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# Study of wood ignition and degradation at the medium scale and comparison with the cone scale

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## Context and Objectives

An increasing number of high-rise building construction projects made largely of wood are either under study or under construction. A key issue for the construction of such buildings is the fire behavior of their structures. Indeed, when the wood is subjected to a high heat flux, it will degrade and it can self-ignite. The aim of the work is to experimentally study the degradation and the auto-ignition of the spruce wood used in buildings at two scales. The first one is at the cone calorimeter scale, commonly used in fire safety community, and the second one at a larger scale involving a one square meter radiant panel.

## Experimental setup

The tests were carried out with four radiant panels oriented vertically to form a radiant surface of approximately 1 m<sup>2</sup>. The aim of these tests was to expose spruce samples to heat fluxes equivalent to those studied at the cone heater scale, in order to observe the effect of the change in scale on wood degradation and auto-ignition. The measurements were MLRPUA with a load cell, surface temperature with an IR camera, in-depth temperature with embedded thermocouples, location and time of flame appearance with fast cameras and critical heat flux. The wooden panels measured 50 cm × 53 cm. The surface area is 26.5 times greater than that of the samples used for the cone tests (100 cm<sup>2</sup> for the cone compared to 2650 cm<sup>2</sup> for the radiant panels).



Fig. 1. Wood sample exposed to 60 kW.m<sup>-2</sup>.

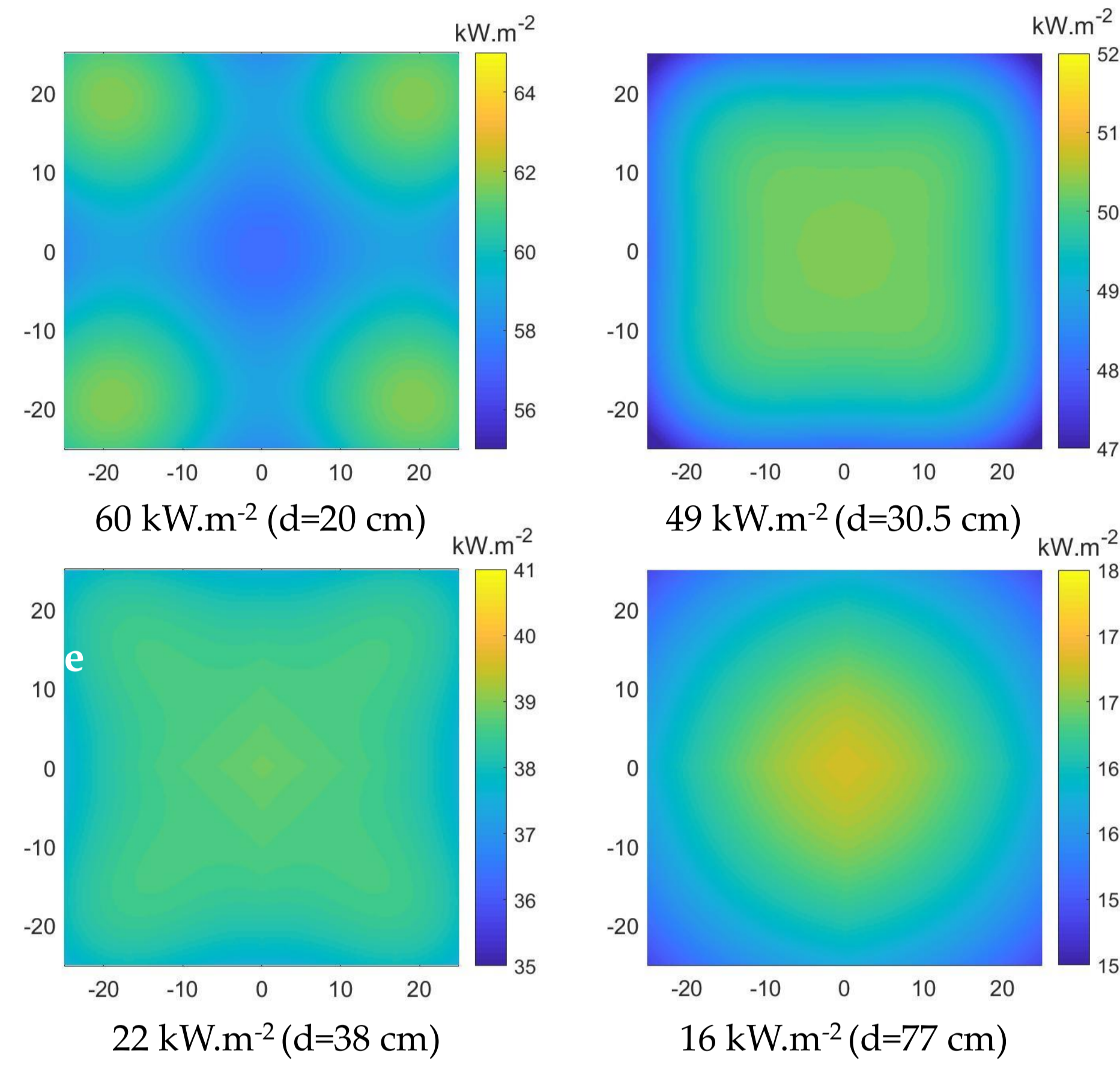


Fig. 2. Panel/sample distance (d) optimization (view factor method) to achieve a desired average heat flux on sample surface.

## Results: Mass Loss Rate, temperatures and t<sub>ig</sub>

At the panel scale with a 16 kW.m<sup>-2</sup> heat flux, onset of smoldering combustion is observed at 22 min with the appearance of glowing zones that spread over the entire surface. It results in an increase in temperature and MLRPUA to a second plateau. For both scale, the phenomena are the same.

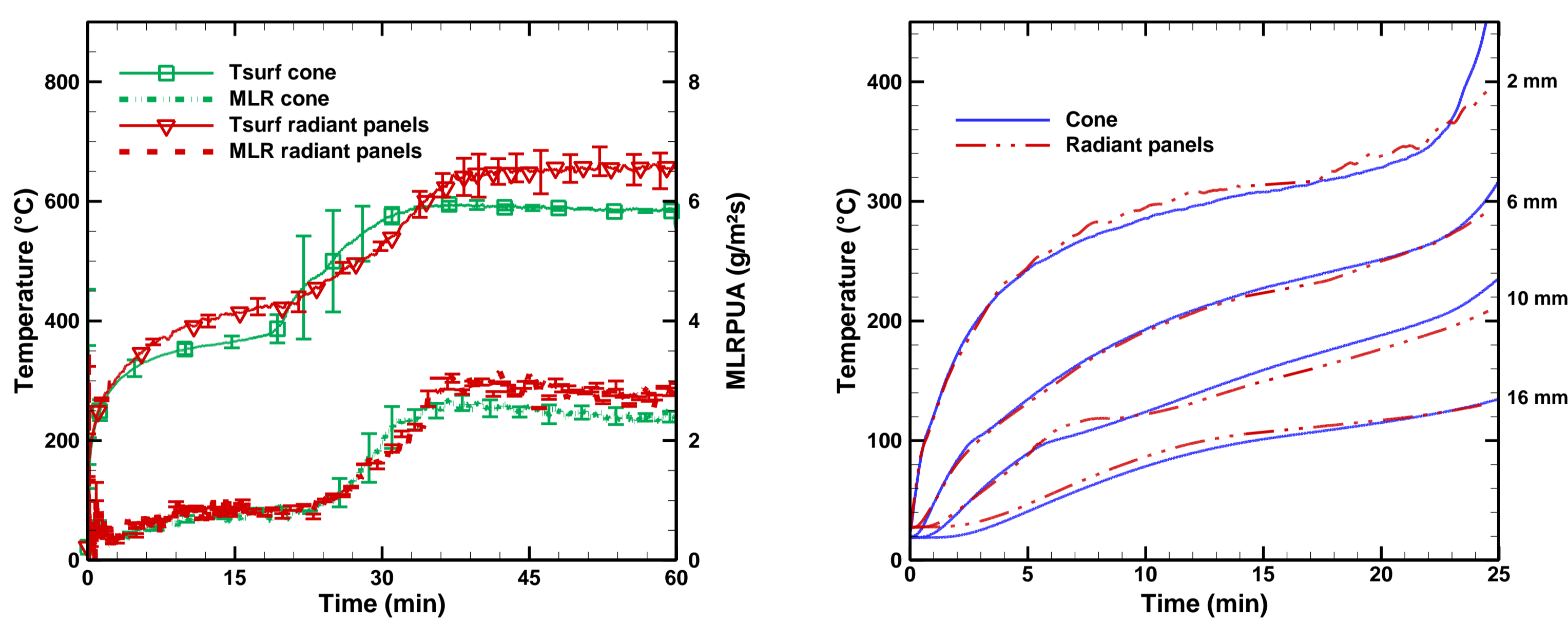


Fig. 3. MLRPUA and surface temperature (a) and in-depth temperatures (b) for spruce wood exposed to 16 kW.m<sup>-2</sup> at the radiant panels and cone heater scales.

The evolution of the in-depth temperatures at 60 kW.m<sup>-2</sup> is similar despite the change in scale. The maximum deviation is 50 °C in the temperature growth phase at 4 mm depth. This comparison supports the interpretations of the differences in surface temperatures (flame emission detected by the camera) as well as the MLRPUA between the two scales (edge effect on degradation).

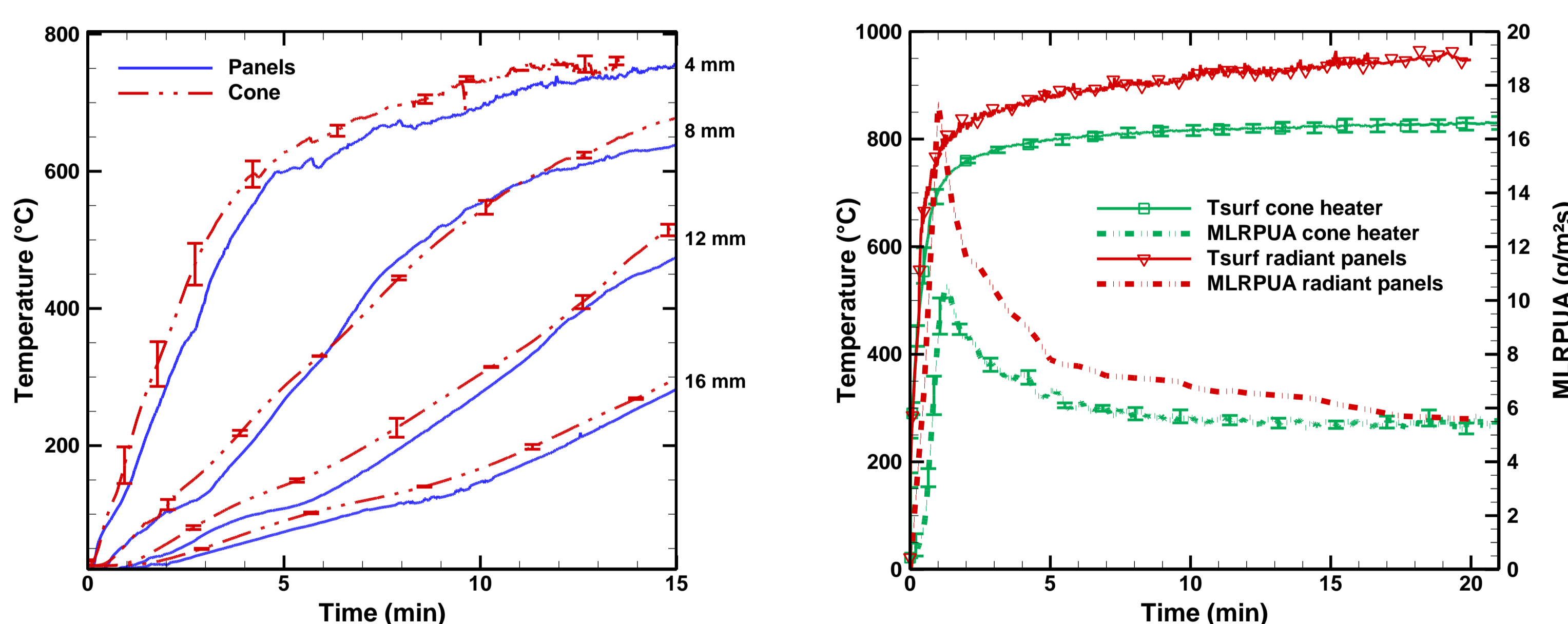


Fig. 4. Comparison of in-depth temperature for samples exposed to 60 kW.m<sup>-2</sup> according to the scale studied.

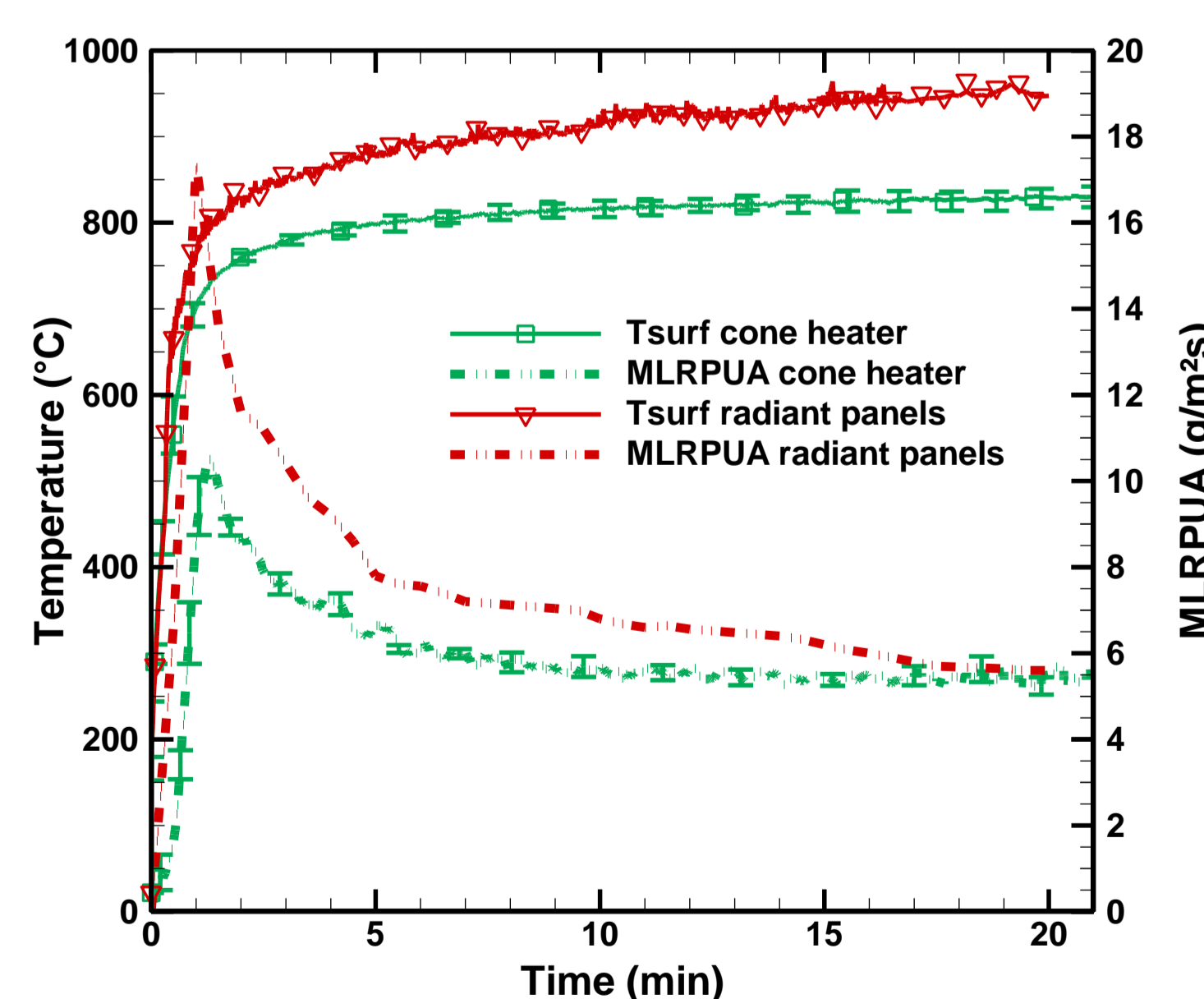


Fig. 5. Comparison of MLRPUA and Tsurf between radiant panel and cone heater for 60 kW.m<sup>-2</sup>.

Table 1. Number of tests and Time-to-auto-ignition (t<sub>ig</sub>) according to the studied scale.

Heat flux (kW.m <sup>-2</sup> )	Radiant panels		Cone heater	
	Tests	t <sub>ig</sub> (s)	Tests	t <sub>ig</sub> (s)
60	7	11 – 19	103	25 – 1200
49	7	51 – 94	10	2900 – 3200
38	4	75 – 235	10	-

- t<sub>ig</sub> is greatly reduced when the scale increases.
- For 60 kW.m<sup>-2</sup>, t<sub>ig</sub> at the panels scale is between 11 and 19 s. At the cone scale, these times were rather obtained for 82 kW.m<sup>-2</sup>.
- Mean t<sub>ig</sub> at 38 kW.m<sup>-2</sup> was 139 s, while no flame appeared at the cone scale.

## Results: auto-ignition location

The location of the flame appearance was revealed using two fast cameras. One was in the visible (3000 fps) and the other in the infrared (4800 fps) with a 4.45 μm filter (hot CO<sub>2</sub>) in order to better visualize the flame which emits in this wavelength. The figures below compare the ignition location at both scales for different values of the heat flux.

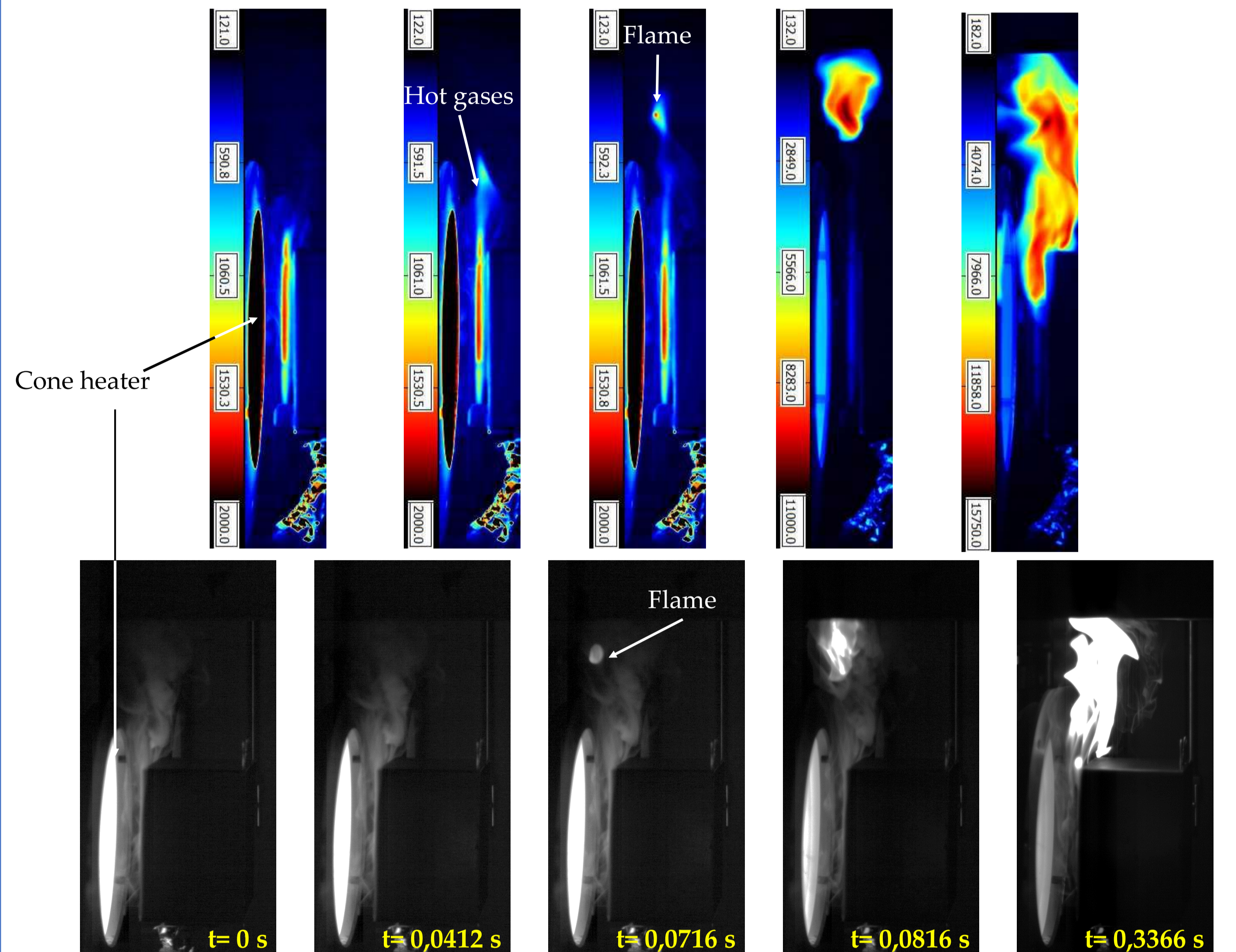


Fig. 6. Gases auto-ignition away from the exposed surface at the cone scale for 60 kW.m<sup>-2</sup>.

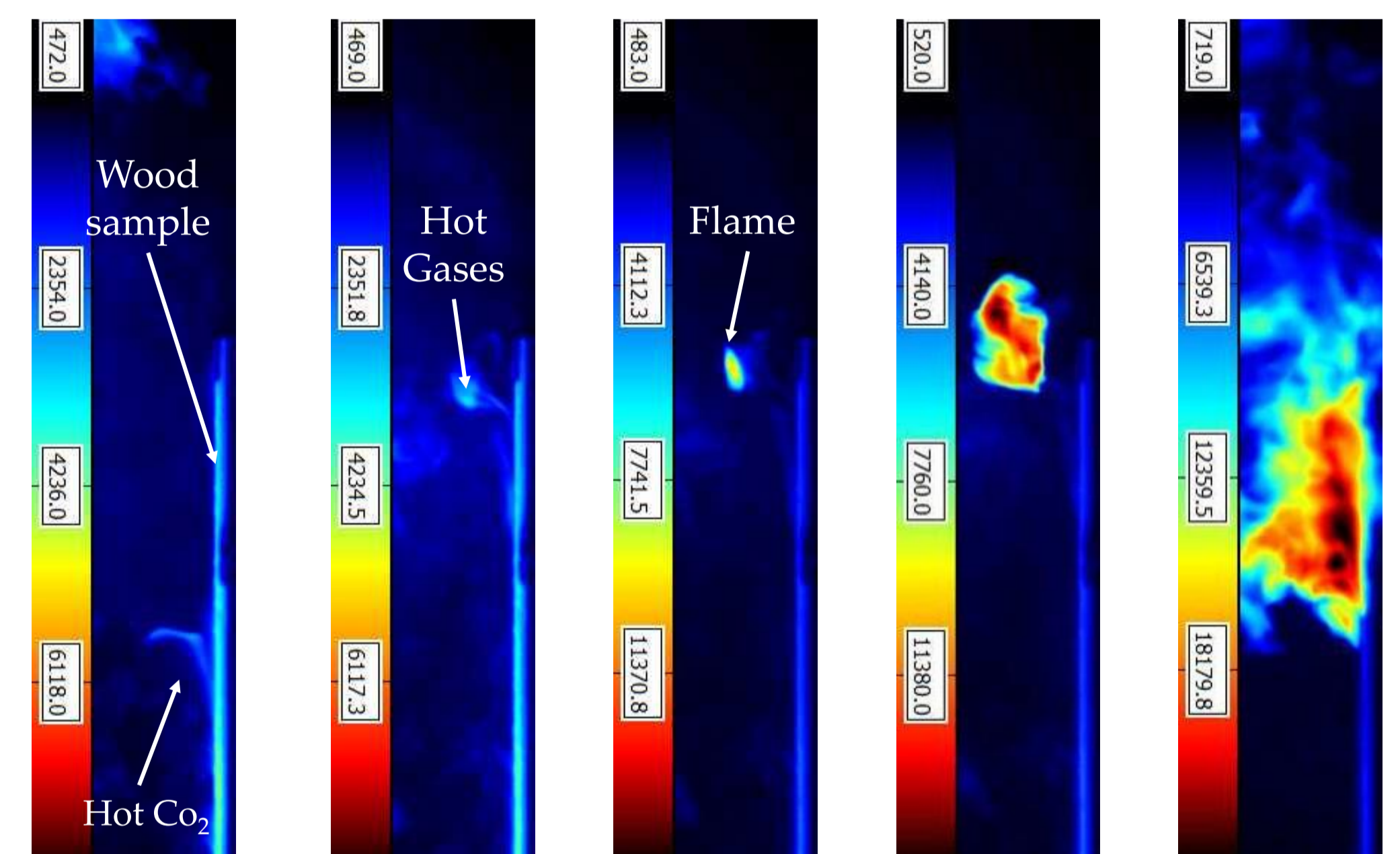


Fig. 7. Gases auto-ignition away from the exposed surface at the panel scale for 60 kW.m<sup>-2</sup>.

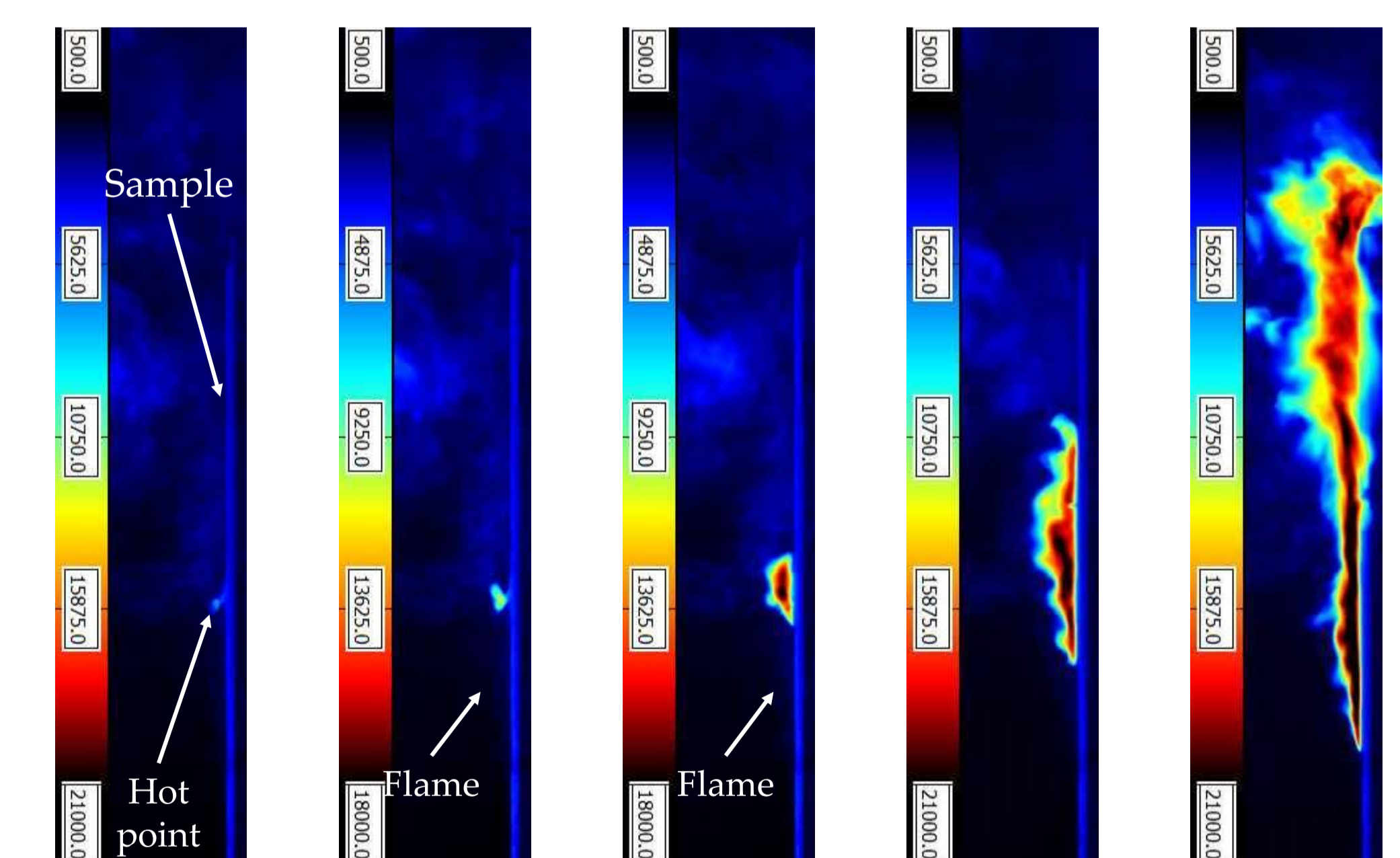


Fig. 8. Gases ignition piloted by the glowing surface at the panel scale for 38 kW.m<sup>-2</sup>.

- At 60 kW.m<sup>-2</sup>, for both scales, the appearance of the flame far from the exposed surface, is initiated by a large concentration of pyrolysis gases (detected by the CO<sub>2</sub> filter) escaping from the surface of the sample. This quantity continuously increases in temperature, while mixing with the air as it rises. Once the temperature and mixing conditions are met, self-ignition occurs.
- At 38 kW.m<sup>-2</sup>, the high-speed camera images show that the ignition occurring near the surface is initiated by a glowing wood splinter that reaches a temperature higher than the average surface temperature.

## Conclusions

- At a low heat flux, results at both scales are very similar.
- For high heat fluxes, the MLRPUA and surface temperature are higher when the scale increases. These differences seem to be caused by both the presence of the flame, which provides an additional heat flux and also by the greater degradation at the side faces of the sample.
- However, comparisons of the in-depth temperature show that the in-depth degradation is close between the two scales studied.
- Tests carried out have shown that for the same imposed heat flux, the time to ignition is always shorter with the radiant panels than with the cone.
- Regarding the auto-ignition location, the phenomena remain very similar for both scales.