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# NECESSITY OF CARRYING OUT FULL-SCALE BURNING TESTS TO MEASURE THE HEAT RELEASE RATE OF COMBUSTIBLES

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## ABSTRACT

Consequent to so many big building fires in Hong Kong, there are concerns on building fire safety. Of all the risk parameters, heat release rate is the most important one affecting the course of a fire. However, data on heat release rate for local combustible products are not yet available. The importance of studying the probable heat release rate by burning those combustibles will be pointed out in this special issue.

Full-scale burning tests should be performed to measure the heat release rate. Putting the heat release rate into the room fire models would give the probable fire environment. The results can be applied to investigate how the fire safety provisions can be improved. These include providing better passive building design such as the structural elements; and appropriate active fire protection systems. The information is necessary for implementing the new generation of building fire safety codes.

## 1. INTRODUCTION

Consequent to so many big fires in Hong Kong, such as the big Garley building fire [1], fire safety regulations should be upgraded. A fundamental question on providing fire safety has never been asked [2]:

***How big is the fire?***

To answer the above question, the heat release rates [3] of a fire resulted from burning the combustible items have to be understood. Heat release rate is an important parameter affecting the course of a fire by acting as the driving force. Reliable methods are not yet available to predict hydrolysis and the burning rate from basic material properties, for most combustibles, and their configurations. There is not yet a theory integrating the intermediate combustion reactions, turbulent mixing of gasified fuel vapour with air, and thermal radiation feedback. Fire models [4], another important fire hazard assessment tool [5], rely on the input heat release rate.

However, there are very few experimental data available from systematic full-scale burning tests [6,7], especially for local products and building configurations. The heat release rates estimated from the existing models might deviate from those of an actual fire. There were big arguments on using too big or too small a design fire.

Issues and problems to be addressed are:

- Review on the combustion characteristics of combustibles identified in a building, i.e. furniture, audio-visual equipments, electrical appliances, partition walls and carpets.
- Carrying out full-scale tests to measure the heat release rates by the oxygen consumption method.
- Assessing the heat release rate models for burning combustible items by experimental data.
- Modelling the probable fire environment in a room with realistic room fire models.

Very few studies on heat release rate measurement for local combustibles had been carried out. There are many buildings in Hong Kong at international leading level. The safety problems should be addressed properly.

However, there are extensive measurements on the fire aspects of different combustibles all over the World. Combustibles such as furniture [8,9], surface and lining materials [e.g. 10] with the oxygen calorimetry [3,11] were tested at the Swedish Testing and Research Institute (SP), Sweden; Building and Fire Research Laboratory (BFRL), National Institute of Standards and Technology, USA; Fire Research Station (FRS), Building Research Institution, UK (in their Cardington full-scale burning facilities); and other big laboratories in USA, Japan, Australia and New Zealand. There are abundant works on the burning of single items [3,8-10], fire models [4], and on burning some compartments such as libraries, retail shops [12] and office workstations [13]. The research programme Combustion Behaviour of Upholstered Furniture (CBUF) in Europe [8] is an obvious example.

Similar studies on local products should be carried out.

## 2. OXYGEN CONSUMPTION CALORIMETRY

The heat release rate when burning an object can be measured by the oxygen consumption method [3]. It has been shown in the literature that burning polymer with 1 kg of oxygen would give out 13 MJ of heat; (or about 3 MJ of heat in burning up 1 kg of air). This is a universal constant [14] as most polymer materials have similar reactions on breaking the carbon-carbon, carbon-hydroxygen and carbon-oxygen bonds. Accurate and fast measurement of the oxygen concentration, air temperature and air flow rate is of key importance.

With the fast development of oxygen analyzers, it is now possible to measure the oxygen concentration accurately and rapidly. The oxygen consumption method was applied to measure the heat release rate of small samples by a cone calorimeter with adjustable heat flux due to a conical heater; the heat release rate of burning furniture by a furniture calorimeter [3]; and in the new single burning item (SBI) test [15]. The concept was also applied in assessing the surface and lining materials in the ISO9705 room-corner fire test [16]; and in burning assemblies by facilities such as the Industry Calorimeter at SP [e.g. 17].

Combustion products together with the air entrained are collected by a canopy hood connected to an exhaust system. Different fan-duct systems are designed for different heat release rates. The key instrument is a 'duct section' fixed at the exhaust duct with gas sampling tubes connected to an instrument station for measuring the oxygen consumption rate as in Fig. 1.

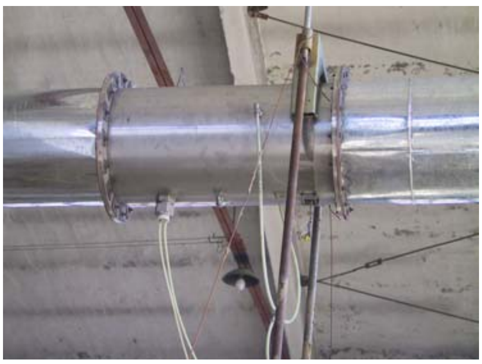


**Fig. 1: Duct section and the instrument**

## 3. THE CHINESE ASSEMBLY CALORIMETER

It is difficult to select a site for full-scale burning tests in Hong Kong as land costs are far too expensive. More importantly, there are tight environmental protection regulations and real fire tests cannot be done. A site far from the urban area should be used for carrying out such studies. In this way, environmental impact of the burning tests can be minimized. Further, there should be water, electricity and heating supply in remote areas which are cold.

A facility, known as the Chinese Assembly Calorimeter [6,7,18], has now been developed in a small town Lanxi in a remote area of Northern China, 200 km away from Harbin as indicated in Fig. 2. There, a full-scale burning hall is designated. This is a joint project with the Harbin Engineering University (HEU) with supports from the Authority. The 'duct section' and the associated instruments including the oxygen analyzer, carbon monoxide analyzer and carbon dioxide analyzer at the Research Centre for Fire Engineering of The Hong Kong Polytechnic University were moved successfully to that site in June 2001.

The burning halls are shown in Fig. 3. A bigger hall was used before in the first two years. A smaller one was used later on due to budget cut.

## 4. SELECTED EXPERIMENTAL STUDIES

Data on the heat release rates of local combustible furnishings and finishes are not yet available. Partition walls used locally have been surveyed [19] and selected samples of typical furnishings and finishes commonly used locally will be tested. This will give characteristics curves for those combustibles.

Data on full-scale burning tests together with cone calorimeter results will be used in modelling the heat release rate of burning combustibles in a karaoke box. Both fire field modelling simulations with Computational Fluid dynamics [20-22] and zone models [e.g. 23,24] should be applied to understand a room fire with the heat release rate measured.

Heat release rate in some of the post-flashover tests in typical small retail shops [25] will be reported in this issue. Those arrangements are:

- Clothing boutique
- Compact disc (CD) shops

- Timber partition in small offices and karaoke music boxes

The arrangement was placed in a small room of size similar to the ISO 9705 room calorimeter [16]. The room is of length 3.6 m, width 2.4 m and height 2.4 m with a door of height 2 m and width 0.8 m as in Fig. 3. An exhaust hood was constructed outside to measure the heat release rates by the oxygen consumption method.

A chamber [6,7] built as in Fig. 4 can be used for studying the heat release rate of combustible assemblies. Trial tests by burning an office layout as shown in Fig. 5a were taken as an example. The measured oxygen concentration and heat release rate are shown in Fig. 5b and c.


**Fig. 2: Location of the site**


(a) The team

(b) The bigger hall

(c) The smaller hall

**Fig. 3: The full-scale burning halls**

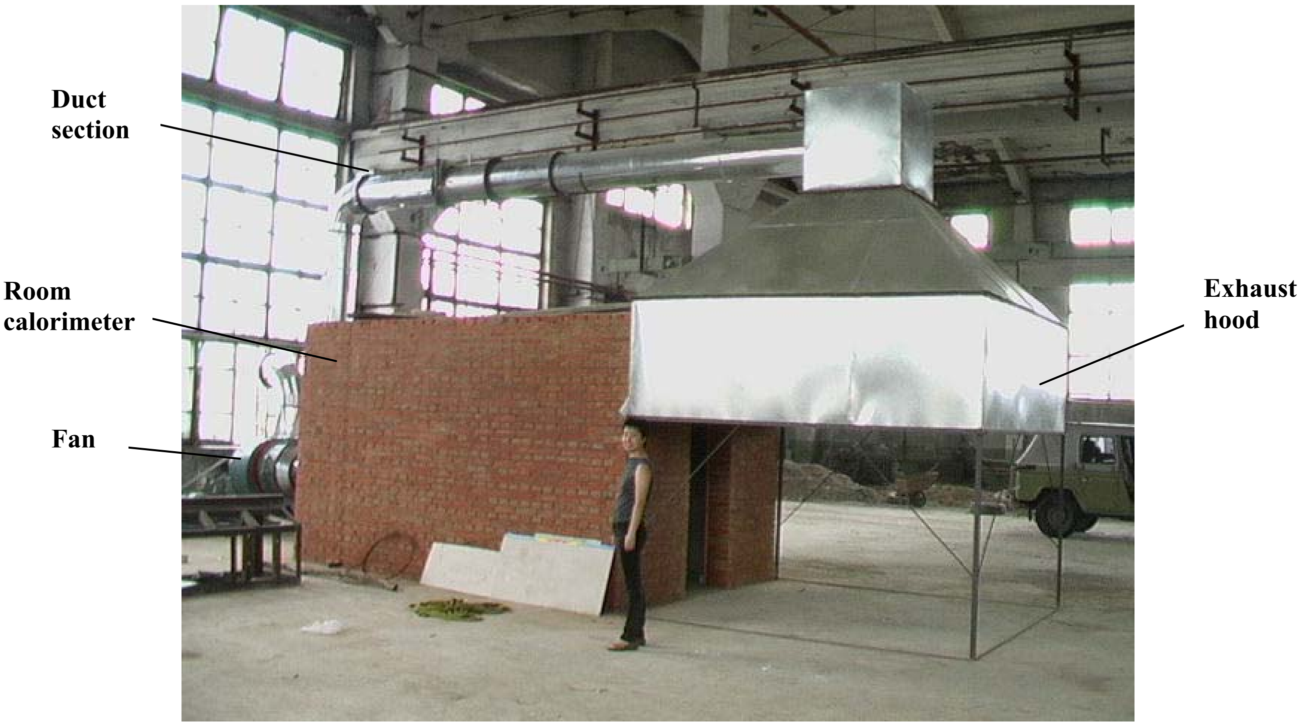
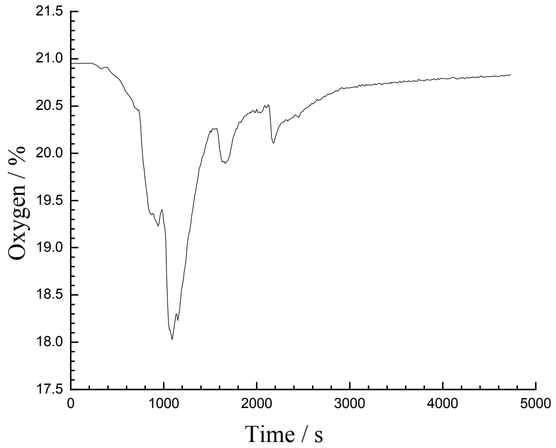
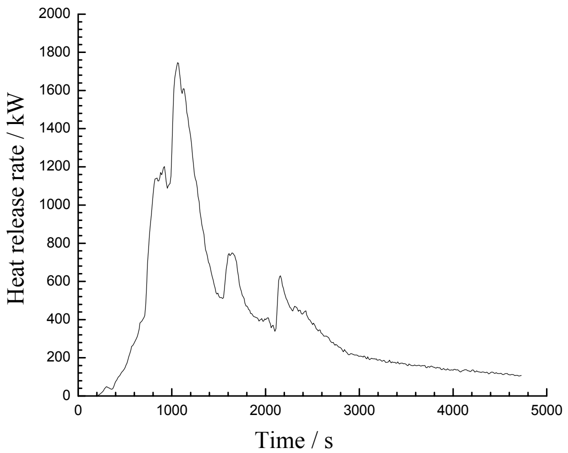



**Fig. 4: Retail shop setup**

(a) An office setup




(b) Oxygen concentration




(c) Heat release rate

**Fig. 5: Typical results on burning furniture**

## 5. CONCLUSION

Heat release rate [e.g. 2,3,11] is the most important parameter in fire hazard assessment. A better understanding of it would provide information for predicting the following [e.g. 9]:

- Fire environment such as the smoke layer temperature, smoke layer interface height, radiative heat flux, rate of smoke flowing out and air intake rate through the openings.
- The likelihood of flashover.
- Upward flame spreading over walls.
- Ignition of items placed adjacent to a burning item.

If there are information on the combustible product yields, their concentrations in the smoke layer can be predicted. The results will be useful in recommending the use of furnishings and finishes combustibles; and the fire safety provisions.

Fire safety regulations cannot be set up without support from research for local products. Local geometrical configurations and heat release rate database for combustibles must be clearly understood. However, such information is absent in Hong Kong.

It is obvious that carrying out full-scale burning tests [7,18] would be very expensive. Further support is necessary, for instance, earning funding from consultancy is a possibility.


## ACKNOWLEDGEMENT

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