

Fire propagation over combustible exterior facades exposed to intensified flame in Japan

Yuhei Nishio¹, Hideki Yoshioka^{2,a} Takafumi Noguchi¹, Manabu Kanematsu³, Tatsuo Ando¹, Masamichi Tamura¹ and Yoshihiro Hase⁴

¹ The University of Tokyo, Japan

² National Institute for Land and Infrastructure Management (NILIM), Japan

³ Tokyo University of Science, Japan

⁴ Mitsubishi Plastics, Inc., Japan

Abstract. With regard to fire safety for exterior walls of a building, fire-resistance performance is considered, according to the current Building Standard Law of Japan. And it was revealed that the fire safety is not specifically regulated from the viewpoint of reaction-to-fire performance, such as fire propagation caused by combustible materials or products installed on the exterior side of fire-resistant load-bearing walls. Actual fire incidents in the world have shown that massive façade fire could occur at the exterior side of building wall even when the wall itself is fire resistant. In previous studies of the authors, a test method of façade fire was proposed for evaluating the vertical fire propagation over an external wall within the same building [1, 2]. Based on these studies, new domestic standard test method was established in Japan as JIS A 1310: 2015, “Test method for fire propagation over building façades” at the end of January 2015 [3]. But there was the argument that heat output of burner inside the combustion chamber was not sufficiently high in the previous study. In this paper, results of fire tests on combustible façades are discussed from the viewpoints of different strength of flame exposing facade. In this research, it was clearly found that JIS A 1310 with heat output of 900kW could be applicable for evaluating fire propagation behaviour over various types of combustible exterior façades.

1. INTRODUCTION

According to the current Building Standard Law of Japan, it is not restricted to install combustible materials over their exterior walls as long as fireproof buildings retain their required fire resistance performances. However, installation of combustible material over the exterior wall could cause large-scale fire propagation. In previous studies of authors, façade test method for evaluation of fire propagation over combustible cladding was proposed, using various types of combustible façade specimens [1, 2]. Heat output of gas burner in a combustion chamber was set 600 kW, because temperature in the chamber was about 1000 °C and temperature at lintel was about 900 °C, which are near at real fire condition.

^a e-mail: yoshioka-h92te@nilim.go.jp

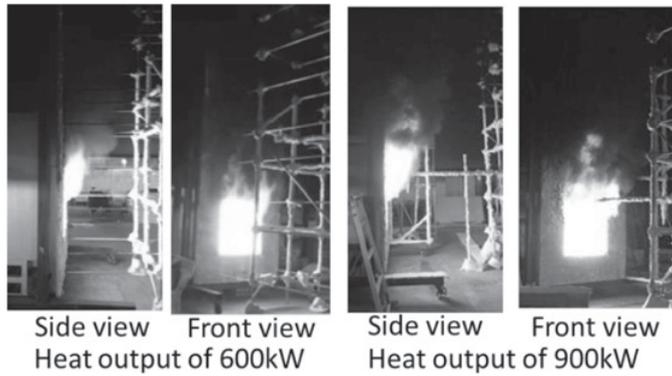


Figure 2. Photograph of flame venting through the opening at a calibration test.

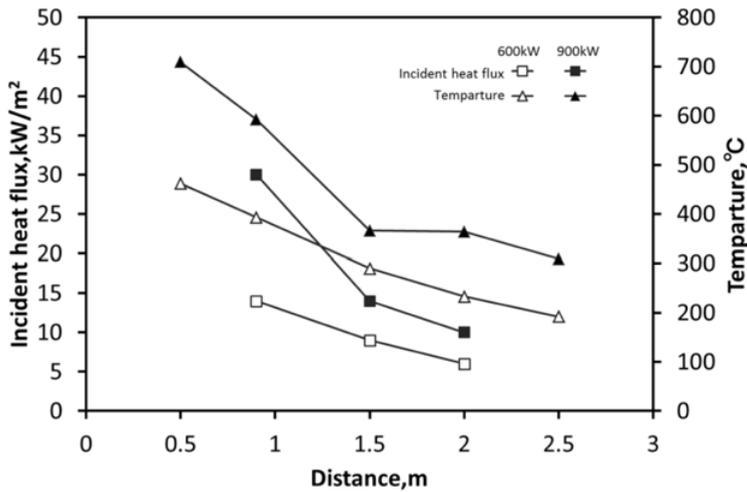


Figure 3. Calibration test result about relationship between distance above the opening and façade surface temperatures and façade surface incident heat fluxes.

3. FLAME PROPERTIES WITH NONCOMBUSTIBLE FACADE

As a calibration test, a fire test was performed with a non-combustible façade which surface was covered with 25 mm thick ceramic fibre blanket. Heat flux meters were installed at HF2, HF3 and HF4, and thermocouples were installed at the position indicated in Fig. 1 (TC1 to TC5).

The author conducted experiments according to JIS A 1310 with a heat output of 600 kW in the previous study. In this research, fire tests were conducted with a higher heat output than the previous study (about 900 kW).

Figure 2 shows appearance of venting flame in stable condition at a calibration test. It seems that flame in the case of 900 kW was higher, thicker and along the façade surface longer than flame in the case of 600 kW. Figure 3 shows comparison between heat output of 600 kW and 900 kW about average façade surface temperatures and façade surface incident heat fluxes in stable condition. At 0.5 m and 0.9 m upward from the lintel, temperature and incident heat flux on façade surface with 900 kW are much higher than that of 600 kW, especially at 0.9 m upward from the lintel, incident heat flux on façade surface was about twice as much of 600 kW. The difference between temperatures and incident

Table 1. Details of façade specimens.

No.	Heat release Rate (HRR)	Details	Specimen	Category
1-a	600 kW	EPS(100 mm); Acrylic resin mortar (2 mm thick);	ETICS	Exterior thermal insulation
1-b	900 kW	Reinforcing net(single layer); Edge: back-wrapping; Finishing material: combustible	100 mm	
2-a	600 kW	Same as No.1 except thickness of EPS(200 mm)	ETICS	Wooden façade
2-b	900 kW		200 mm	
3-a	600 kW	Horizontal planks of Japanese cedar on furring	W	Wooden façade
3-b	900 kW			
4-a	600 kW	Horizontal planks of Japanese cedar with chemical treatment on furring	W-FR	Wooden façade
4-b	900 kW			
5-a	600 kW	Core: polyethylene(3 mm thick); Surface: aluminium facing(0.5 mm thick) on both sides	ACP	Aluminium
5-b	900 kW			
6-a	600 kW	Core: Al(OH) ₃ + polyethylene(3 mm thick); Surface: aluminium facing(0.5 mm thick) on both sides	ACP-FR	composite panel
6-b	900 kW			
7-a	600 kW	Water resistant exterior finish paint, (Dry film thickness: 2 to 3 mm)	RP	Resinous paint
7-b	900 kW			

heat fluxes on façade surface of 600 kW and 900 kW is relatively smaller at 1.5 m or higher distance from the lintel.

4. SPECIMENS

Table 1 summarizes overall information on façade specimens. All the specimens are installed upon substrate, calcium silicate boards. Attached “-a” at end of specimen’s number were conducted experiments at heat output of 600 kW, while attached “-b” at end of specimen’s number were at 900 kW. As for an exterior thermal insulation system, which is composed of EPS boards, glass fibre mesh, adhesive (mortar based) and finish coat (cement-based), the authors conducted fire tests for two different thicknesses of EPS (100 mm and 200 mm). As for wooden façade, which have recently been used for decorative purposes at exterior façade, two types of specimens were used. The difference is mainly whether applied chemical treatment to enhance fire-retardant performance or not. Specimens Nos. 5 and 6 are thin aluminium composite panels. Both surfaces are covered by aluminium facings. The core material of No. 5 is polyethylene, while that of No. 6 is composed of 30% weight polyethylene and 70% weight aluminium hydroxide (Al(OH)₃) for fire-retardant purpose. The composite panel of No. 6 holds various fire-safety certifications around the world. No. 7 is coated with water-resistant exterior finish paint, coated over the substrate. Only specimen Nos. 5 and 6 have a vertical joint at the center line of the façade, in order to make a weak point which is possible even in an actual building.

5. FIRE PROPAGATION BEHAVIOUR IN COMBUSTIBLE FAÇADE

Observation of fire propagation behaviour is an essential element to understand fire performance of combustible façade. As follows, we show fire propagation behaviours in each specimen.

Figure 4 shows fire propagation behaviours in specimens of exterior thermal insulation system with 100 mm thickness of EPS. Although fire propagation at No. 1-a was slightly visible from 4 to 5 min after the start of the test, fire propagation at No. 1-b was easily visible from 1 to 5 min.

Figure 5 shows fire propagation behaviours in specimens with exterior thermal insulation system with 200 mm thickness of EPS. Different from the case of 100 mm thick EPS, fire propagations were observed at both specimens (No. 2-a and No. 2-b). Although fire propagation at No. 2-b was observed from 1.5 min after the start of the test, fire propagation at No. 2-a was not visible until 5 min.

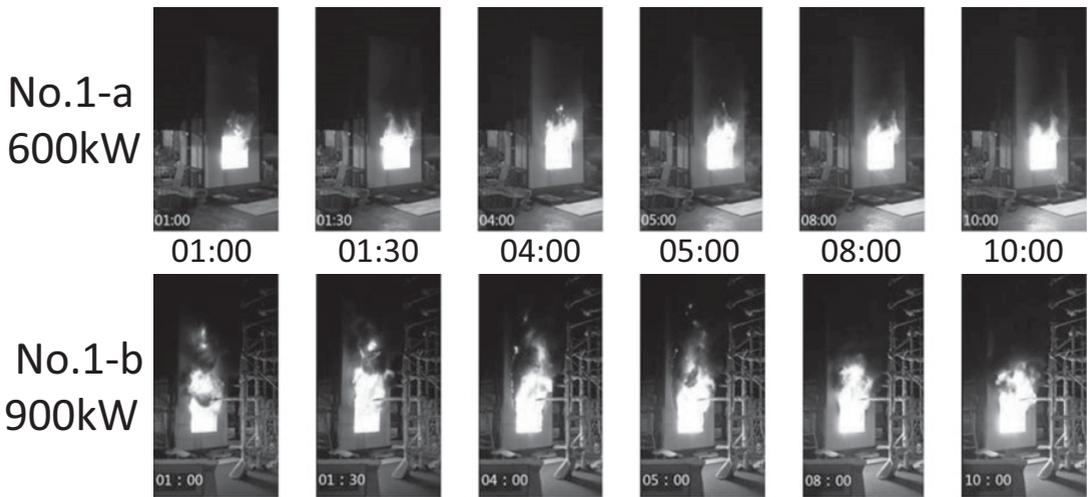


Figure 4. Specimens of exterior thermal insulation system with 100mm thick EPS (No. 1-a and 1-b) 1, 1.5, 4, 5, 8 and 10 min after the start of the test.

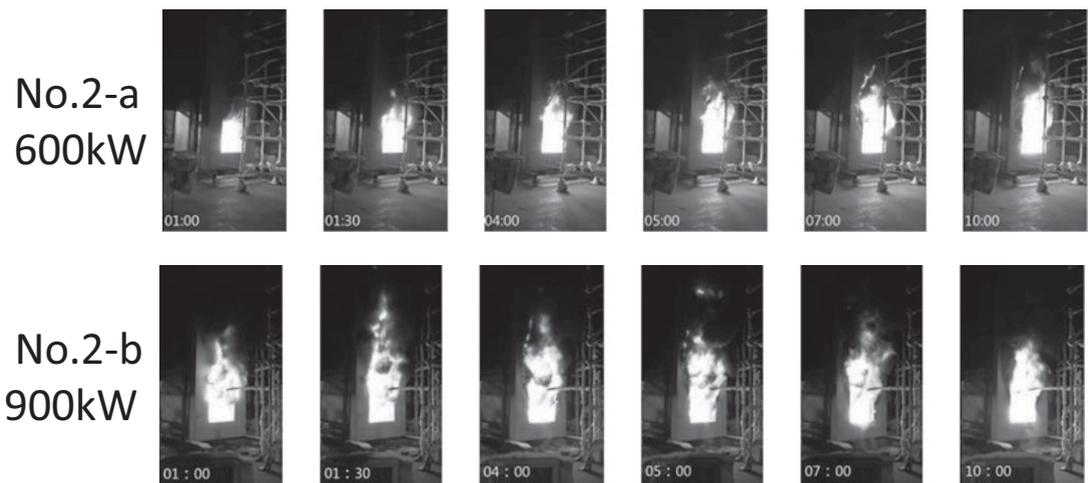


Figure 5. Specimens of exterior thermal insulation system with 200 mm thick EPS (No. 2-a and 2-b) 1, 1.5, 4, 5, 7 and 10 min after the start of the test.

Figure 6 shows fire propagation behaviours in specimens of wooden façade with no fire-retardant treatment. Although fire propagation at No. 3-a was occurred from 13.5 min after the start of the test, fire propagation at No. 3-b easily occurred from 1 min and continued until the end of the experiment.

Figure 7 shows fire propagation behaviours in specimens of wooden façade with chemical fire-retardant treatment. In spite of different flaming properties, remarkable fire propagations were not observed at both specimens (No. 4-a and No. 4-b).

Figure 8 shows fire propagation behaviours in specimens of aluminium composite panel with polyethylene core. At No. 5-a, fire propagation occurred 10 min after the start of the test and only the vertical joint of panels located on the centre line of the specimen were seriously damaged. On the other hand, at No. 5-b, fire propagation occurred 3 min after the start of the test and many parts of the specimen were burned out 8 min after the start of the test.

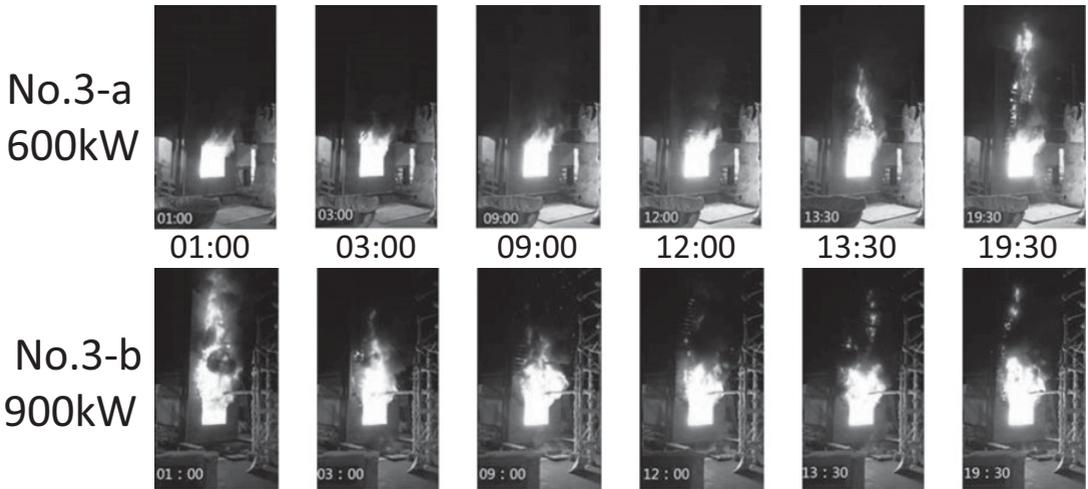


Figure 6. Specimens of wooden façade with no fire-retardant treatment (No. 3-a and 3-b) 1, 2, 9, 12, 13.5 and 19.5 min after the start of the test.

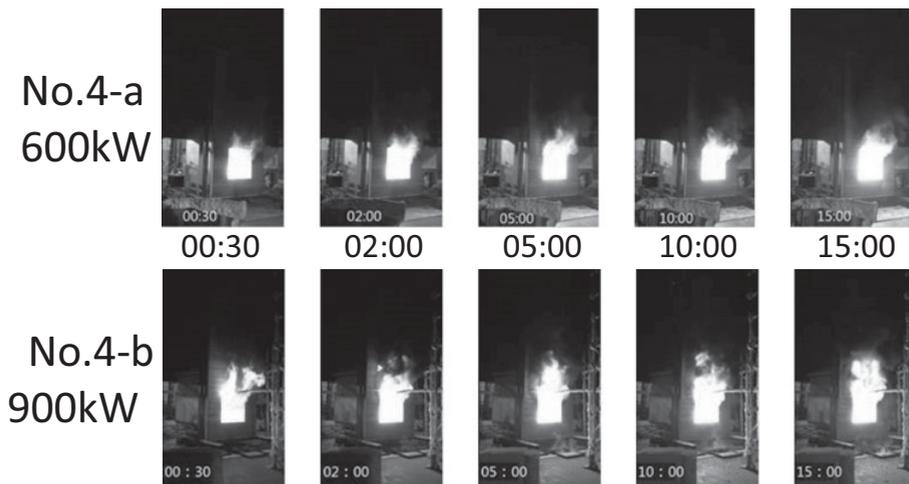


Figure 7. Specimens of wooden façade with chemical fire-retardant treatment (No. 4-a and 4-b) 0.5, 2, 5, 10 and 15 min after the start of the test.

Figure 9 shows fire propagation behaviours in specimens of aluminium composite panel with fire-retardant polyethylene core. Severe fire propagation did not occur with No. 6-a. On the other hand, with No. 6-b, although fire propagation occurred to some extent at 5 min after the start of the test, severe fire propagation, such as observed at No. 5-b, did not occur.

Figure 10 shows fire propagation behaviours of specimens coated with resinous paint. At No. 7-a, slight fire propagation occurred 3.5 min after the start of the test. On the other hand, at No. 7-b, fire propagated to the top of the specimens immediately and larger fire propagation occurred, but flames mostly disappeared just 5 min after the start of the test.

Compared with the experiments conducted by heat output of 600 kW, clearly different and more severe fire propagation behaviours were observed in some specimens, such as wooden façade without

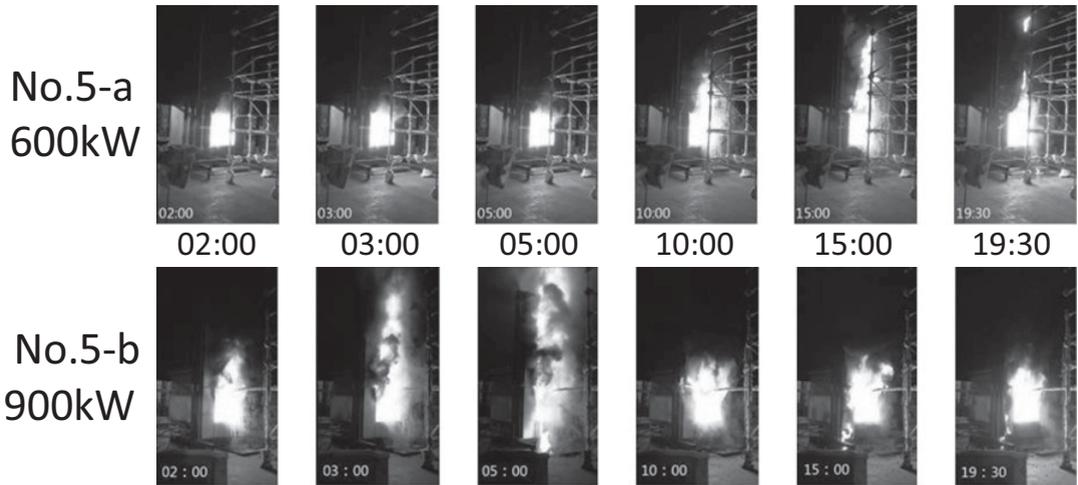


Figure 8. Specimens of aluminium composite panel with polyethylene core (No. 5-a and 5-b) 2, 3, 5, 10, 15 and 19.5 min after the start of the test.

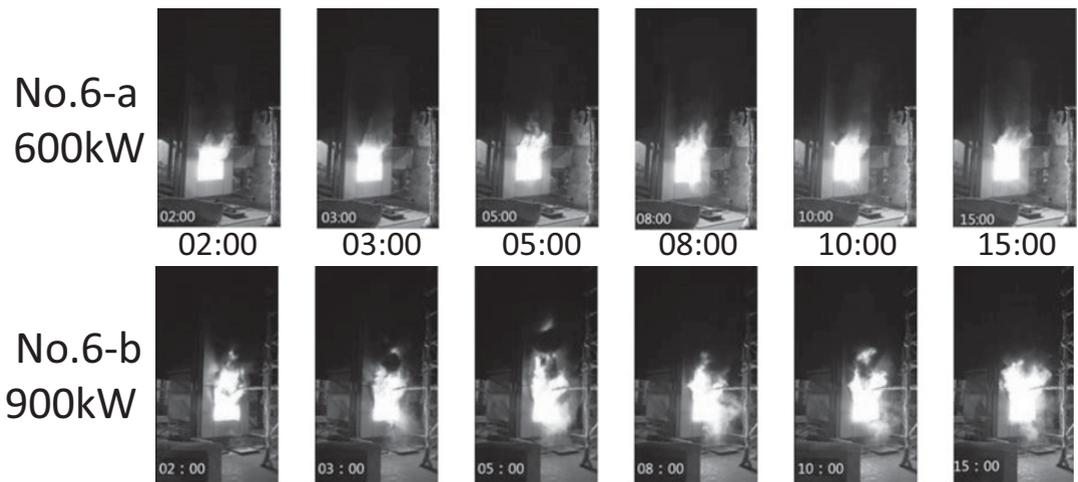


Figure 9. Specimens of aluminium composite panel with fire-retardant polyethylene core (No. 6-a and 6-b) 2, 3, 5, 8, 10 and 15 min after the start of the test.

fire-retardant treatment, aluminium composite panel with polyethylene core and rein paint. On the other hand, no severe fire propagation occurred even though intensified flame in specimens with fire-retardant treatment such as No. 4 and No. 6. It is concluded that fire propagation could occur in the fire test at heat output of 900 kW, while no severe flame propagation observed at the fire test with heat output of 600 kW.

6. COMPARISON OF 600 KW AND 900 KW

Figures 11 and 12 show correlation of respectively, peak flame height and peak incident heat flux on the specimen's top (HF6 in Fig. 1) between test results with heat output of 600 kW and 900 kW. Flame height means the height from the lintel to the point which measured over 500 °C and was most distant

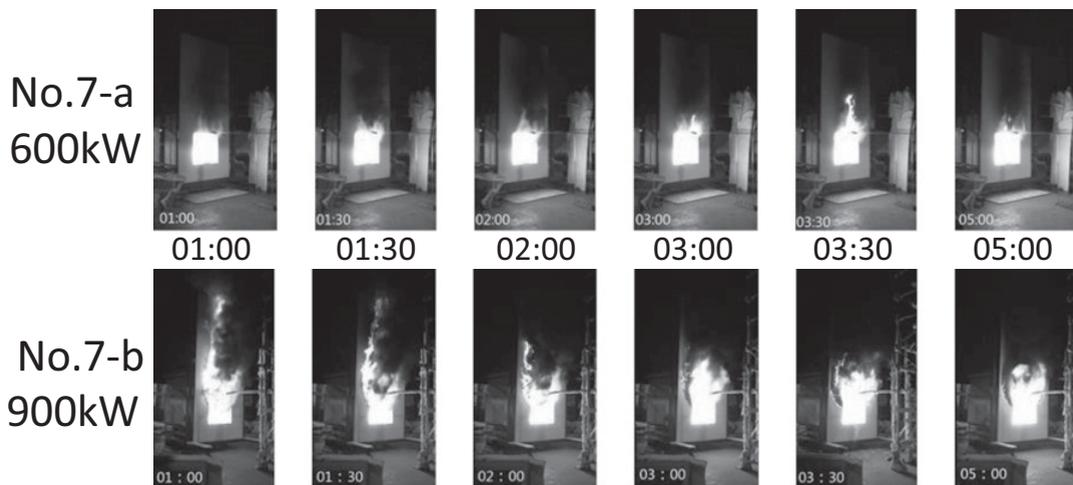


Figure 10. Specimens with resin paint (No. 7-a and 7-b) 1, 1.5, 2, 3, 3.5 and 5 min after the start of the test.

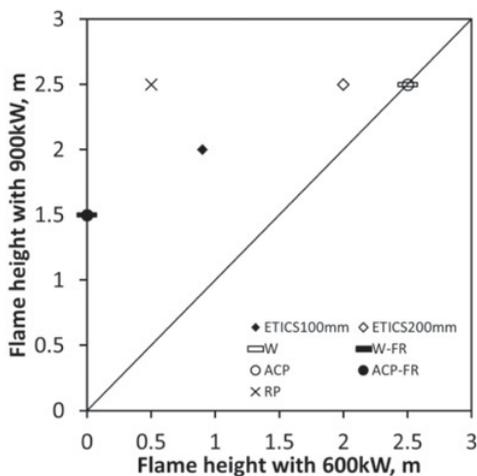


Figure 11. Peak flame height.

from the lintel (chosen among TC1 to TC5). Flame height was 0 m if the peak temperature at TC1 didn't exceed 500 °C.

With respect to flame height, flame heights with 900 kW were obviously higher because original flame height with no combustible façade was higher. For the distance from the lintel to specimen's top was about 2.7 m, maximum flame height were 2.5 m even though flame was likely to spread over the specimen's top, especially in the case of 900 kW. Difference between 600 kW and 900 kW about flame height was greater at specimens with resin paint.

With respect to heat flux at specimen's top (HF6), most of the specimens with heat output of 600 kW had about 10 kW/m² except for aluminium composite panel with polyethylene core and wooden façade with no fire-retardant treatment. On the other hand, specimens with heat output of 900 kW had different values at HF6 in each specimen. Especially, at specimens of aluminium composite panel and resin paint, at which larger fire propagation were observed, relatively high heat fluxes were measured. Heat fluxes at specimen's top with heat output of 900 kW showed clear difference from specimens exposed of 600 kW.

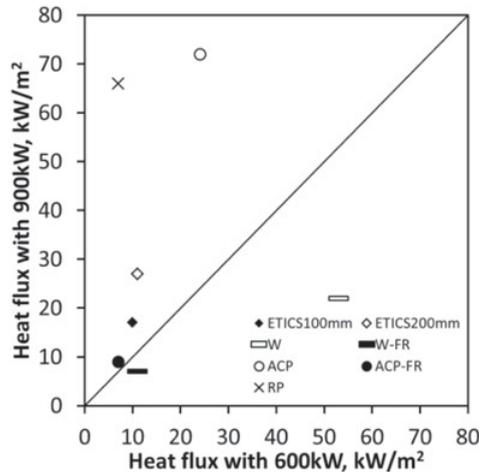


Figure 12. Peak incident heat flux on HF6.

7. CONCLUSION

As a result of conducting JIS A 1310 test with intensified flame, it becomes clearer to distinguish between combustible exterior façades with higher performance and those which propagates fire easily compared with the previous study.

Indeed JIS A 1310 with heat output of 600 kW could classify combustible exterior façades in which severe fire propagation occurred (specimens such as aluminium composite panel with polyethylene core, resin paint and wood with no treatment for fire retardancy) and those in which severe fire propagation didn't occur though ignition and combustion occurred by flame from the opening (specimens such as aluminium composite panel with fire-retardant polyethylene core and wood with treatment for fire retardancy), but there were combustible façade like rein paint at which flame propagation didn't occur with heat output of 600 kW. JIS A 1310 with heat output of 900 kW could make differences more remarkably in terms of flame propagation behaviour and heat flux measured at the specimen's top. In this research, it was clearly found that JIS A 1310 with heat output of 900 kW could relatively make fire performance clear of various types of combustible exterior façades.

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