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by

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Rate of Heat Release Experiments with Lining Materials

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Abstract

Results from rate of heat release (RHR) experiments with lining materials are presented. A total of 13 materials including both cellulosic and synthetic materials were tested. In small scale RHR was measured using a modified Ohio State University (OSU) RHR apparatus. In intermediate/large scale RHR measurements were carried out in a room-corner configuration with the tested material mounted on the walls and the ceiling. The measurements were in both cases based on the oxygen consumption technique.

Introduction

This paper presents some results from experimental studies of lining materials carried out within the project "Fire Hazard - Fire Growth in Compartments in the Early Stage of Development (Pre-flashover)". The project is a joint activity between Lund Institute of Technology and the Swedish National Testing Institute. The ultimate goal of the project is to develop test methods for surface lining materials as well as furniture and other products from which the behaviour of the tested material or product in a natural fire can be predicted /1/. To achieve this goal it will be necessary to develop and exploit theoretical analyses based on reliable mathematical models for all the fire processes. A long research period will be required to reach the final goal. People working in the project are also involved in the ISO committees dealing with fire test standards /2/,/3/.
During the first three year period efforts have been concentrated at the development of a full scale room/corner fire test, because of the immediate need for a method that could be used for classification of all surface lining materials and also for evaluation of the validity of small scale test methods. At present 13 materials including both cellulosic and synthetic materials are studied in a full-scale room, in a model scale room and in several small scale methods (ISO ignitibility, ISO spread of flame, IMO spread of flame, OSU-RHR, open RHR /4/, NBS smoke density chamber, Swedish box test /5/). In this paper RHR measurements in the room experiments and in the OSU-RHR apparatus will be presented.

Oxygen consumption

Oxygen consumption technique has been used for all RHR measurements discussed in this paper. The determination of RHR from oxygen consumption is based on the fact that the energy release per unit oxygen consumed is nearly constant for complete combustion of the organic compounds that are of interest in fire studies /6/,/7/. The RHR is calculated as

$$\dot{q} = h\ (\dot{x}_0 - \dot{x})$$

where h is the heat release per mole of oxygen consumed and $\dot{x}_0$ and $\dot{x}$ are the molar flow rate of oxygen in the incoming and outflowing gases respectively.
An advantage with the OSU-apparatus is that the airflow is determined at the entrance. This is much easier than flow measurements in e.g. room experiments, where the flow is measured in the exhaust duct from the hood collecting all gases leaving the room. Often the difference between oxygen content in the exhaust gases and the ambient air is very small. This calls for the use of an

accurate and fast oxygen analyzer in combination with a carefully designed filtering system.

OSU-RHR equipment

Many different apparatuses have been used for RHR measurements /8/. The most common equipment is the OSU apparatus, which was constructed with a measurement system based on the enthalpy of the flue gases /9/. A major problem with this technique is that the signal is dependant on the radiation level from the panel /10/. Another problem is that the baseline of the signal is unstable because of temperature changes when the tested material is inserted into the apparatus. When oxygen consumption is used a better precision is possible.
To obtain high accuracy, when measuring with oxygen consumption in the OSU apparatus, certain changes in the original construction were made. The upper part of the apparatus has a double wall design. When the apparatus is used as in the ASTM proposal 3/4 of the total airflow flows between the double walls to increase the fraction of the heat release appearing as convective heat. For oxygen consumption measurements this airflow acts only as a dilution and therefore it was shut off. To improve mixing of the exhaust gases the standard stack was replaced by a longer one.
The experimental set-up is illustrated in fig 1. One of the most important components is of course the oxygen analyzer. During the experiments two different instruments were used, a MSA803P stack gas analyzer (zirconium oxide type) and a Siemens Oxymat 2 (paramagnetic). The paramagnetic one is preferable, but the less expensive zirconium instrument is an acceptable alternative for this kind of RHR measurements. Recurring calibrations of the equipment with gases under varying conditions has shown a ±3% error in RHR.
A non-impinging pilot flame was used. The pilot was a tube with inner diameter 4.8 mm positioned 10 mm above the center of the specimen, 5 mm behind the surface and directed towards the radiation source. It was fed with 72 W of propane and enough air to get a blue flame.

Test Rooms

The full-scale test room /11/, fig 2, built at the National Testing Institute is a lightweight concrete construction with dimensions according to the proposed ASTM standard room fire test /12/. The fire gases leaving the room are collected in a hood connected to an evacuation system via an exhaust duct. Rate of mass flow is measured by a pitot tube /13/ and a thermoccouple in the center of the duct. To obtain a fully developed velocity profile at a rather short distance from the hood guide vanes are installed in the duct. For the room tests the paramagnetic oxygen analyzer (Siemens Oxymat 2) has proved to be the only useable instrument. The test room has been extensively calibrated with results indicating that the total inaccuracy of the system is within 25 kW or ±10% of the measured value /14/. In the full scale test series the material was mounted on the ceiling and all walls except the doorway wall. The material was ignited with a 0.17 m square propane sand burner located in one corner of the test room. During the first 10 minutes of an experiment the gas burner heat output was kept at 100 kW, which produced a flame that reached the ceiling. If flashover had not occured the heat output was then increased to 300 kW and the experiment was discontinued after another 10 minutes.
The scaled down test room, which is made from refractory, is a third-scale model of the full-scale room. It is constructed with a loose front and the room on wheels to make material mounting easier. To obtain a similar fire buildup in the two scales the door width is scaled down with the square root of the scale factor /15/. The system for collecting the fire gases and massflow measu-

rements is similar, but a little less complicated, than the corresponding full-scale equipment. The accuracy in RHR of the model scale equipment is equivalent to that of the full scale. The ignition burner used in the test series was a 0.07 m square sand bed burner and the burner heat output was scaled proportional to the square of the scale factor.

Results

The 13 materials were chosen such that a large variation in behaviour could be expected. Time to flashover, defined as sustained flaming out the doorway, varied from 14 s (PUR foam) to almost 11 minutes (textile wall-paper on gypsumboard), but two materials (gypsumboard and paper wall-paper on gypsumboard) caused no flashover.
The typical behaviour of a relatively thick cellulosic material in the three experimental equipments is illustrated in fig 3, which shows RHR curves for a 10 mm thick chipboard (density 750 kg/m^3). In the OSU apparatus time to ignition decreases and maximum RHR increases when the exposure level increases. In full-scale time to flashover was 150 s and in model scale 230 s. The room experiments were discontinued soon after flashover because of the limited capacity of the exhaust systems. A possible explanation for the difference in time to flashover between the two scales, is the scale dependance of the radiation inside a room.
Figure 4 shows the RHR of a textile wall-paper (370 g/m^2) glued on two different materials, gypsum board and mineral wool. In the OSU-apparatus this kind of material causes a high peak value, but very short duration of the heat release, especially when glued on a low density material. In the room experiments the difference between the two backing materials is much more dramatic. A cautious conclusion that could be drawn from the textile wall-paper experiments is, that the RHR measured in a small scale test can not alone directly answer questions about the behaviour of a material in a full scale scenario. One activity within the project in the near future will be a study of the correlation between the small scale tests studied and the results from the room experiments. Another activity will be a sensitivity study in the model scale room with variation in different parameters like ventilation, burner heat output, burner position and material amount and orientation.

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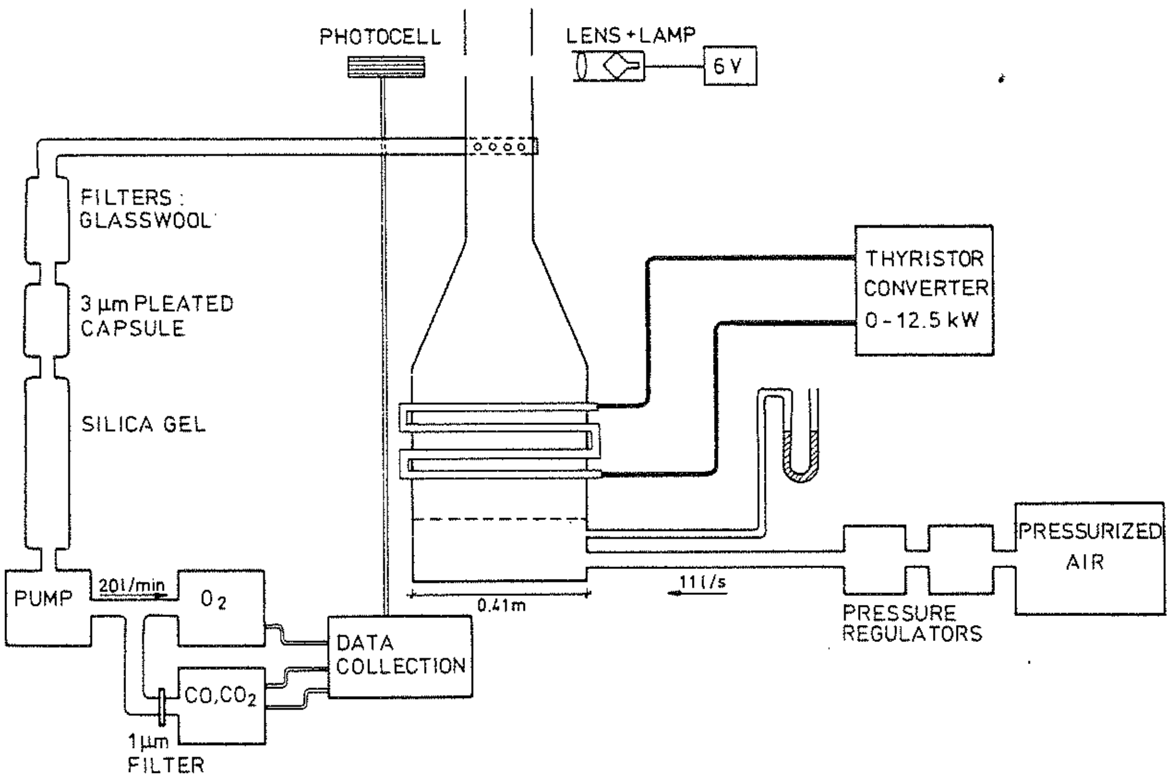


Fig 1 The OSU-apparatus with instrumentation.

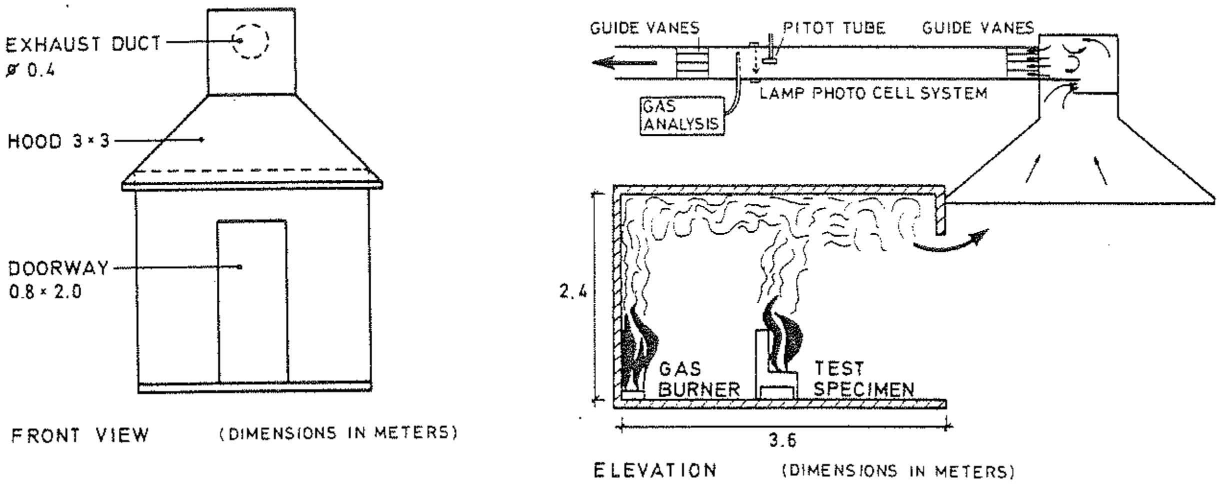


Fig 2 Test room and vent system. (Lining materials and furnishing are usually not tested in the same experiment as shown in the figure.)

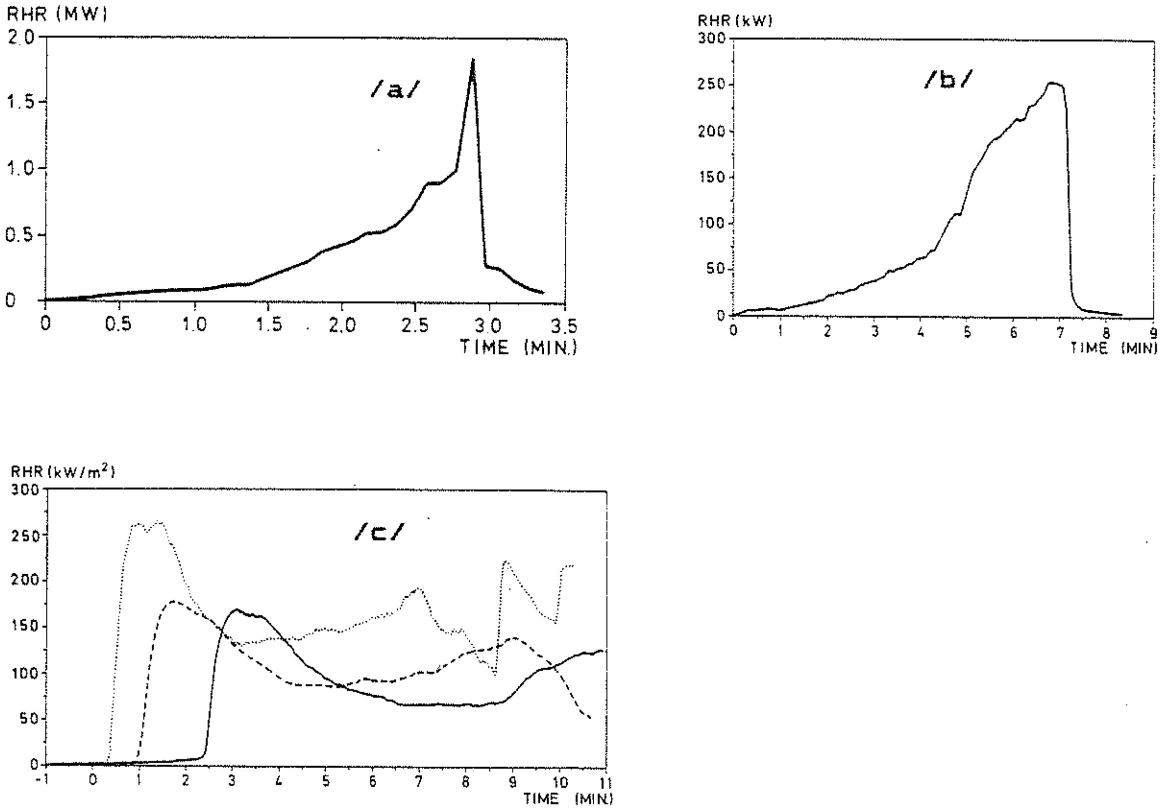
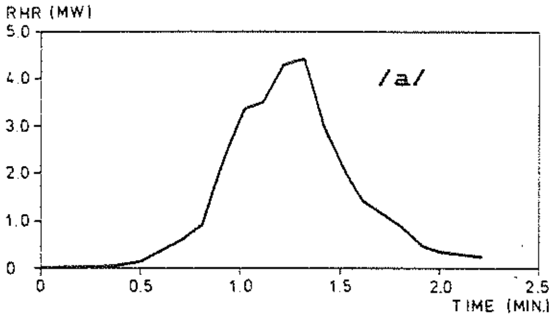
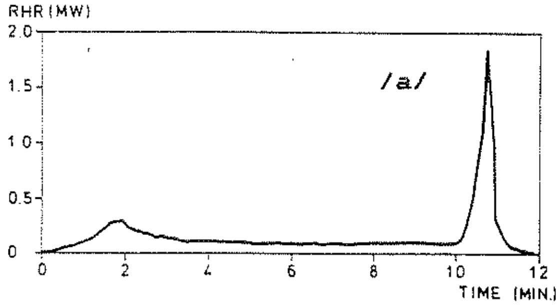
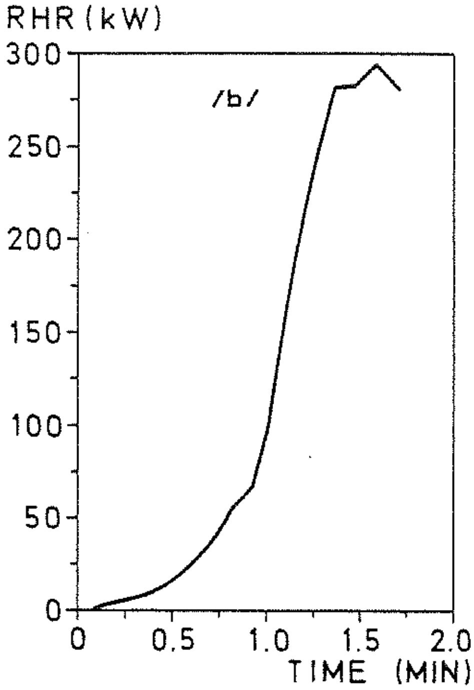
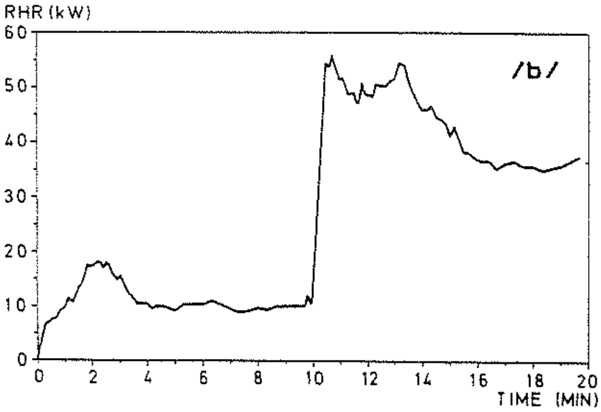


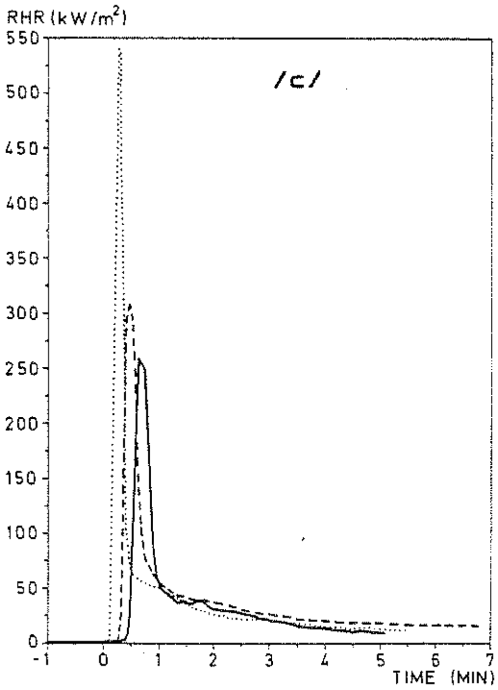
Fig 3 RHR measured in the three equipments for a 10 mm chipboard.
/a/ full scale /b/model scale /c/ OSU
In the OSU-apparatus the levels of exposure were 2 W/cm^2 solid line, 3 W/cm^2 dashed line and 5 W/cm^2 dotted line. (The specimen was inserted into the combustion chamber at time 0.)











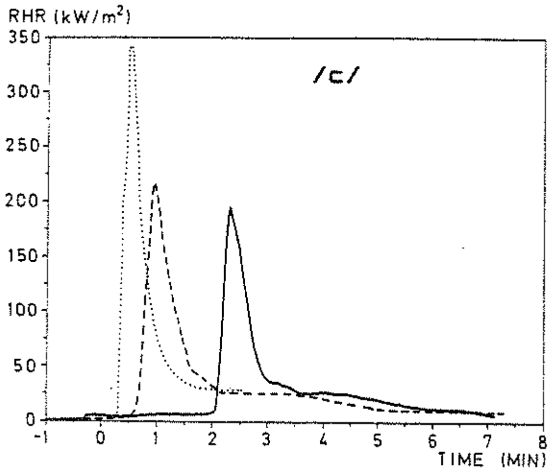


Fig 4

RHR measured in the three equipments for a textile wall-paper glued on mineral wool - left side and gypsum board - right side.
/a/ full scale /b/ model scale /c/ OSU
In the OSU-apparatus the levels of exposure were 2 W/cm^2 solid line, 3 W/cm^2 dashed line and 5W/cm^2 dotted line