Polish Fire Suppression Systems Foundation

EUROPEAN FIRE SPRINKLER NETWORK

ITB

Protection of glass façades with sprinklers

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Experimental investigation into fire behaviour of glazed façades with pendant type sprinklers

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Plan

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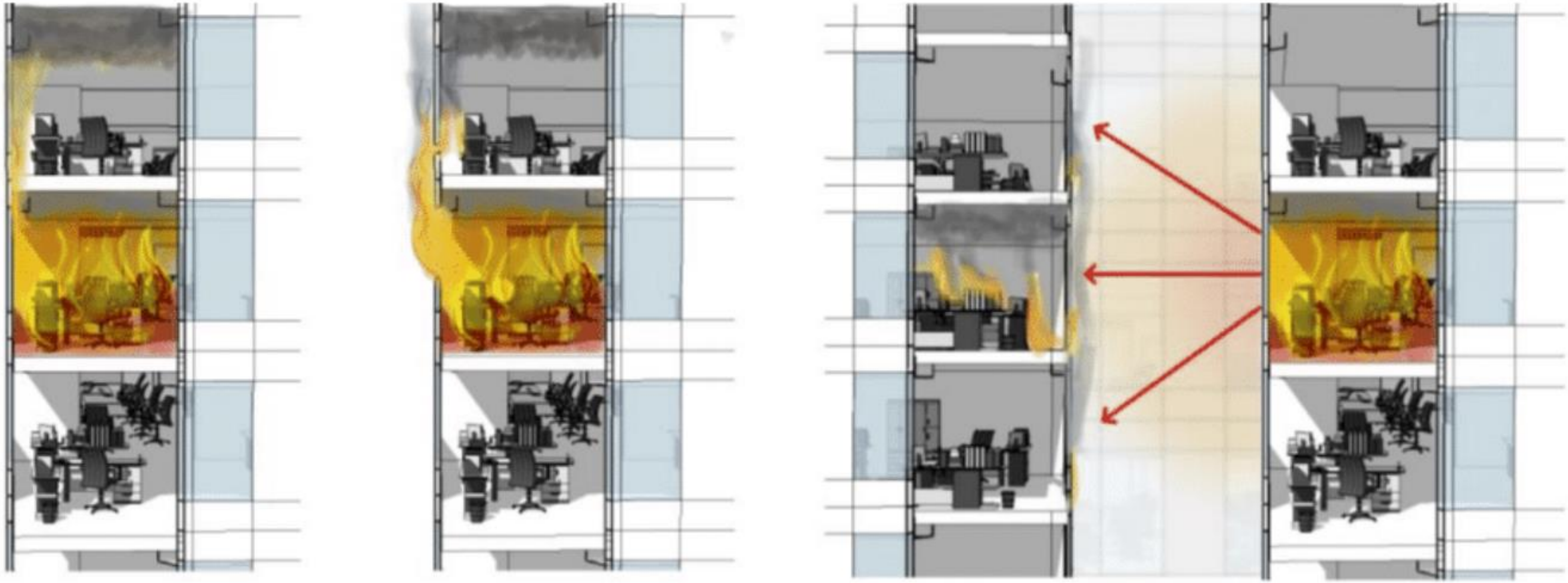
Fire Safety of Building Facades

- Facades and facade systems
  - Expression of art, architecture, most noticeable part of buildings
  - can represent 20% of the building cost
  - can be quite technologically complex
- Facade engineering is developing rapidly (PV, climate adaptive etc.)
- Facade systems are key in external spread of fire (B2B, F2F, C2C)
- Many examples – Grenfell Tower (2017), Address Hotel Dubai (2015)…

Fire spread scenarios



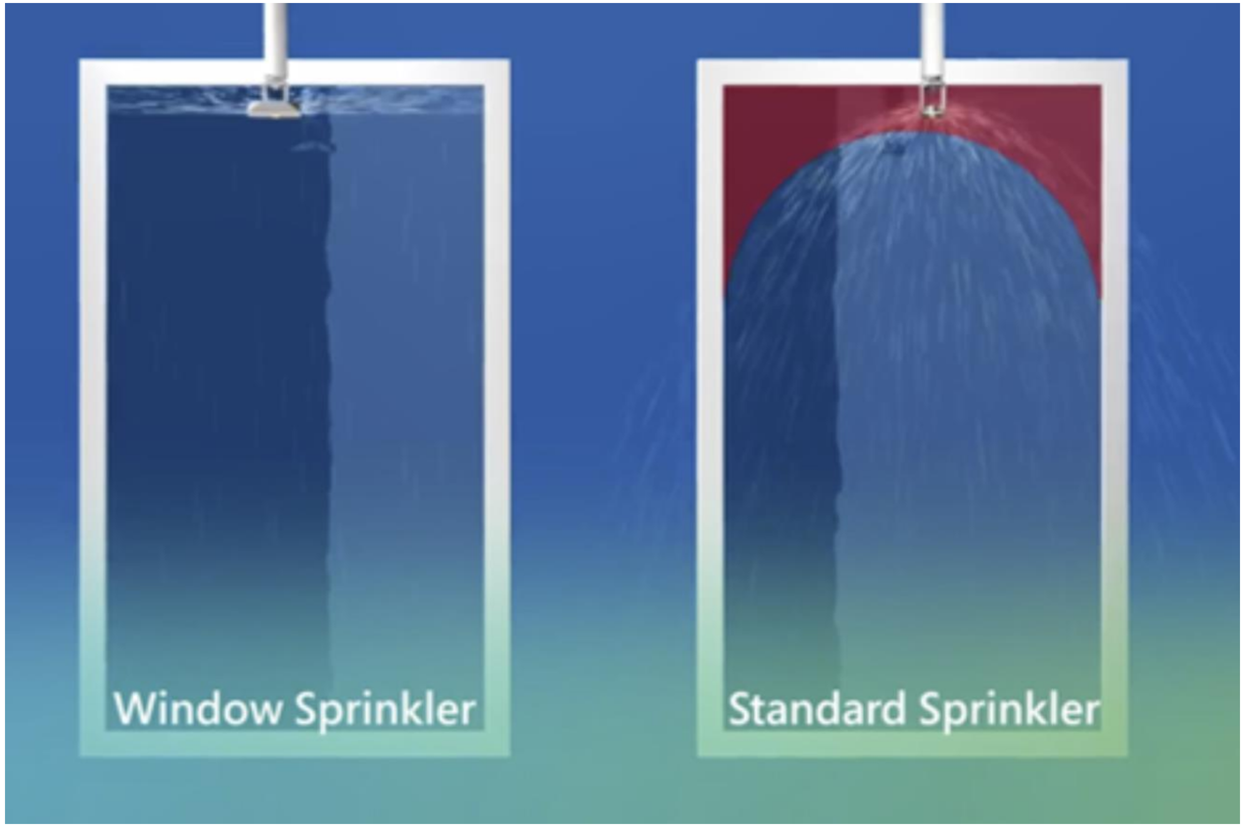
(a) (b) (c)

Figure 1. The main routes of fire spread which should be prevented by the building façade: (a) internal flame spread at the anchoring of the façade to the floor slabs; (b) external flame spread; and (c) radiation towards neighbouring buildings and compartments

Goals of the research

- Investigate the feasibility of common pendant-type sprinklers to:
  - shield non-fire-rated glazed building facades enhancing their protective capabilities against three key scenarios of the spread of fire
  - improve the fire behaviour of Insulating Glass Units (IGU) installed in an aluminium frame façade system, used as curtain walls. IGU consisted of two or three glass layers separated by cavities with 90% Argon
- Sprinklers allow for smaller building separation (in Poland 25% reduction, but large openings increase the separation by 50% or even 100%)
- No additional benefits are usually given to additional internal sprinkler protection of the external glass façade using standard pendant sprinklers
- Such solution allows for a cost-effective use of existing infrastructure (pumps, risers, water supply) designed for the protection of the office, to enhance the fire safety of façade system.

Commercial window sprinklers



NFPA 13 & 13R (2016)

8.15.26* Sprinkler-Protected Glazing.

Where sprinklers are used in combination with glazing as an alternative to a required fire-rated wall or window assembly, the sprinkler-protected assembly shall comply with the following:

1) Sprinklers shall be listed as specific application window sprinklers unless the standard spray sprinklers are specifically permitted by the building code.
2) Sprinklers shall be supplied by a wet-pipe system.
3) Glazing shall be heat-strengthened, tempered, or glass ceramic and shall be fixed.
4) Where the assembly is required to be protected from both sides, sprinklers shall be installed on both sides of the glazing.
5) The use of sprinkler-protected glazing shall be limited to non-load-bearing walls.
6) The glazed assembly shall not have any horizontal members that would interfere with uniform distribution of water over the surface of the glazing, and there shall be no obstructions between sprinklers and glazing that would obstruct water distribution.
7) The water supply duration for the design area that includes the window sprinklers shall not be less than the required rating of the assembly


Amica
LG NanoCell TV
CCC
H&M
C&A

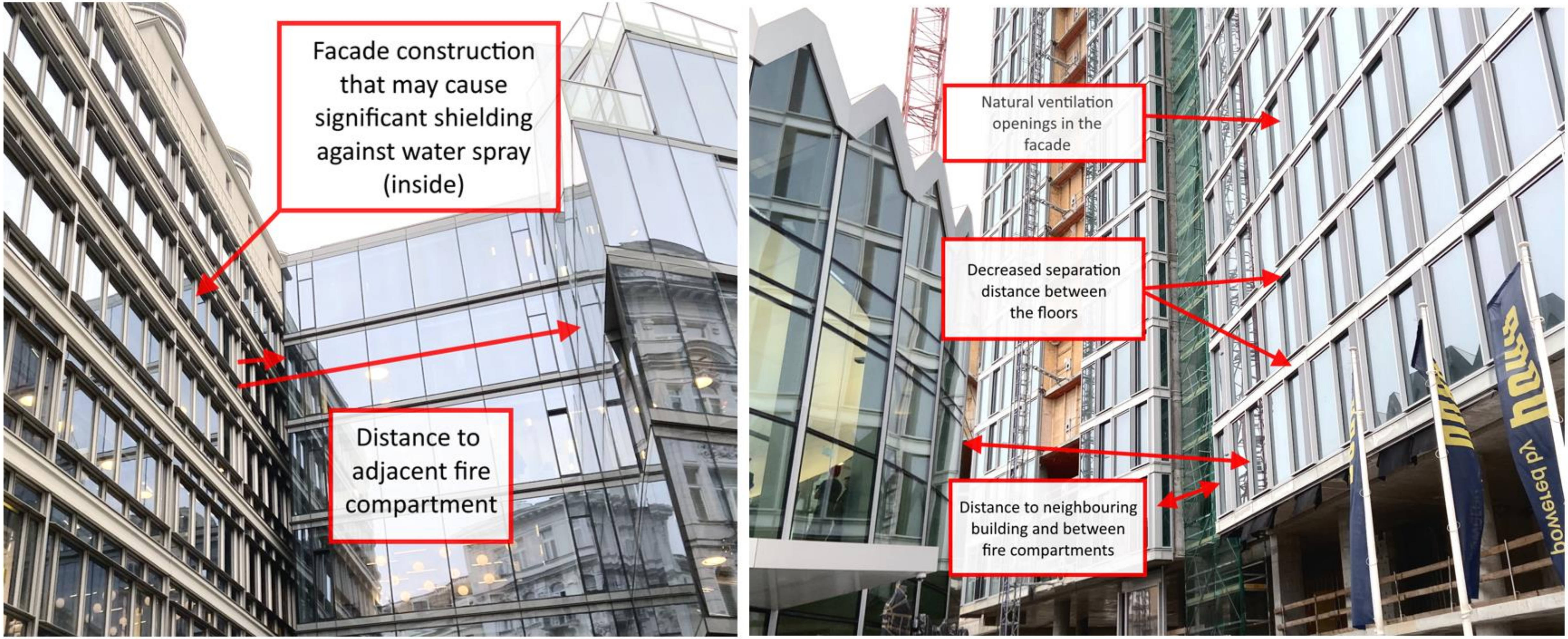


Figure 3. Challenges in the design of façades of the buildings used in this study: building (a) represents experiments #1 and #2; building (b) represents experiments #3 and #4

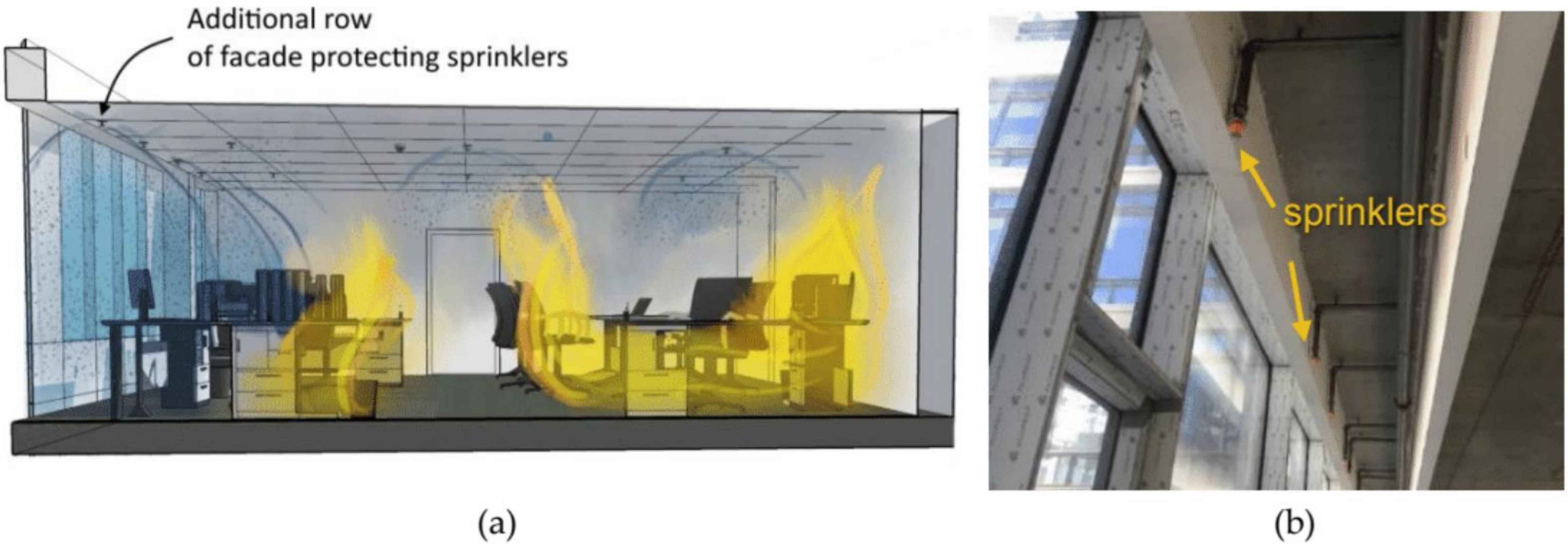
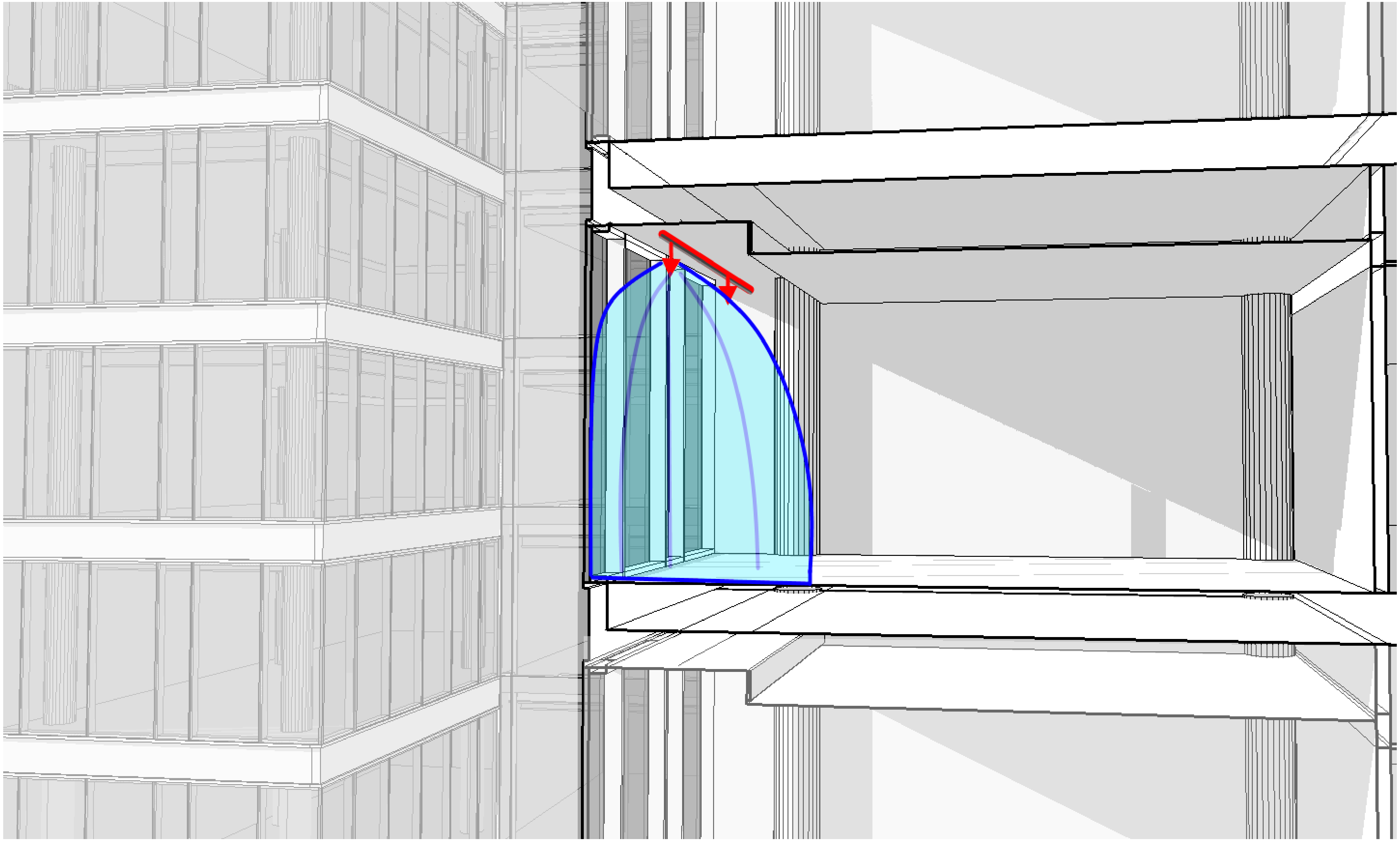


Figure 2. (a) Operation of the additional row of sprinklers in protection of the external glazing; (b) the finished sprinkler system installed in a building



Experimental overview

- Four experiments were performed in the Fire Testing Laboratory of the Building Research Institute (ITB) in Pionki, Poland.
- These experiments were part of a performance-based engineering process for two iconic office buildings under construction in Warsaw, Poland.
- A full scale special test rooms were built
- Fire - gas burners. HRR = 2.5-3.5 MW
- Ventilation – via door
- HRR > ventilation limit, so flames outside the door
- Only two pendant sprinklers over the window (ceiling sprinklers were omitted)

Table 1. Overview of important information related to the experiments

<table>
<tr><th></th><th colspan="2">Building A
Experiments #1 and #2</th><th>Building B
Experiment #3</th><th>Building B
Experiment #4</th></tr>
<tr><td>Floor area (W × D)</td><td colspan="2">4.05 m × 7.20 m</td><td>3.00 m × 5.00 m</td><td>3.00 m × 5.00 m</td></tr>
<tr><td>Height</td><td colspan="2">3.61 m</td><td>2.95 m</td><td>2.95 m</td></tr>
<tr><td>Details of the IGU</td><td colspan="2">Overall thickness – 38.76 mm
Two layers:
AGC 8mm Stopray Vision 50TTG /20+90%Ar/ 55.2 Stratobel Clearlite (2x Planibel Clearlite)</td><td colspan="2">Overall thickness – 58.8 mm
Three layers:
Cool-Lite Xtreme 50/22 II 8TTG HST/90% AR/Optifloat Clear 6TTG HST/90% Ar/ 66.2 Stadip Planitherm XN</td></tr>
<tr><td>Internal glass layer (side exposed to the fire)</td><td colspan="2">Coated + Laminated
PVB interlayer</td><td colspan="2">Coated + Laminated
PVB interlayer</td></tr>
<tr><td>Ventilation in the façade</td><td colspan="2">No</td><td>Yes (see Fig. 6)</td><td>No</td></tr>
<tr><td>Experiment duration</td><td>63 mins</td><td>40 mins</td><td>75 mins</td><td>91 mins</td></tr>
<tr><td>Sprinkler type</td><td colspan="4">2 × DN15 K80 T=68°C, Quick Response pendant type</td></tr>
<tr><td>Sprinkler separation distance</td><td colspan="2">1,830 mm</td><td>1,514 mm</td><td>1,514 mm</td></tr>
<tr><td>Sprinkler distance from glass</td><td colspan="2">145 mm</td><td>550 mm</td><td>550 mm</td></tr>
<tr><td>Sprinkler operating pressure</td><td colspan="2">0.5 bar</td><td>0.35 – 0.5 bar</td><td>0.35 – 0.5 bar</td></tr>
<tr><td>Characteristic feature</td><td colspan="2">Large mullions creating uneven water distribution on the façade</td><td>Corner of the façade with side panel, vertical opening for natural ventilation;
1 m vertical extension of the façade</td><td>Large-sized single pane of glass; 1 m vertical extension of the façade</td></tr>
<tr><td>Ambient conditions</td><td colspan="2">15°C, moderate wind
(the experiment was shielded against the direct wind, to limit the wind effects on the course of fire, Fig. 4)</td><td>14°C, no wind</td><td>14°C, light wind</td></tr>
</table>

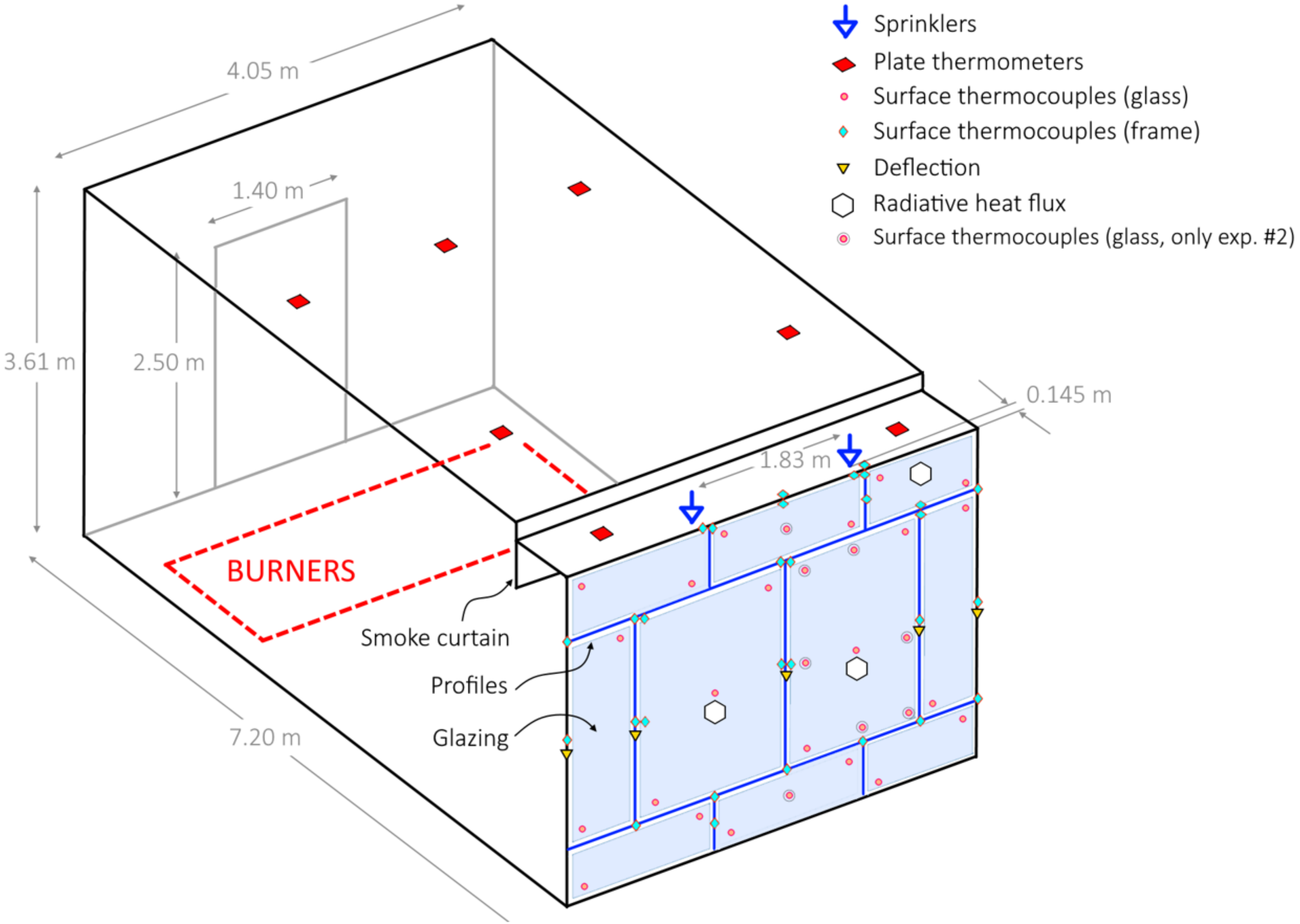


Figure 7. Overview of the location of measurement points in experiments #1 and #2. The thermocouples on the profiles were not used in exp. 2, and instead surface thermocouples were placed on the interior of the glazing in locations matching thermocouples on the unexposed side.

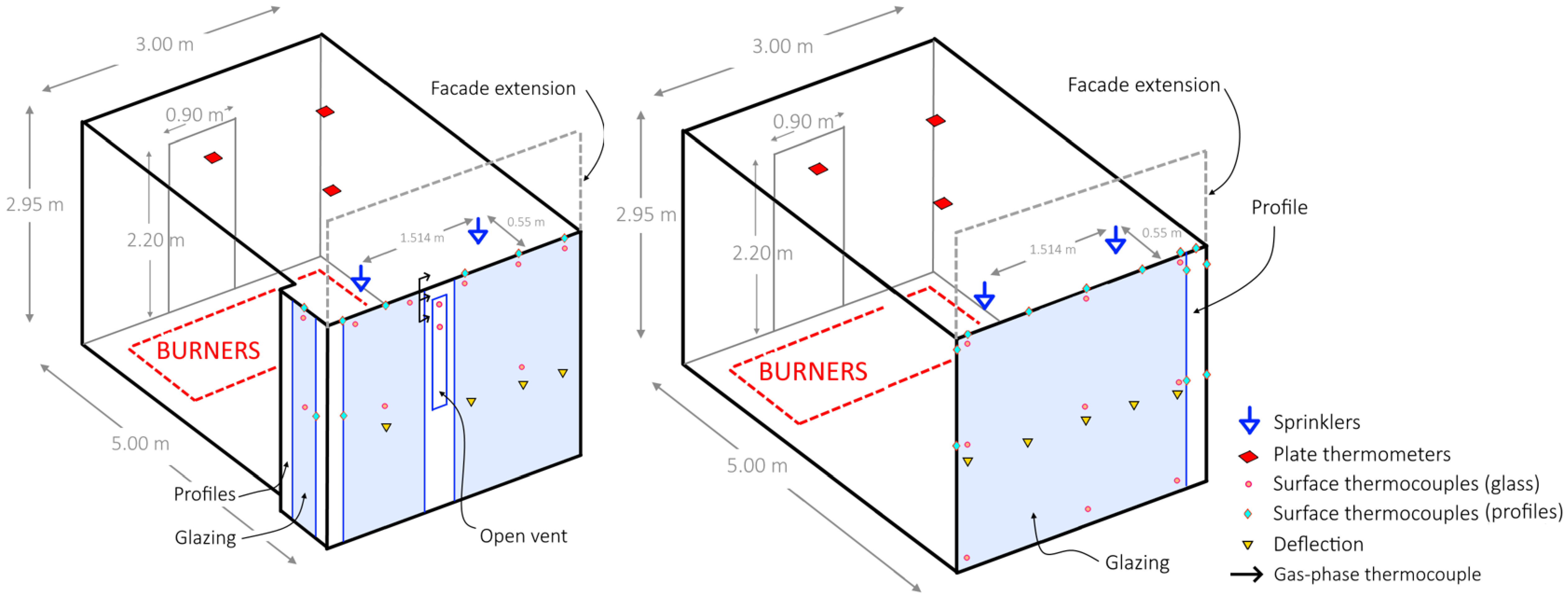


Figure 8. Overview of the location of measurement points in experiments #3 and #4

(a) (b)

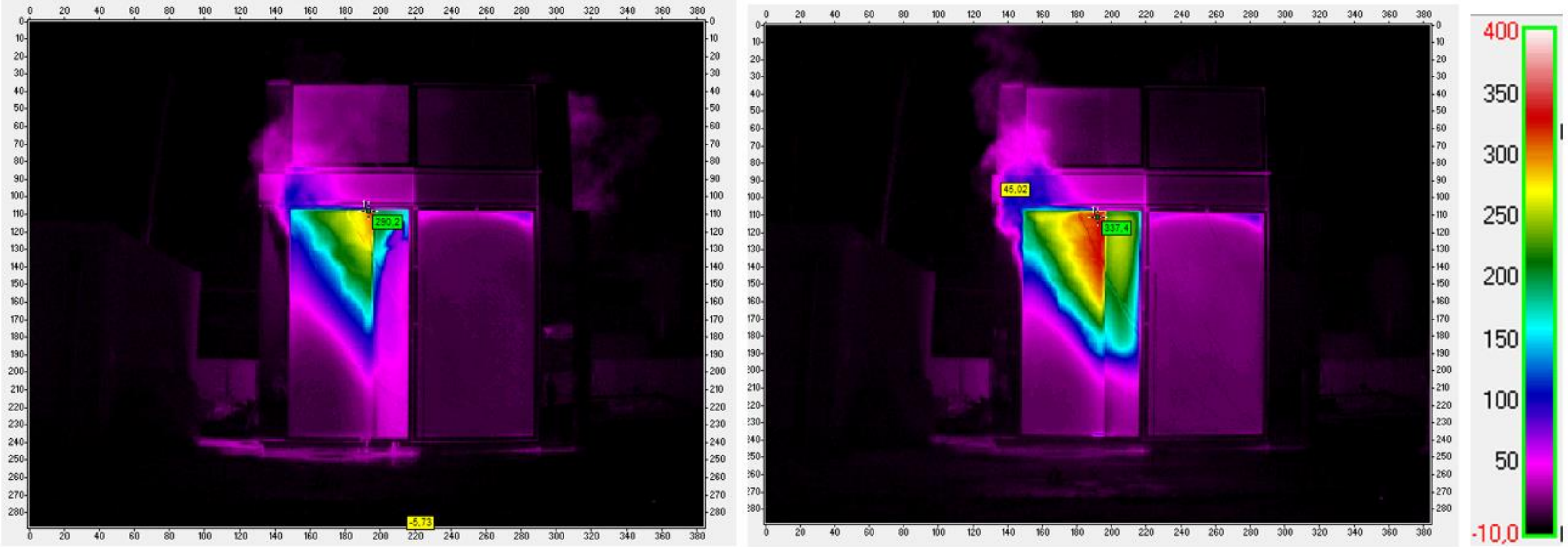
Figure 4. (a) External and (b) internal views of the compartment used in experiments #1 and #2. Large sheet of the material visible on the left of the experimental compartment was used to shield the facility from the side-wind (other sides were shielded by surrounding buildings)

(a) (b)

Figure 5. (a) External view of compartment used in experiment #3 and (b) in experiment #4

Figure 6. Figure (a) presents the sprinkler configuration for experiments #1 and #2. A smoke barrier was mounted approximately 500 mm towards the back of the room, and deep mullions of the façade system are visible. Figure (b) presents the sprinkler configuration for experiments #3 and #4, along with the façade with a ventilation opening used for experiment #3. Figure (c) presents the thermocouple configuration at the exterior of the ventilation opening of experiment #3

Left view, 60th minute | Right view, 60th minute



60th minute | 75th minute

Figure 10. Above: smoke plume from the ventilation opening and soot deposition on the glass in the 60th minute of experiment #3; no significant damage of the glazing next to and above the plume is visible. Bottom: thermographic image of the façade shortly before the water supply was shut off (60th minute), and at the end of the experiment (75th minute)

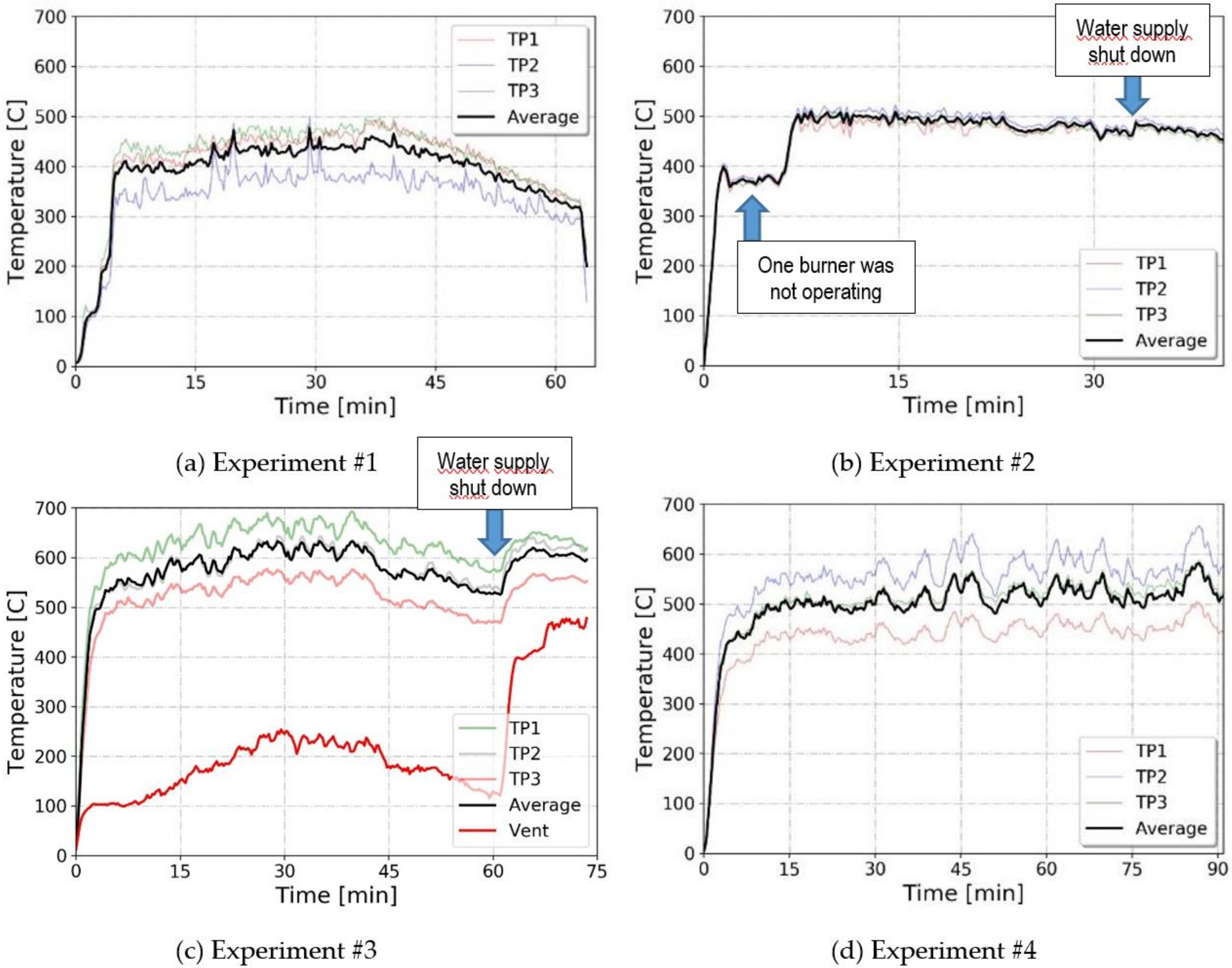


Figure 9. Gas phase temperatures recorded in four experiments. In exp. #2 and #3, the water supply was cut off towards the end of the experiment. In exp. #3, the temperature of gasses in the natural ventilation opening of the façade is shown.

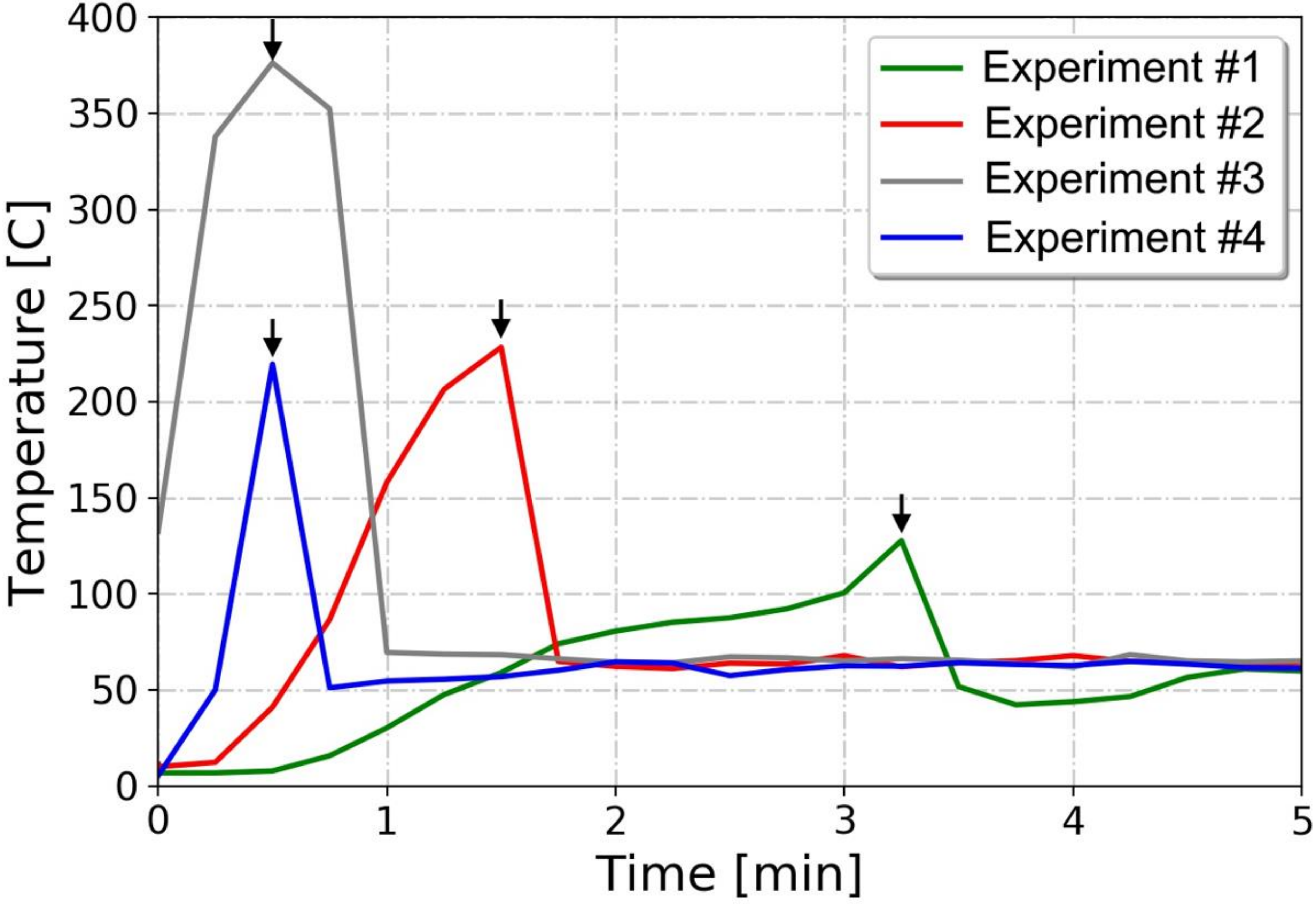


Figure 11. Gas temperatures at the sprinkler heads. Arrows indicate the activation of the first sprinkler in the compartment

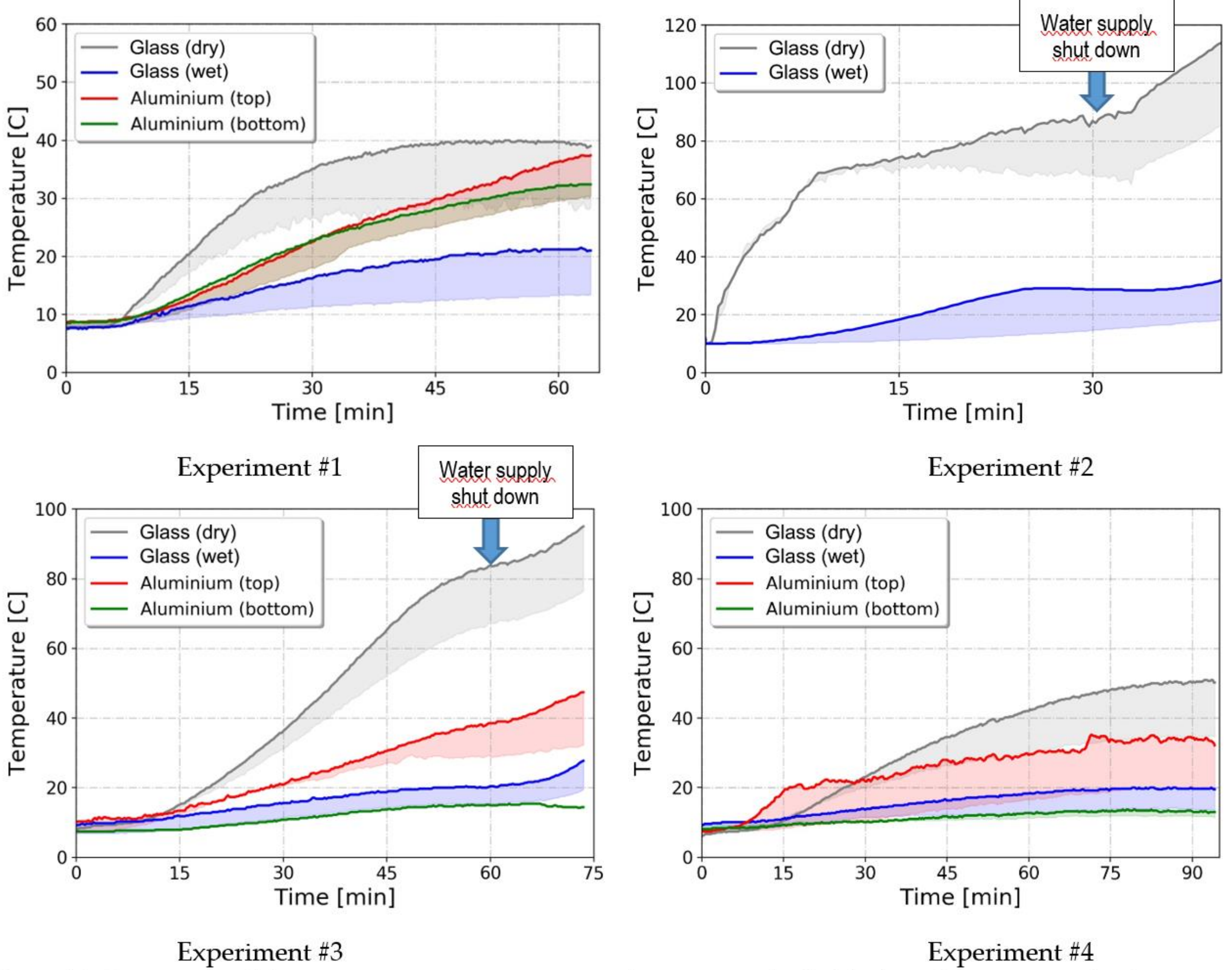
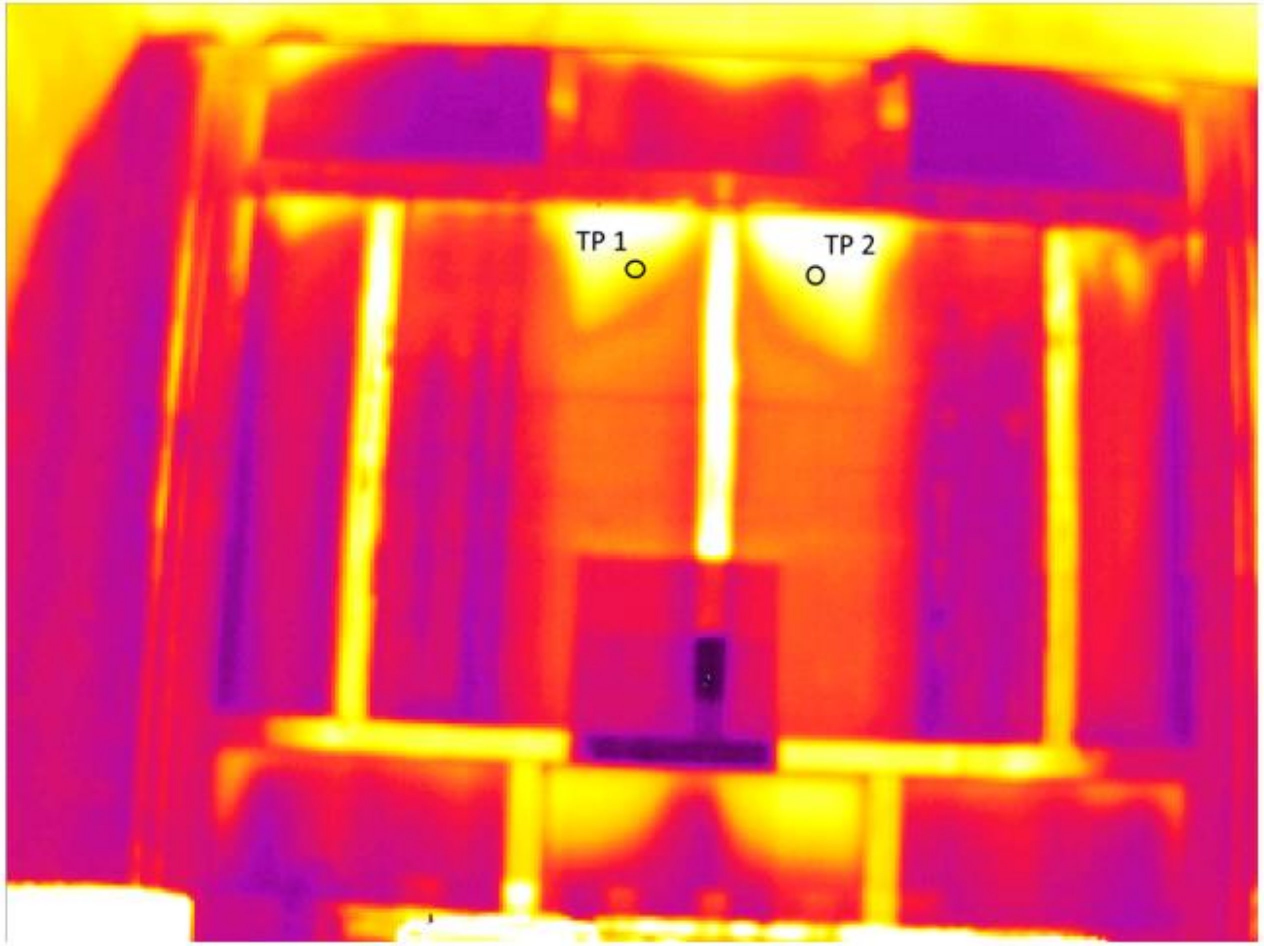
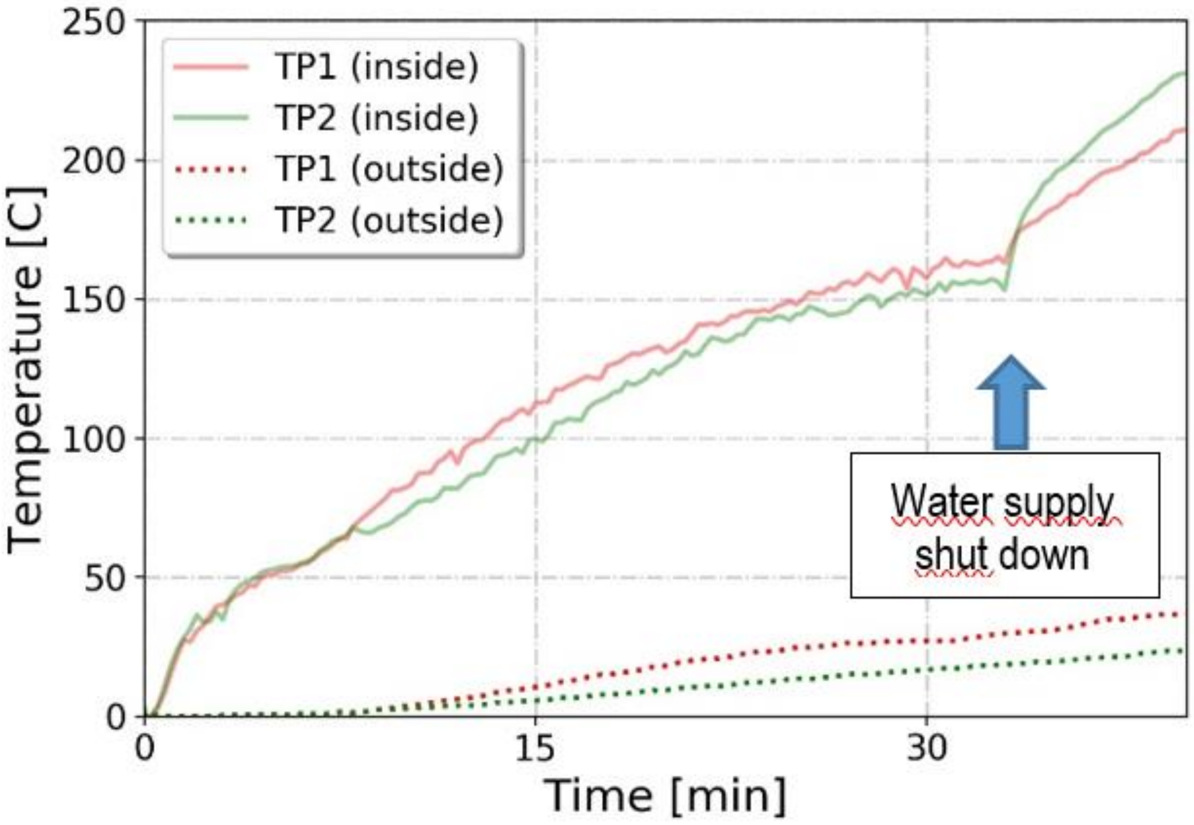


Figure 14. Comparison of the temperature measurements on the unexposed side. The line plots represent the thermocouple with the highest temperature recorded for a given group of elements, while shaded plots represent the range of data obtained from each group of thermocouples



(a)



(b)

Figure 15. (a) Thermographic image of the exposed side of the façade in experiment #1 with visible fragments of the glass with increased temperature (the dry area – covered with soot), (b) temperature rise measured in these locations in experiment #2 on the exposed and unexposed sides of the window in matching locations

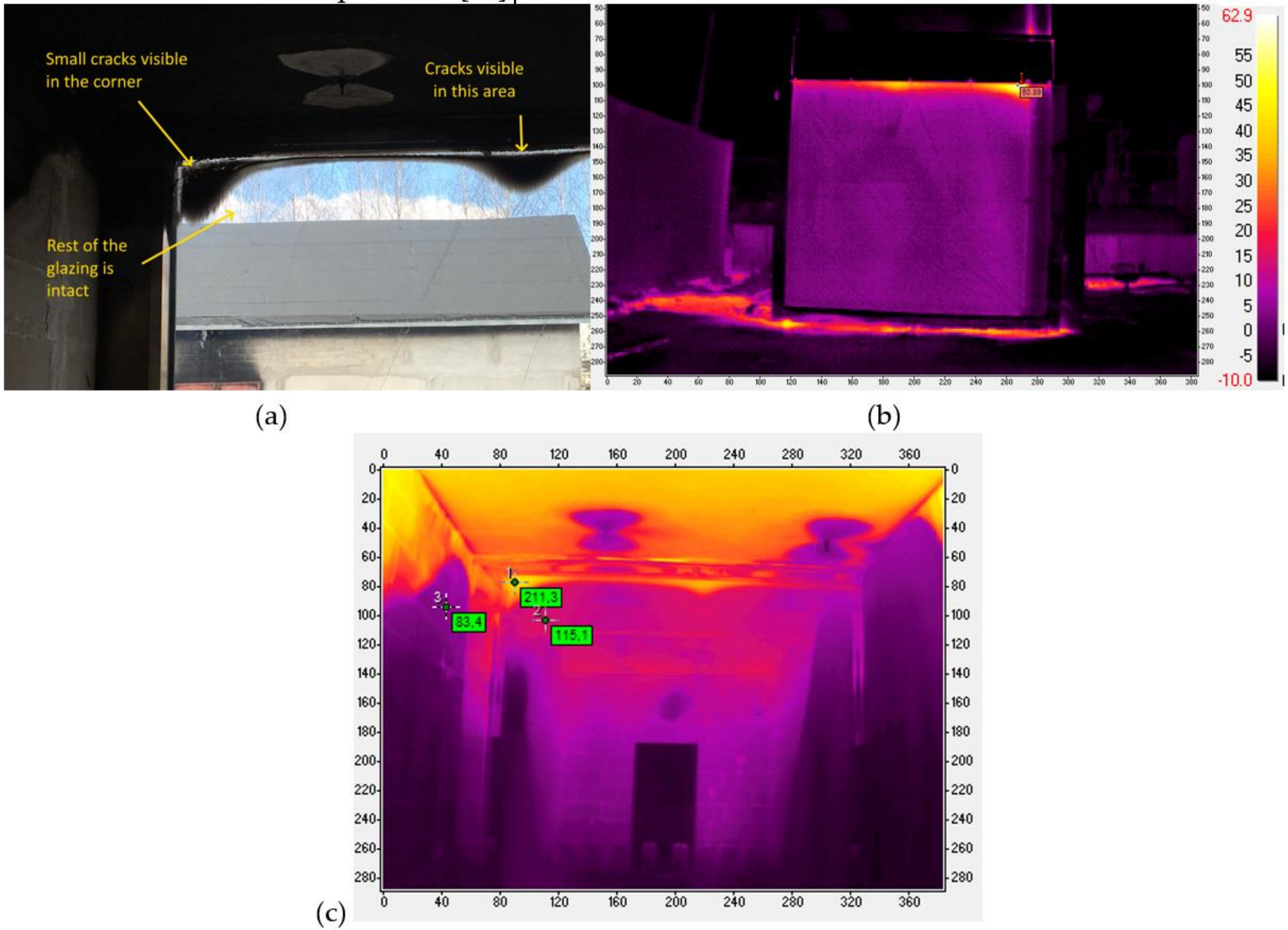


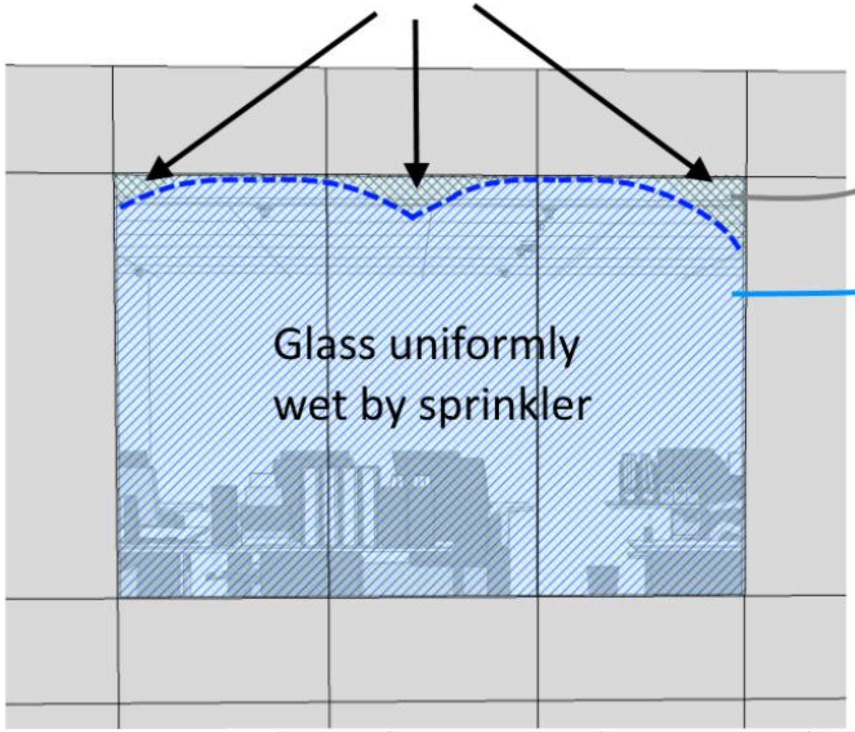
Figure 16. (a) Damage to the large single glass pane of experiment #4, and (b) the temperature of the glass surface on the unexposed and (c) exposed sides in the 90th minute of the experiment

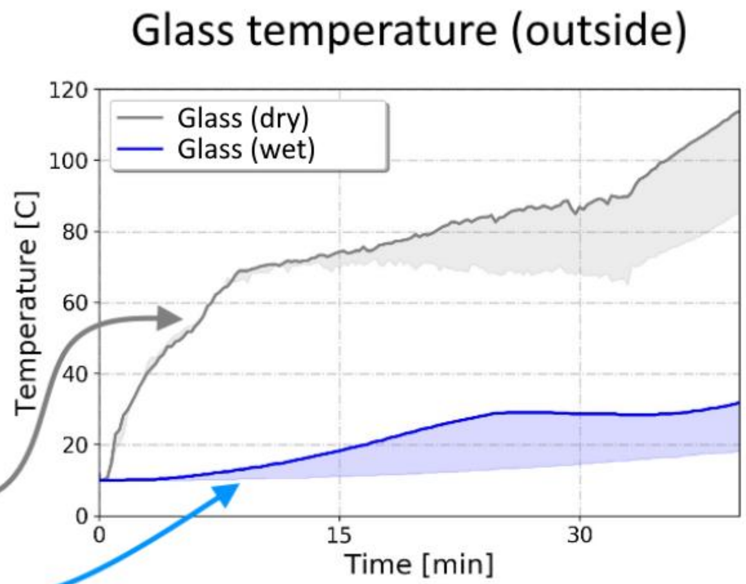
Figure 13. Soot deposition on the walls and the glazing of experiment #4, illustrating the range of water spray coverage in the compartment

Figure 17. Damage to the test element after experiment #1: cracks are visible in the dry area (covered with soot), while the wet part of the glazing is intact (with the exception of a single vertical crack running through the middle of the element)

Figure 18. Delamination of the inner glass pane observed after water spray shut-down in experiment #3

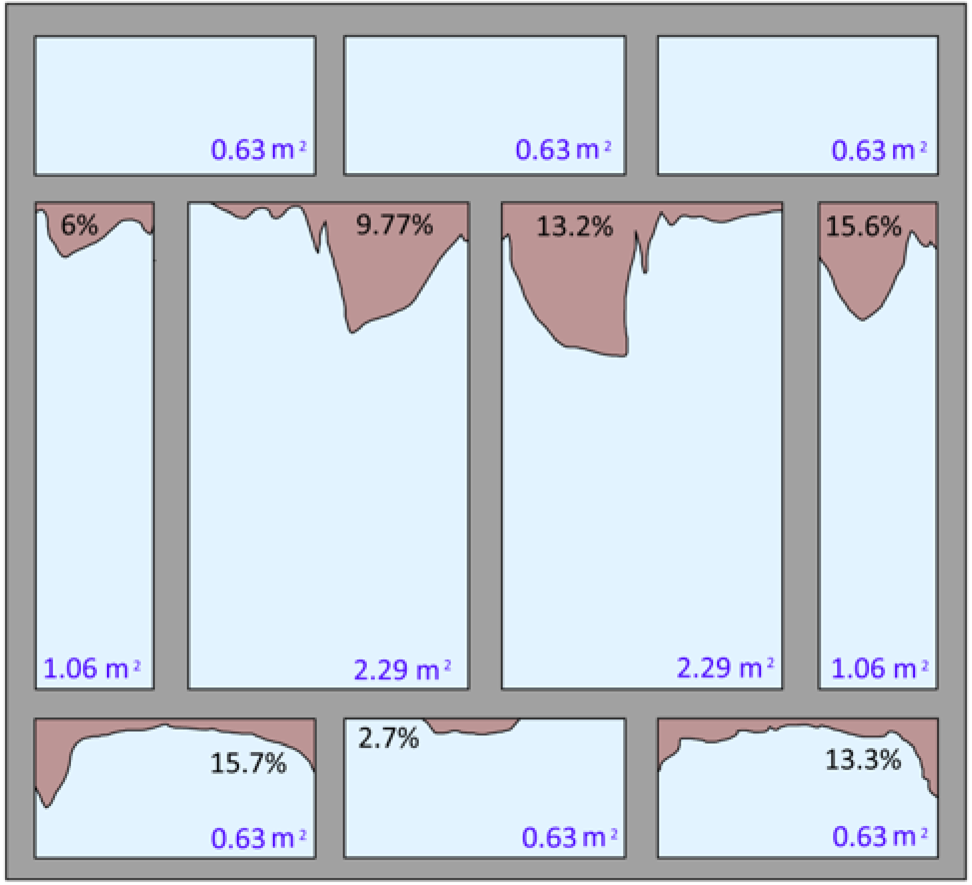
Some parts of glass are not wet by the sprinklers due to construction of facade or sprinkler water spray characteristic



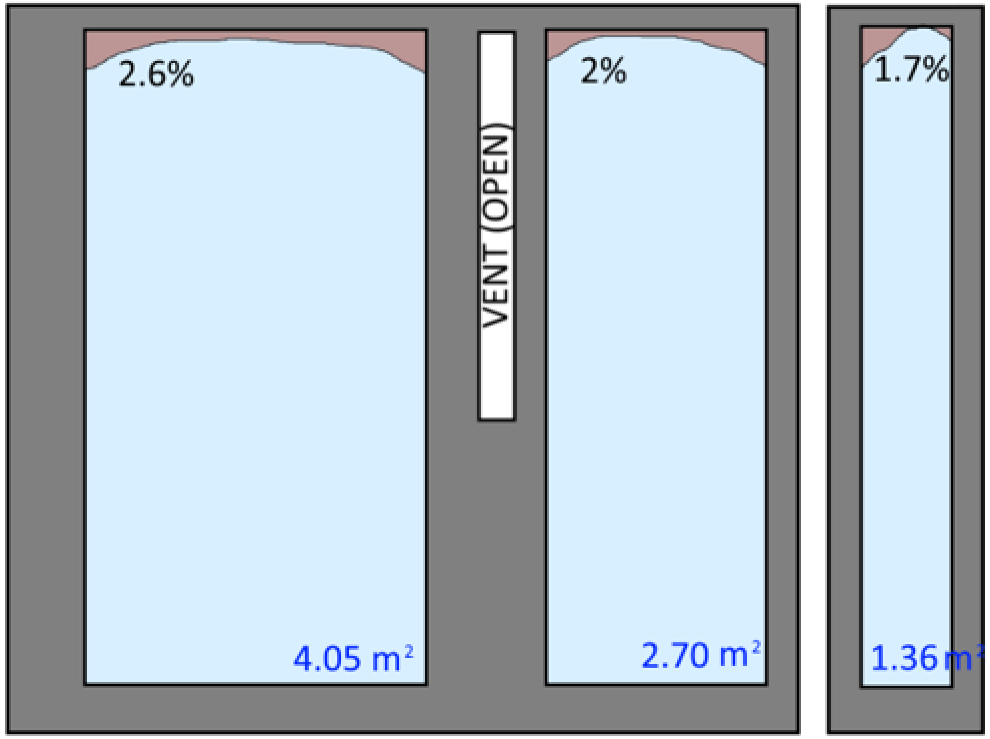


Damage in dry area

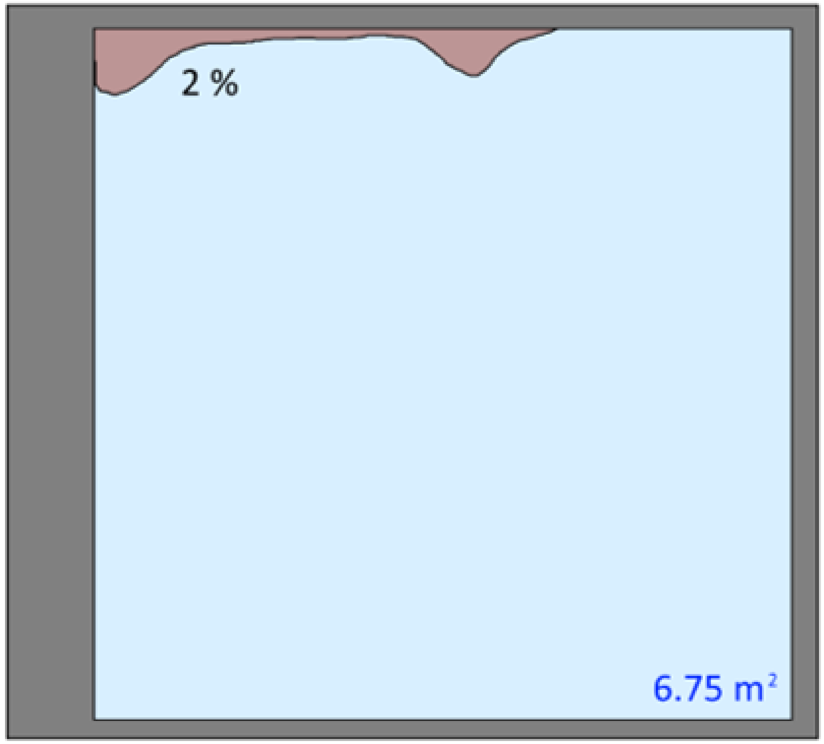
In our experiments 1.7% - 15.7% of glass area was dry, with visible soot deposition



(Experiment 1)

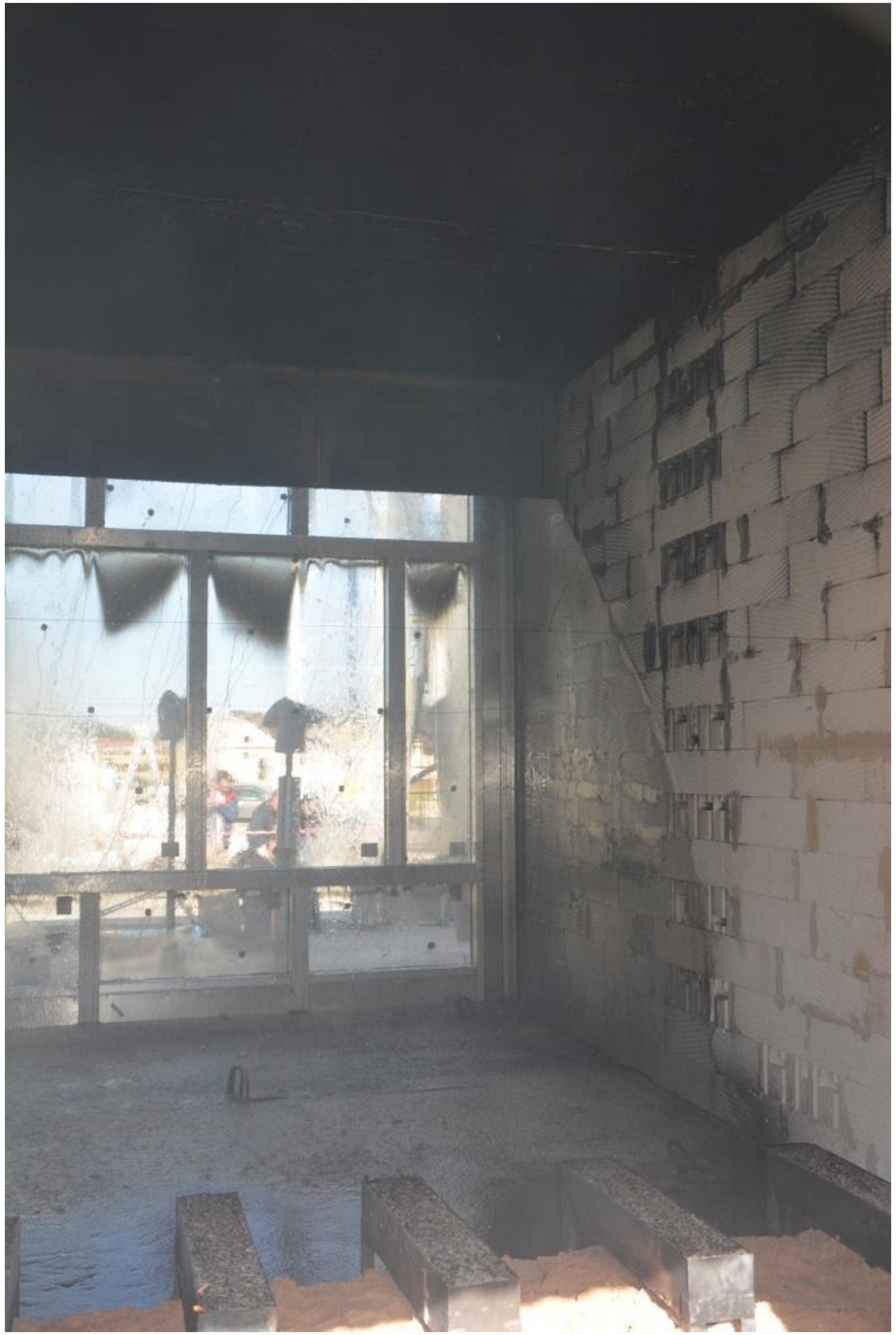


(Experiment 3)



(Experiment 4)

Figure 12. Non-water sprayed fragments of the glazing in experiments 1, 3 and 4. The percentage is an estimation of the part of the glass that was not wet, area indicates the total area of glazing.



Summary

- Four full-scale experiments were performed to investigate the protection of non-fire-rated glazed façades by using dedicated conventional pendant-type sprinklers
- This is a cost-effective solution as it does not require significant alterations to the conventional sprinkler systems used in modern offices.
- The solution can significantly improve the fire safety of façades against the of fire through the interior and exterior of the façade, as well as through the thermal radiation towards neighbouring compartments.

Summary

- The aim of the experiments was to test the performance of the proposed solution in realistic fire conditions in a naturally ventilated compartment. The designed fire was based on ventilation through the doors, which could support the burning rate.
- The aluminium façades with two- and three layered Insulating Glass Units used in the research were 1:1 mock-up façades of real buildings under construction in Warsaw, Poland.
- Our working hypothesis was that sufficient water distribution can be achieved with traditional pendant-type sprinklers, which would reduce the cost of installation and design of the façade protection system.
- The same water supply can be used for both the protection of the office area and the façade. This, however, must be decided on a case-by-case basis, as a separate piping, pump and water-supply setup could be used for the façade-protecting system to increase its reliability.

Summary

- The intrinsic design features of the façade–sprinkler setup (e.g. large mullions and transoms, uncommon sprinkler separation distance, and the use of traditional pendant sprinklers) led to the shielding of parts of the façade from the water spray.
- In our setup, these areas were up to 13.2% of the surface area of large glass panes (>2 m2) and up to 15.7% area of small glass panes (<2 m2). These areas were dry, covered in soot and exposed to significantly higher temperatures than the water-sprayed parts of the façade.
- This, however, resulted only to local damage (cracks) to the innermost layer of the glazing, which was laminated and coated glass. This damage did not lead to loss of the structural integrity of the building envelope. The mechanical response of the façade to fire was excellent.
- The façade was not significantly deflected (the maximum of 1/500th span deflection of an element was measured).
- The experiments confirmed that the sprinkler protection of external façades is a valid approach to increase the fire safety of a building, increasing protection against the spread of fire in the interior and exterior of the building envelope. The water spray did reduce the radiative heat flux emitted through the glazed façade, to a level where it was possible to stand next to the façade without any discomfort.

Summary

- Measured heat-flux in experiment #1 indicate almost no increase over the ambient value, and the performance of the façade in this experiment was comparable to walls with fire resistance index ‘W’.
- Adequate protection of the external façade was obtained with a conventional sprinkler system, operating at the usual pressure/flow rate parameters.
- This means that protection can be achieved with solutions compatible with typical code-compliant sprinkler systems used in existing office compartments.
- Considering the results obtained it can be stated that additional façade protection using standard pendant sprinklers should be studied further and may eventually be considered as a measure which can be included in fire regulations as a cost effective method of reducing the separation distance between buildings in some scenarios.
- Further work is however needed to define these scenarios and key factors.

3D Mapping of the Sprinkler Activation Time

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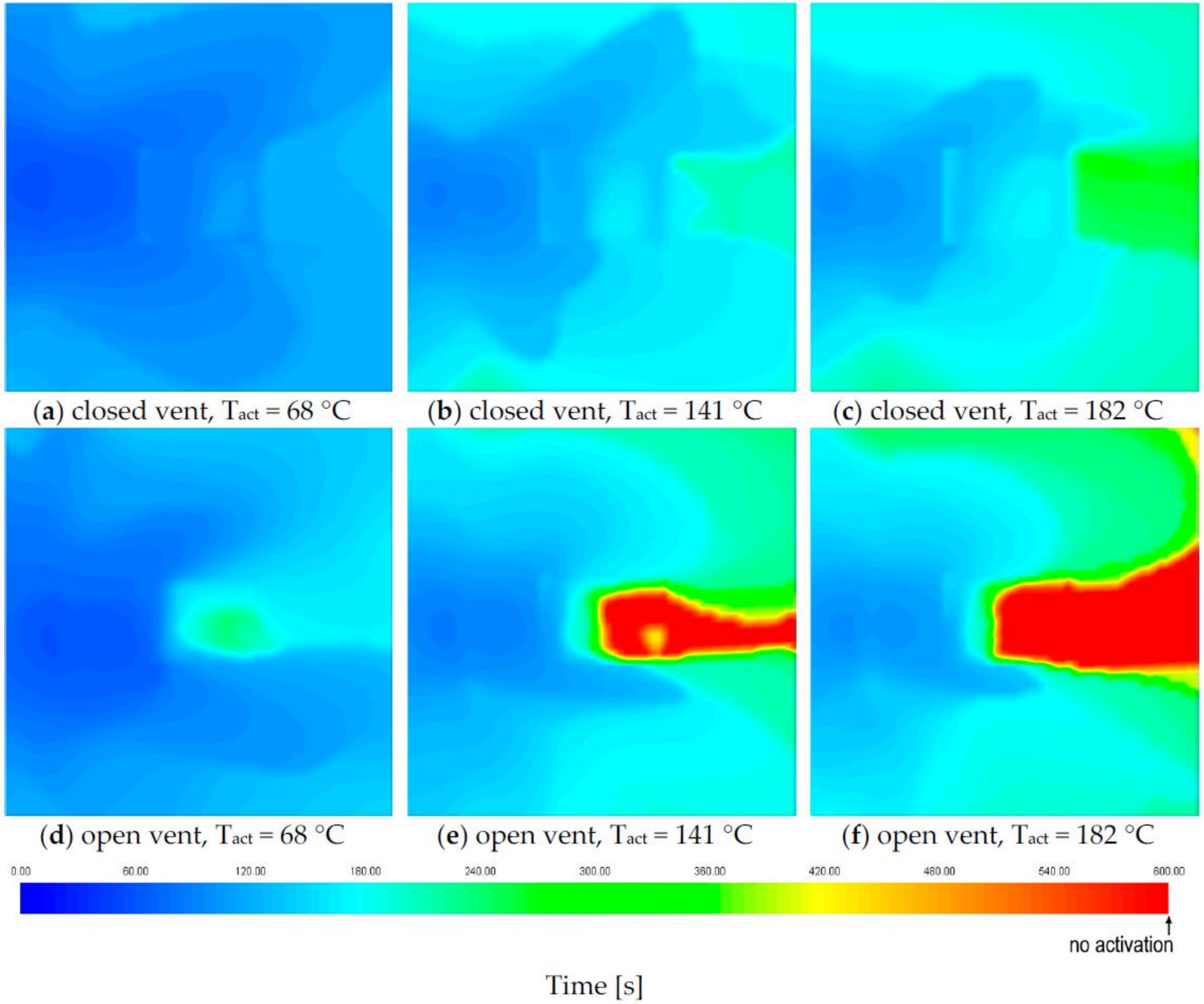


(**a**) closed vent, T_{act} = 68 °C

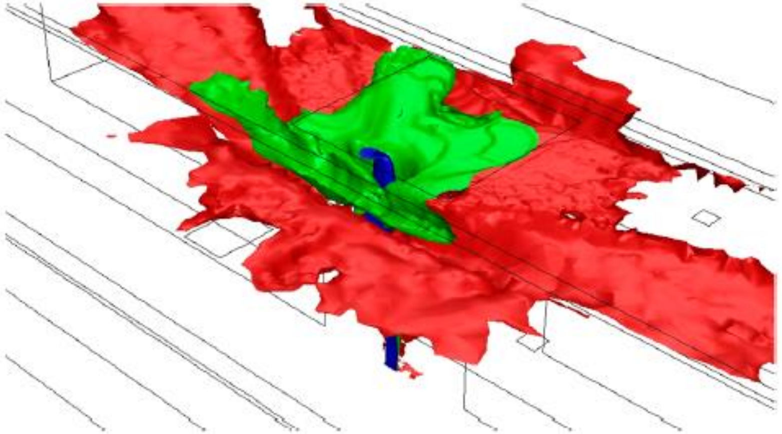
(**b**) closed vent, T_{act} = 141 °C

(**c**) closed vent, T_{act} = 182 °C

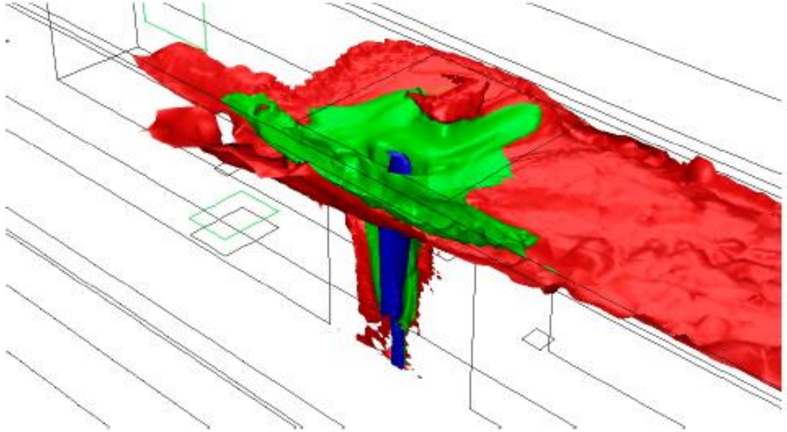
(**d**) open vent, T_{act} = 68 °C

(**e**) open vent, T_{act} = 141 °C

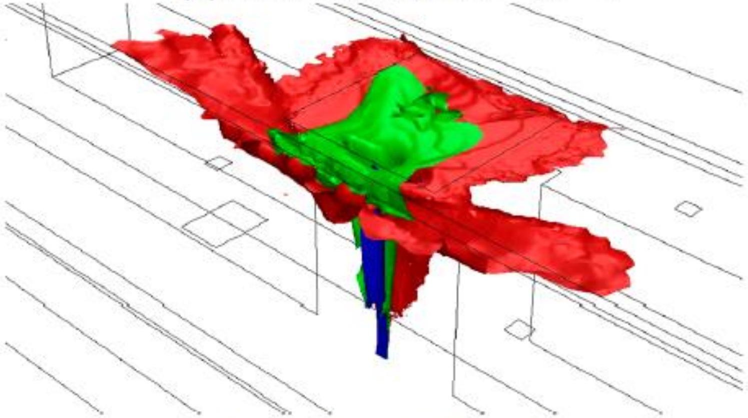
(**f**) open vent, T_{act} = 182 °C



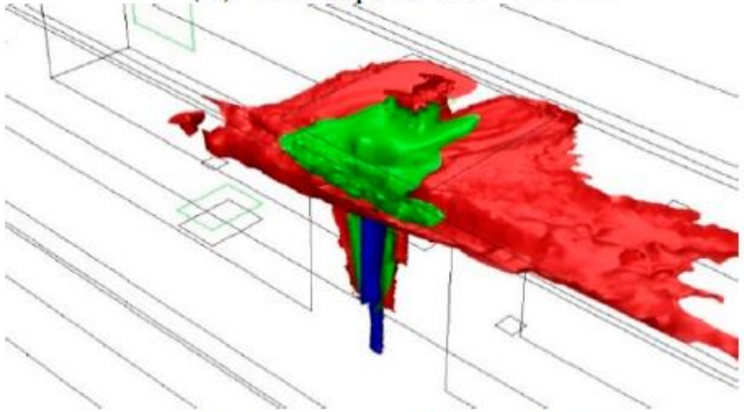
(**a**) Vent closed, T_{act} = 68 °C



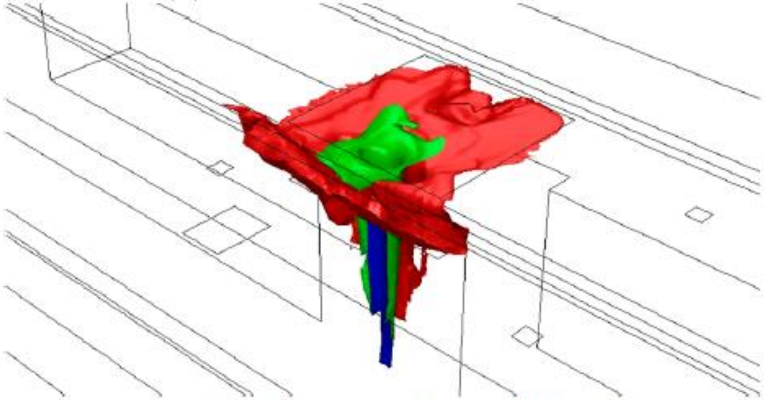
(**b**) Vent open, T_{act} = 68 °C



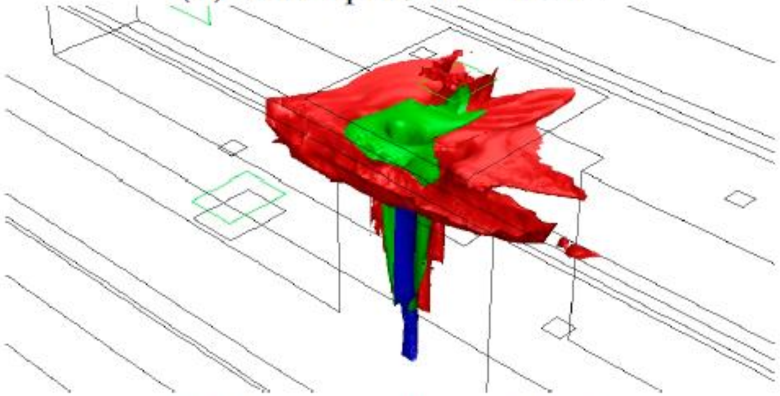
(**c**) Vent closed, T_{act} = 92 °C



(**d**) Vent open, T_{act} = 92 °C



(**e**) Vent closed, T_{act} = 141 °C



(**f**) Vent open, T_{act} = 141 °C

THANK YOU

Questions?

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