NISTIR 6030

THIRTEENTH MEETING OF THE UJNR PANEL ON FIRE RESEARCH AND SAFETY, MARCH 13-20, 1996

VOLUME 2

Kellie Ann Beall, Editor

June 1997
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Gaithersburg, MD 20899

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HEAT RELEASE RATES MEASURED BY THE CONE CALORIMETER AND INTERMEDIATE SCALE ELECTRICAL RADIANT PANELS

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INTRODUCTION

Heat release rate is widely considered one of the most dominant material properties on the growth of fire. Its measurement in simulated fire environment was made possible by the introduction of oxygen consumption method, and the Cone Calorimeter is becoming the most standard tool to evaluate heat release rate of building materials. There are already numbers of mathematical fire growth models using Cone Calorimeter data as input. However, there is considerable experimental evidence that heat flux to burning surface is dependent on the size of the flame, and since heat flux to a burning surface is the driving force of heat release in fire, some size effect is anticipated on the heat release characteristics of materials. In order to investigate into the possible size effect in heat release rate, comparative study has been made using the Cone Calorimeter and an intermediate scale vertical electrical radiant panel.

EXPERIMENTAL DESCRIPTION

Efforts have been made to reproduce identical experimental conditions other than the size in the two series of experiments. Particle board and Medium Density Fiberboard(MDF) has been used as specimens; specimens of each material were prepared from a same lot and were delivered directly from manufacturers. Surface and backsurface temperature of specimen and heat flux to the surface were monitored with type-K thermocouples and Schmidt-Boelter heat flux gages respectively at both series of the test. Heat flux levels from the radiation sources were between 5 and 25 kW/m^2. From previous vertical flame spread tests at BRI, any significant upward flame spread had not been observed on this material for external heat flux weaker than 5 kW/m^2, whereas for external heat flux higher than 15 kW/m^2 upward flame spread was too fast for visual observation. If flame spread is so fast, it is believed that surface ignition dominates the life safety and there is not any strong need to predict flame spread at least from the firesafety point of view. The level of external heat flux for the present tests was chosen to reproduce fire exposure at which surface flame spread is considered the most relevant to life safety. Tests at heat flux levels not higher than 20 kW/m^2 were carried out in FY 1994, and those at 25 kW/m^2 were run in FY 1995. Partly because of the limitation in the power capacity of the intermediate scale electrical radiant panels, uniform heat flux distribution was not achieved on the specimen at heat flux level higher than 25 kW/m^2 with the intermediate scale tests. At several tests, heating of the specimen preceded the ignition as previous flame spread tests by the authors suggest importance of the initial surface temperature or preheat condition on the time history of local heat release rate. Identical heat flux gage was used for the Cone Calorimeter and for the intermediate scale tests. The heat flux gage was calibrated against a black body cavity at every interval of the tests. Temperature of the electrical heater was kept constant at both of the Cone Calorimeter tests and the intermediate scale tests.

Cone Calorimeter Tests

Specimens were placed in the vertical orientation in order to make it possible to measure surface heat flux to the specimen although the draft international standard(ISO5660) specifies only the horizontal orientation. Since the selected range of heat flux was too weak for the spark igniter, ignition was made using solid alcohol arranged on the specimen holder at the level of the lower edge of the specimen. Figure 1 shows arrangement of the specimen. The ignition source made an uniform flame layer covering the whole surface of the specimen. At some of the tests, an invertor was used to achieve stable weak heat flux level.

Intermediate-scale Heat Release Measurements

Two 0.5 m wide 1.9m tall electrical radiant panels as shown in Figure 2 were placed beneath a smoke collection hood originally built for the ISO 9705 Room Corner Test. A 0.53 m x 0.57 m specimen was mounted vertically on the BRI's wall flame heat transfer apparatus, and was placed in front of the radiant panels. Level of external heat flux was controlled by changing the distance of the specimen from the radiant panels. Heat flux was monitored at the center of the specimen. The specimen was ignited with a methane porous line burner at the lower edge level of the specimen which makes a flame layer covering the specimen surface. Blank tests both on the Cone Calorimeter and the intermediate-scale radiant panels using fiber cement board have confirmed that heat flux to the specimen due to the igniter in the two series of the tests is very close.

TEST RESULTS AND DISCUSSION

Figure 3 and 4 compare time histories of heat release rate for different external heat flux levels obtained from intermediate scale radiant panels and the Cone Calorimeter. Figure 3 represents low level of external heat flux and Figure 4 does higher heat flux level. Heat release rate per unit area measured with the Cone Calorimeter is always lower than that with the intermediate scale radiant panels. Flaming combustion was not sustained enough long in some of the Cone Calorimeter tests, especially at low heat flux levels, although combustion seemed to be stabler in the intermediate scale tests. With approximation of the time history of heat release rate after ignition on a charring material by $q_0 \cdot \exp(-\lambda t)$, the peak heat release rate, q_0, is smaller and the decay coefficient, λ, is larger for the Cone Calorimeter than for the intermediate scale apparatus as seen in Figures 5 and 6. It means that use of heat release data from the Cone Calorimeter may always lead to safer side prediction than that from the intermediate scale apparatus. The heat release data were applied to the Baroudi-Kokkala diagram for upward flame spread(Figure 7). Experimental x_{poff}/x_{po} values for the identical heat flux conditions were ①$x_{poff}/x_{po}=14$, ②$x_{poff}/x_{po}=18$, ③$x_{poff}/x_{po}>40$, ④$x_{poff}/x_{po}>26$, ⑤$x_{poff}/x_{po}>40$, and ⑥$x_{poff}/x_{po}>40$. Results of the flame spread tests were always better explained by the heat release data from the intermediate scale tests than by the Cone Calorimeter data.

Surface and backsurface temperatures and surface heat flux measured at the same test with Figure 3 are summarized in Figures 8 and 9. There is not notable difference in temperature nor in surface heat flux until around the peak of heat release between the Cone Calorimeter and the intermediate scale test. However, decay of surface heat flux starts earlier at the Cone Calorimeter than at the intermediate scale test, and this earlier decay of heating seems to be a main cause for the unstable burning behavior observed in the Cone Calorimeter tests.

During the FY1994 tests with relatively low heat flux levels, this considerably lower heat release rate from smaller testing apparatus was attributed to the possible lower combustion efficiency at smaller tests as the total CO generation per unit specimen surface area was always noticeably higher at the Cone Calorimeter measurement than at the intermediate scale test. If it is the reason, increase of external heat flux should result in closer heat release rate output between the Cone Calorimeter and the intermediate scale test apparatus. The comparison for higher heat flux was done partly to verify this assumption. As shown in Figure 6, the peak Cone heat release rate to the peak intermediate scale heat release rate increases with the level of external heat flux, and at the heat flux level, 25kW/m^2, difference in measured heat release rate became less than 20%. This result at least suggests increase of the external heat flux level can compensate the size effect in heat release.

CONCLUSIONS

From the comparison of the heat release data obtained with the Cone Calorimeter(vertical orientation) and those with the intermediate scale electrical radiant panels, the following conclusions could be drawn.

(1) The Cone Calorimeter(vertical orientation) gives generally lower heat release rate than the intermediate scale radiant panels.

(2) Results of large scale upward flame spread tests can be better explained by the intermediate scale tests than by the Cone Calorimeter(vertical orientation).

(3) Difference in heat release rate is reduced as the external heat flux level is increased.

The Cone Calorimeter tests were conducted only in the vertical orientation in order to measure surface heat flux to the specimen. Therefore the above conclusions should not be applied directly to the ISO 5660 which specifies only the horizontal sample orientation. It is perhaps worth comparing the present data with those in the horizontal orientation at identical heat flux levels.

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1. Hasemi,Y., Yoshida,M., Goto,T., Kikuchi,R., Hosomi,M., and Yamamoto,E.: On the predictability of turbulent upward flame spread based on material fire tests, Proceedings of the 1995 Annual Meeting of the Japan Association of Fire Science and Engineering, p.286- 289, 1995(in Japanese).

2. Hasemi,Y., Yoshida,M., Yasui,N., and Parker,W.J.: Upward Flame Spread Along a Vertical Solid for Transient Local Heat Release Rate, Proceedings of the Fourth International Symposium on Fire Safety Science, Ottawa, 1994.

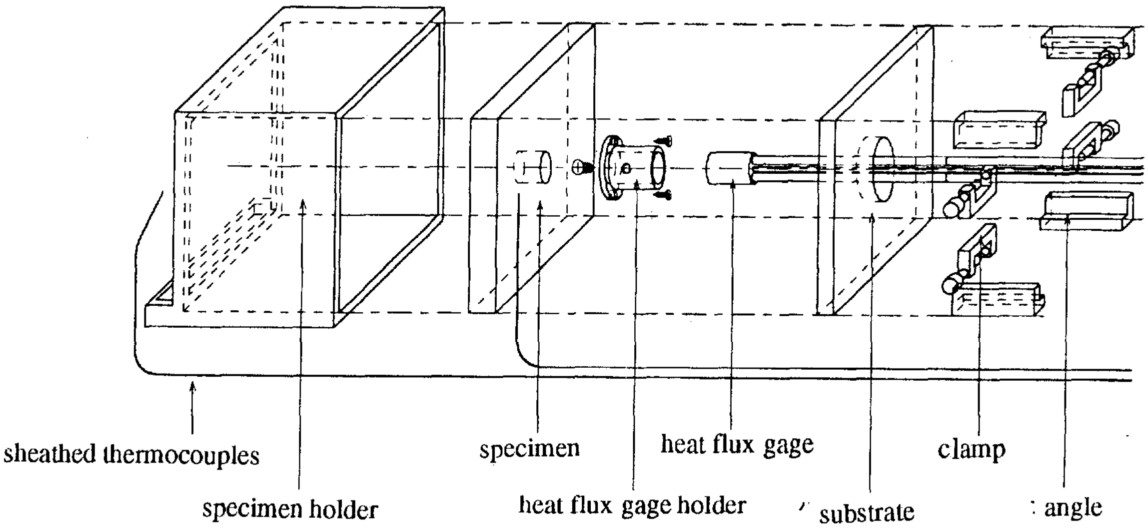

Figure 1 Arrangement of specimen and heat flux gage, Cone Calorimeter vertical orientation

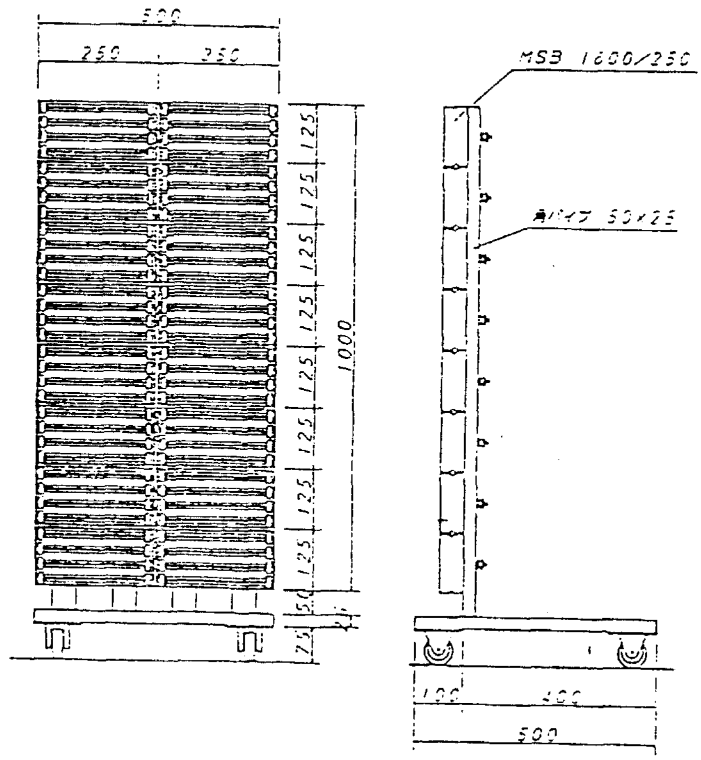

Figure 2 Intermediate scale electrical radiant panel

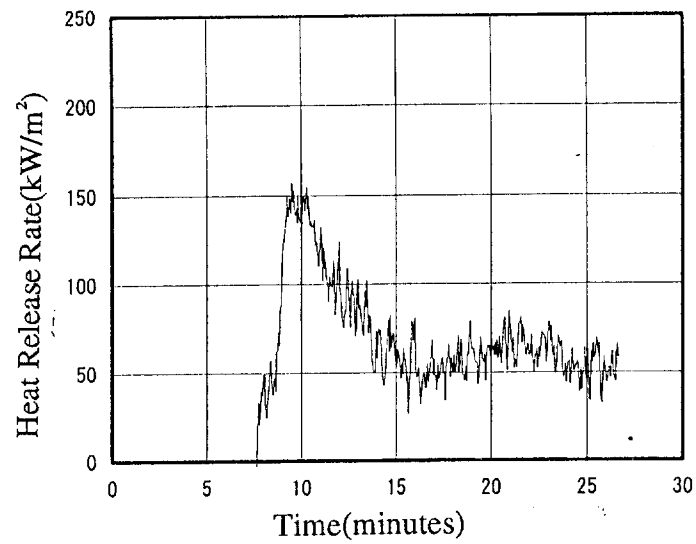

Figure 3(a) Heat release rate
Intermediate scale electrical panels
Particle board, qe=5kW/m² Tini=130C

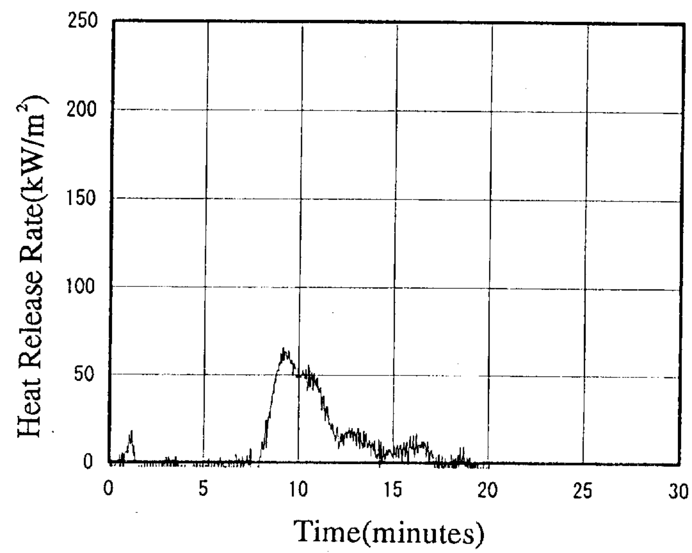

Figure 3(b) Heat release rate
Cone Calorimeter(vertical)
Particle board, qe=5kW/m² Tini=130C

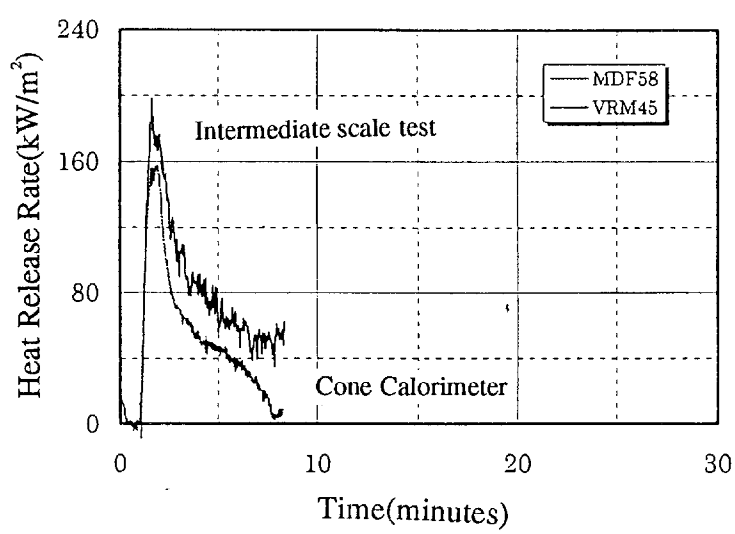

Figure 4 Heat release rate
Intermediate scale electrical panels &
Cone Calorimeter

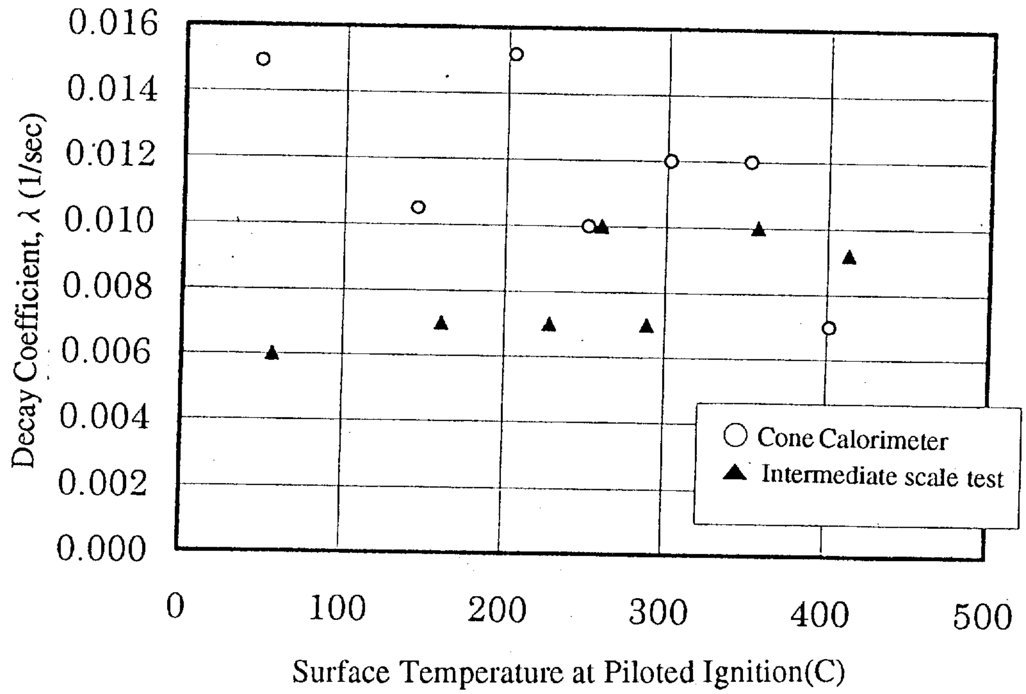

Figure 5 Heat release rate decay coefficient vs. Surface temperature just before piloted ignition

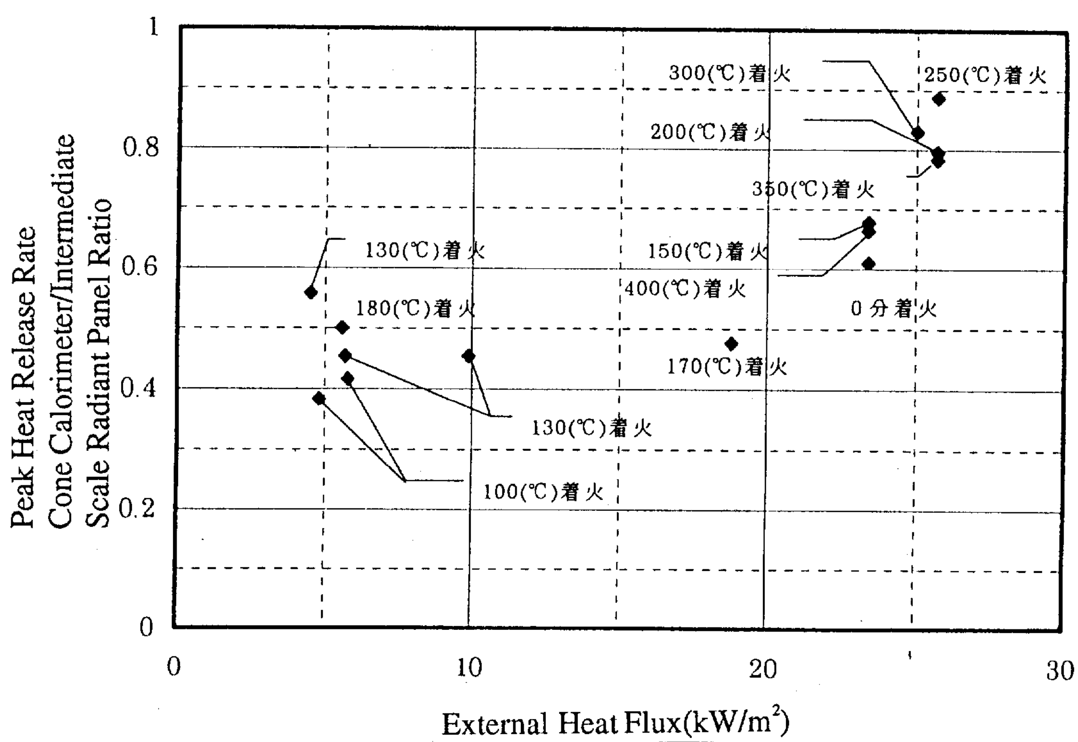

Figure 6 qo from Cone Calorimeter to qo from intermediate scale test ratio

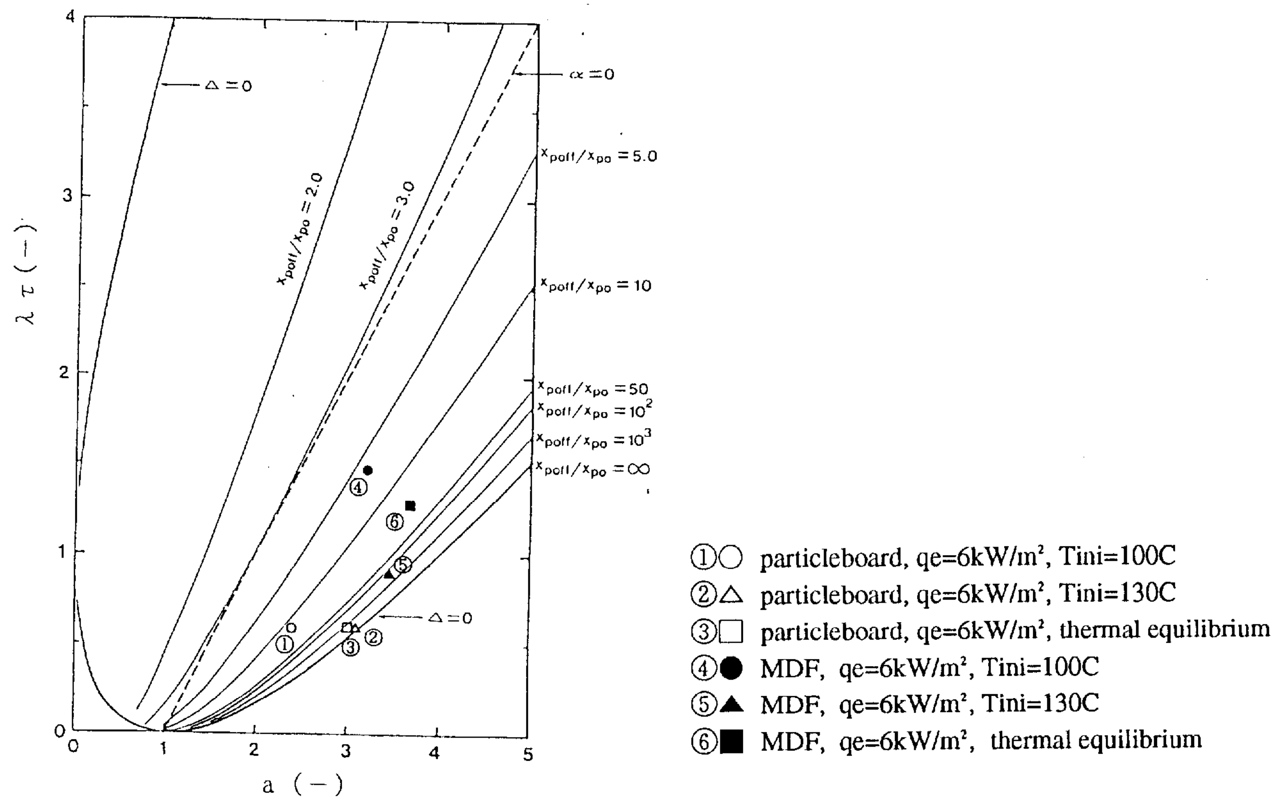

Figure 7(a) Application of heat release data to the Baroudi-Kokkala diagram, Intermediate scale test

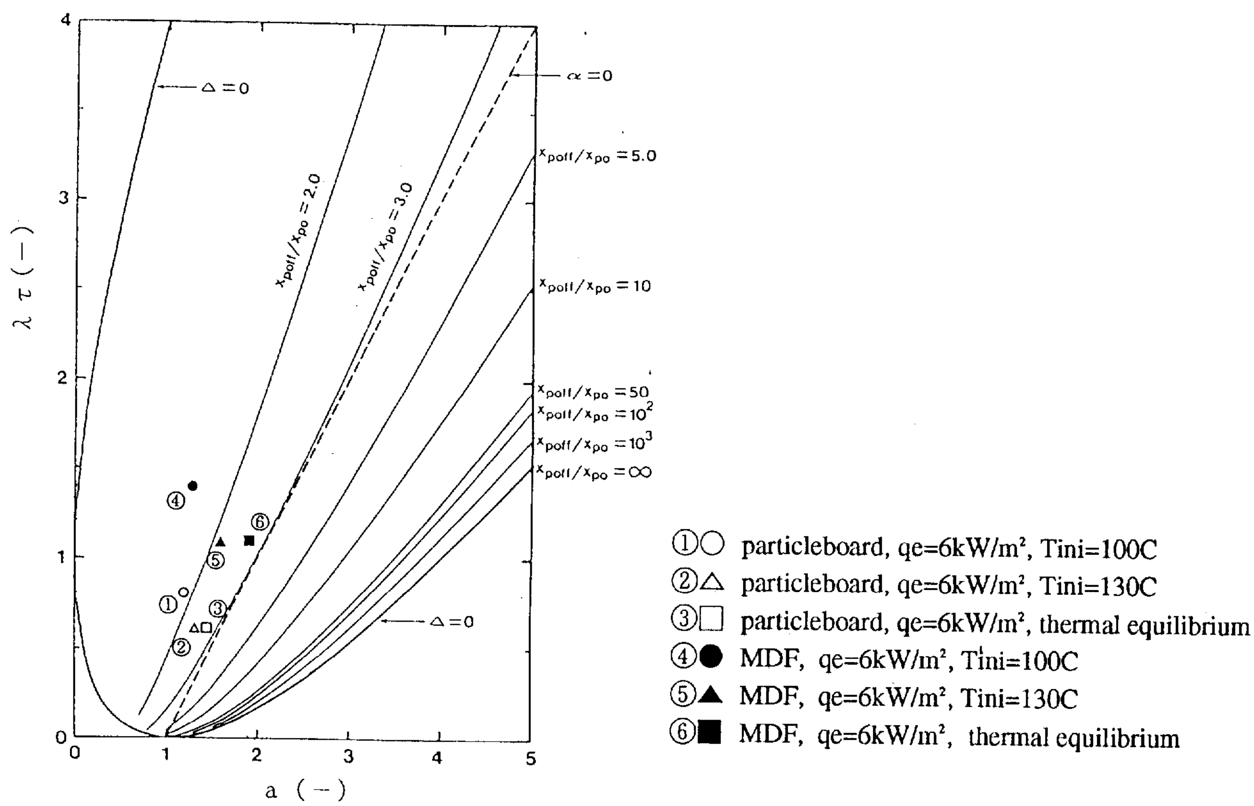

Figure 7(b) Application of heat release data to the Baroudi-Kokkala diagram, Cone Calorimeter

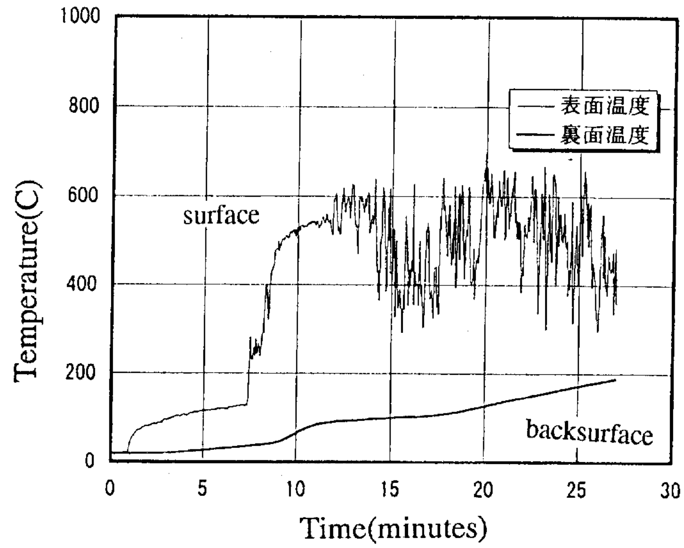

Figure 8(a) Surface and backsurface temperatures, Intermediate scale test
(thin curve: surface, thick curve: backsurface)

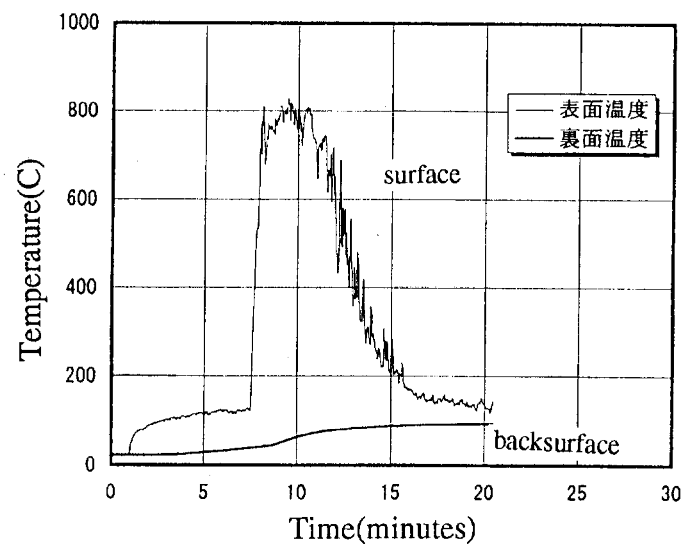

Figure 8(b) Surface and backsurface temperatures, Cone Calorimeter
(thin curve: surface, thick curve: backsurface)

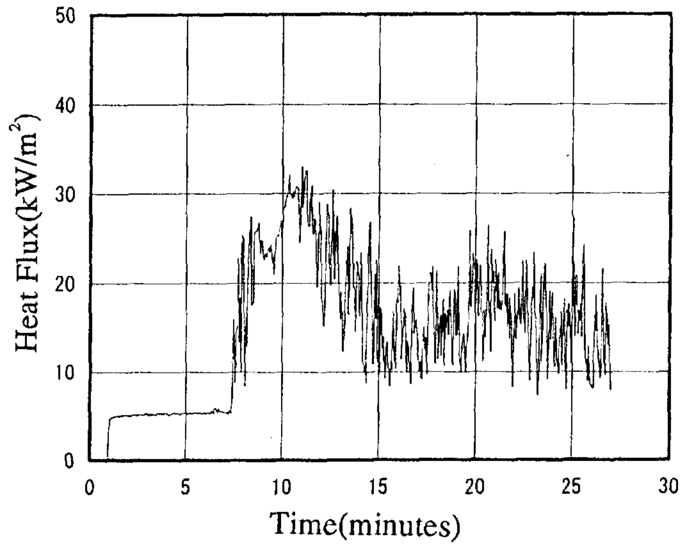

Figure 9(a) Surface heat flux, Intermediate scale test

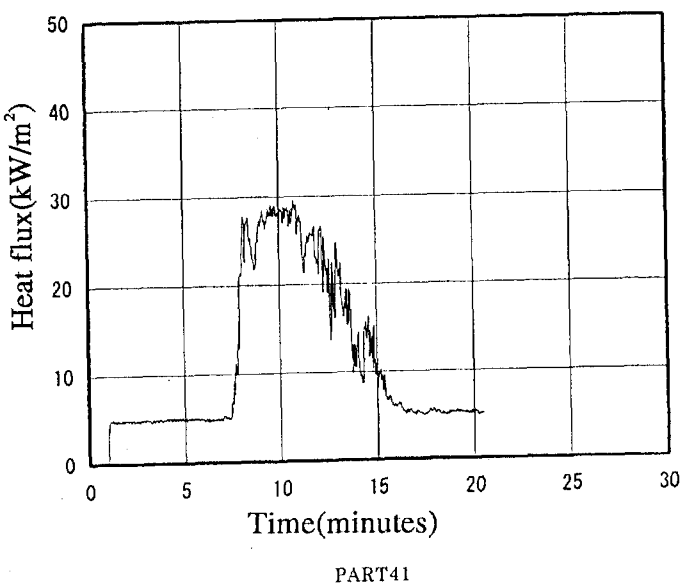

Figure 9(b) Surface heat flux, Cone Calorimeter

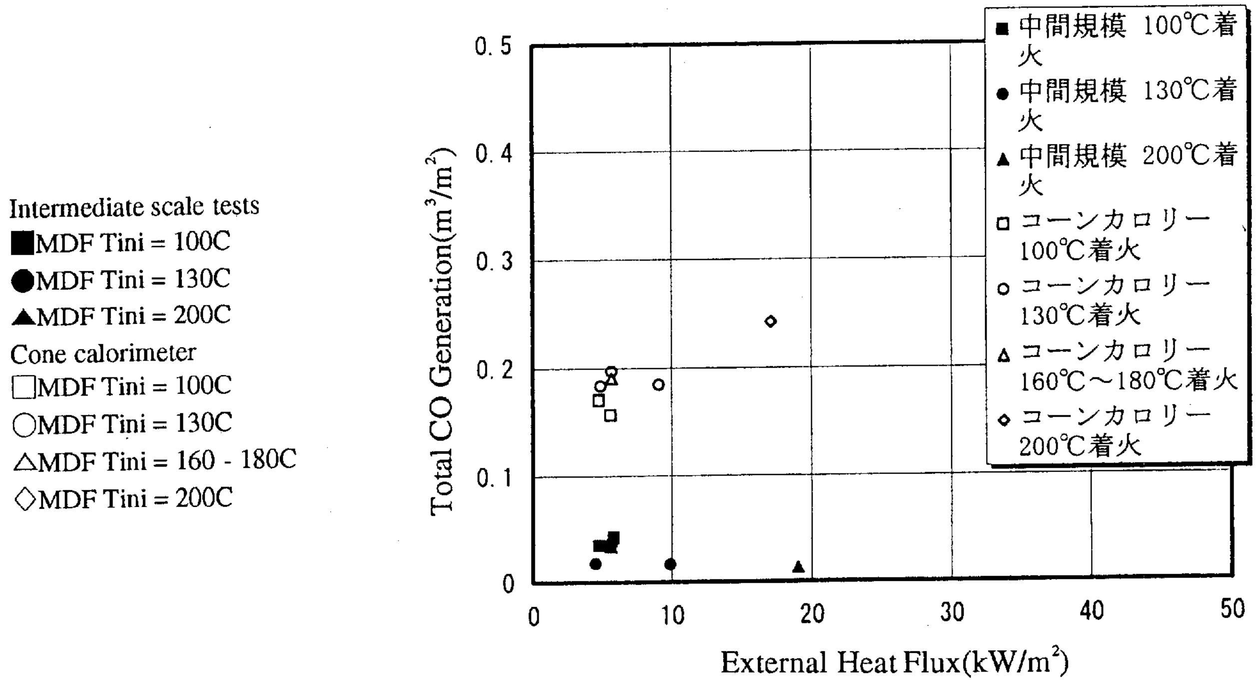

Figure 10 Comparison of CO generation between the Cone Calorimeter and the intermediate scale test