Insulator: FR Cotton/nylon/polyester pad, 7 mm, 90 kg/m^3
Padding: Cotton/polyester felt, 38 mm, 43 kg/m^3
Ticking: Polyester, 170 g/m^2
Size: 0.99 x 1.91 x 0.18 m^3
Mass: 12 kg
Test M06

Test procedure:
See page Y6/13

Also available:
See page Y6/13

Reference:
See page Y6/13



Beds

Mattress used in sample 22-24:
Filling: Standard PU foam, 35 kg/m^3
Cover: Cotton, 135 g/m^2
Size: 0.9 x 2.0 x 0.1 m^3
Mass: 6.0 kg

22: Mattress
Test 1

23: Mattress
Freeburning
Test 11

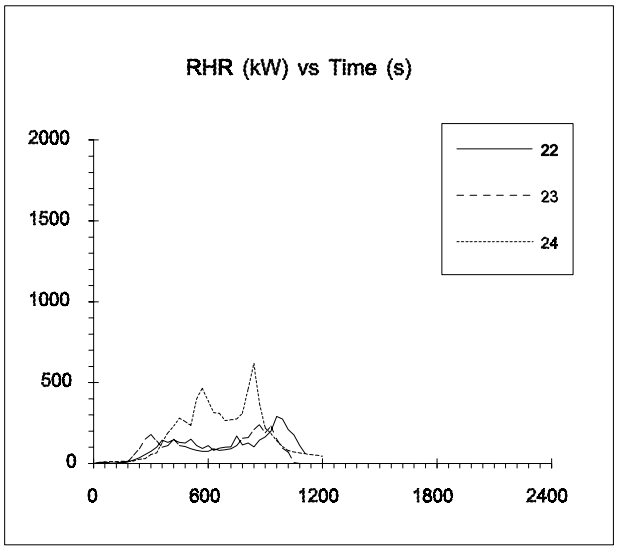
24: Complete bed
Bedding:
Sheet: Cotton 180 g/m^2
Quilt, filling: Polyester fibre, 200 g/m^2
Quilt, cover: Viscose fabric, 110 g/m^2
Bedding mass: 2.4 kg
Test 3

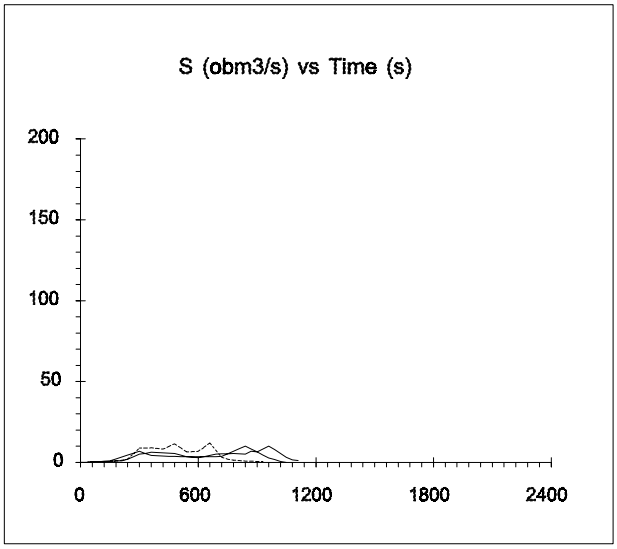
Test procedure:
Method: Room calorimeter
Ignition source: 40 g wooden cribs placed in center of bed 0.5 m from the head end.

Sample:	22	23	24
H_{eff} (MJ/kg):	22	22	20

Also available:
Flame spread rate, gas temp. and total prod. of smoke, CO, CO_2 and NO_X

Reference:
Andersson, B
Fire Behaviour of Beds and Upholstered Furniture - an Experimental Study
Division of building fire safety and technology
Lund Institute of Technology
Report LUTVDG / ISSN 0282 - 3756
Lund 1985





Pillows

50:
Filling: One piece latex foam
Cover: 50% cotton / 50% polyester fabric
Pillow mass: 1.003 kg
Mass (including pillow case and ign. source): 1.238 kg

51:
Filling: Shredded PU foam
Cover: Nonwoven fabric
Pillow mass: 0.650 kg
Mass (including pillow case and ign. source): 0.885 kg

52:
Filling: Shredded PU foam
Cover: Nonwoven
Pillow mass: 0.628 kg
Mass (including pillow case and ign. source): 0.863 kg

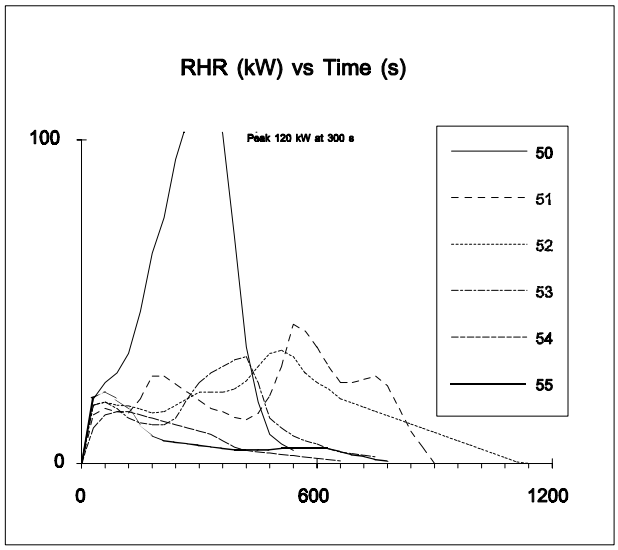
53:
Filling: Polyester fibres
Cover: 80% polyester / 20% cotton
Pillow mass: 0.602 kg
Mass (including pillow case and ign. source): 0.837 kg

54:
Filling: Feathers
Cover: Cotton
Pillow mass: 0.966 kg
Mass (including pillow case and ign. source): 1.201 kg

55:
Filling: Polyester fibres
Cover: Fibreglass
Pillow mass: 0.687 kg
Mass (including pillow case and ign. source): 0.922 kg

Test procedure:
Method: Freeburning in furniture calorimeter
Ignition source: Balled up newspaper sheets

Sample:	50	51	52	53	54	55
H_{eff} (MJ/kg):	27.6	22.0	23.7	20.0	18.3	17.4



Reference:
Babrauskas, V.
Burning Rates
The SFPE Handbook of Fire Protection Engineering, pp 2-1 to 2-15
U.S.A., 1988

10: Trevira CS
FR polyester, loosely woven fabric
Surface weight: 150 g/m^2
Test 22L

11: FR Cotton
FR cotton, closely woven single cloth
Surface weight: 220 g/m^2
Test 11R

12: Mod-Acrylic
Mod-acrylic, loosely woven fabric
Surface weight: 190 g/m^2
Test 17R

13: Cotton
Cotton, closely woven single cloth
Surface weight: 190 g/m^2
Test 20L

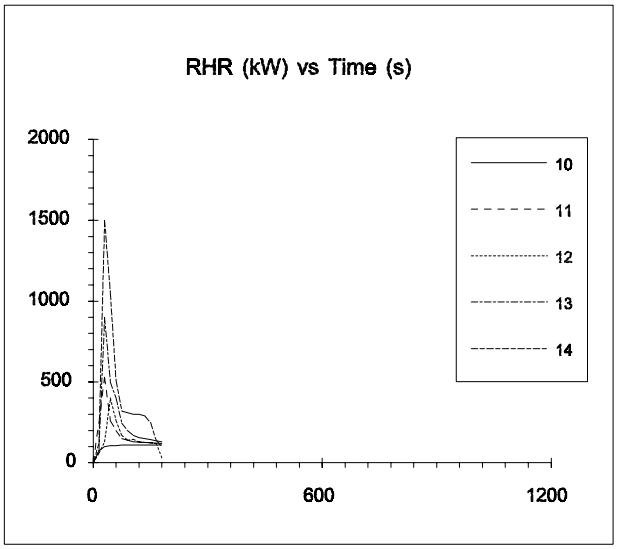
14: Acrylic
Acrylic, pile fabric
Surface weight: 360 g/m^2
Test 8R

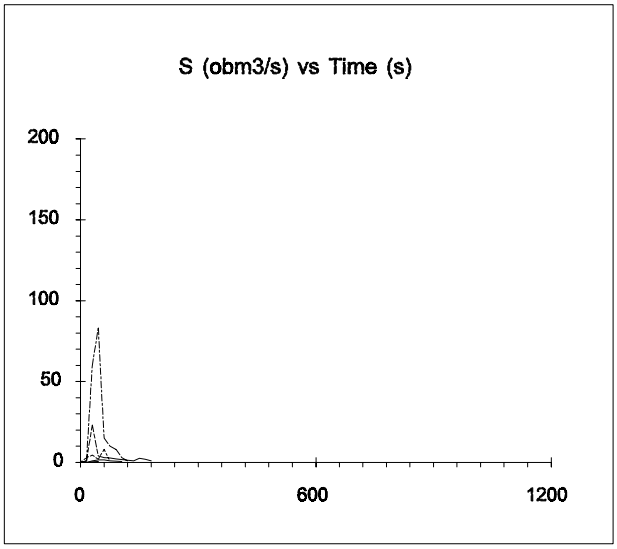
Test procedure:
Method: Room calorimeter. The curtain is 3 (pleated to one third) by 3 m^2 and is hanging freely against a wall whith an airgap of about 0.1 m.
Ignition source: 100 kW gas burner under the curtain.

Sample:	10	11	12	13	14
W. loss (%)	29	49	80	100	100

Sample 10: 20-30 % melted and dripped away, is not included

Reference:
Wetterlund, I. & Göransson, U.
A Full Scale Fire Test Method for Free-hanging Curtain and Drapery Textiles
Fire Technology
SP Report 1988:45, ISSN 0284-5172
Borås, Sweden 1988





15:
Cotton velvet
Surface weight: 310 g/m^2,
Mass: 1.87 kg
Expt.no. 9

16:
45% acryl, 39% cotton, 16% polyester
Surface weight: 230 g/m^2
Mass: 1.43 kg
Expt.no. 10

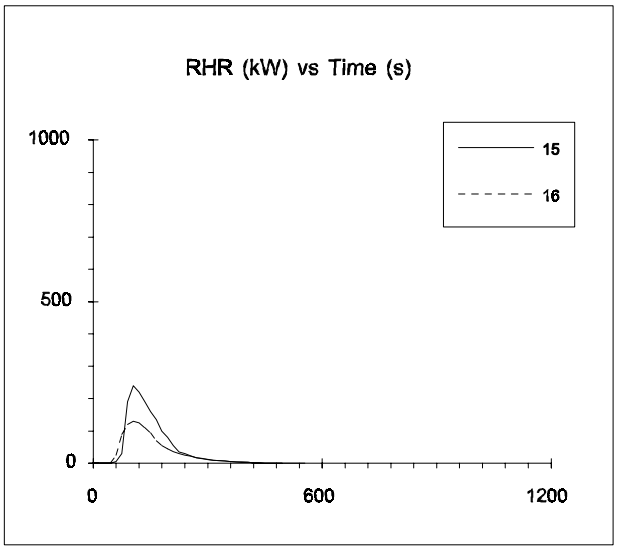
Test procedure:
Method: Room calorimeter. 2 curtains were hanging in the corner of the room. The curtain size was 1.24 (folded to half the width) x 2.42 m^2. They were hanging freely against the wall with an airgap of 100 mm.
Ignition source: Tray with 5 ml isopropanol located in the corner under the curtains

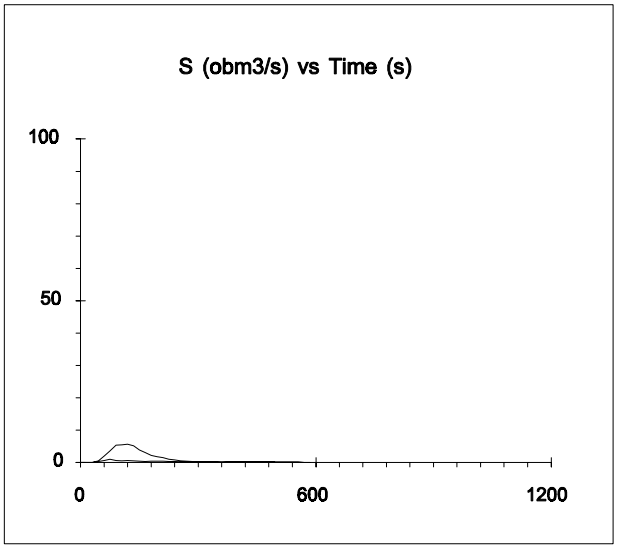
---

Sample:	15	16
H_{eff} (MJ/kg):	14	13

Also available:
Radiation and gas temp.

Reference:
Ahonen, A, Kokkala, M & Weckman, H.
Burning Characteristics of Potential Ignition Sources of Room Fires
Technical Research Center of Finland
Research reports 285
Espoo, Finland 1985





Artificial plants

All the plants were of the height about 1 m.

10: Palm, small and bushy
Palm leaves treated with glycerine mounted on an artificial stem.

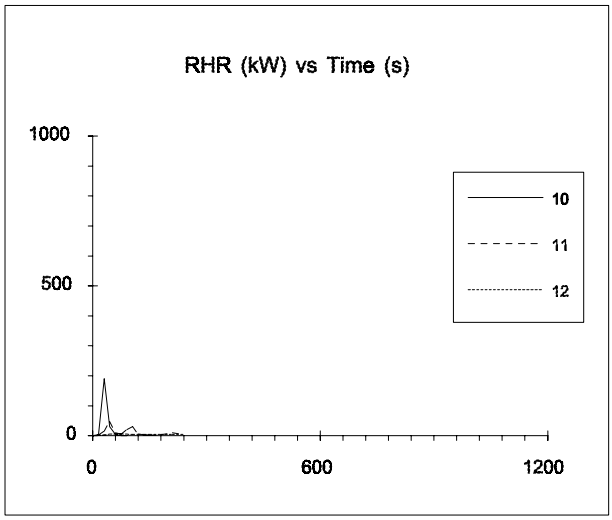
11: Palm, tall and slim
Palm leaves treated with glycerine mounted on an artificial stem.

12: Ficus Benjamina
Polyester treated textile leaves mounted on an natural stem.

Test procedure:
Method: Freeburning in furniture calorimeter
Ignition source: 10 and 11: Match, 12: Gas burner

Note:
Sample 12 was hard to ignite and gave a low heat release.

Reference:
Ondrus, J
Brandförsök med prydnadsväxter
Departement of Fire Safety Engineering, Lund Institute of Technology, Lund University
Lund, Sweden 1991
Not published



Christmas trees

All trees were spruces (Picea excelsa) with the height of about 2.4 m

20:
Mass: 6.5 kg
Condition: Green
Expt.no. 16

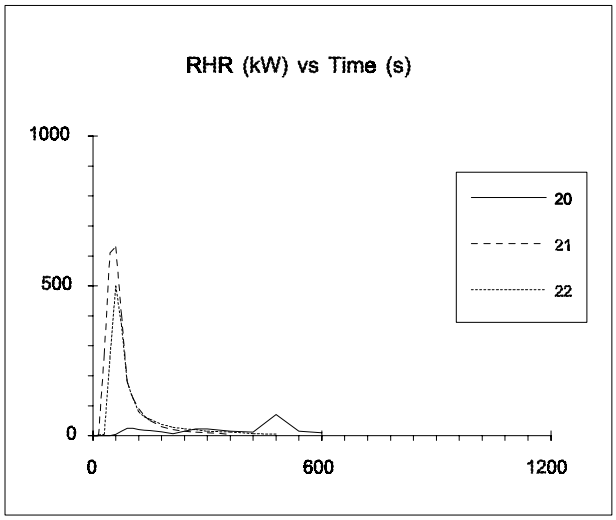
21:
Mass: 7.0 kg
Condition: Dried (Needles beginning to fall off)
Expt.no. 17

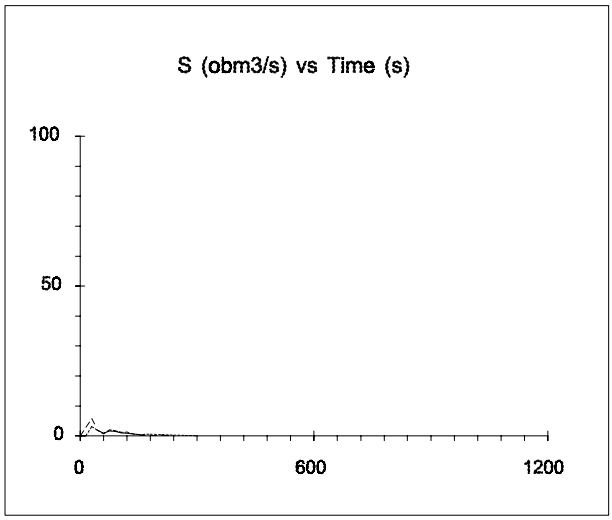
22:
Mass: 7.4 kg
Condition: Dried (Needles beginning to fall off)
Expt.no. 18

Test procedure:
Method: Room calorimeter. The trees were located in the corner of the room
Ignition source: Isopropanol tray standing on the floor under the undermost branches.

Also available:
Radiation and gas temp.

Reference:
Ahonen, A, Kokkala, M & Weckman, H.
Burning Characteristics of Potential Ignition Sources of Room Fires
Technical Research Center of Finland
Research reports 285
Espoo, Finland 1985





30: Stuffed fox
DDT and Arsenic treated

Test procedure:
Method: Freeburning in furniture calorimeter.
Ignition source: Heptane tray (∅ 0.15 m) under the fox.

Note:
The fox gave a very low RHR, only the heptane burned.
No data available.

The smoke is presumeably quite poisonous due to the DDT and arsenic.

Reference:
Eriksson, H. et al.
Malmö slott
Departement of Fire Safety Engineering
Lund Institute of Technology, Lund University
Lund, Sweden 1990

Expression for freeburning pools of varying size

Material	Density [kg/m^3]	H_C [MJ/kg]	m''_∞ [kg/m^{2}s]	$k\vartheta$ [m^{-1}]
Cryogenics (for pools on dry land)				
Liquid H_2	70	120	0.017	6.1
LNG, mostly CH_4	415	50.0	0.078	1.1
LPG, mostly C_3H_8	585	46.0	0.099	1.4
Alcohols				
methanol, CH_3OH	796	20.0	0.017	*
ethanol , C_2H_5OH	794	26.8	0.015	*
Simple organic fuels				
butane, C_4H_{10}	573	45.7	0.078	2.7
hexane, C_6H_{14}	650	44.7	0.074	1.9
heptane, C_7H_{16}	675	44.6	0.101	1.1
benzene, C_6H_6	874	40.1	0.085	2.7
xylene, C_8H_{10}	870	40.8	0.090	1.4
acetone, C_3H_6O	791	25.8	0.041	1.9
dioxane, $C_4H_8O_2$	1035	26.2	0.018**	5.4**
diethyl ether, $C_4H_{10}O$	714	34.2	0.085	0.7
Petroleum products				
benzine	740	44.7	0.048	3.6
gasoline	740	43.7	0.055	2.1
kerosine	820	43.2	0.039	3.5
JP-4	760	43.5	0.051	3.6
JP-5	810	43.0	0.054	1.6
transformer oil, hydrocarbon	760	46.4	0.039**	0.7**
fuel oil, heavy	940 -1000	39.7	0.035	1.7
crude oil	830 -880	42.5 -42.7	0.022 -0.045	2.8
Solids				
Polymethylmethacr.	1184	24.9	0.020	3.3
Polypropylene	905	43.2	0.018	NA
Polystyrene	1050	39.7	0.034	NA

* Independant of diameter
** Uncertain estimation

Note:
The pool fires are not available in the database.

Reference:
Babrauskas, V
Burning Rates
The SFPE Handbook of Fire Protection Engineering, pp 2-1 to 2-15
U.S.A., 1988

RHR calculation:
The RHR may be calculated by the formula:

$$RHR = H_C \times m'' \times A$$

where

$$m'' = m''_\infty \left(1 - e^{-k\vartheta D} \right)$$

Alcohols are independant of the diameter, giving:

$$m'' = m''_\infty$$

Nomenclature:

A	[m^2]	Pool area
D	[m]	Pool diameter
H_C	[MJ/kg]	Heat of combustion
$k\vartheta$	[m^{-1}]	Extinction-absorption coefficient of the
m''	[kg/m^{2}s]	Mass loss rate
m''_∞	[kg/m^{2}s]	Mass loss rate for a pool with an infinite diameter

Complicating effects
The expressions above represents an idealized pool burning. In some cases the error may be as much as a factor 2. Some of the complicating effects are:

Boil-over
This effect is rare, but can occur for certain grades of petroleum crude and petroleum products with moisture.

Transients
The burning rate is often increasing with the time, due to the heating of tank walls et.c. For a conservative estimation, the effect can be ignored.

Lip heights
The effect is uncertain, in lack of experimental data

Winds
This effects can change the burning rate up to a factor 2. The wind has been reported to both increase and decrease the burning rate, and at velocitys greater than about 5 m/s some fires may be blown out.

Very large pool diameters
For pool diameters larger than 5 to 10 m, a decrease in the order 20 % in the RHR is usually noted, attributed to poorer mixing, poorer combustion and a layer of cold smoke above the surface.

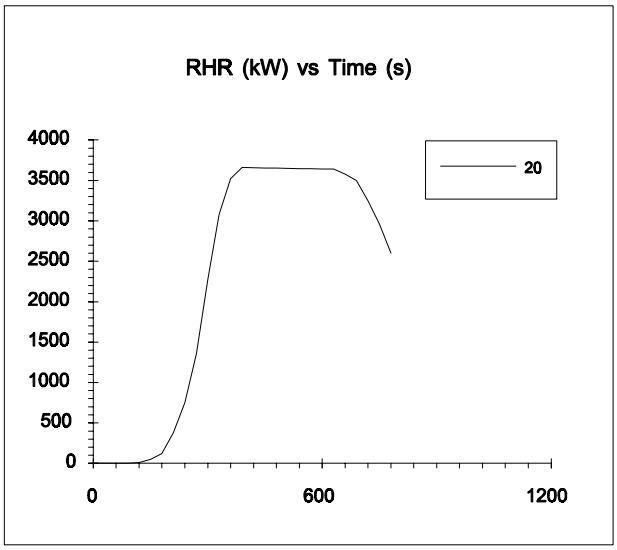
Expression for freeburning wood pallet stacks of varying size

Stacked standard wood pallets
Size: 1.22 x 1.22 x 0.14 m^3

20:
Height: 1.22 m

Note:
The pallet fires except sample 20 are not available in the database.

Reference:
Babrauskas, V
Burning Rates
The SFPE Handbook of Fire Protection Engineering, pp 2-1 to 2-15
U.S.A., 1988



RHR calculation:
The RHR may be calculated by the formulas:

$RHR = 1450\ (1 + 2.14h_C)(1 - 0.027M)$
(expression for single stacks)

$RHR = A \times 970\ (1 + 2.14h_C)(1 - 0.027M)$
(expression on a per-unit-pallet-floor-area basis)

Nomenclature:

h_C	[m]	Stack height
M	[-]	Moisture content
A	[m^2]	Covered floor area

The heat of combustion is assumed to be 12 MJ/kg

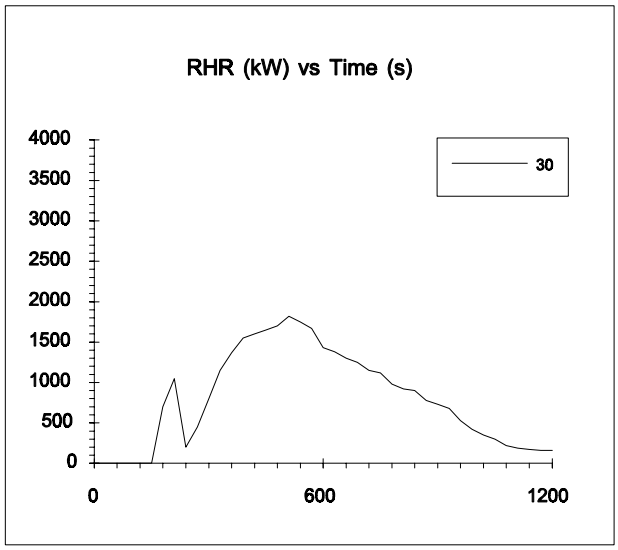
Complicating effects:
The expression overpredict the RHR if applied to stacks shorter than 0.5 m

30: Stacked PS boards
Stacked boards of expanded PS. The stack is lying directly on the floor.
Size: 1.20 x 0.60 x 0.10 m^3
Mass: 1.4 kg
Stack: 12 x 2 boards
Total size: 1.20 x 1.20 x 1.20 m^3
Total mass: 16.8 kg

Test procedure:
Method: Freeburning in industry calorimeter
Ignition source: 1000 kW gas burner at the side of the stack.

Note:
The first peak on the RHR is caused by the gas burner.

Reference:
Dahlberg, M
Polystyren
Fire Technology
Borås, Sweden
Not published



10: A half tram car
Half a standard tram car from Gothenburg. The car was cut in two parts and the hole was closed.
Seats: Upholstered with plastic faced fabric
Floor: Rubber carpet
Walls: Plastic laminate
Ceiling: Masonite boards and aluminium sheets
Length: 6 m

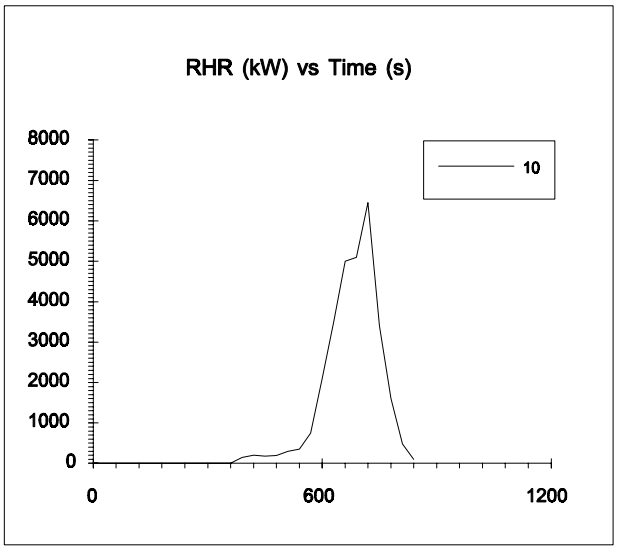
Test procedure:
Method: Freeburning in industry calorimeter
Ignition source: 127 g wooden cribs at one seat.

Note:
Only about 80% of the smoke was exhausted by the hood. The real RHR would therefor be higher.

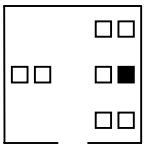
Due to the size, only half a car was burned. A whole car would presumeably have a RHR of the double size and the same rate of rise. The time to flashover would be a little longer.

At 300 s the fire had spread from the ignition seat
At 390 s the first window broked.
At 530 s the other windows starts to broke.
At 720 s the extinction started

Reference:
Dahlberg, M
Spårvagn
Fire Technology
Borås, Sweden
Not published



Simulated bus/train
Four double bus seats in a 2.4 x 3.6 x 2.4 m^3 room.
The room was furnished as in the figure.



Ceiling: Ordinary bus ceiling material.

11:
Chairs: City bus
Padding: High resilient PU foam
Cover: 40% viscose, 20% wool, 20% polyester, 20% polyamide fabric

12:
Chairs: Inter-city train
Padding: High resilient PU foam
Cover: 100% wool fabric
Walls and floor covered

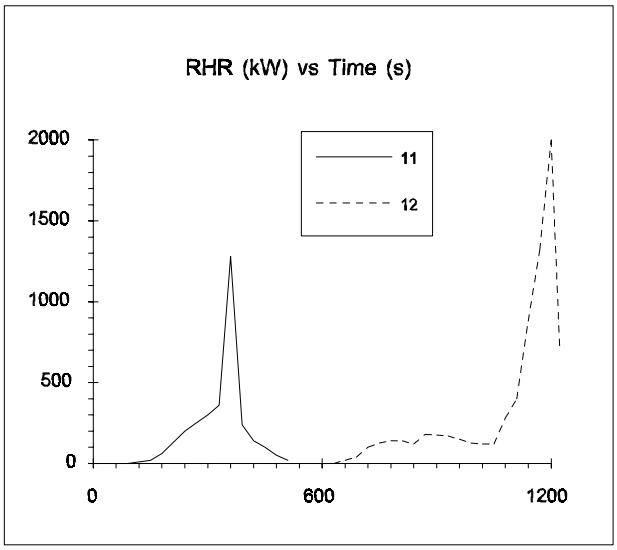
Test procedure:
Method: Room calorimeter
Ignition source: Wooden cribs at one seat.

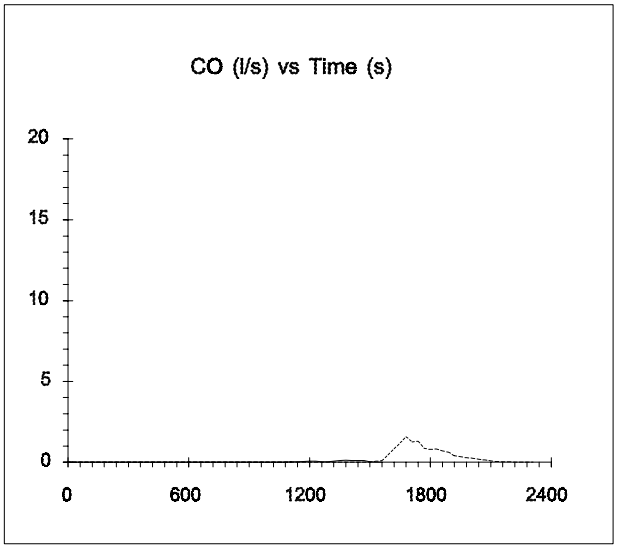
Also available:
Sample 12: CO_2 production

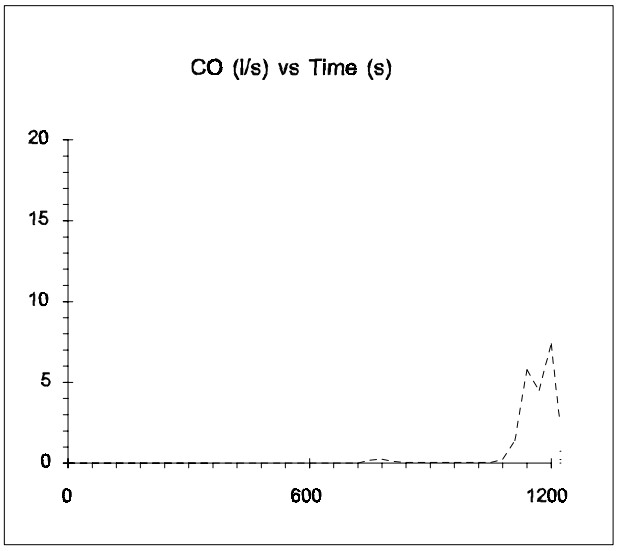
Note:
The fire produced a large amount of smoke, but did not ignite the wall or ceiling until two chairs were burning

The fires were extinguished after about 360, and 1200 s, respectively.

Reference:
Göransson, U. & Lundqvist, A.
Fires in Buses and Trains, Fire Test Methods
Fire Technology
SP REPORT 1990:45, ISSN 0284-5172
Borås, Sweden 1990







Passenger cars
Ordinary sedan passenger cars manufactured in the late 1970's

The total energy release is estimated to be 4000 MJ.

20:
Test 1

21:
Test 2

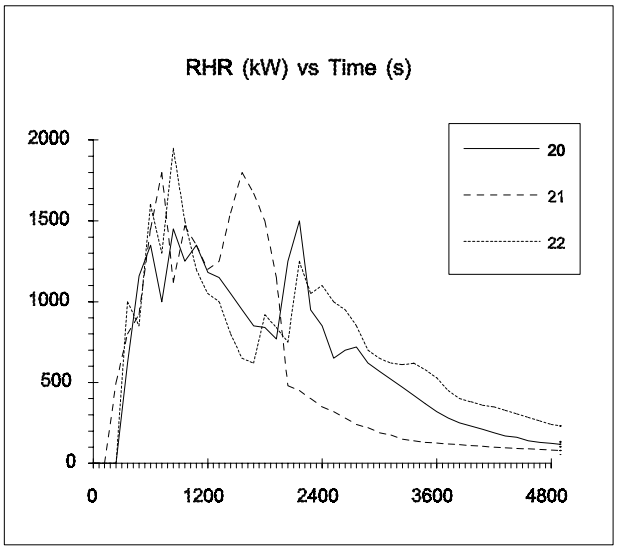
22:
Test 3

Test procedure:
Method: Freeburning in calorimeter

Note:
The first RHR peak is due to the compartment fire and the second to the fuel fire.

Sample 20: The fuel burned from the mouth of the filler pipe.
Sample 21: The fuel burned from the mouth of the fuel tank and from a pool under the car, when the filler pipe and the fuel hose had melted.
Sample 22: The fuel burned from the mouth of the fuel tank, when the filler pipe had melted.

Reference:
Mangs, J. & Keski-Rahkonen, O.
Fire Safety for Open Car Park Buildings
VTT
Espoo, Finland
To be published



REGISTER

The code shows only the first page where a sample appears. Many objects are also to be found in the following pages.

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Animals, stuffed	Y8/30
Bedding	Y6/50
Beds	Y6/10
Bedrooms	Y0/10
Boards	O
Bookcases	Y3.3/10
Bottles, plastic, in crates	Y3.3/59
Business machines	Y1/25
Buses	Z3/11
Cabins, navy	Y0/10
Cables	J4
Cable trays	J4
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Cars, tram	Z3/10
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Chemical laboratories	Y0/30
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Curtains	Y7
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Drapery textiles	Y7
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Electric cables	J4
Expanded plastic boards	O6, Z1/30
Expanded stone boards	O5
Fibre boards	O4
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Furniture	Y
Gypsum plaster boards	O1
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Insulating boards	O5, O6/20
Insulation	K, O5, O6/20
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Laminates	O6
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Metal panels	O2
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Navy cabins	Y0/10
Office furniture	Y0/20, Y3.3/10, Y5
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Paper baskets	Y3.4/10
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Surface materials	O
Technical fittings	Y1
Television sets	Y1/20
Textiles	Y7
Thermal insulation	K, O5, O6/20
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Tram cars	Z3/10
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Trees, christmas	Y8/20
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Upholstered furnitures	Y5
Vehicles, large	Z3/10
Vehicles, small	Z3/20
Wallcovering	O
Wardrobes	Y3.1
Waste baskets	Y3.4/10
Wiring	J4
Wood laminates	O3/20
Wood panels	O3/10
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