EXPERIMENTAL MEASUREMENT ON AIR TEMPERATURE IN A GLASS FAÇADE FIRE

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ABSTRACT

There are concerns on the behaviour of glass façade under a big fire. Preliminary real-scale experiments on a single skin façade were carried out at a big laboratory in Southern China. Burning behaviour of a three-storey high single skin glass façade with double glazing due to an adjacent fire was studied. A glass pane of the façade was taken out with a model fire chamber placed next to the opening. Flashover in the chamber was set up with flame spreading out to act at the glazing system. Air temperature outside the glazing above the fire chamber was measured and reported in this paper.

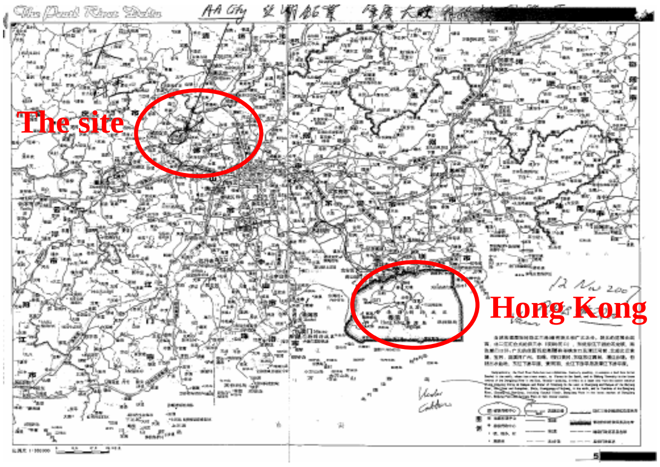
1. INTRODUCTION

Despite of so many glass façade buildings [1,2] in the Far East, fire safety has not yet been investigated in detail as expected [3,4]. This concern was just raised by the general public [5,6]. Surprisingly, understanding on the behaviour of the glass façade under big fires is limited. Although some experimental work on glass panels has been reported in the literature [e.g. 7-9], very few studies are related to the entire façade system. Experimental studies [e.g. 8] of glass façade under small fires even indicated that very little damage resulted. Therefore, very few fire safety provisions were provided for buildings with glass façades in performance-based design [2], at least in Hong Kong. Note that the term 'glass façade' is not yet included in local codes. There are only fire safety provisions specified for curtain walled buildings on fire resistance period and sprinkler [10,11].

The assumption of having only small fires with little damages to glass pane is different from real accidental fires [12-16] in buildings with glass façades. Three authors of this paper observed such a fire [17] in the real fire site at Dalian, Liaoning, China in 2005. Glass panels fell down rapidly with flames spreading out, indicating flashover occurred. Storing large amount of combustibles should give very big fires to break the glass panes. External air can be supplied through openings of fallen glass to give an even bigger fire. Hot flame spread out from broken glass pane in that room fire would act at the glass pane at levels above and adjacent to break it. This would ignite the combustibles stored at those levels to give another big fire. Flame then spread out to act at other higher levels in a sequence by repeating the process. A big fire involving the entire building is then resulted.

Note that very few experimental studies were reported in the literature [3,4], even none under very big fires [7-9]. A detailed hazard assessment on large glass panels and the associated components should be carried out. Real-scale burning tests on glass façades under big post-flashover fires [18] should be carried out as soon as possible to identify possible hazardous scenarios.

A long-term real-scale burning testing programme was worked out [e.g. 2]. Part of a glass façade after testing wind action and water penetration was burnt. The rig was located at a big aluminum manufacturing plant in Southern China as shown in Fig. 1a and b. Results deduced at the first stage of study on the measured air temperature next to the external façade surface will be reported in this paper.



(a) Location of the site

(b) The site

(c) The rig

(d) The glass façade

Fig. 1: The rig

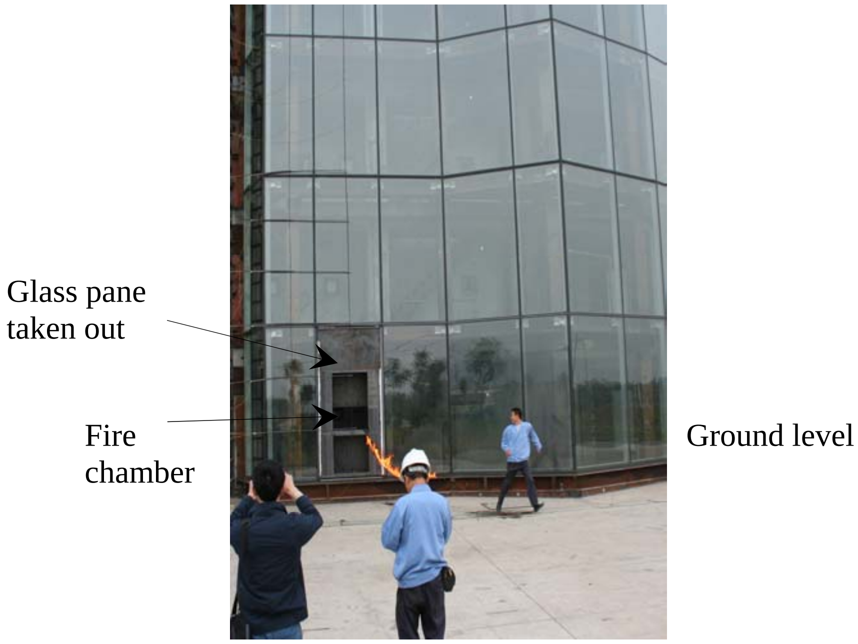
2. THE EXPERIMENTAL RIG

Part of a real-scale single skin façade was burnt in a testing chamber as in Fig. 1c. The façade is of length 12 m and height 13 m, made of glass panes of width 1.5 m and height 3 m as shown in Fig. 1d. The geometrical details of the glazing system are shown in Fig. 2a. The single skin façade is a double-glazing of two glass sheets, each of 6 mm thick. There is an air gap of 12 mm, giving a total width of 24 mm.

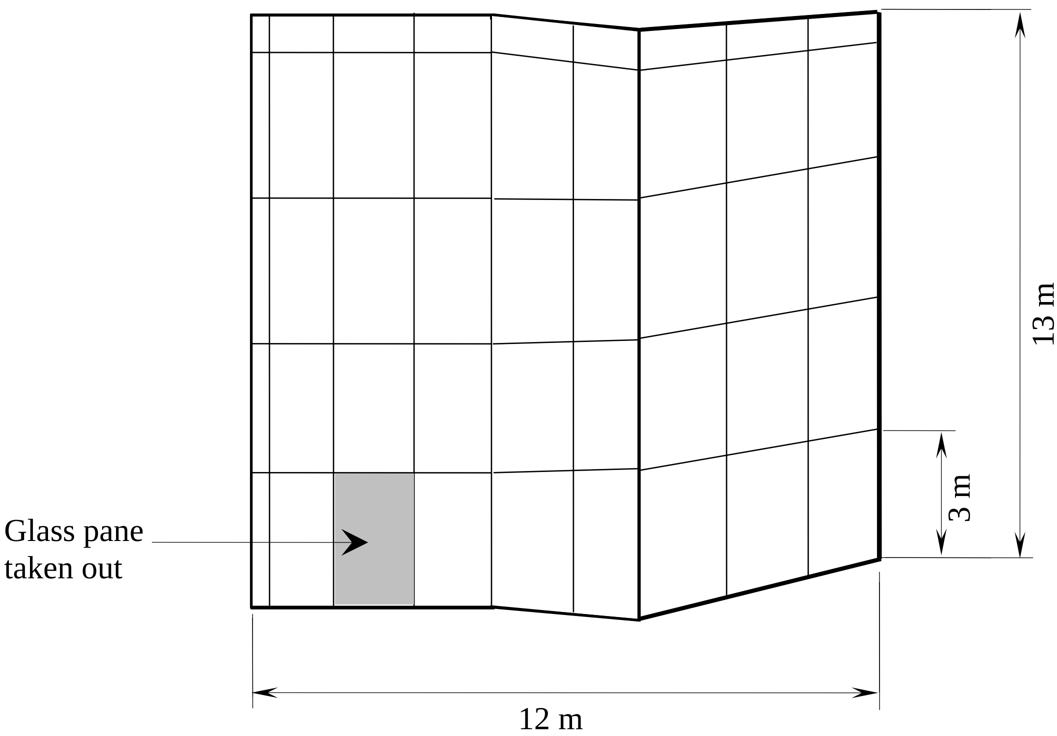
A glass pane at the ground level was taken away as in Fig. 2b with a fire chamber placed inside next to it. This is similar to a scenario that a post-flashover room fire occurs and breaks the glass pane. This arrangement would indicate how flame moves out of the room and spreads up the glass façade.

The fire chamber is made of steel with size 1.4 m by 0.7 m by 2 m as shown in Fig. 3. There is a door of size 0.8 m by 2 m at the front for directing flame spreading out. A rectangular gasoline pool fire of size 1.4 m by 0.7 m and depth 0.1 m as shown in Fig. 4 was set up in the chamber at 0.9 m above the floor as shown in Figs. 3 and 4. A rear opening of size 1.4 m by 0.5 m was constructed as shown in Fig. 3 for supplying fresh air to sustain combustion.

Volume of 50 litres gasoline was burnt in the pool fire to give a heat release rate of about 2 MW and burning duration of about 10 minutes. This arrangement would give a flashover fire in the chamber with flame moving out of the front door.



(a) Outlook

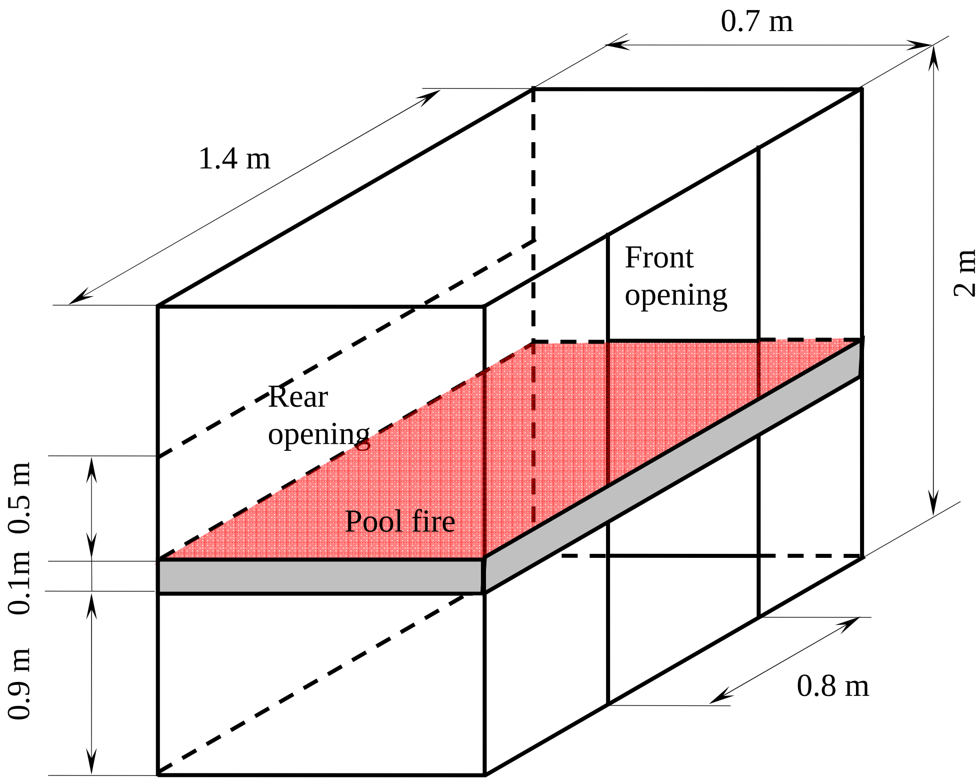


(b) Size

Fig. 2: The single skin façade with double glazing

(a) Front view

(b) Back view

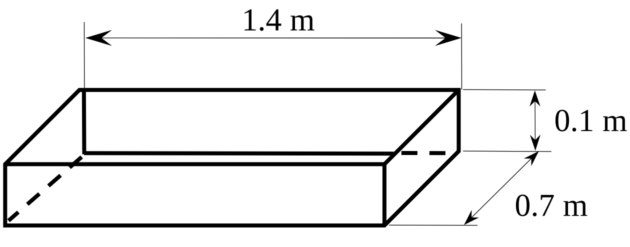


(c) Dimensions

Fig. 3: The chamber

(a) Top view

(b) Front view



(c) Dimensions

Fig. 4: The pool fire

3. TEMPERATURE MEASUREMENT

Type K thermocouples of diameter 0.51 mm (gauge 24) were used to measure air temperature outside the glass panes above the fire room. Two types of thermocouples were used at different positions with different temperatures. The first type was bare thermocouple wires with polyvinyl chloride insulation as shown in Fig. 5a. The accuracy was ±2 ^{o}C from -110 ^{o}C to 285 ^{o}C, but ±0.75% reading from 285 ^{o}C to 1250 ^{o}C. The second type was sheathed thermocouple with 3 mm diameter metal sheaths as shown in Fig. 5b. The accuracy was ±1 % reading from 200 ^{o}C to 1370 ^{o}C.

The data acquisition system for thermocouples as in Fig. 5c was used. There are 48 channels for recording temperature with sampling time adjusted to 1 s.

Two thermocouple trees were set up. Tree A at 0.8 m away from the edge of the fire chamber, and tree B at the centre of fire room were put in positions as in Fig. 6. There were ten type K thermocouples spaced at 1 m intervals on each thermocouple tree. The thermocouples were labeled as A1 to A10 and B1 to B10 from top to bottom near the outer skin of the single skin façade.

Bare thermocouples were used for measuring upper points A1 to A3 and B1 to B3; and the lowest points A10 and B10. There, the air temperatures were not too high. Sheathed thermocouples were used for measuring points A4 to A9 and B4 to B9. Flames were coming out of the chamber to give high temperatures there.

4. RESULTS ON OUTSIDE AIR TEMPERATURE

Results on outside air temperature profiles T_A and T_B near to the external glass façade are shown in Figs. 7 and 8 respectively. Temperature-time curves at positions A6 to A9 and B6 to B9 with higher temperatures are highlighted. Outside air temperatures measured at thermocouple tree B are much higher than those at tree A.

Outside air temperatures above the fire room were quite high. Values were up to 900^{o}C for position B7 which was 2 m above the fire room. Glass panes at those areas were broken and fell down.

Air temperatures at thermocouple tree A were only up to about 80^{o}C for a 2 MW fire. This is a good demonstration that glazing areas directed 1.5 m away from the positions with flames spreading out would not be heated up quickly.

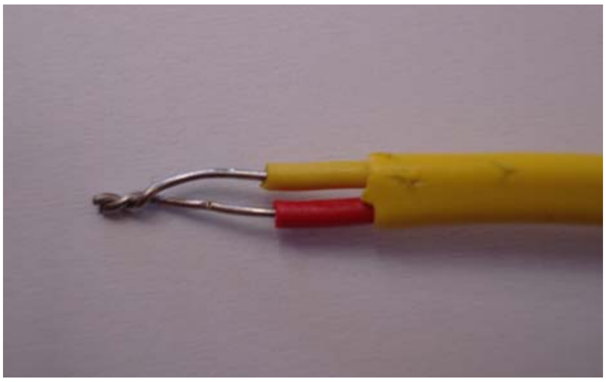
5. CONCLUSIONS

Real-scale burning tests on part of a glass façade with a scenario on flashover fire in an adjacent room were carried out. A fire chamber was put adjacent to the opening of the glass façade. A 2 MW gasoline fire would onset flashover in the chamber.

Outside air temperature in this hazardous scenario in breaking the glass pane next to the fire room was measured. These are only results compiled at the preliminary stage of a long-term study. Measured air temperatures are also useful in modeling fire behaviour of glass systems [19,20].

The outside air temperature could be up to 900^{o}C in areas above the fire room. Air temperature next to the fire room was only up to 80^{o}C. Appropriate fire safety provisions must be designated in areas above the fire room. Specifying only the fire resistance period and requesting to use non-combustible materials in the local code [10] might not be adequate. Vertical spandrel as specified [10] might work, though horizontal apron is another solution.

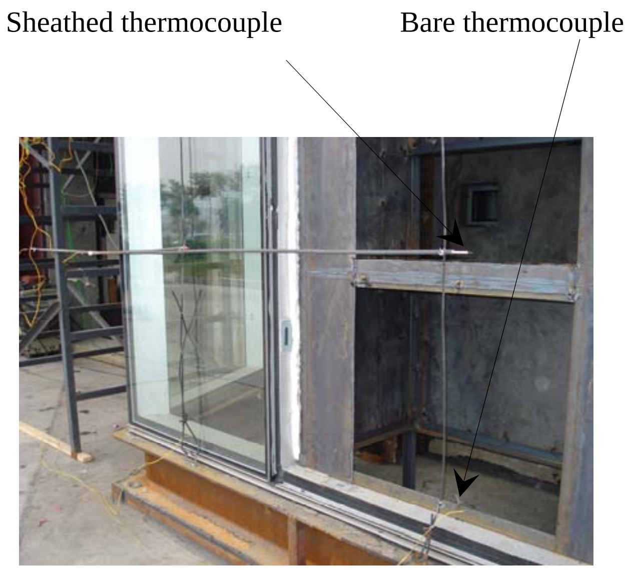
Anyway, such specification for safety provisions cannot be justified without studying behaviour of glass façades under big fires. Vertical spreading of flame would give a fire involving the whole building. The big fire can then spread horizontally to adjacent buildings with glass façade easily. Note that separation distances of buildings in high density cities used to be small. Wind effect would facilitate to induce a mass fire. Disasters might then be resulted in such big cities of the Far East [1,2] with so many curtain walled buildings.



(a) Bare wire

(b) Sheathed wire

(c) Data acquisition system



(d) Thermocouples

Fig. 5: Thermocouples

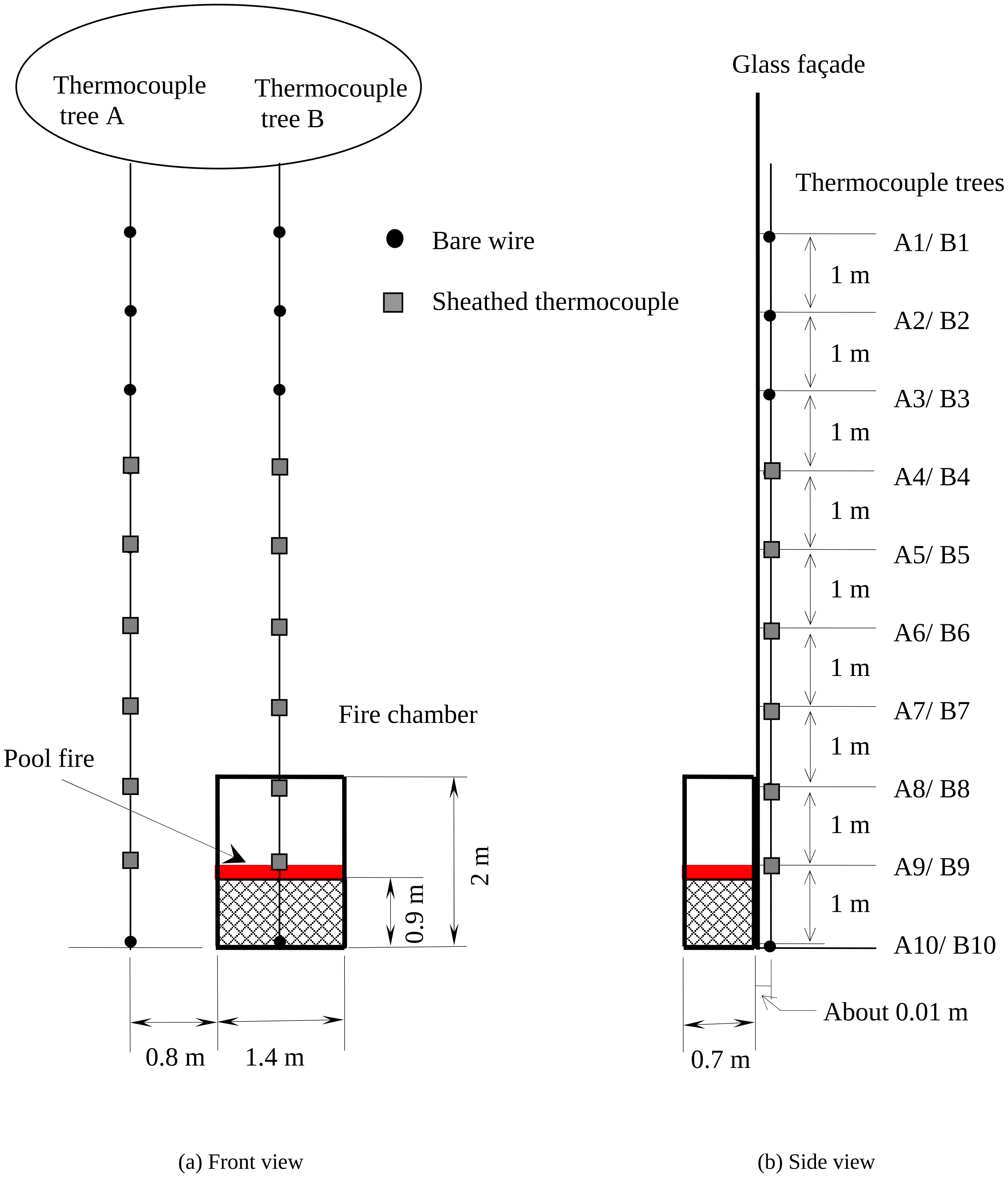


Fig. 6: Location of thermocouples

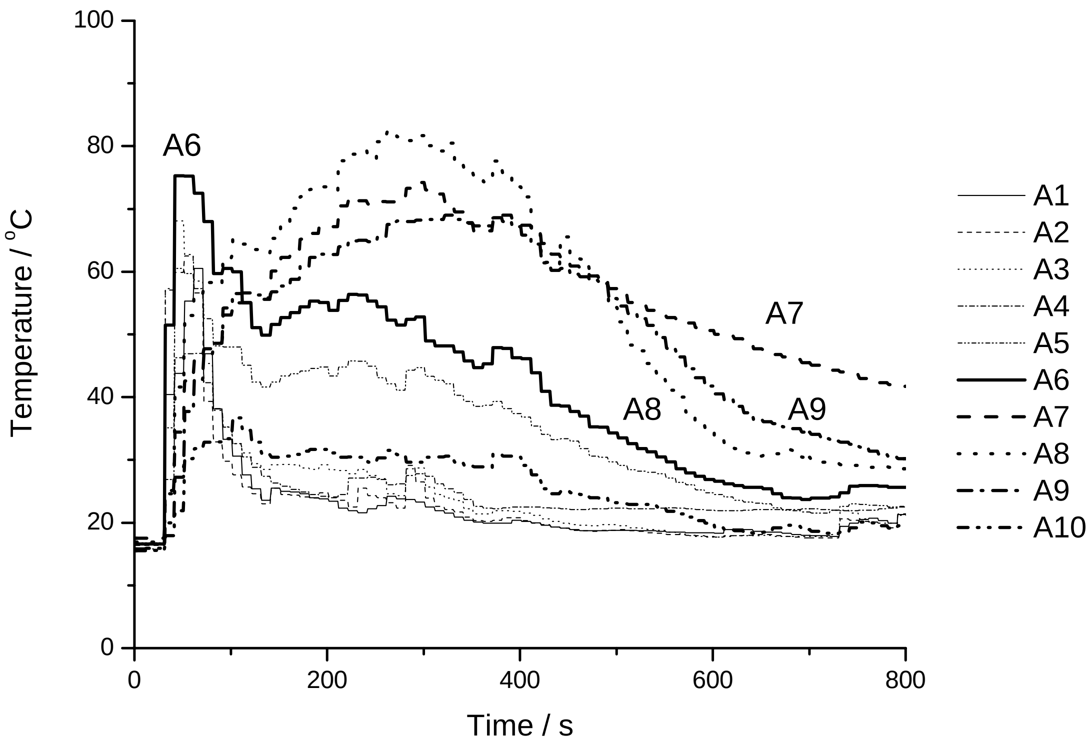


Fig. 7: Temperature profile of thermocouple tree A

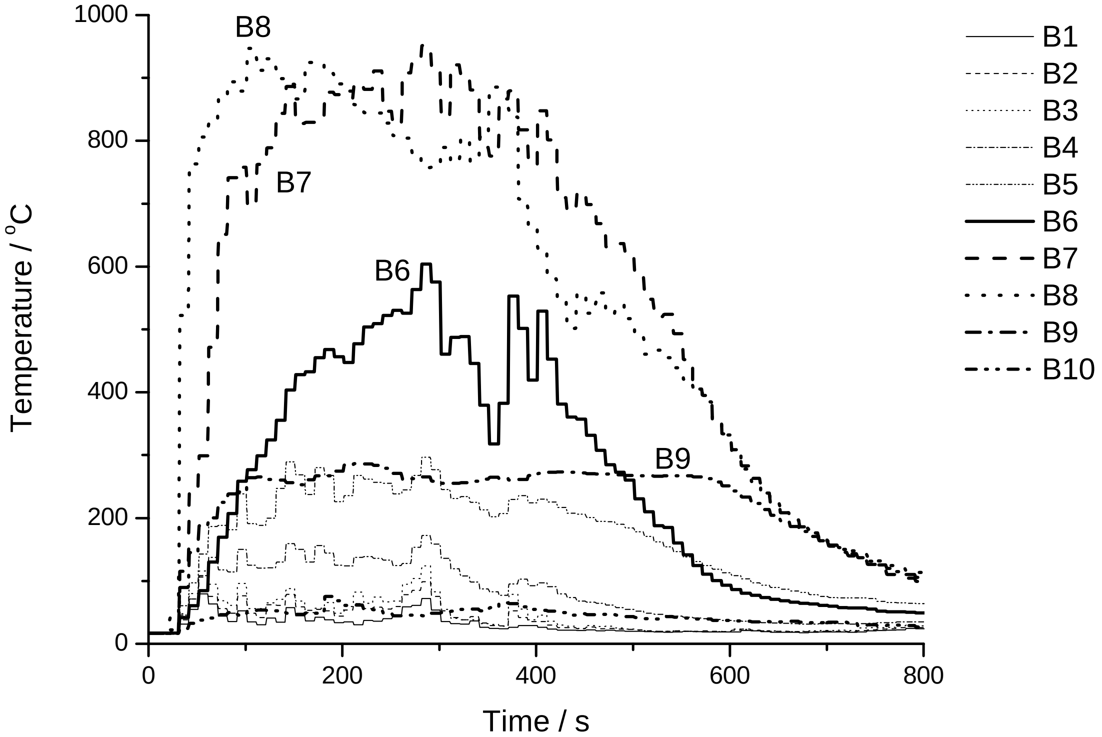


Fig. 8: Temperature profile of thermocouple tree B

ACKNOWLEDGEMENT

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