# FULL-SCALE BURNING TESTS ON HEAT RELEASE RATES OF FURNITURE

**W.K. Chow and S.S. Han**
Department of Building Services Engineering, The Hong Kong Polytechnic University, Hong Kong, China

**H. Dong, Y. Gao and G.W. Zou**
Department of Building Engineering, Harbin Engineering University, Harbin, Heilongjiang, China

*(Received 4 October 2004; Accepted 21 October 2004)*

## ABSTRACT

Full-scale burning tests on studying the heat release rates of furniture will be reported in this paper. Nine tests on sofa with and without fire retardant, wood desk and the fire source itself to start the burning were arranged. Exhaust rates of the fan-duct system lower than the normal operation values were adjusted to check the consistency of the results. Response to furniture under small accidental fires and bigger pool fires to onset flashover were tested.

Heat release rate, oxygen concentration, thermal radiative heat fluxes at floor level and air temperatures at some selected positions were measured. All these results will be reported in this paper.

It is observed that the starting fire will affect the burning behaviour of the furniture. Information under flashover fires will be useful in designing fire retardant for fire safe furniture.

## 1. INTRODUCTION

The number of big building fires starting from burning furniture in the Far East appears to be increasing. There were big fires in the Garley building [1] and Mei Foo Sun Chuen [2]. The fire behaviour of furniture, especially foam sofa, has to be understood. Although there had been numerous studies in the literature [3], such as the Combustion Behaviour of Upholstered Furniture CBUF project [4] in Europe; and others in USA [5,6], there were not much works on local furniture samples. The heat release rate in burning local furniture has to be measured.

As there are so many arson fires in small enclosures such as karaoke boxes [7,8] and train vehicles [8,9], studying the burning behaviour under flashover fire, not just from small accidental fire such as 100 kW to 300 kW in the gas ignitor for standard test ISO 9705 [12,13], is essential.

A set of full-scale burning test on studying heat release rates of selected furniture samples under accidental and flashover fires was carried out. Experiments were conducted in a room calorimeter [14] similar to the one for ISO 9705 in August 2003. An exhaust hood with a fan-duct system was installed. The facility was built in a remote area in North China, at a small town known as Lanxi in Harbin, Heilongjiang.

Nine sets of tests on foam sofa, desk and a fire source were arranged. Heat release rate, oxygen concentration, radiative heat fluxes at floor level and air temperatures at some selected positions were measured. Carbon monoxide CO and carbon dioxide $CO_2$ were not measured due to resources limitation.

## 2. FULL-SCALE BURNING TESTS

The room calorimeter [14] including locations of thermocouples for measuring air temperatures is shown in Fig. 1. Three sets of four-seater sofa and two wood desks as in Fig. 2 were selected. A total number of nine tests were carried out. As the testing room is too small, only half of the four-seater sofa with two seats was taken out as one set to be tested. The sofa samples are labeled as SF1 and SF2 as shown in Fig. 2a. Note that there was more foam in arrangement SF1 than in SF2.

The testing arrangements are:

- Burning under accidental fire

  An ignition source by burning 0.5L of gasoline in a pool of diameter 0.2 m was set up first with six sets of tests:

  Test T1: Testing SF1 under normal exhaust rate.

Test T2: Testing SF2 under normal exhaust rate.
Test T3: Testing SF1 with lower exhaust rate by reducing the fan power.
Test T4: Testing SF1 with the surface of sofa sample protected by a commercial fire retardant coating commonly used in China.
Test T5: Testing the wood desk.
Test T6: Testing SF1 and a wood desk.

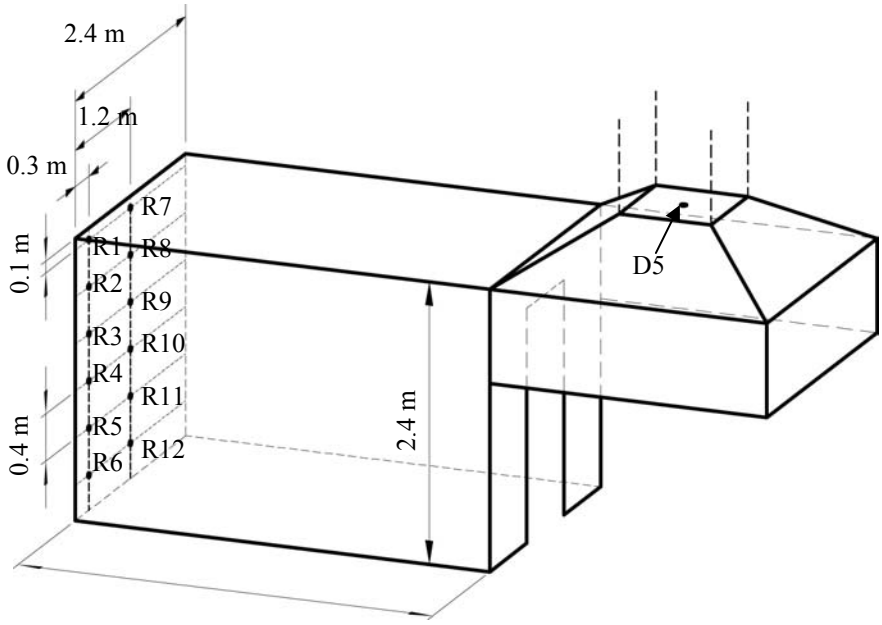
- Testing under flashover condition

Test T7: Testing SF2 by setting up a bigger pool of diameter 1 m with 12L gasoline to onset flashover in the room first.

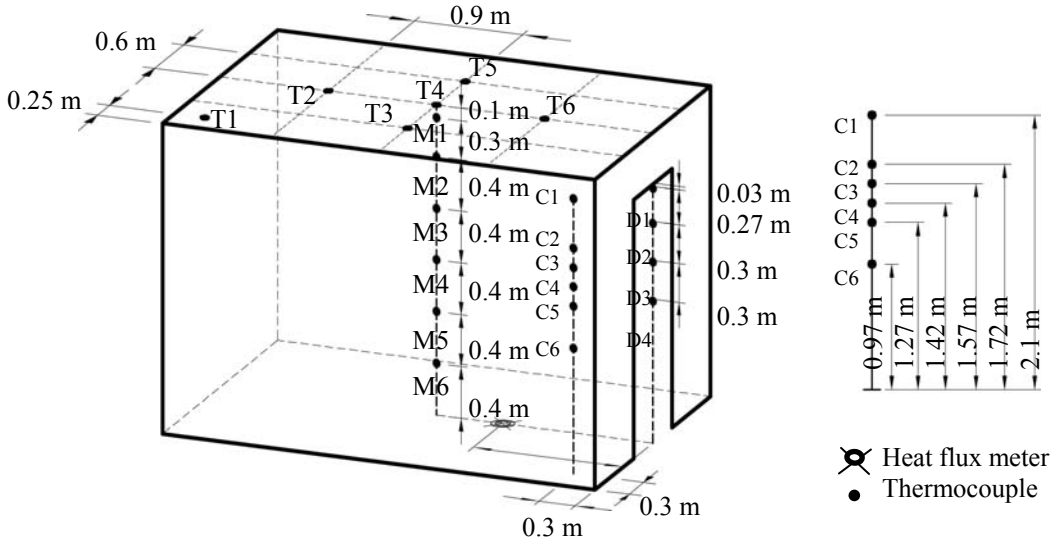
- Measuring the heat release rates of the gasoline pool fires

Test T8: Testing a 1 m pool fire of 12L gasoline to onset flashover.
Test T9: Testing with a pool fire of 0.5L gasoline, used as small starting fire for tests T1 to T6 on simulating accidental fire.

In tests T1 to T6, furniture was put near to the rear wall. The small fire source of 0.5L gasoline was placed adjacent to the furniture. For test T7, a gasoline pool of 1 m diameter with 12L was put at the centre of the room to onset flashover first.




(a) Setup with temperature measuring points at rear wall




(b) Temperature measuring points

**Fig. 1: Schematic diagram of the setup**


(a) Sofa (b) Desk

(c) Sofa SF1 (d) All the testing samples

**Fig. 2: Furniture samples tested**

Thermocouples were put in positions labeled in Fig. 1 as:

C : Corner of wall near the room opening;
M : Centre of the room;
T : Near to the ceiling,
Rc (R1 to R6) : Near to the rear wall corner;
Rm (R7 to R12): Near to the middle of the rear wall;
D1 to D4 : Room opening;
D5 : A point at the top of exhaust hood near to the duct.

A thermal radiation heat flux meter was placed at the floor level as shown in Fig. 1b.

## 3. RESULTS

The results on heat release rate curves, oxygen consumption rates and heat fluxes at floor level position are shown in Figs. 3 to 5. A summary of the key information such as the burning time, peak heat release rate pkHRR, time to pkHRR and peak heat flux is shown in Table 1. Temperatures at different measuring points are shown in Figs. 6 to 12.

The following key points were observed:

- As there is more foam for sofa arrangement SF1 than SF2, bigger fire was observed for SF1 in test T1. Obviously, unprotected foam is very dangerous upon ignition. The materials should be treated with fire retardants before used, say while manufacturing the furniture.

- Treating foam with this selected commercial sample of fire retardants commonly used in the market would delay the time to peak heat release rate by at least several minutes, while testing with the accidental small fire source. However, the material will be ignited under a flashover fire while testing by the bigger

gasoline pool as in test T7. Once ignited, the materials will be kept on burning with similar heat release rate as unprotected sofa foam in test T1.

- Under flashover condition in test T7, SF2 was ignited quickly with most of the combustibles burnt up. Note that amount of gasoline used was only to onset flashover as shown in results for test T8. Once flashover was achieved, almost all the gasoline was consumed, but the sofa was kept on burning.

Further, flame spread over the furniture item was observed to be affected by ventilation through the door in the room calorimeter.

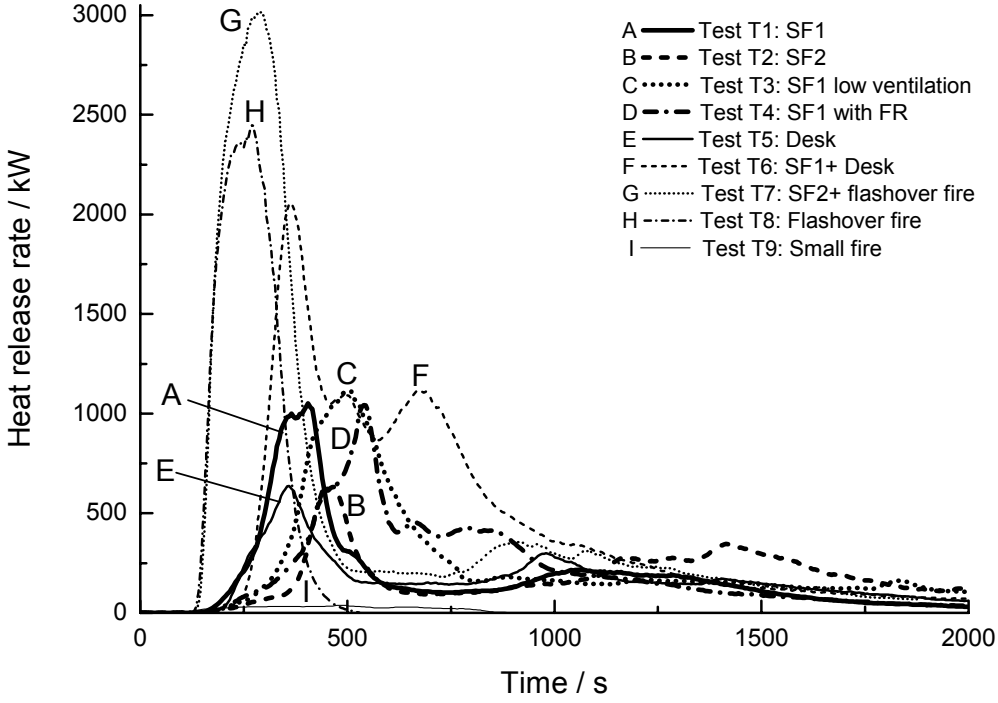



**Fig. 3: Heat release rate of each test**

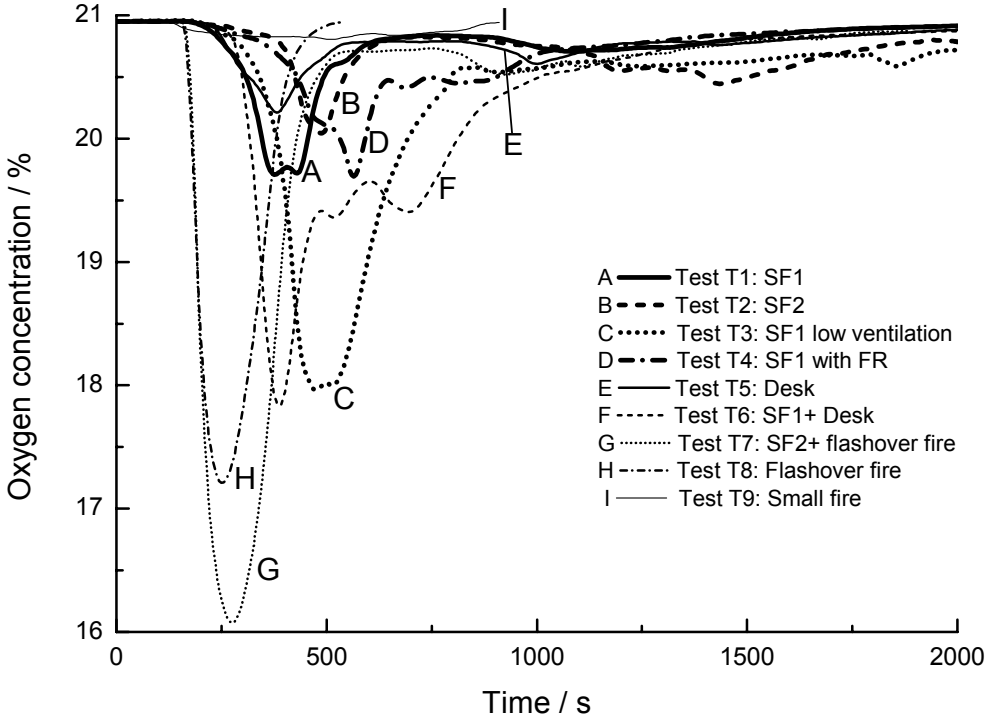



**Fig. 4: Oxygen concentration of each test**

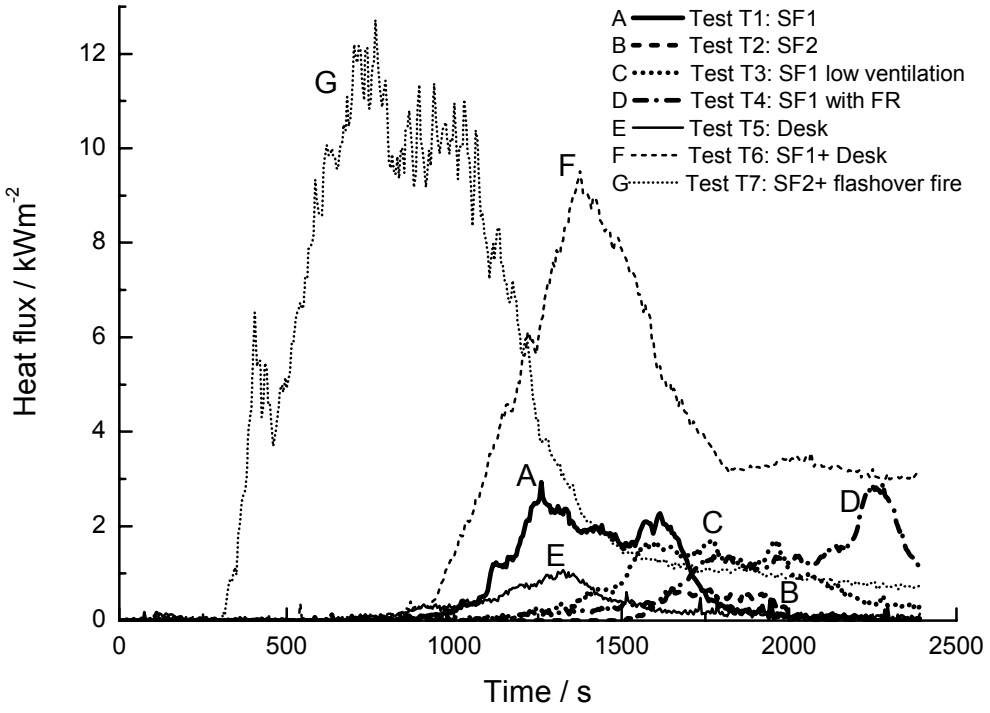



**Fig. 5: Heat flux of each test**

**Table1: Summary of full-scale burning results**

| Test number / Parameters | Accidental fire | | | | | | Pool fire to onset flashover | | |
|---|---|---|---|---|---|---|---|---|---|
| | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 | T9 |
| Burning time / s (min) | 1664 (28) | 2000 (33) | 2330 (39) | 1643 (27) | 2033 (34) | 1576 (26) | 1715 (29) | 317 (5) | 718 (12) |
| pkHRR / MW | 1.05 | 0.63 | 1.12 | 1.05 | 0.64 | 2.06 | 3.01 | 2.45 | 0.04 |
| Time to pkHRR / s | 405 | 465 | 496 | 541 | 360 | 365 | 290 | 270 | 475 |
| Peak heat flux / $kWm^{-2}$ | 2.93 | 0.67 | 1.71 | 2.92 | 1.07 | 9.52 | 12.72 | - | - |

## 4. CONCLUSIONS

Nine full-scale burning tests on different furniture arrangements were carried out in a facility on measuring heat release rate by the oxygen consumption calorimetry.

From this preliminary study, furniture treated with fire protective coating appears to be safe while testing under small accidental fires as in other standards without flashover [15]. However, it might be ignited easily under a flashover fire. This point is important in designing fire safe furniture with sofa foam. Furniture samples treated with fire retardant should be tested under flashover fire.

Further, analysis [16,17] on the data and modeling of heat release rate will be reported separately.

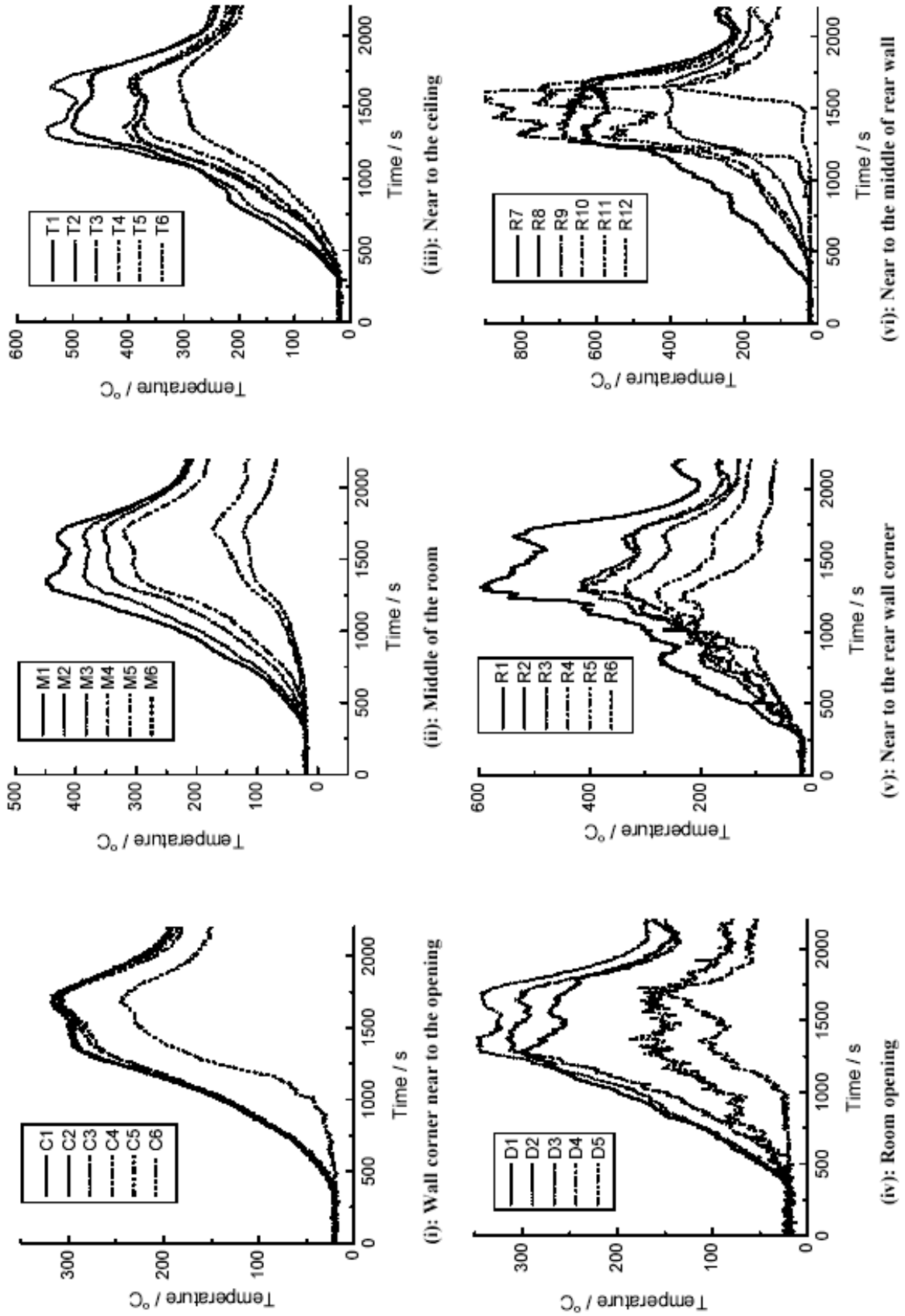



**Fig. 6: Air temperatures of test T1**

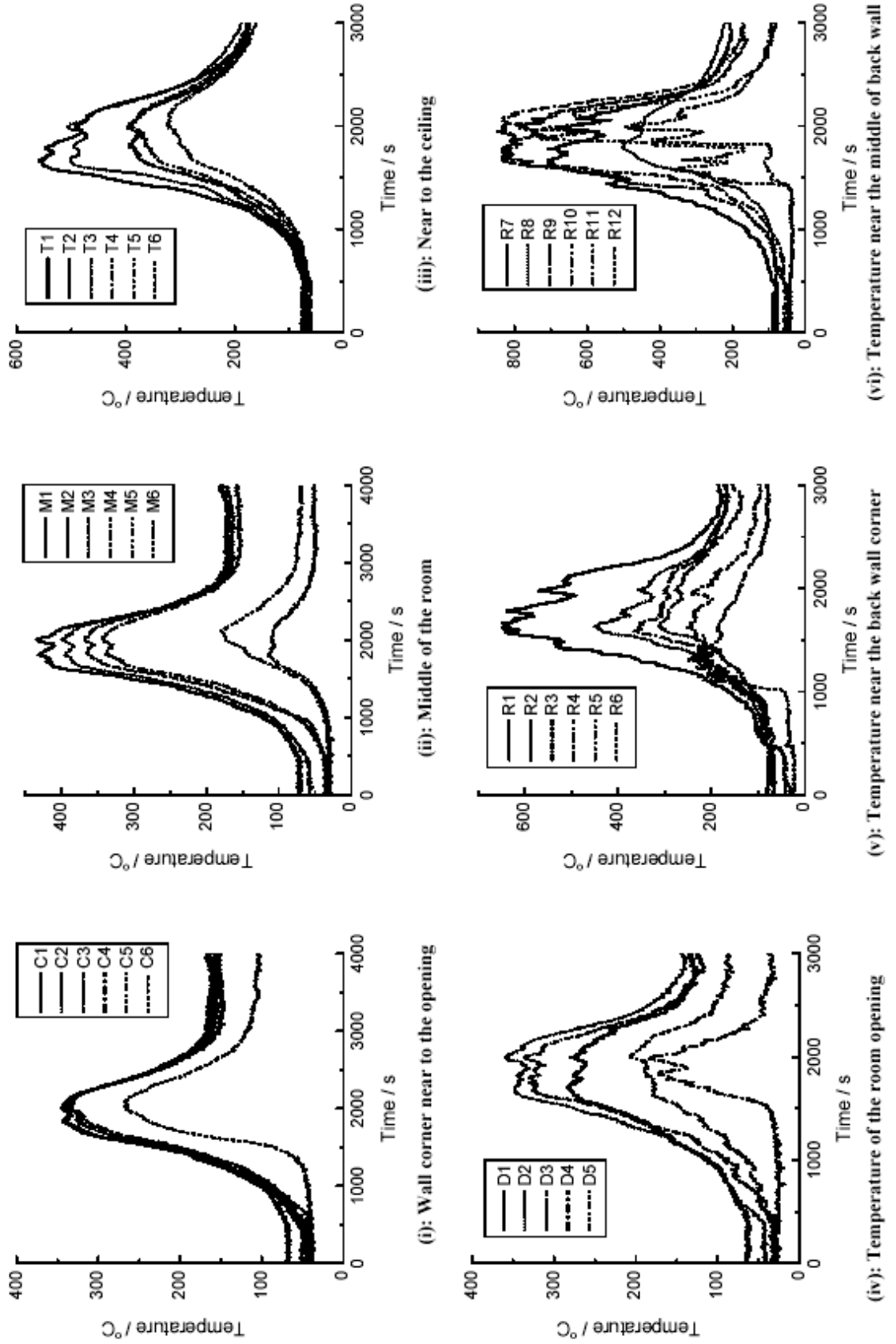



**Fig. 7: Air temperatures of test T3**

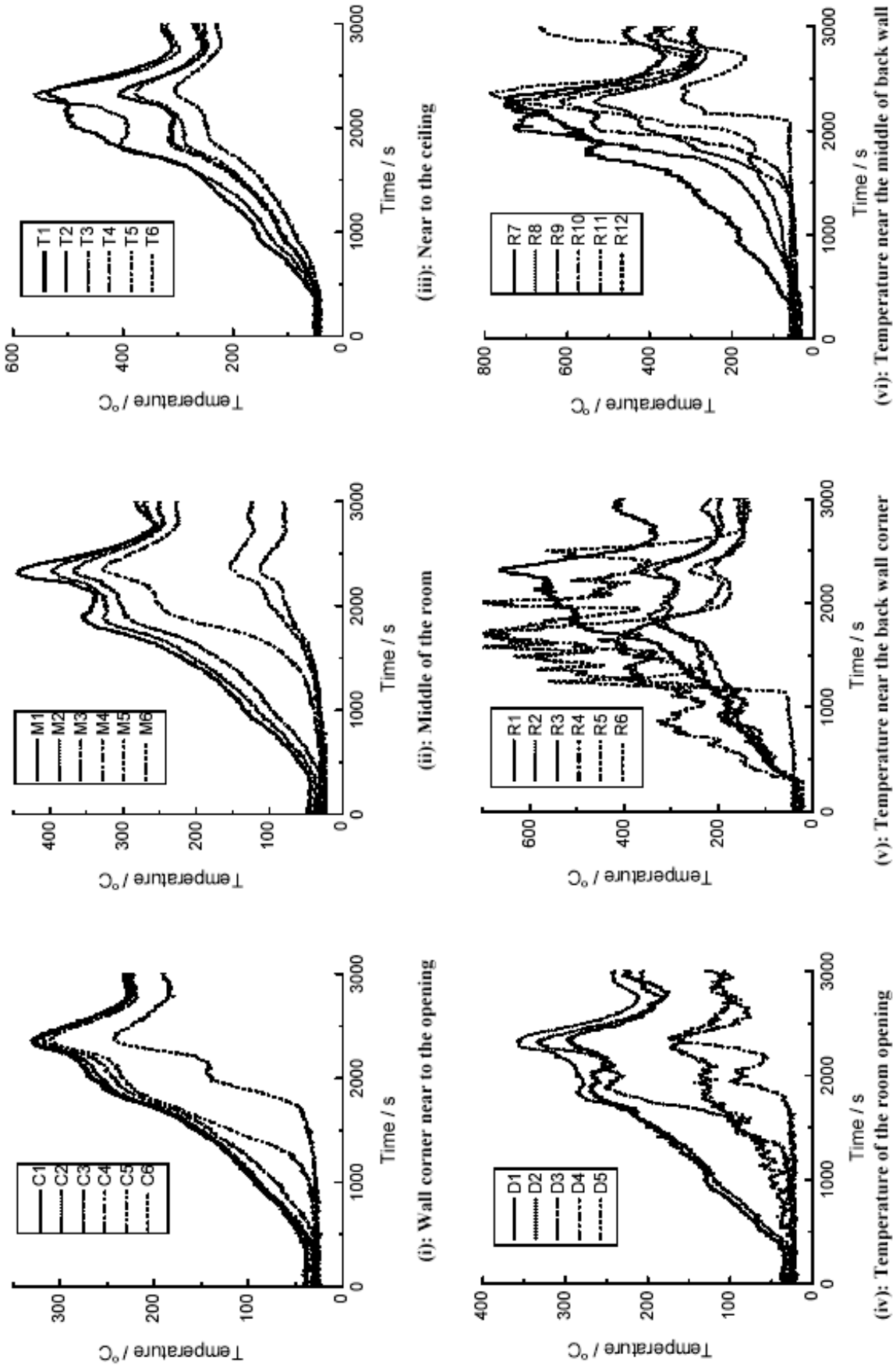



**Fig. 8: Air temperatures of test T4**

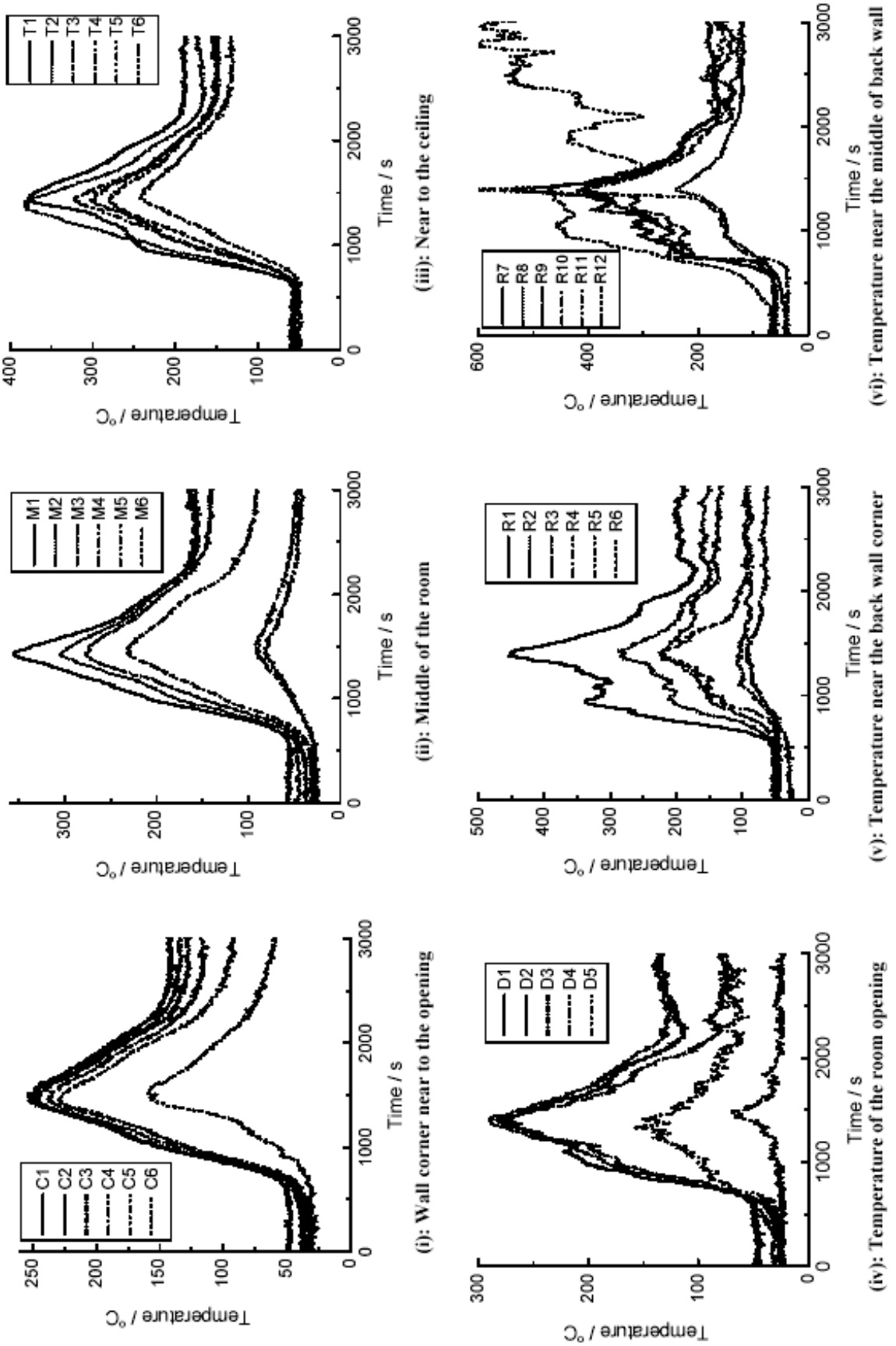



**Fig. 9: Air temperatures of test T5**

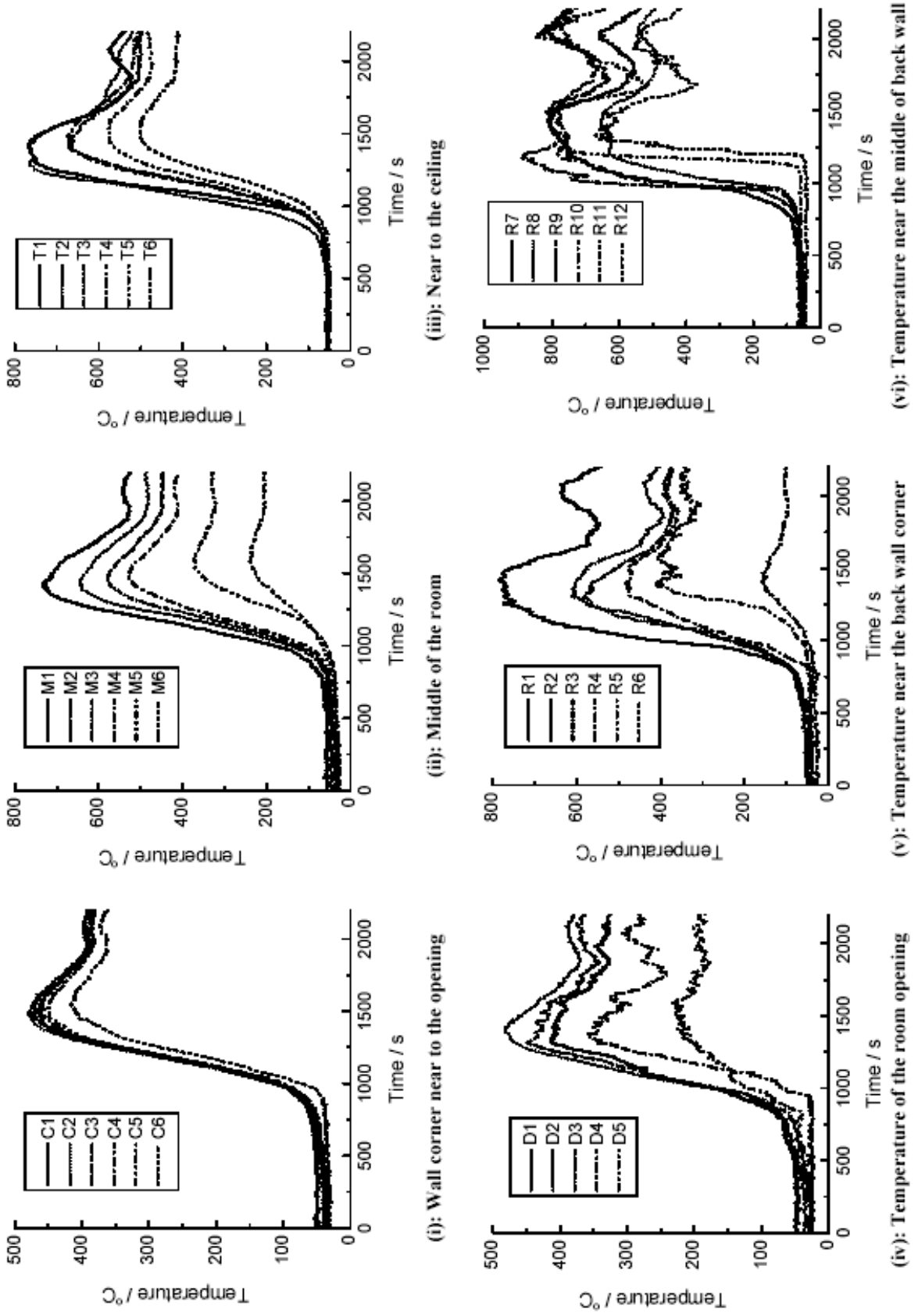



**Fig. 10: Air temperatures of test T6**

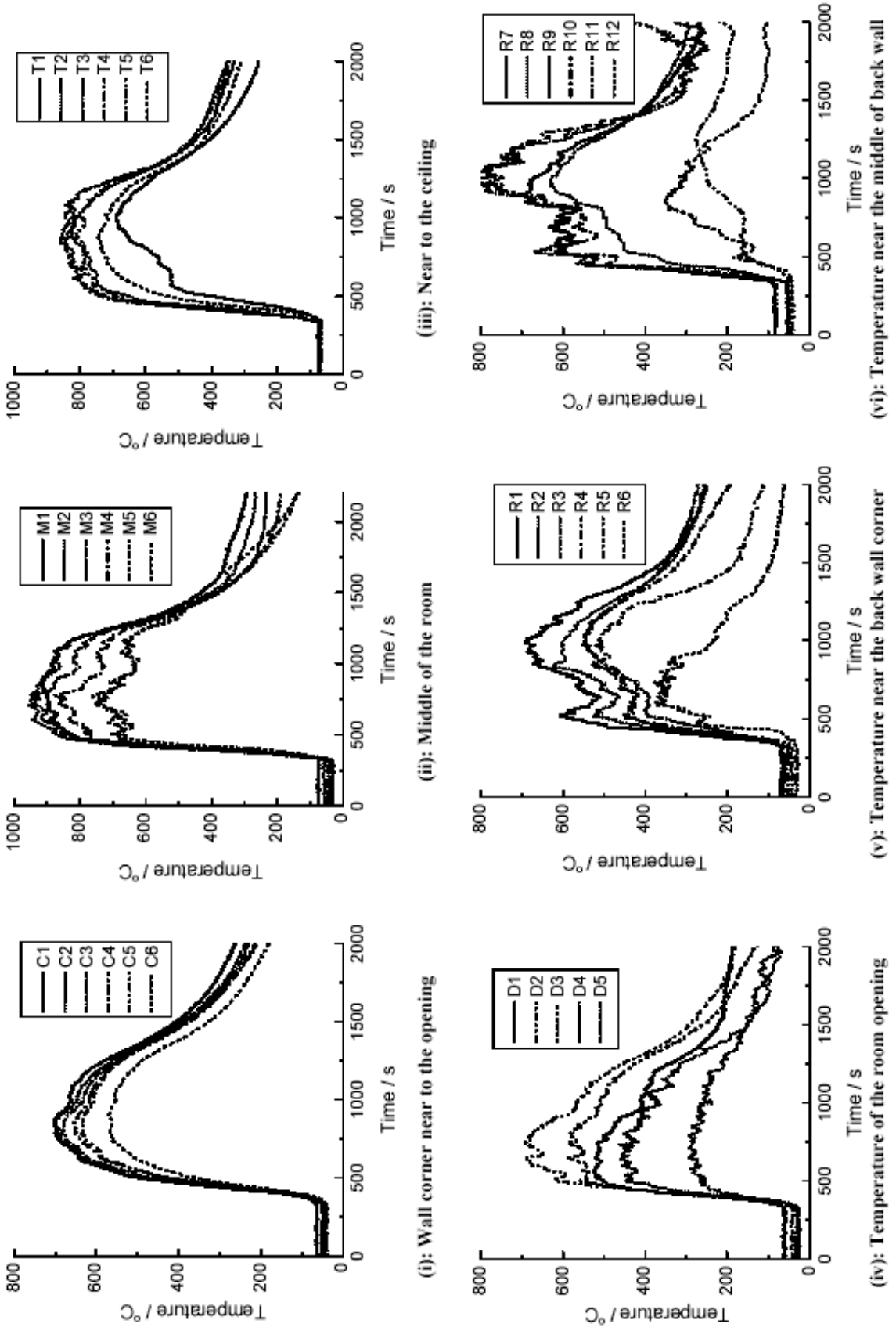



**Fig. 11: Air temperatures of test T7**

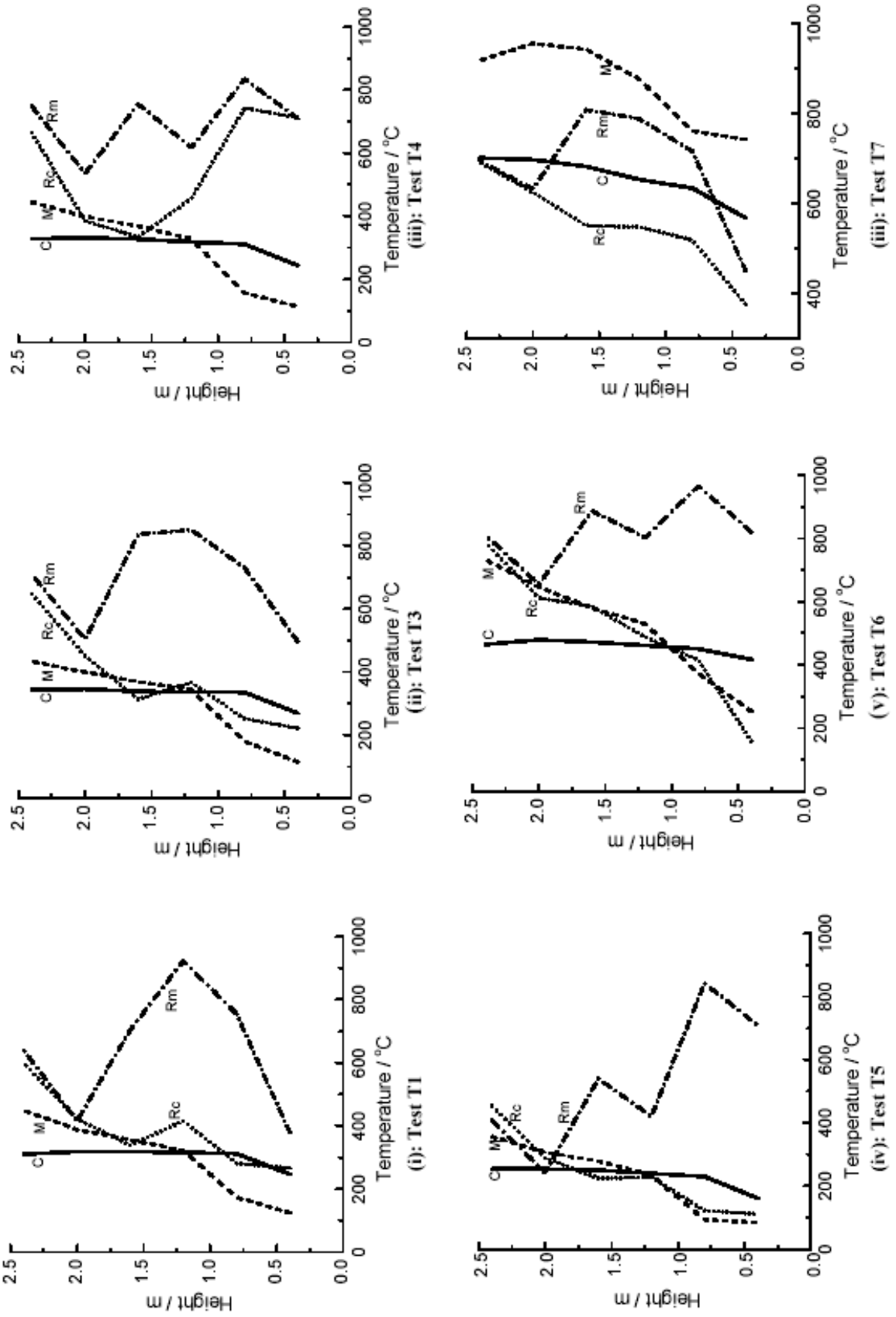



Fig. 12: Vertical temperature profiles

## ACKNOWLEDGEMENT

The project is funded by a PolyU research studentship with account number G-W 136.

## REFERENCES

1. "Garley fire", South China Morning Post, Hong Kong, 21 November (1996).
2. "Mei Foo Sun Chuen fire", South China Morning Post, 17 April (1997).
3. V. Babrauskas and S.J. Grayson, Heat release in fires, Elsevier Applied Science, London and NY (1992).
4. B. Sundstöm, Fire safety of upholstered furniture - The final report on the CBUF Research Programmes, London: Interscience Communication Ltd (1995).
5. V. Babrauskas, J. Lawson, W. Walton and W. Twilley, Upholstered furniture heat release rates measured with the furniture calorimeter, NBSIR 82-2604, National Bureau of Standards, Gaithersburg, Maryland, USA (1982).
6. J. F. Krasny, W.J. Parker and V. Babrauskas, Fire behavior of upholstered furniture and mattresses, New York: Noyes Publications (2001).
7. W.K. Chow, "Review on heat release rate of burning furniture", International Journal on Engineering Performance-based Fire Codes, Vol. 4, No. 2, pp. 54-59 (2002).
8. W.K. Chow, "Assessment on heat release rate of furniture foam arrangement by a cone calorimeter", Journal of Fire Sciences, Vol. 20, No. 4, pp. 319-328 (2002).
9. "15 die as fire rips through karaoke bar", South China Morning Post, Hong Kong, 26 January (1997).
10. "Taegu's subway line has been beset by disaster", South China Morning Post, Main Section, p. 10, Hong Kong, 19 February (2003).
11. "14 injured in peak-hour MTR arson attack", South China Morning Post, Editorial, p. A1, Hong Kong, 6 January (2004).
12. ISO 9705: 1993(E), Fire tests – Full-scale room test for surface products, International Standards Organization, Geneva, Switzerland (1996).
13. T.G. Cleary, T.J. Ohlemiller and K.M. Villa, "Influence of ignition source on the flaming fire hazard of upholstered furniture", NISTIR 4847, 71p., June (1992); Fire Safety Journal, Vol. 23, pp. 79-102 (1994).
14. W.K. Chow, G.W. Zou, H. Dong and Y. Gao, "Necessity of carrying out full-scale burning tests for post-flashover retail shop fires", International Journal on Engineering Performance-Based Fire Codes, Vol. 5, No. 1, pp. 20-27 (2003).
15. ASTM E 1537-02a, Standard test method for fire testing of upholstered furniture, American Society for Testing and Materials (2003).
16. W.K. Chow and H.W. Au Yeung, "On the superposition of heat release rate for polymeric materials", Architectural Science Review, Vol. 46, No. 2, pp. 145-150 (2003).
17. W.K. Chow, "Support on carrying out full-scale burning tests for karaokes", International Journal on Engineering Performance-Based Fire Codes, Vol. 3, No. 3, pp. 104-112 (2001).