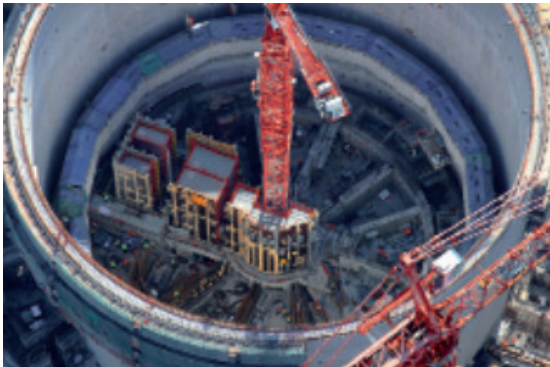
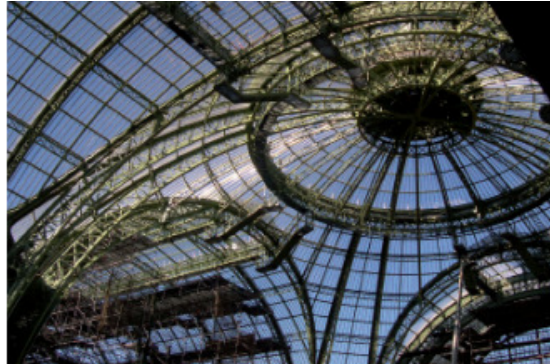


# Kitimat Modernization Project

## Fire modeling of the winterized roads





- **Presentation of setec tpi and Equipments & Safety Hub**
- **Context and objectives**
- **1<sup>st</sup> part: Analysis of survival conditions for workers**
  - Determination of HRR
  - Fire modeling within the winterized roads – FDS software use
  - Results of survival conditions
- **2<sup>nd</sup> part: Thermal solicitations and behavior of the structure**
  - Temperature within steelworks
  - Behavior of steel structure – Pythagore software use
- **Conclusion**





# Presentation of Setec tpi

KMP – Fire modeling of the winterized roads

# Presentation of setec tpi and Equipments & Safety Hub

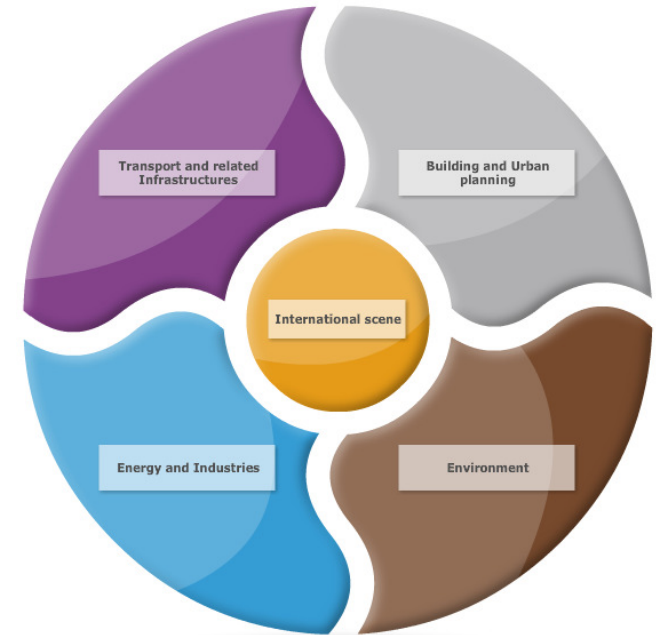


## Setec group:

- French engineering firm (~ 2400 employees)
- More than 40 companies in France and abroad, specialised in different professions

## Setec tpi:

- Specialised in civil engineering
- Various technical departments : transport infrastructure, underground structures, complex buildings, industrial facilities...



## Equipments & Safety Hub

- Engineers and experts in electromechanical, electrical and electronical equipments and in ***Security and safety of road or railroad infrastructures***
- Use of Specific softwares (emergency evacuation in large structures, aerodynamic and thermodynamic phenomena in underground structures)

KMP – Fire modeling of the winterized roads



# Context and objectives

KMP – Fire modeling of the winterized roads



## Context

- Aluminium production plant building in British Columbia with fully enclosed winterized roads
  - Road tunnels
- Fire loss experience: Mainly diesel-powered vehicles for potrooms operations involved
- No fire risk assessment with fire modeling

## Objectives

- Use CFD modeling to determine survival conditions within the winterized roads
- Estimate the behavior of the structure during a fire involving diesel-powered vehicles
- Make recommendations for the possible modification to the design of the winterized roads



## → Fire safety engineering

KMP – Fire modeling of the winterized roads



# 1<sup>st</sup> part: Analysis of survival conditions for workers

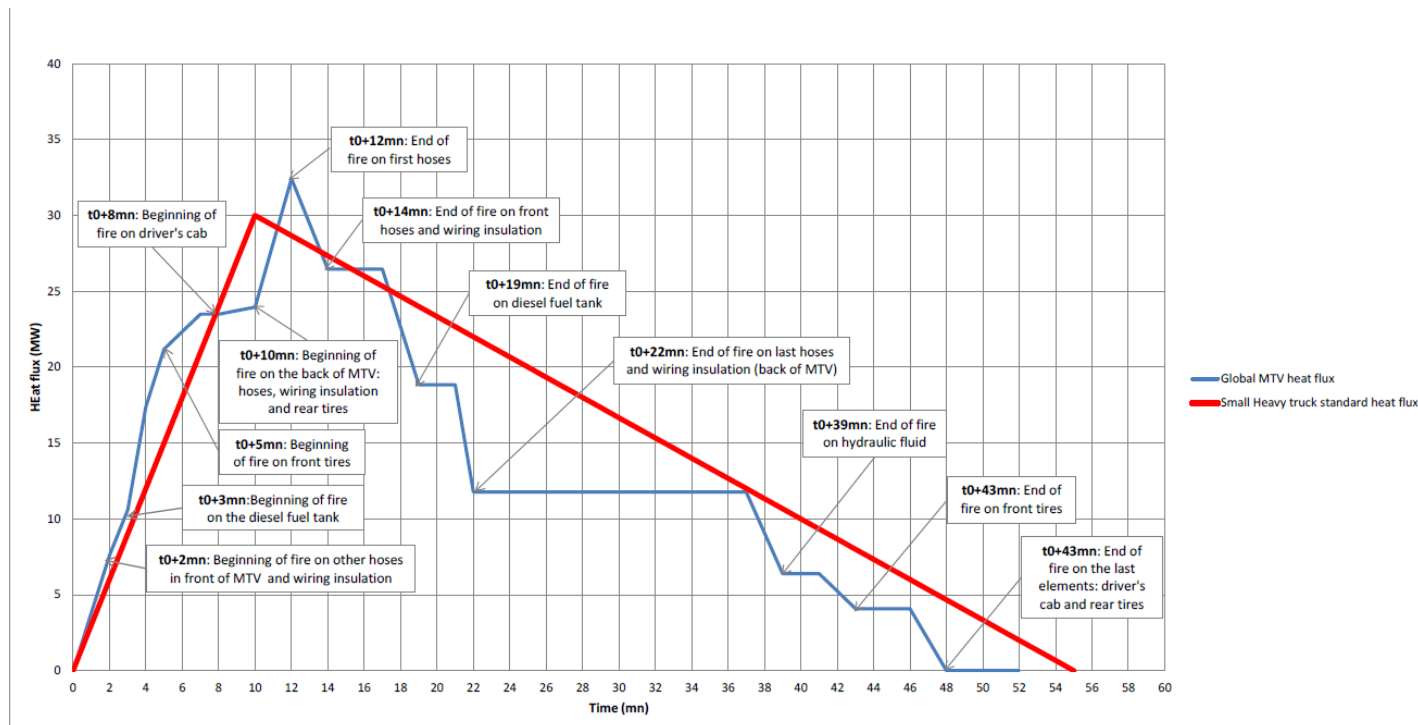
KMP – Fire modeling of the winterized roads

# 1<sup>st</sup> part: Analysis of survival conditions for workers



## Determination of HRR

- Analysis of vehicles heat load (inventory of vehicle components given by the client)
- Determination of a realistic scenario for a fire on the vehicle with the higher HRR (Setec experience on industrial vehicles fires studies and Client Society experience on its own vehicles fires)



KMP – Fire modeling of the winterized roads

# 1<sup>st</sup> part: Analysis of survival conditions for workers



## Fire modeling within the winterized roads

- Software: Fire Dynamics Simulator (FDS) version 5.5.3
- Determination of modeling parameters:
  - Global HRR :
    - 1 vehicle in fire → 30 MW peak after 10 mn of fire development
    - 2 vehicles successively in fire → 56 MW peak after 15 mn of fire development (spread of fire 1<sup>st</sup> → 2<sup>nd</sup> vehicle after 5 mn)
  - Combustion model : polyurethane fire with soot and CO production
  - Material characteristics: floor and road in concrete, wall in concrete on 1m height and cladding aluminium above, roof in aluminium and steelwork.
  - External temperature: summer conditions (~ 31 °C) and mild winter conditions (~ 0 °C)
  - 1st case of scenarios : no evolution of geometry with thermal modifications within the winterized roads

- 4 scenarios

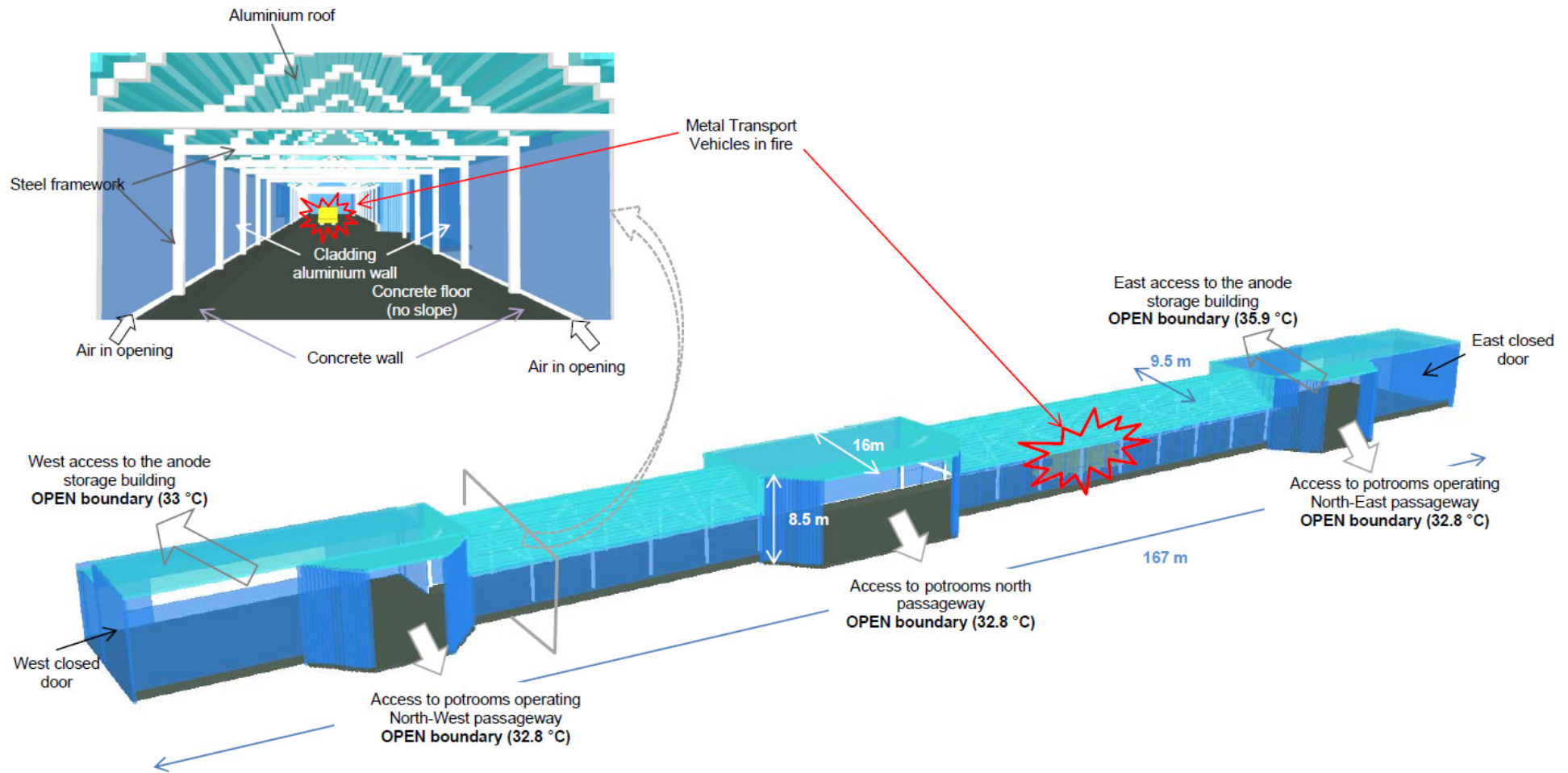
| SCENARIO | METEOROLOGICAL CONDITIONS | NUMBER OF VEHICLES INVOLVED IN FIRE |
|----------|---------------------------|-------------------------------------|
| 1        | Soft winter (0 °C)        | 1                                   |
| 2        |                           | 2                                   |
| 3        | Summer (31 °C)            | 1                                   |
| 4        |                           | 2                                   |

KMP – Fire modeling of the winterized roads

# 1<sup>st</sup> part: Analysis of survival conditions for workers



## Fire modeling within the winterized roads



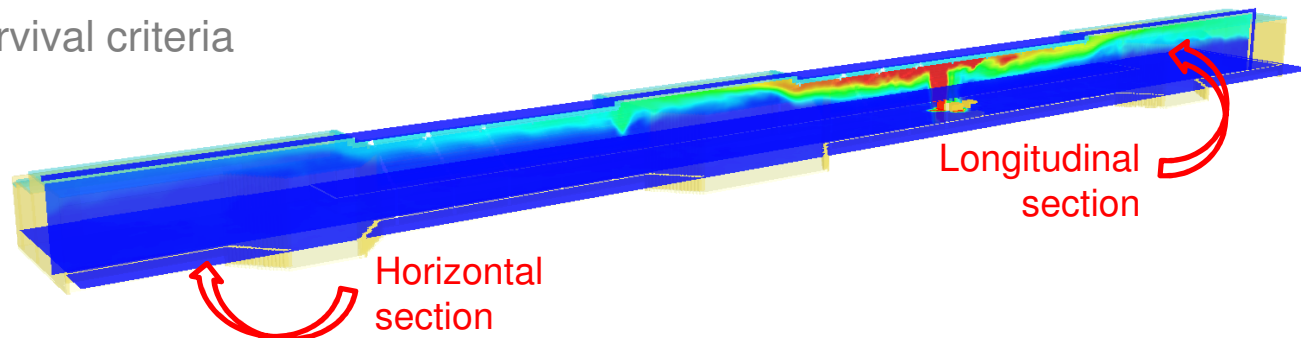
KMP – Fire modeling of the winterized roads

# 1<sup>st</sup> part: Analysis of survival conditions for workers



## Fire modeling within the winterized roads

- Output data and performance criteria from French standards (for information) :
  - smoke evolution,
  - Visibility (m) :
    - $V > 20 \text{ m} \rightarrow \text{speed walk} = 1 \text{ m/s}$
    - $5 < V < 20 \text{ m} \rightarrow \text{speed walk} = 0.5 \text{ m/s}$
    - $V < 5 \text{ m} \rightarrow \text{speed walk} = 0.3 \text{ m/s}$
  - Temperature ( $^{\circ}\text{C}$ ) : acceptable exposure time at  $80^{\circ}\text{C}$  :  $\sim 15 \text{ mn}$
  - CO toxicity (ppm): acceptable exposure time : 60 mn at 500 ppm  $\rightarrow$  10 mn at 3000 ppm
  - Thermal radiation ( $\text{kW/m}^2$ ): non-equipped people: 10 mn at  $2 \text{ kW/m}^2$  and equipped firefighter : 10 mn at  $5 \text{ kW/m}^2$
- Graphics sections: horizontal (1.75m high) and longitudinal (place of fire)
- Scales: survival criteria



KMP – Fire modeling of the winterized roads

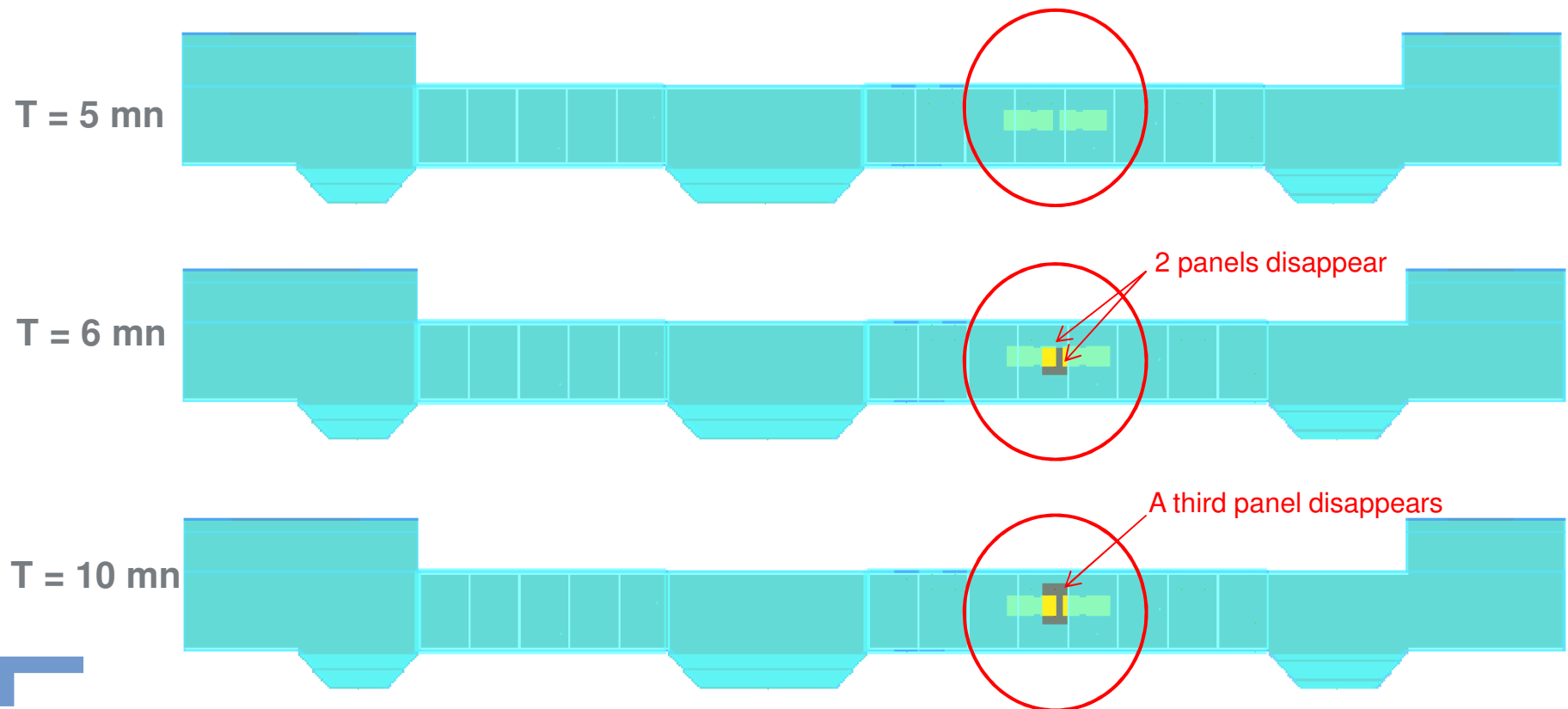
## 1<sup>st</sup> part: Analysis of survival conditions for workers



### Results of survival conditions

→ worst case: scenario 4 (summer external conditions with 2 vehicles in fire)

- 1<sup>st</sup> case : No evolution of geometry during the fire development
- 2<sup>nd</sup> case : Evolution of geometry with disappearance of aluminium panels in the roof when the melting point is reached (607 °C)



KMP – Fire modeling of the winterized roads

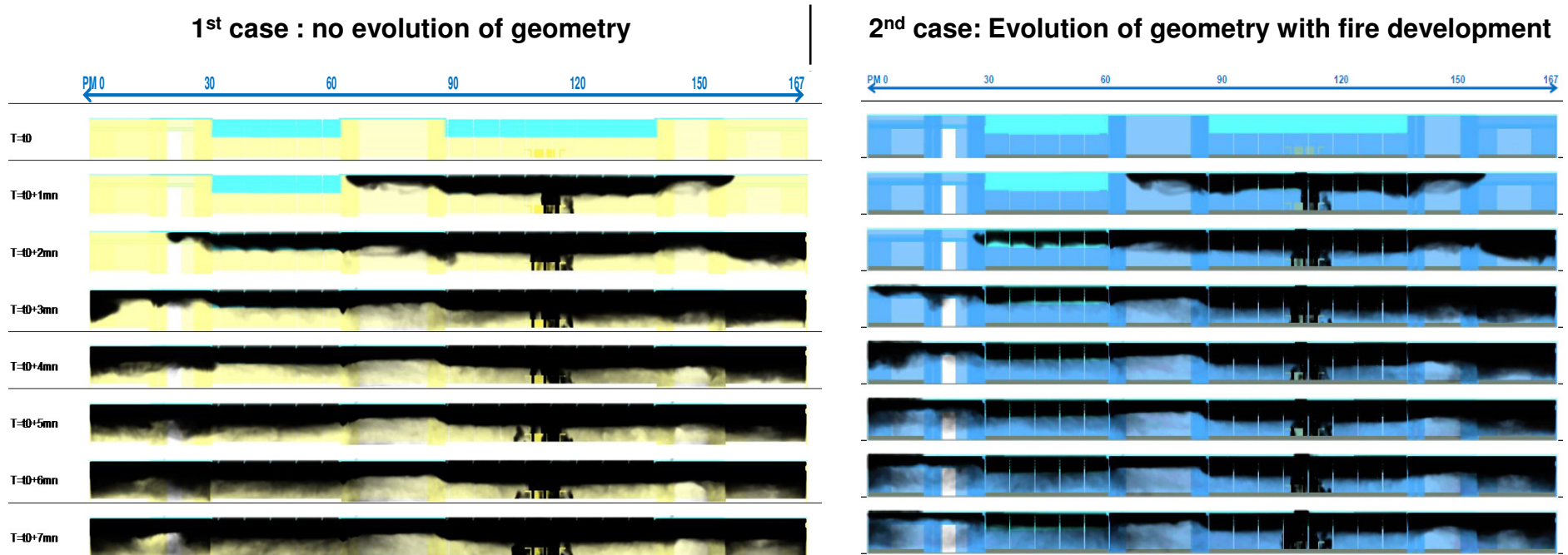
# 1<sup>st</sup> part: Analysis of survival conditions for workers



## Results of survival conditions

→ worst case: scenario 4 (summer external conditions with 2 vehicles in fire)

### Smoke evolution



KMP – Fire modeling of the winterized roads

# 1<sup>st</sup> part: Analysis of survival conditions for workers



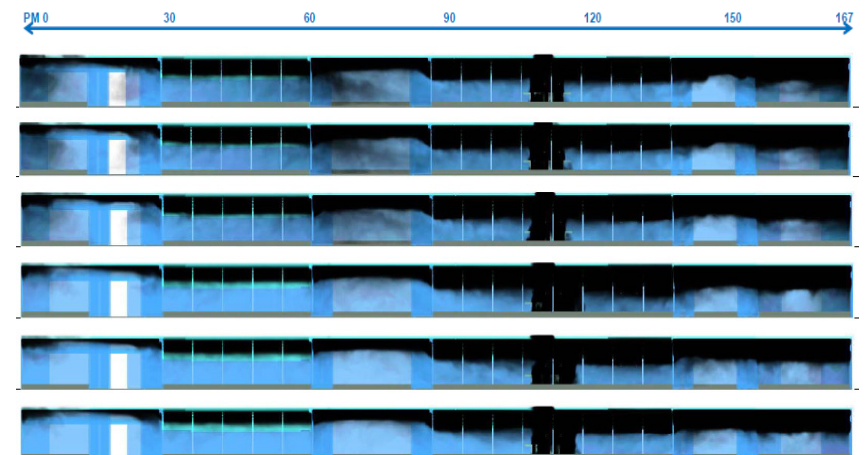
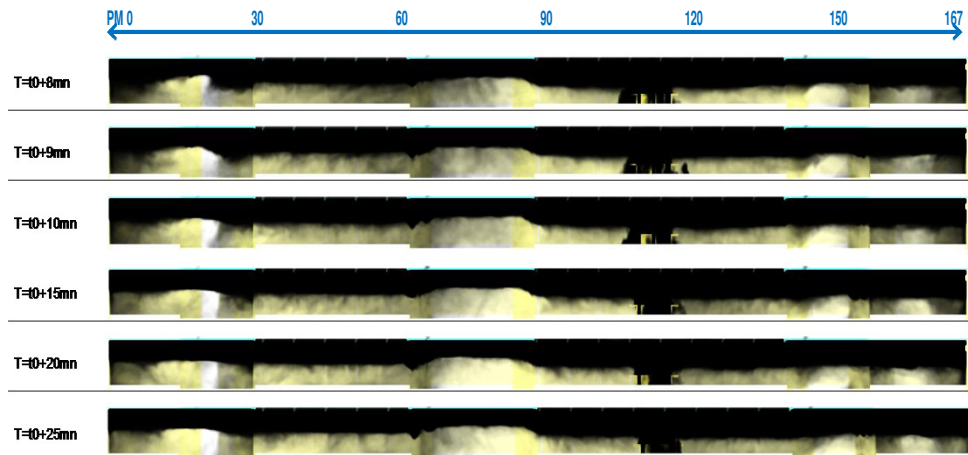
## Results of survival conditions

→ worst case: scenario 4 (summer external conditions with 2 vehicles in fire)

### Smoke evolution

**1<sup>st</sup> case : no evolution of geometry**

**2<sup>nd</sup> case: Evolution of geometry with fire development**



KMP – Fire modeling of the winterized roads

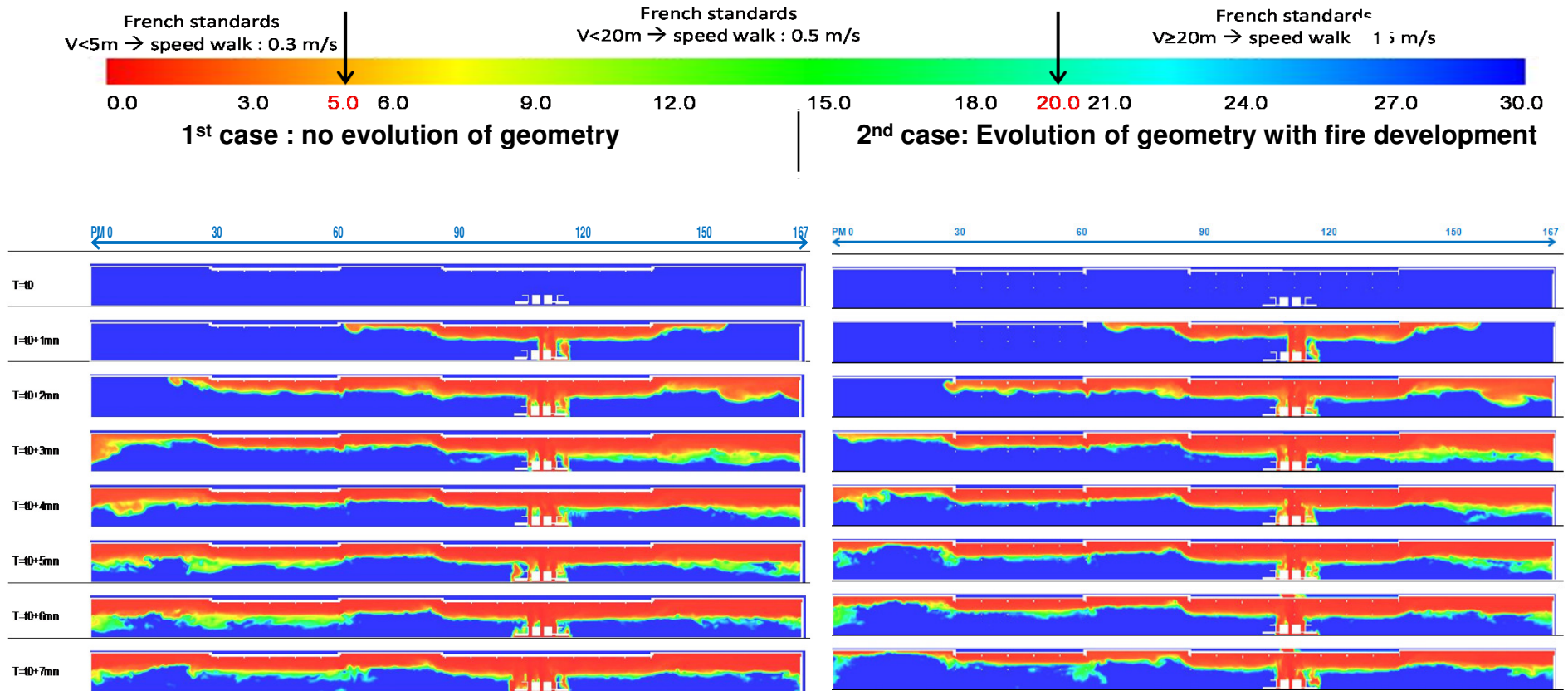
# 1<sup>st</sup> part: Analysis of survival conditions for workers



## Results of survival conditions

→ worst case: scenario 4 (summer external conditions with 2 vehicles in fire)

### Visibility (m) – Longitudinal sections



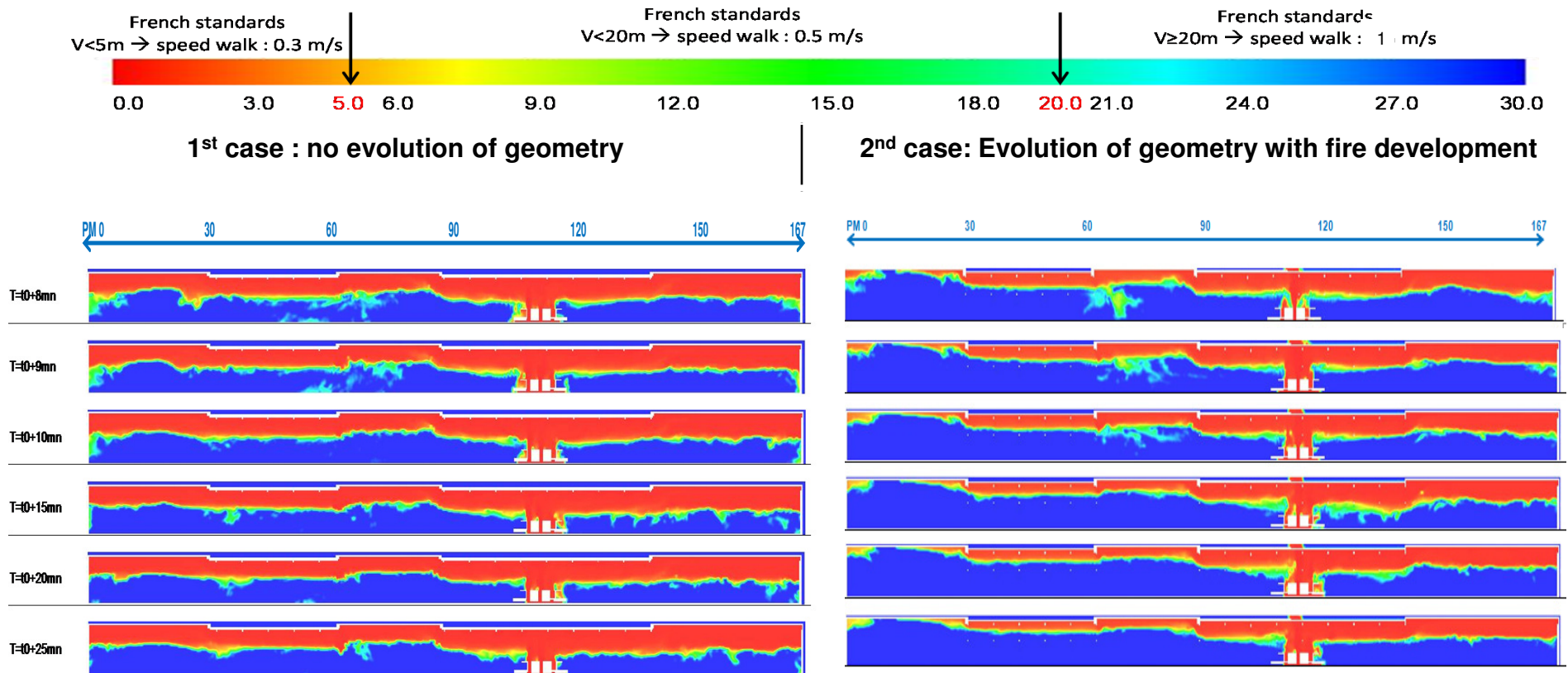
# 1<sup>st</sup> part: Analysis of survival conditions for workers



## Results of survival conditions

→ worst case: scenario 4 (summer external conditions with 2 vehicles in fire)

### Visibility (m) – Longitudinal sections



KMP – Fire modeling of the winterized roads

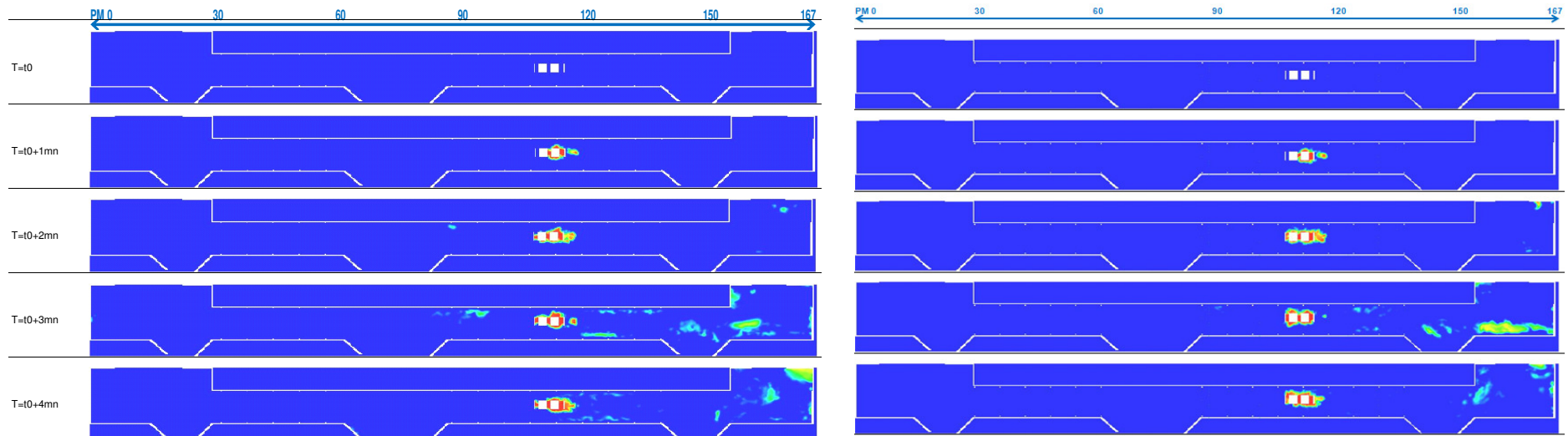
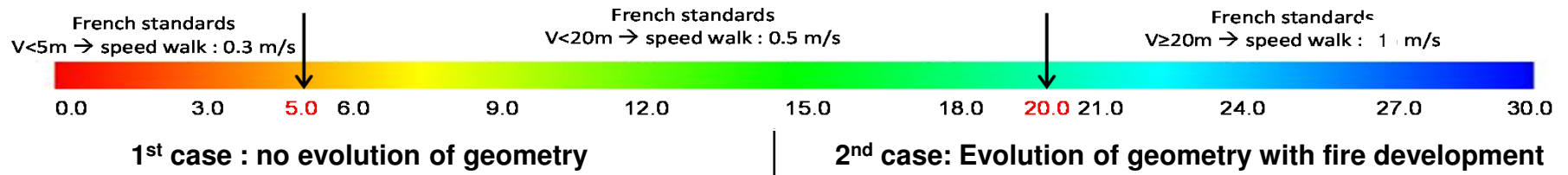
# 1<sup>st</sup> part: Analysis of survival conditions for workers



## Results of survival conditions

→ worst case: scenario 4 (summer external conditions with 2 vehicles in fire)

### Visibility (m) – Horizontal sections (1.75m high)



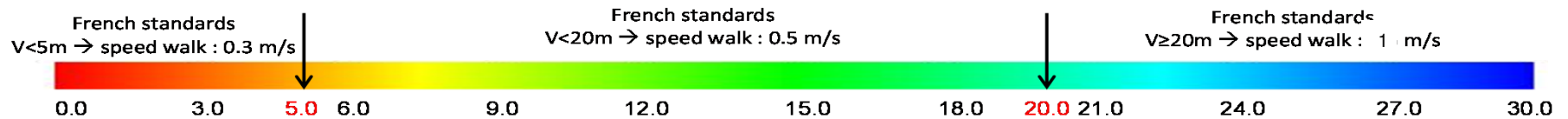
# 1<sup>st</sup> part: Analysis of survival conditions for workers



## Results of survival conditions

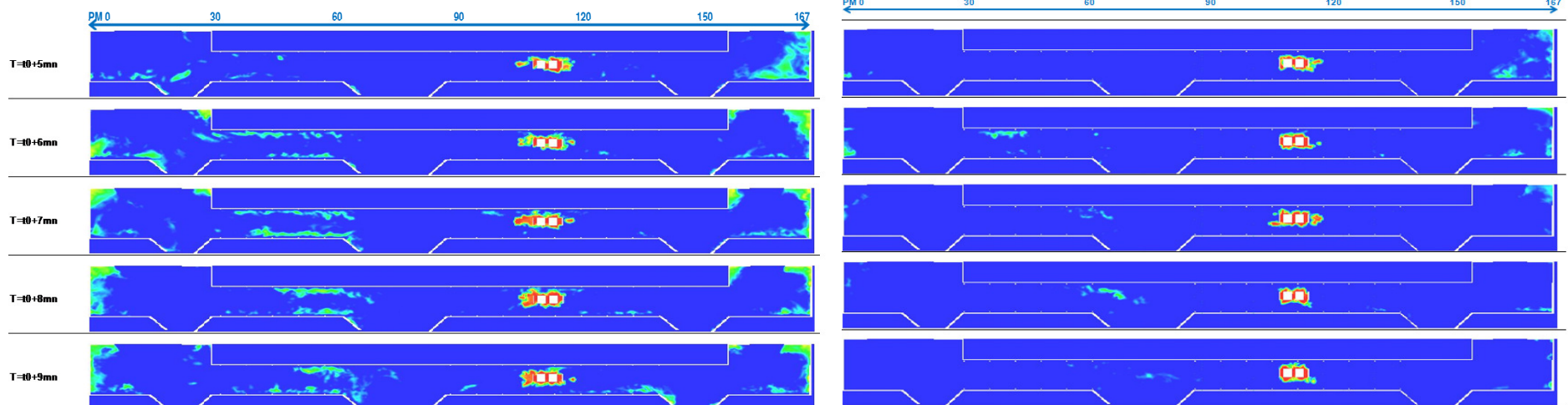
→ worst case: scenario 4 (summer external conditions with 2 vehicles in fire)

### Visibility (m) – Horizontal sections (1.75m high)



1<sup>st</sup> case : no evolution of geometry

2<sup>nd</sup> case: Evolution of geometry with fire development



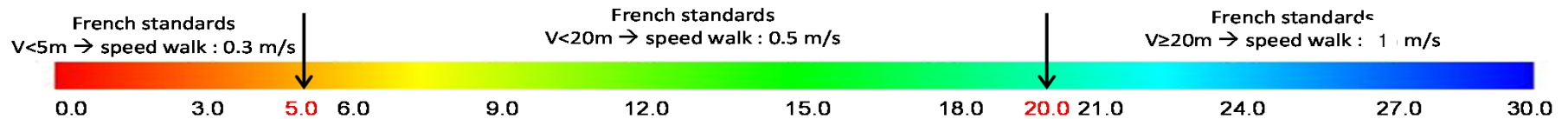
# 1<sup>st</sup> part: Analysis of survival conditions for workers



## Results of survival conditions

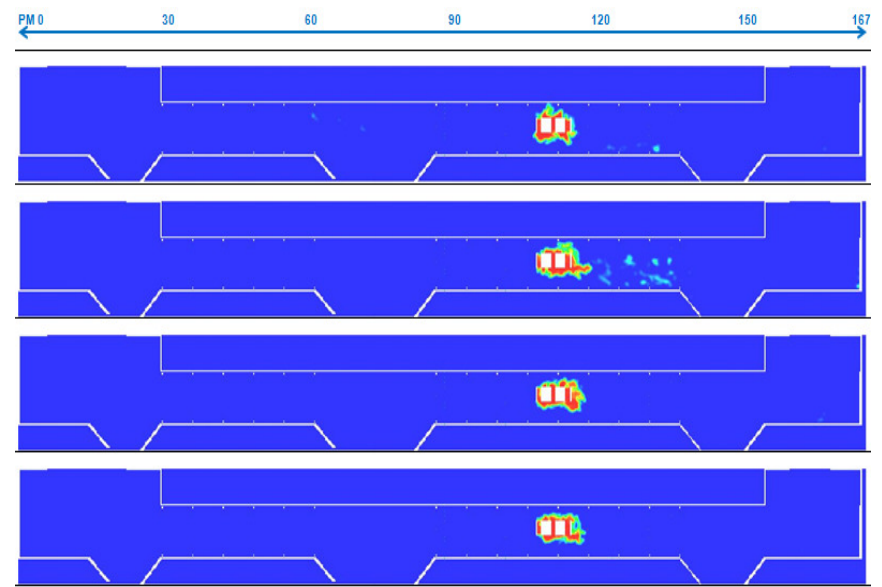
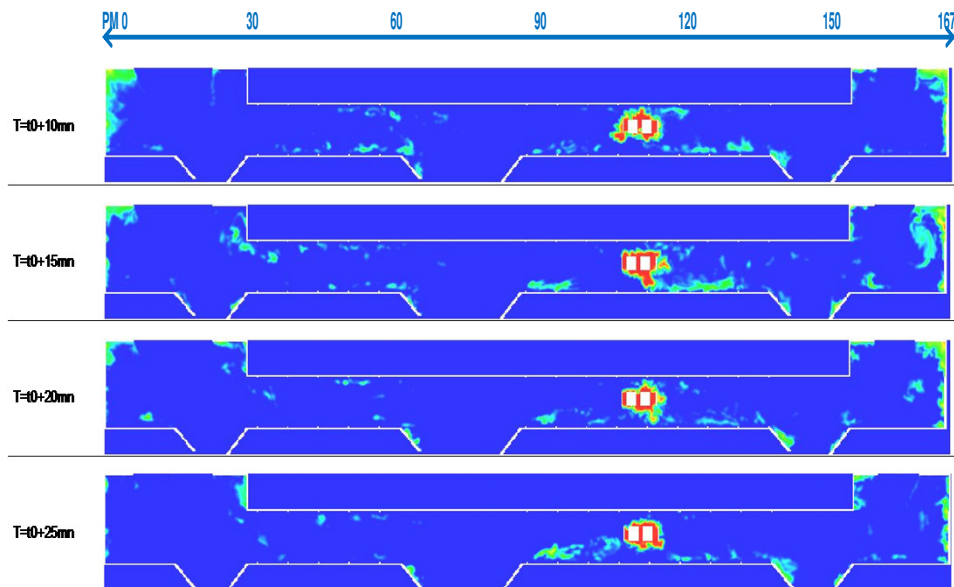
→ worst case: scenario 4 (summer external conditions with 2 vehicles in fire)

### Visibility (m) – Horizontal sections (1.75m high)



#### 1<sup>st</sup> case : no evolution of geometry

#### 2<sup>nd</sup> case: Evolution of geometry with fire development



KMP – Fire modeling of the winterized roads

# 1<sup>st</sup> part: Analysis of survival conditions for workers



## Results of survival conditions

→ worst case: scenario 4 (summer external conditions with 2 vehicles in fire)

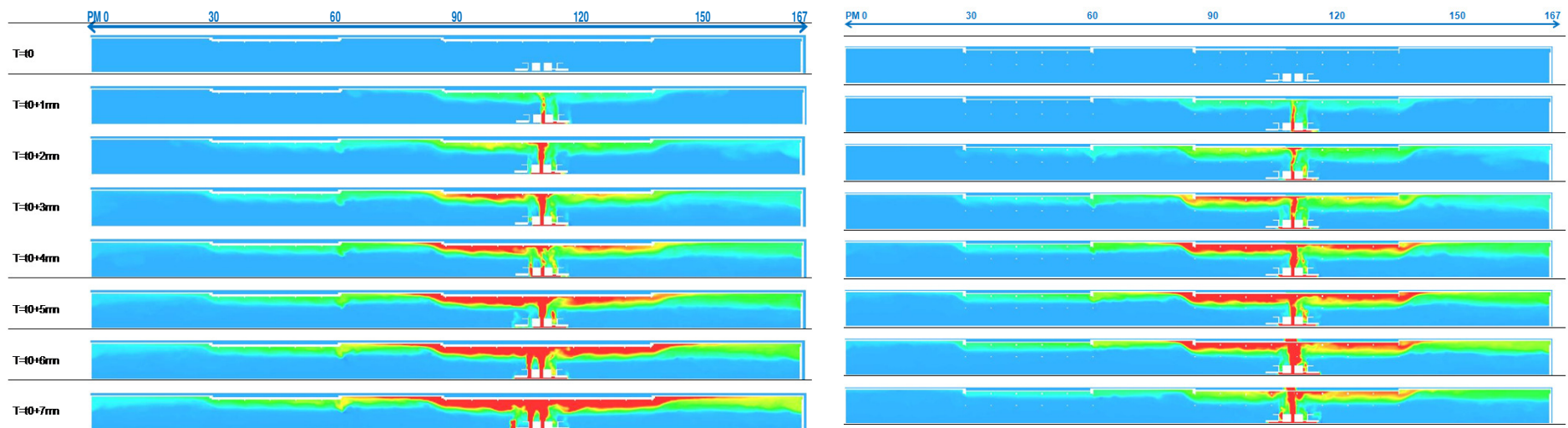
### Temperature (°C) – Longitudinal sections

French standards  
Acceptable exposure time at  
80°C: 15 mn



1<sup>st</sup> case : no evolution of geometry

2<sup>nd</sup> case: Evolution of geometry with fire development



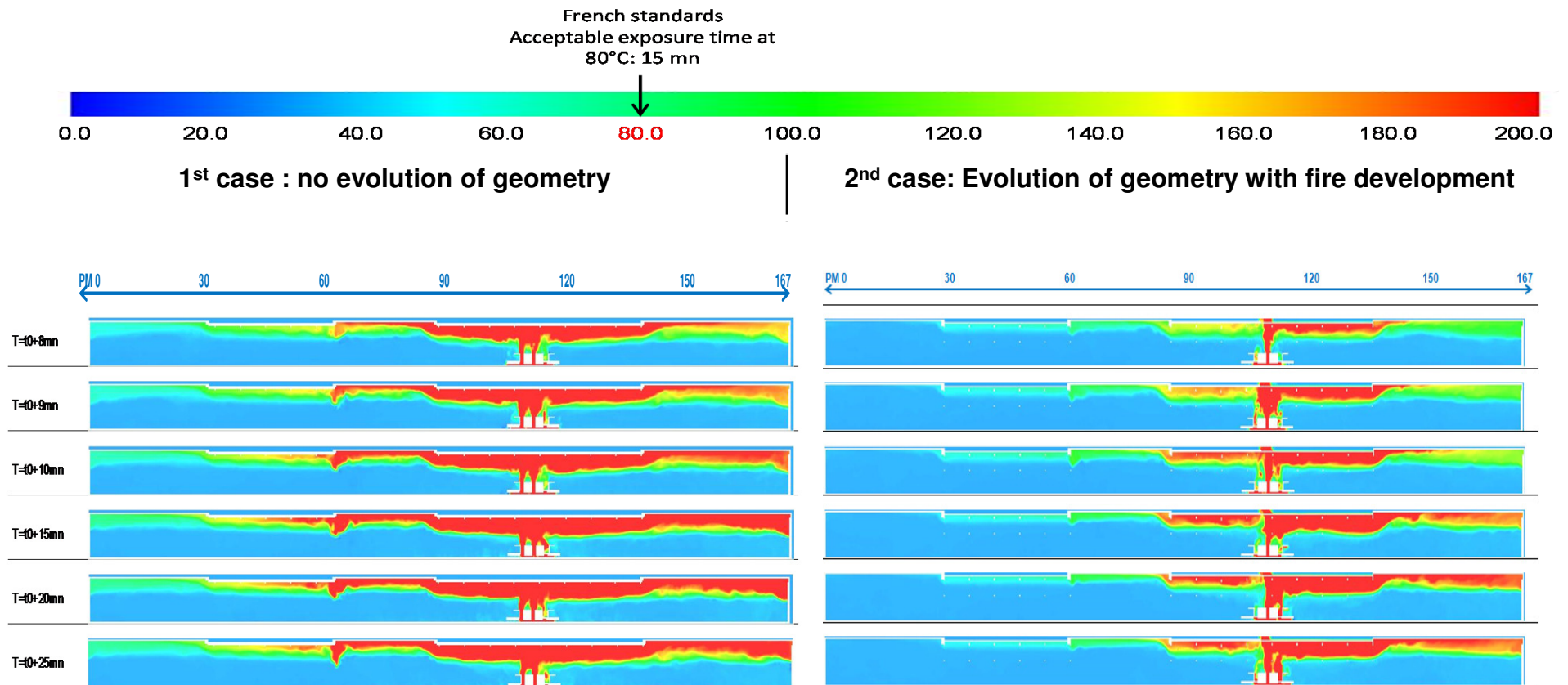
# 1<sup>st</sup> part: Analysis of survival conditions for workers



## Results of survival conditions

→ worst case: scenario 4 (summer external conditions with 2 vehicles in fire)

### Temperature (°C) – Longitudinal sections



KMP – Fire modeling of the winterized roads

# 1<sup>st</sup> part: Analysis of survival conditions for workers



## Results of survival conditions

→ worst case: scenario 4 (summer external conditions with 2 vehicles in fire)

### Temperature (°C) – Horizontal sections (1.75m high)

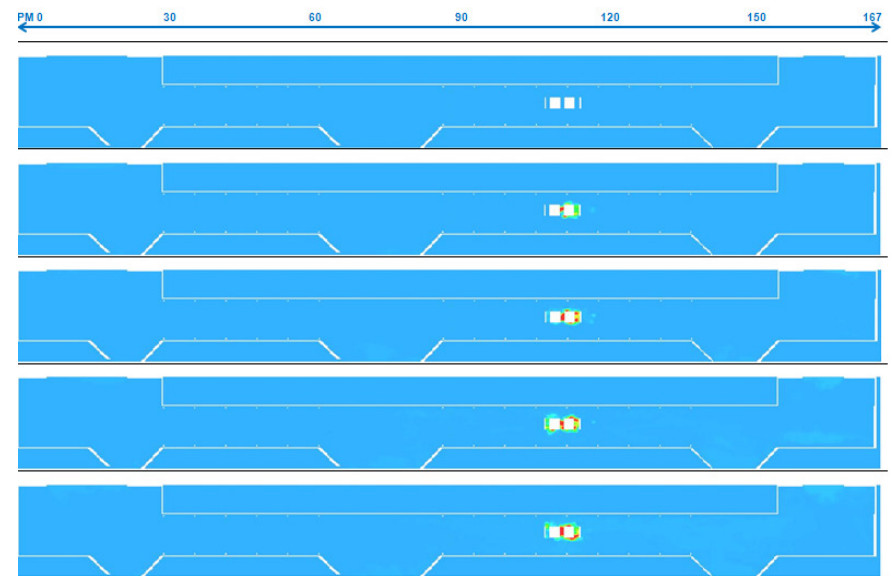
French standards  
Acceptable exposure time at  
80°C: 15 mn



#### 1<sup>st</sup> case : no evolution of geometry



#### 2<sup>nd</sup> case: Evolution of geometry with fire development



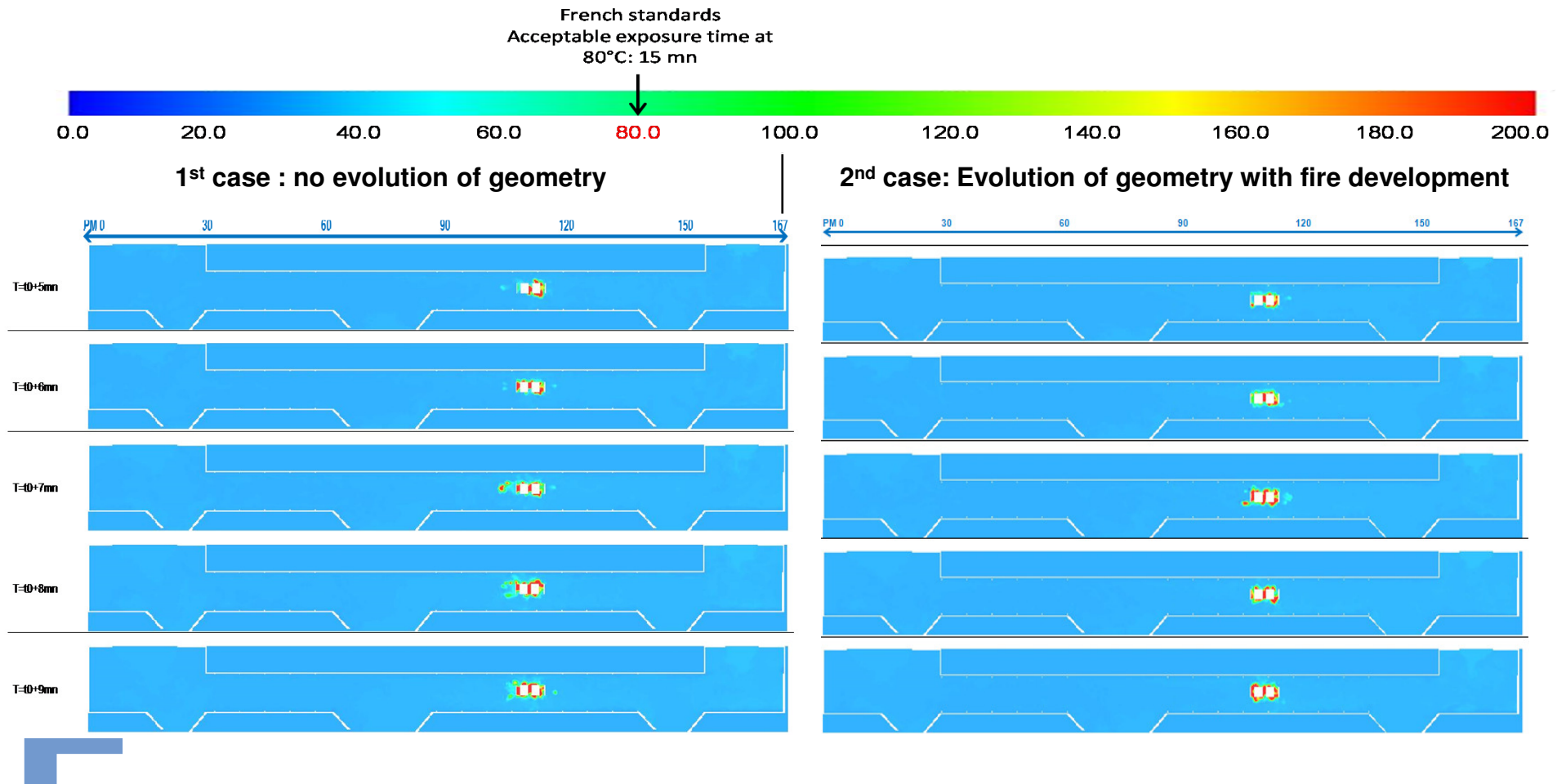
# 1<sup>st</sup> part: Analysis of survival conditions for workers



## Results of survival conditions

→ worst case: scenario 4 (summer external conditions with 2 vehicles in fire)

### Temperature (°C) – Horizontal sections (1.75m high)



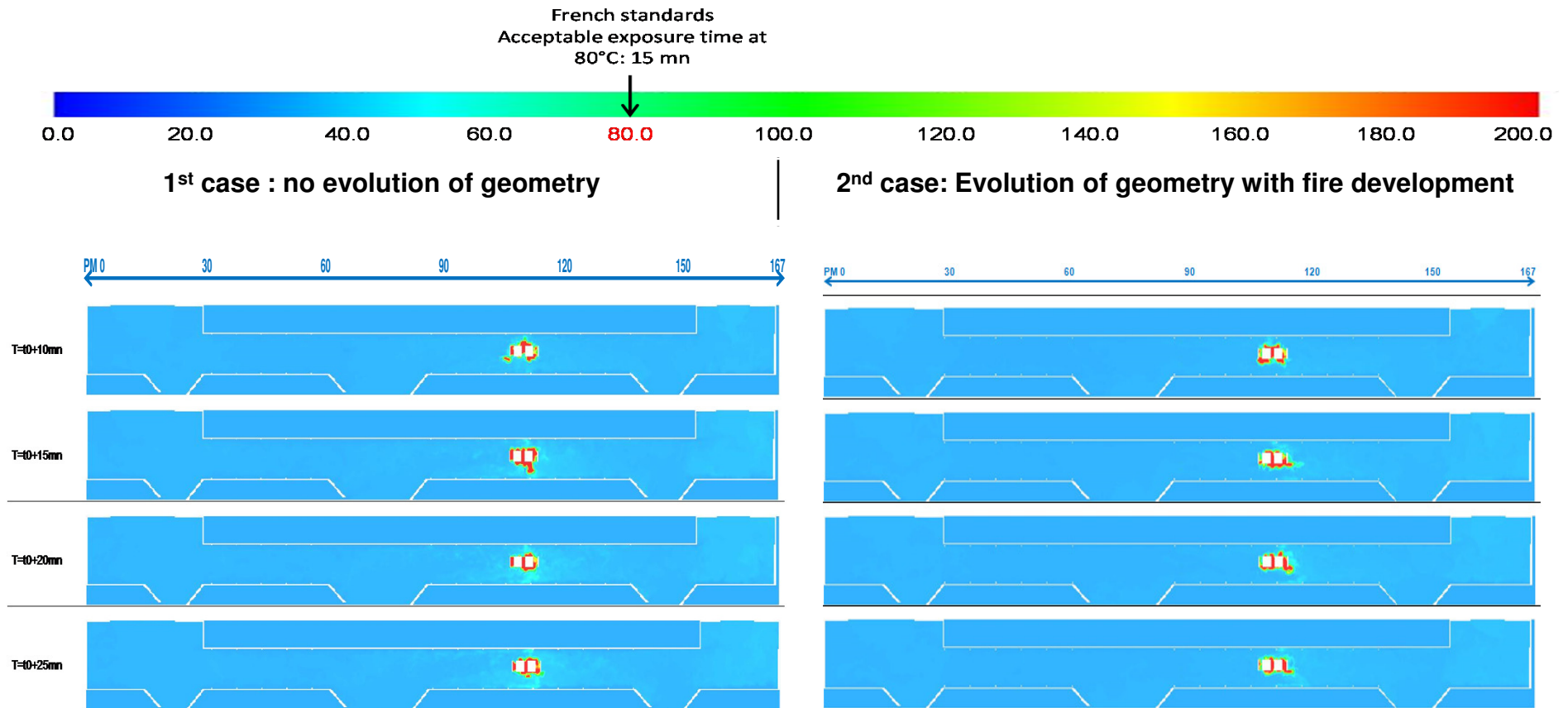
# 1<sup>st</sup> part: Analysis of survival conditions for workers



## Results of survival conditions

→ worst case: scenario 4 (summer external conditions with 2 vehicles in fire)

### Temperature (°C) – Horizontal sections (1.75m high)



KMP – Fire modeling of the winterized roads

# 1<sup>st</sup> part: Analysis of survival conditions for workers

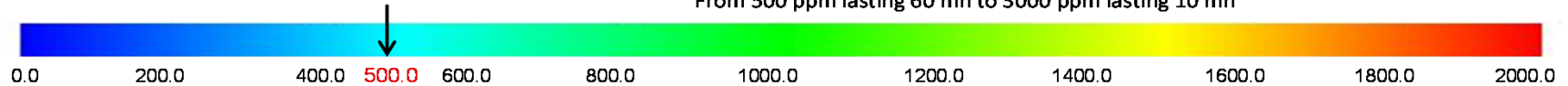


## Results of survival conditions

→ worst case: scenario 4 (summer external conditions with 2 vehicles in fire)

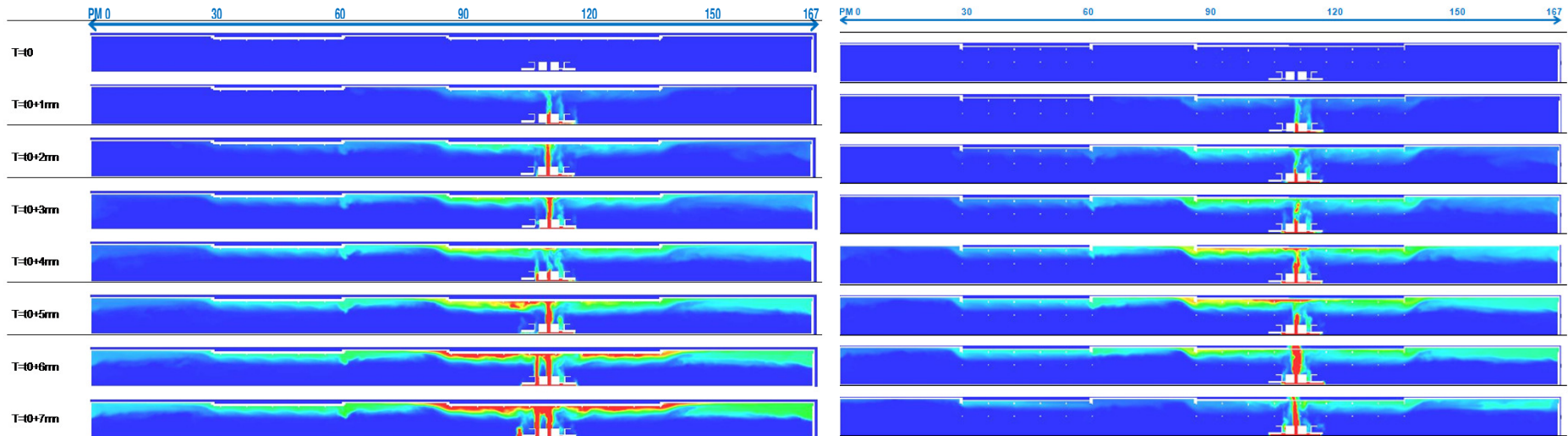
### CO toxicity (ppm)– Longitudinal sections

French standards  
Acceptable exposure time  
From 500 ppm lasting 60 mn to 3000 ppm lasting 10 mn



1<sup>st</sup> case : no evolution of geometry

2<sup>nd</sup> case: Evolution of geometry with fire development



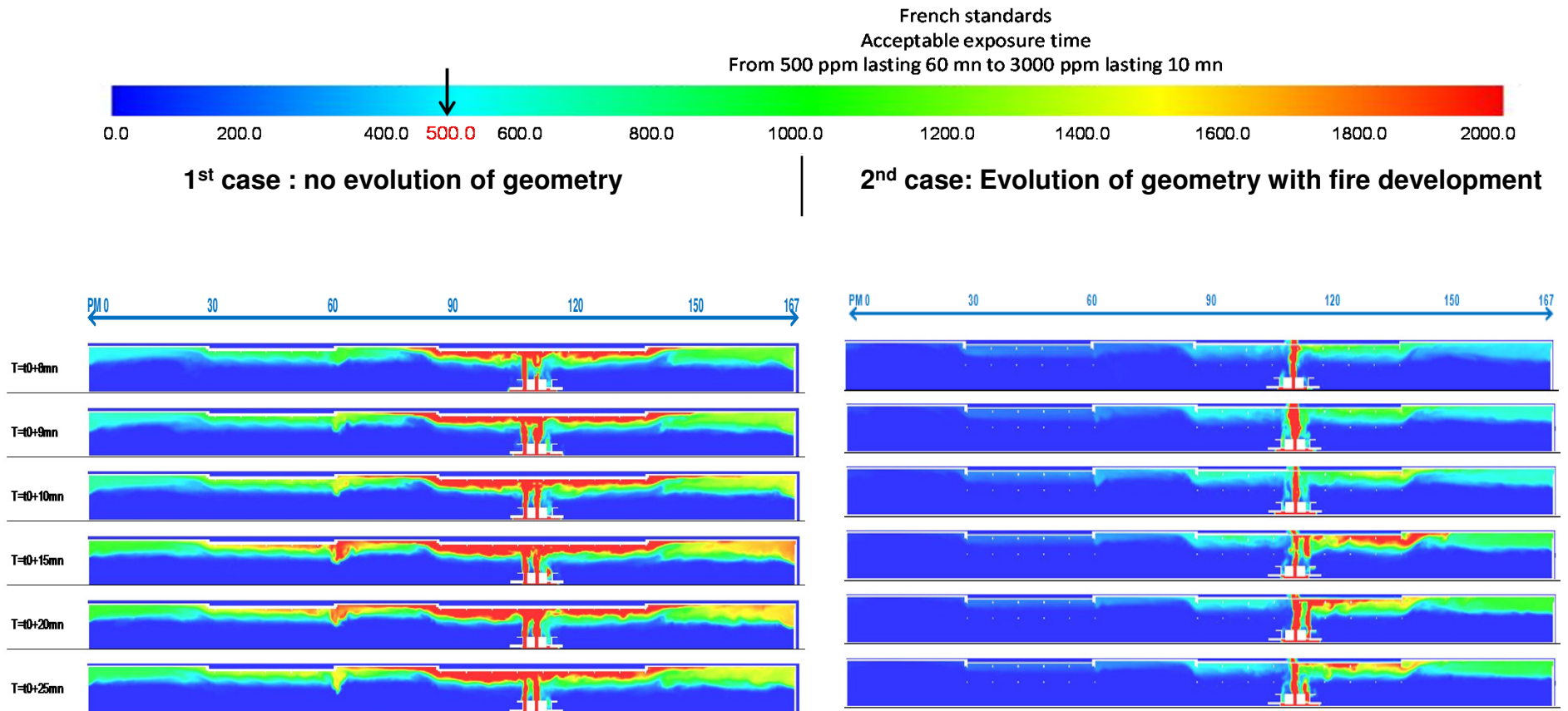
# 1<sup>st</sup> part: Analysis of survival conditions for workers



## Results of survival conditions

→ worst case: scenario 4 (summer external conditions with 2 vehicles in fire)

### CO toxicity (ppm)– Longitudinal sections



KMP – Fire modeling of the winterized roads

# 1<sup>st</sup> part: Analysis of survival conditions for workers

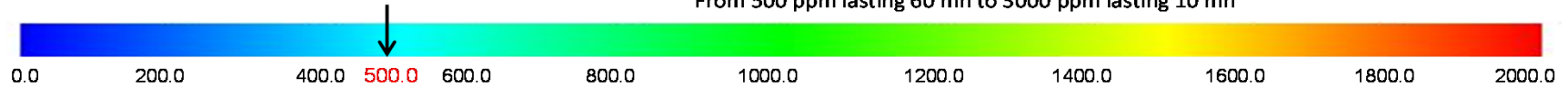


## Results of survival conditions

→ worst case: scenario 4 (summer external conditions with 2 vehicles in fire)

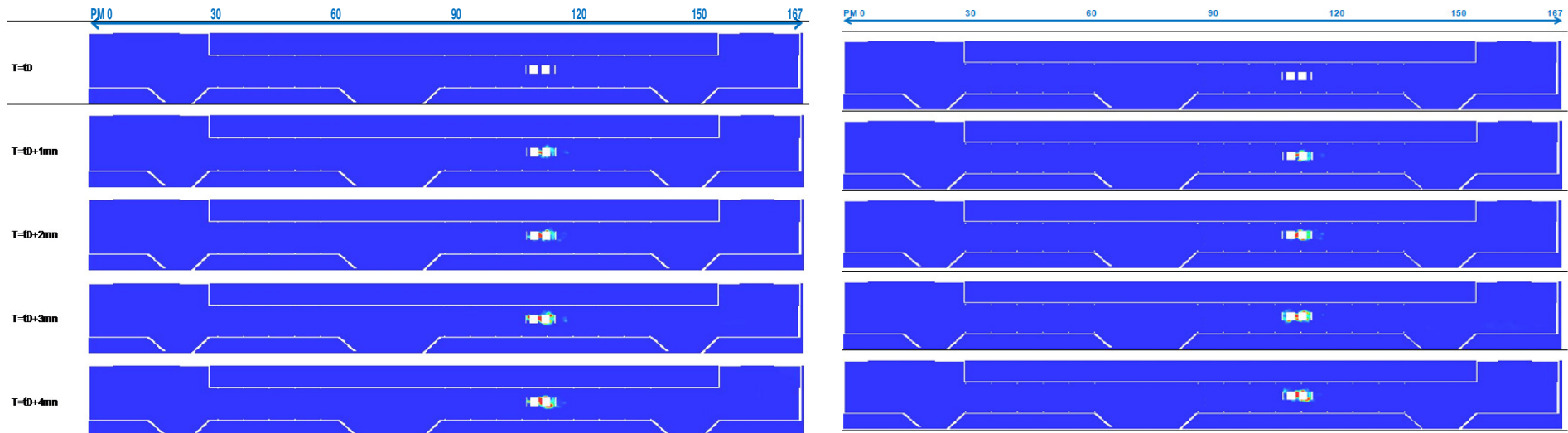
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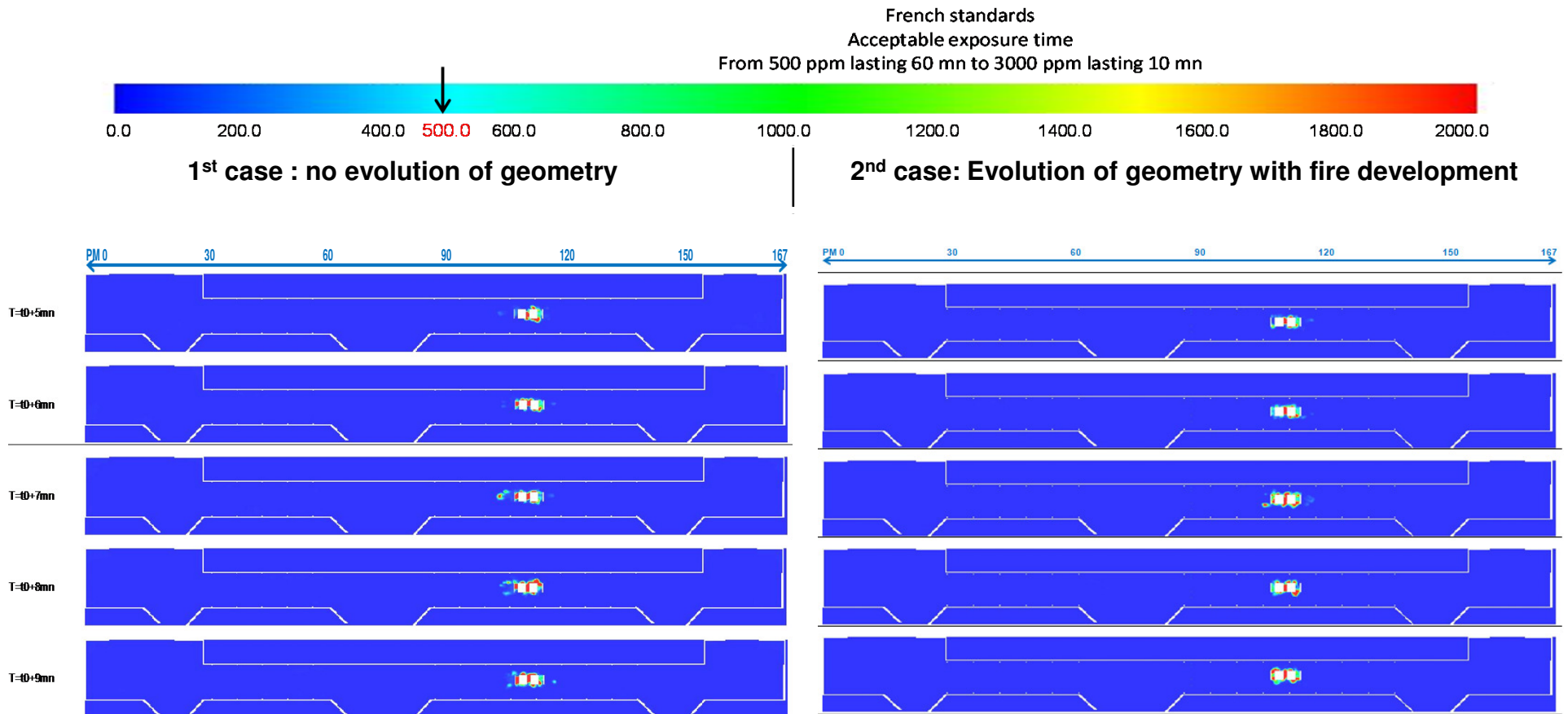
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## Results of survival conditions

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### CO toxicity (ppm)– Horizontal sections (1.75m high)



# 1<sup>st</sup> part: Analysis of survival conditions for workers

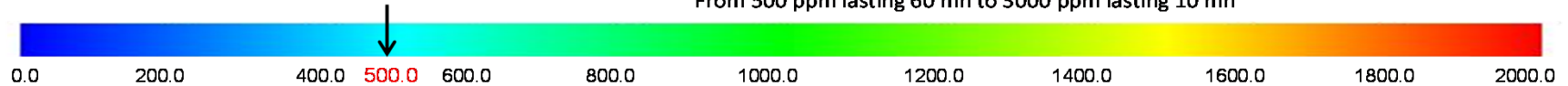


## Results of survival conditions

→ worst case: scenario 4 (summer external conditions with 2 vehicles in fire)

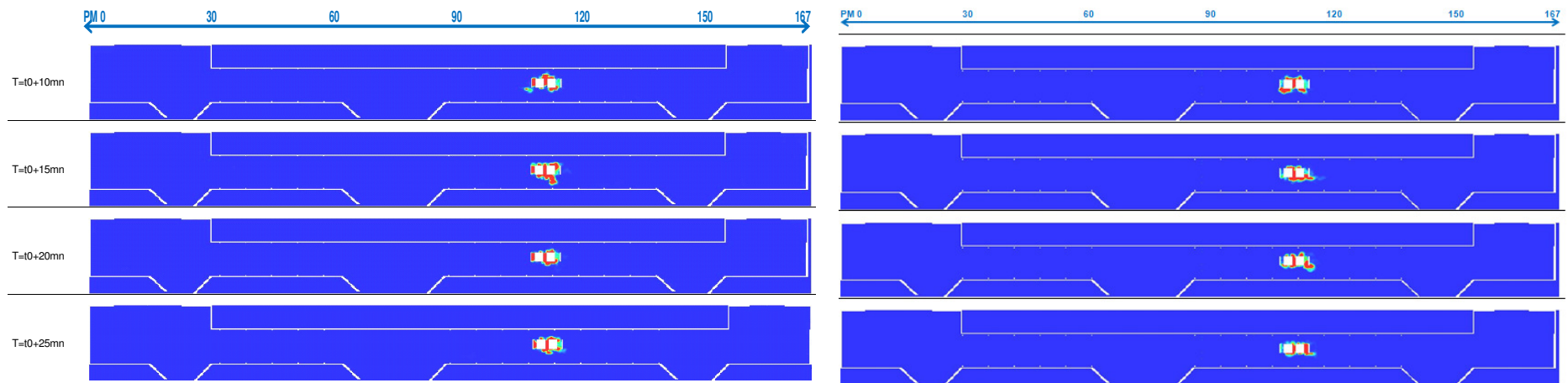
### CO toxicity (ppm)– Horizontal sections (1.75m high)

French standards  
Acceptable exposure time  
From 500 ppm lasting 60 mn to 3000 ppm lasting 10 mn



1<sup>st</sup> case : no evolution of geometry

2<sup>nd</sup> case: Evolution of geometry with fire development



KMP – Fire modeling of the winterized roads

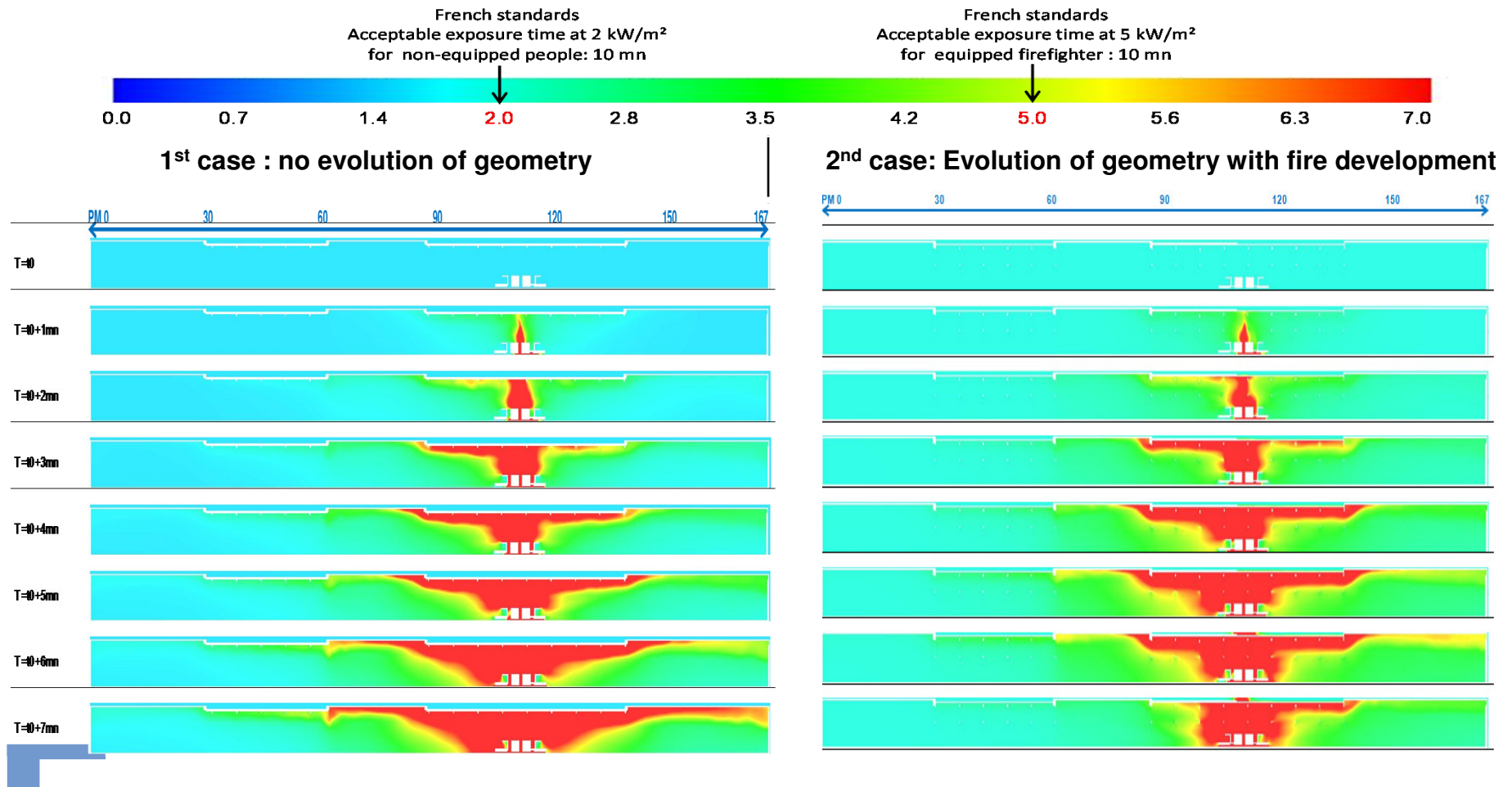
# 1<sup>st</sup> part: Analysis of survival conditions for workers



## Results of survival conditions

→ worst case: scenario 4 (summer external conditions with 2 vehicles in fire)

### Thermal radiation (KW/m<sup>2</sup>)– Longitudinal sections



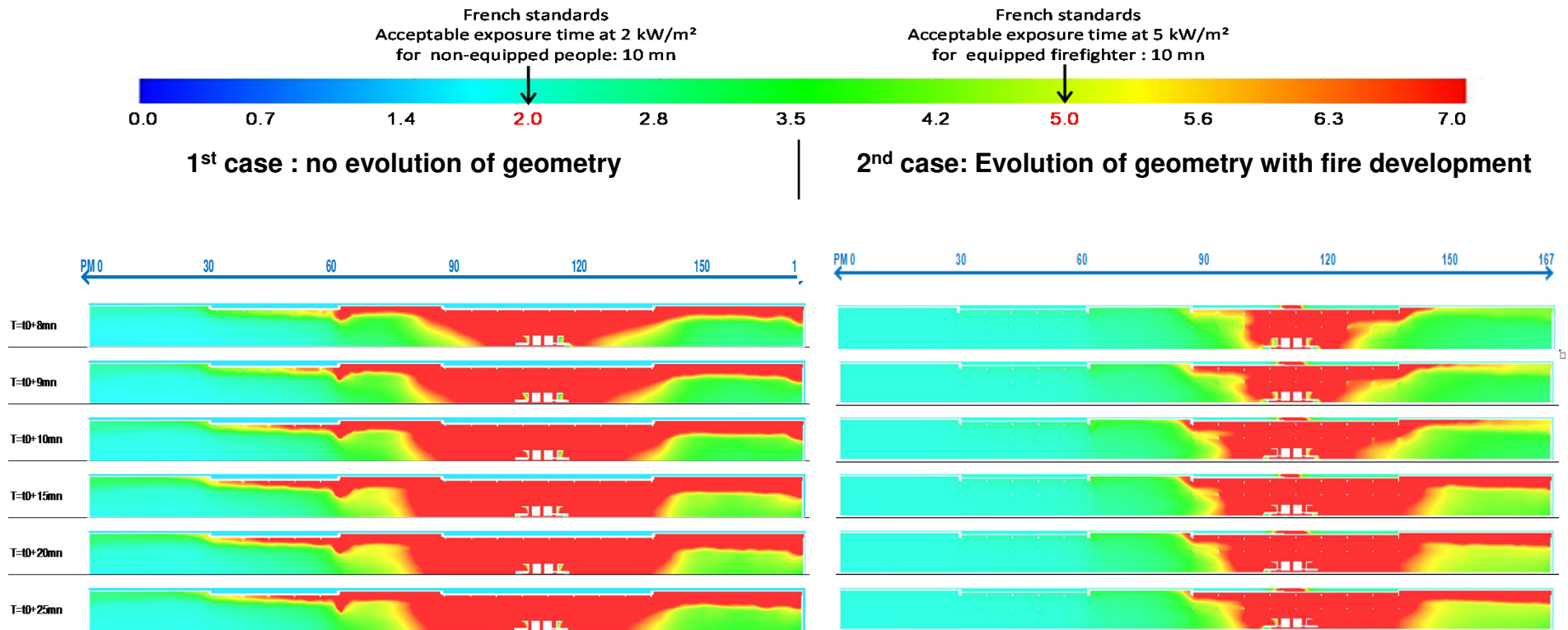
# 1<sup>st</sup> part: Analysis of survival conditions for workers



## Results of survival conditions

→ worst case: scenario 4 (summer external conditions with 2 vehicles in fire)

### Thermal radiation (KW/m<sup>2</sup>)– Longitudinal sections



KMP – Fire modeling of the winterized roads

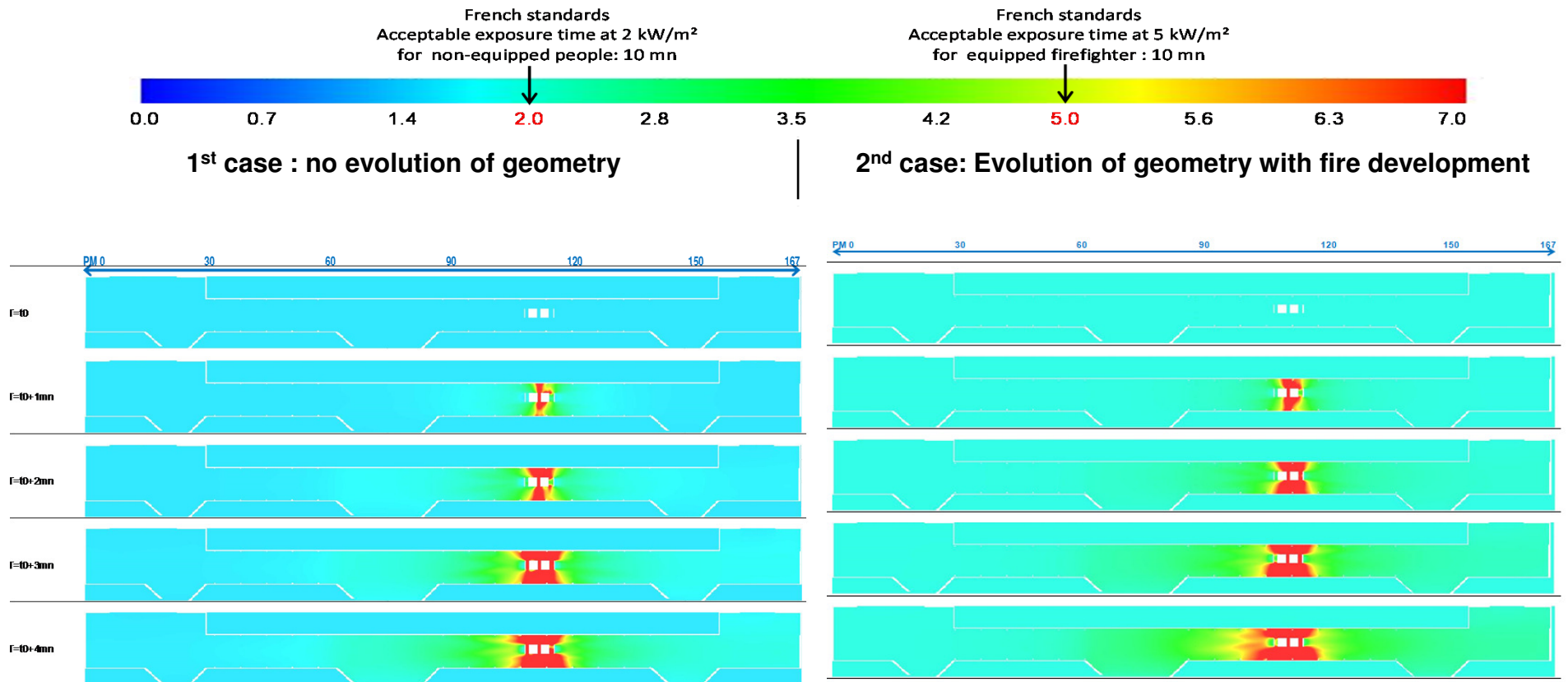
# 1<sup>st</sup> part: Analysis of survival conditions for workers



## Results of survival conditions

→ worst case: scenario 4 (summer external conditions with 2 vehicles in fire)

### Thermal radiation (KW/m<sup>2</sup>)– Horizontal sections (1.75m high)



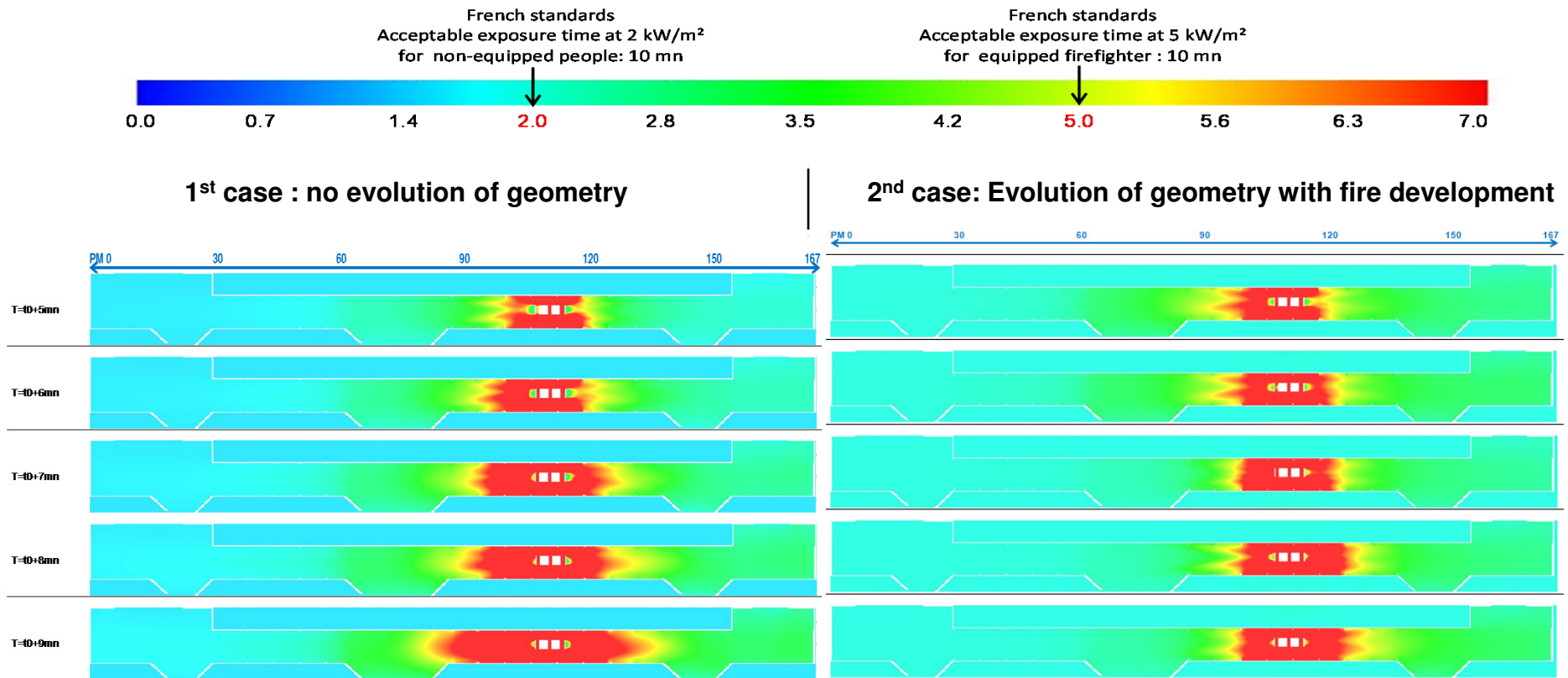
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## Results of survival conditions

→ worst case: scenario 4 (summer external conditions with 2 vehicles in fire)

### Thermal radiation ( $\text{KW/m}^2$ )– Horizontal sections (1.75m high)



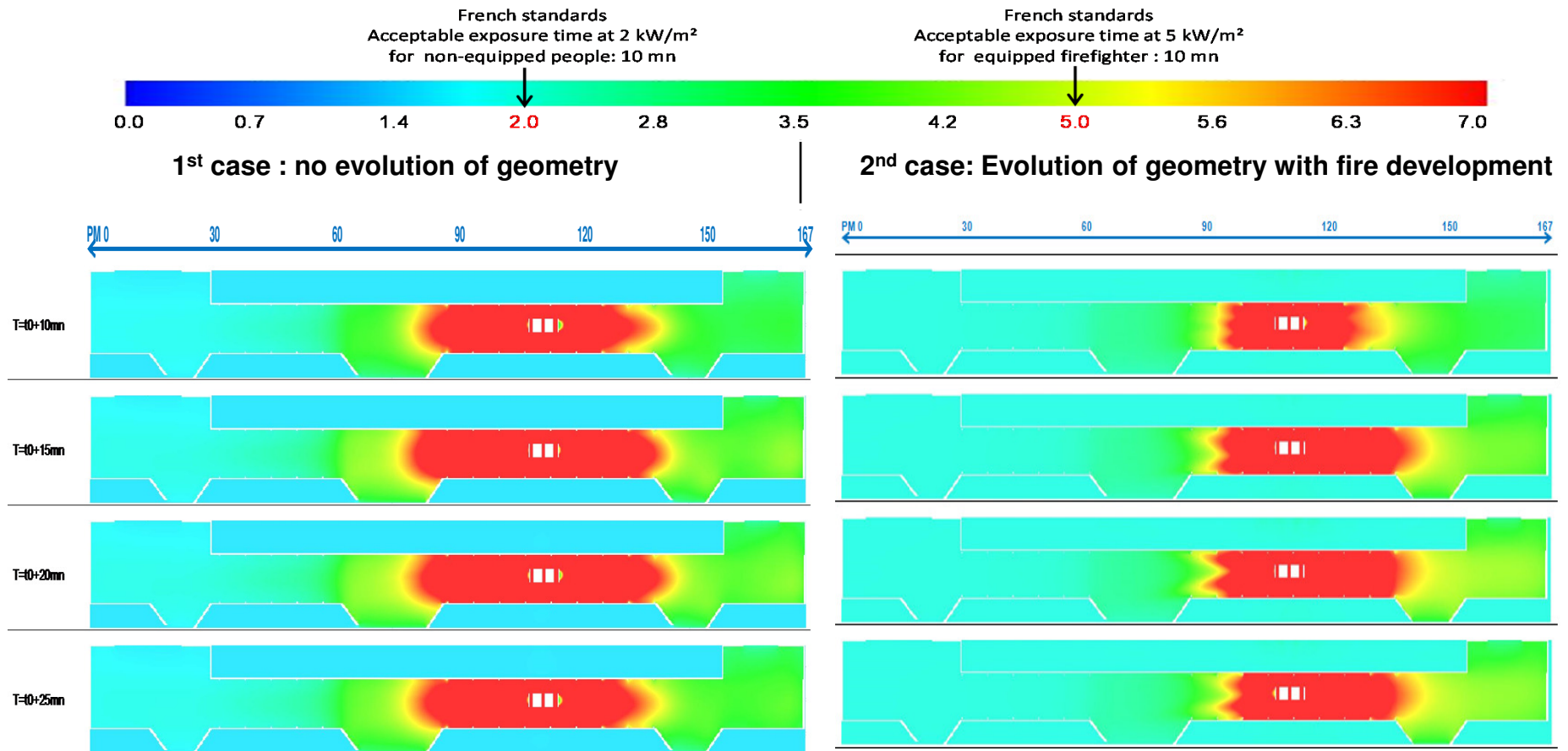
# 1<sup>st</sup> part: Analysis of survival conditions for workers



## Results of survival conditions

→ worst case: scenario 4 (summer external conditions with 2 vehicles in fire)

### Thermal radiation ( $\text{KW/m}^2$ )– Horizontal sections (1.75m high)



KMP – Fire modeling of the winterized roads

# 1<sup>st</sup> part: Analysis of survival conditions for workers



## Results of survival conditions

- Conclusion:

- Good stratification of smoke with fresh air layer at workers height
- Roof openings with aluminium melt enlarge the fresh air layer at workers height
  - Good visibility, temperature and no very few CO particles at workers height
- Important thermal radiation emitted by fire (global heat load : 56 MW peak)
  - Workers quickly go away from the dangerous area (center of fire), no impact on their health
- Low impact of thermal radiation emitted by smoke on workers thanks to roof openings
- Firefighter attack after 20 mn of fire development:
  - Thermal radiation emitted by fire and aluminium roof elements which melt can restrain firefighter approach
  - Careful approach with a first general refreshment action from outside





## **2<sup>nd</sup> part: Thermal solicitations and behavior of the structure**

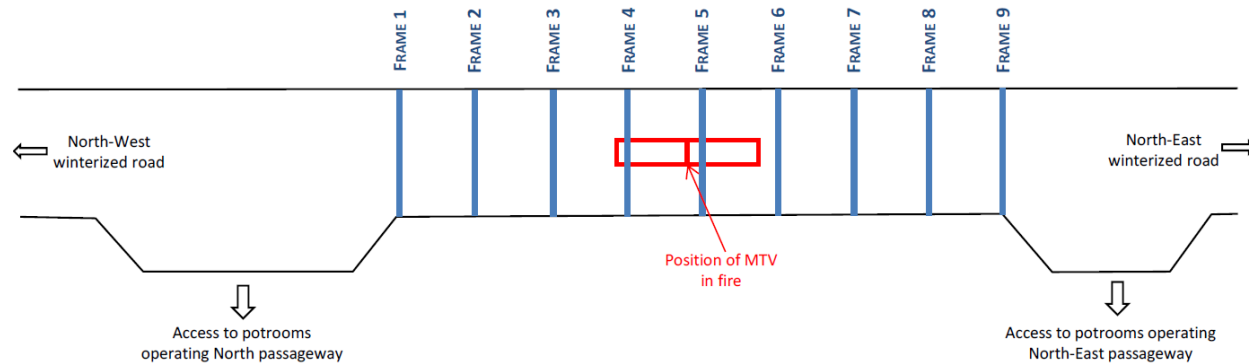
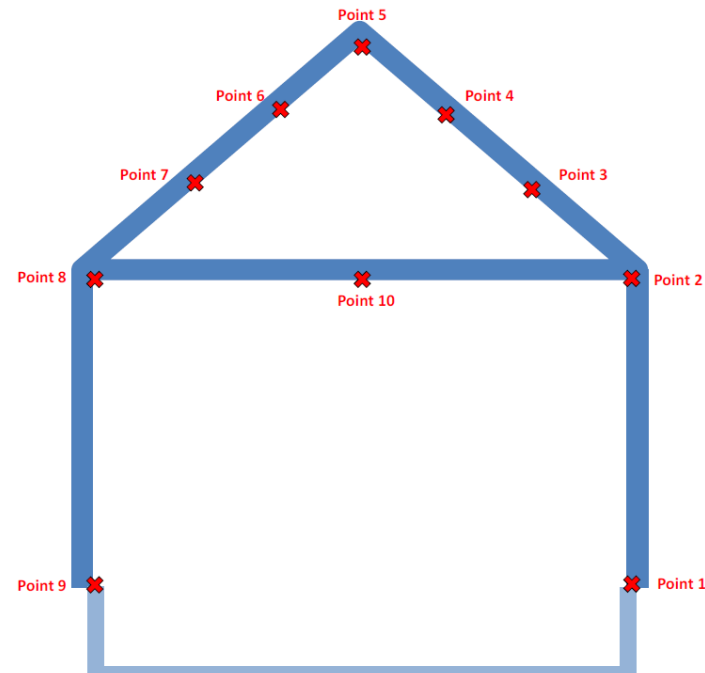
KMP – Fire modeling of the winterized roads

## 2<sup>nd</sup> part: Thermal solicitations and behavior of the structure



### Temperature within steelworks

- Measuring points:



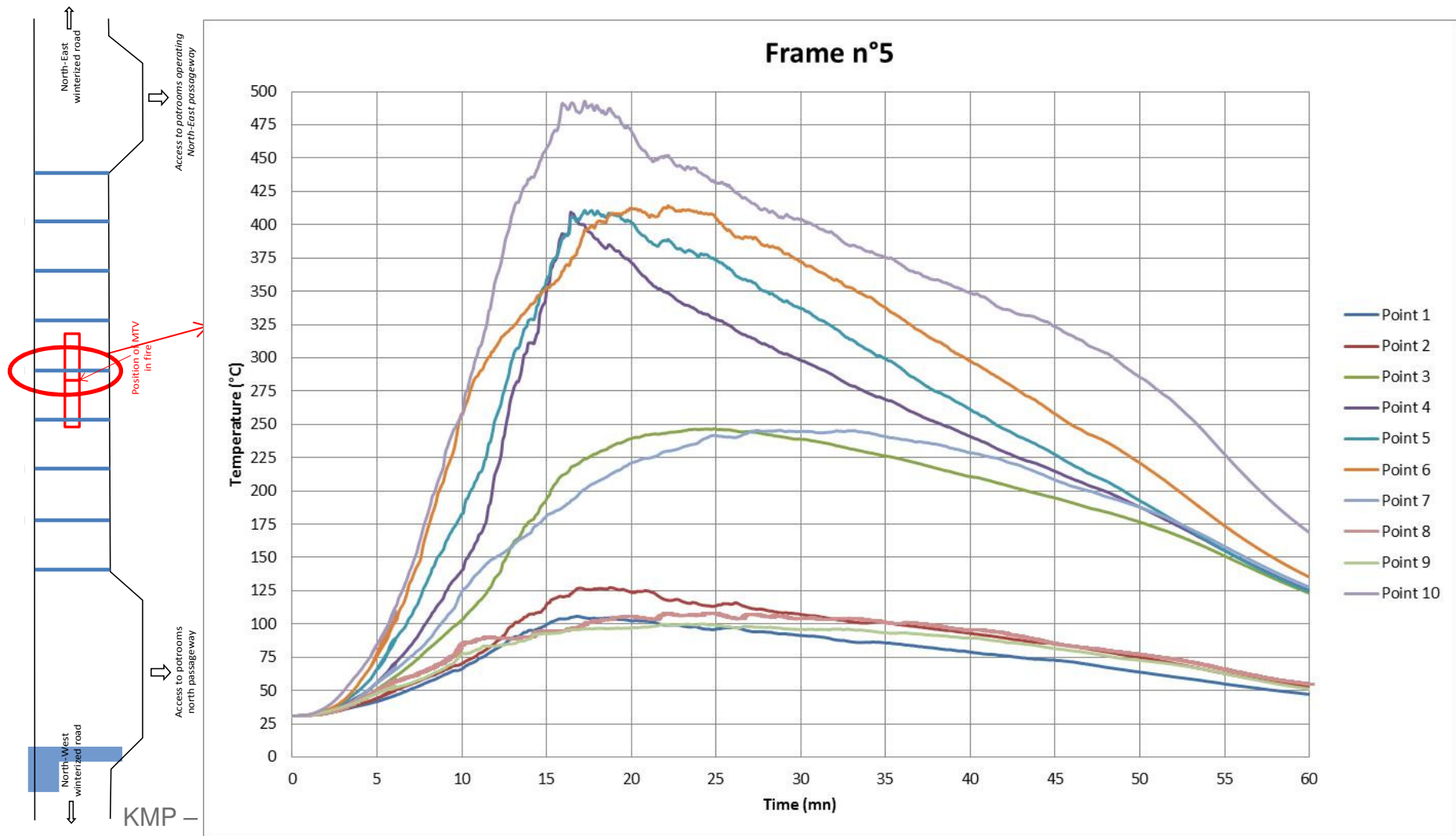
KMP – Fire modeling of the winterized roads

## 2<sup>nd</sup> part: Thermal solicitations and behavior of the structure



### Temperature within steelworks

- Results on the frame situated at the center of the fire (most elevated temperatures)
  - Temperatures within the structure  $\leq 500^{\circ}\text{C}$  on a short time

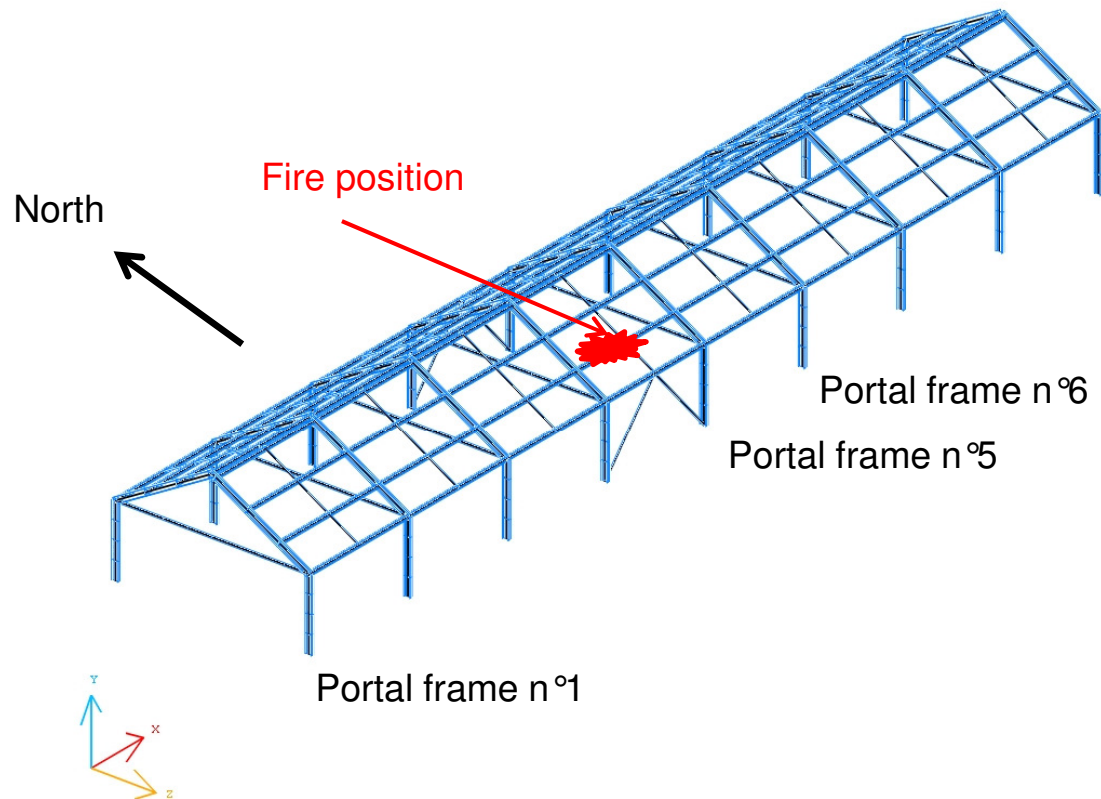


## 2<sup>nd</sup> part: Thermal solicitations and behavior of the structure



### Behavior of steel structure

- Use of Pythagore software (structural modeling) → Assessment of the duration of the mechanical stability of steel structure
- Model presentation



KMP – Fire modeling of the winterized roads

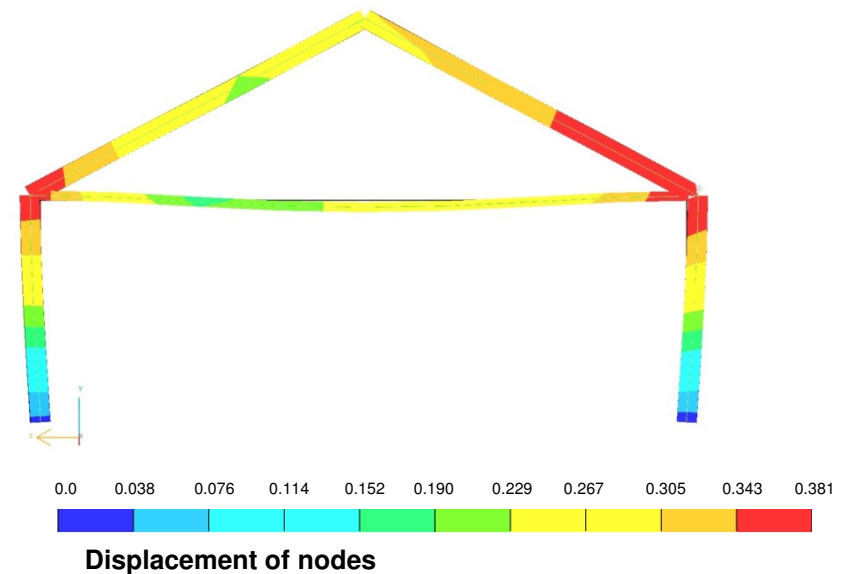
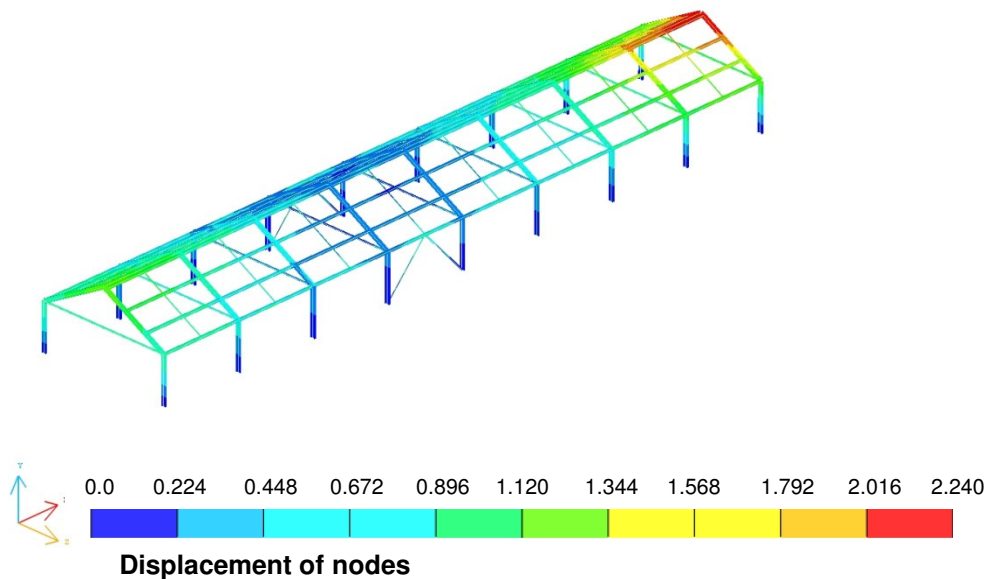
## 2<sup>nd</sup> part: Thermal solicitations and behavior of the structure



### Behavior of steel structure

- Behavior at  $t = 5$  mn

→ Distorted shape (cm) on entire framework & portal frame n°5



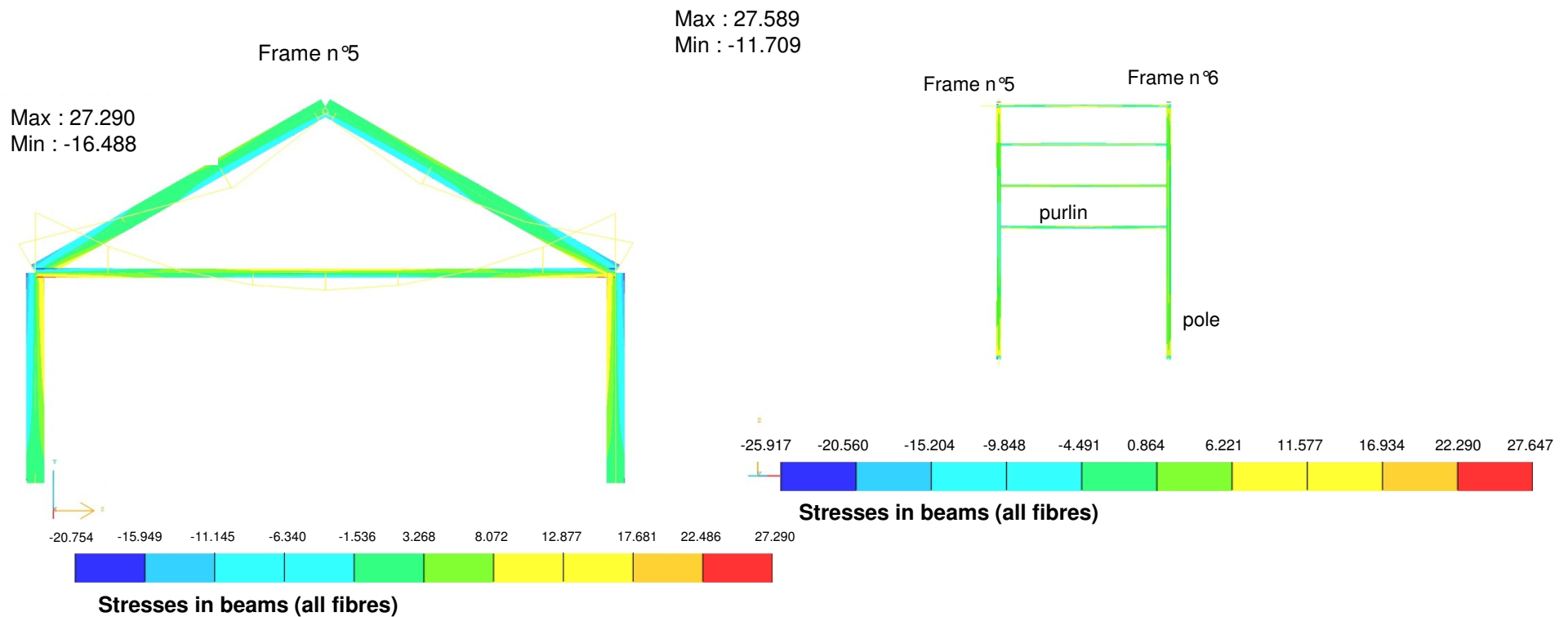
## 2<sup>nd</sup> part: Thermal solicitations and behavior of the structure



### Behavior of steel structure

- Behavior at  $t = 5$  mn

→ Stresses (MPa) on portal frames n°5 & 6



KMP – Fire modeling of the winterized roads

## 2<sup>nd</sup> part: Thermal solicitations and behavior of the structure



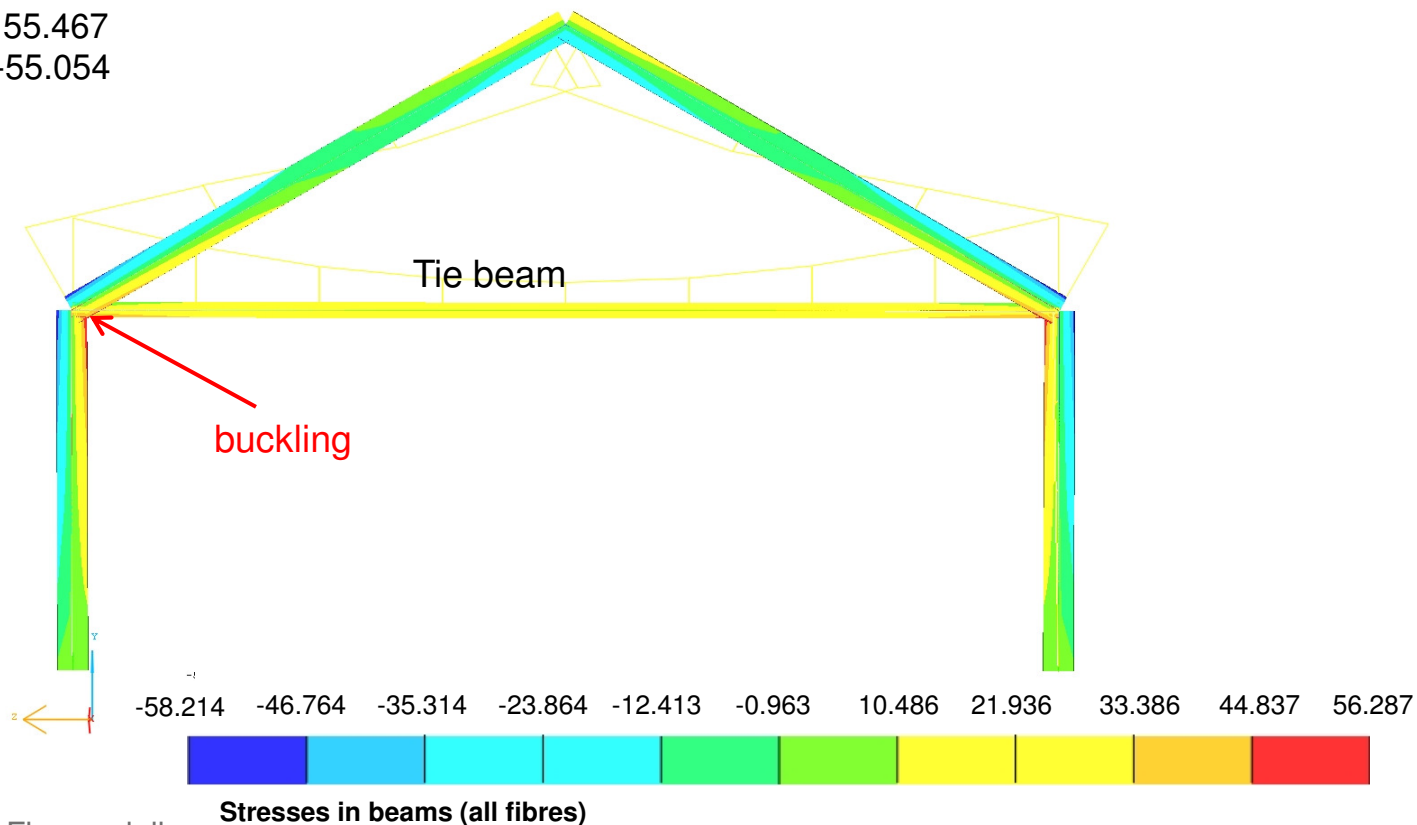
### Behavior of steel structure

- Behavior at  $t = 12$  mn

→ Tie beam doesn't verify the buckling under bending and axial compression (local instability) → Not consider anymore as a structural element in the modeling since this time

Max : 55.467

Min : -55.054



KMP – Fire modeling of the whitened roads

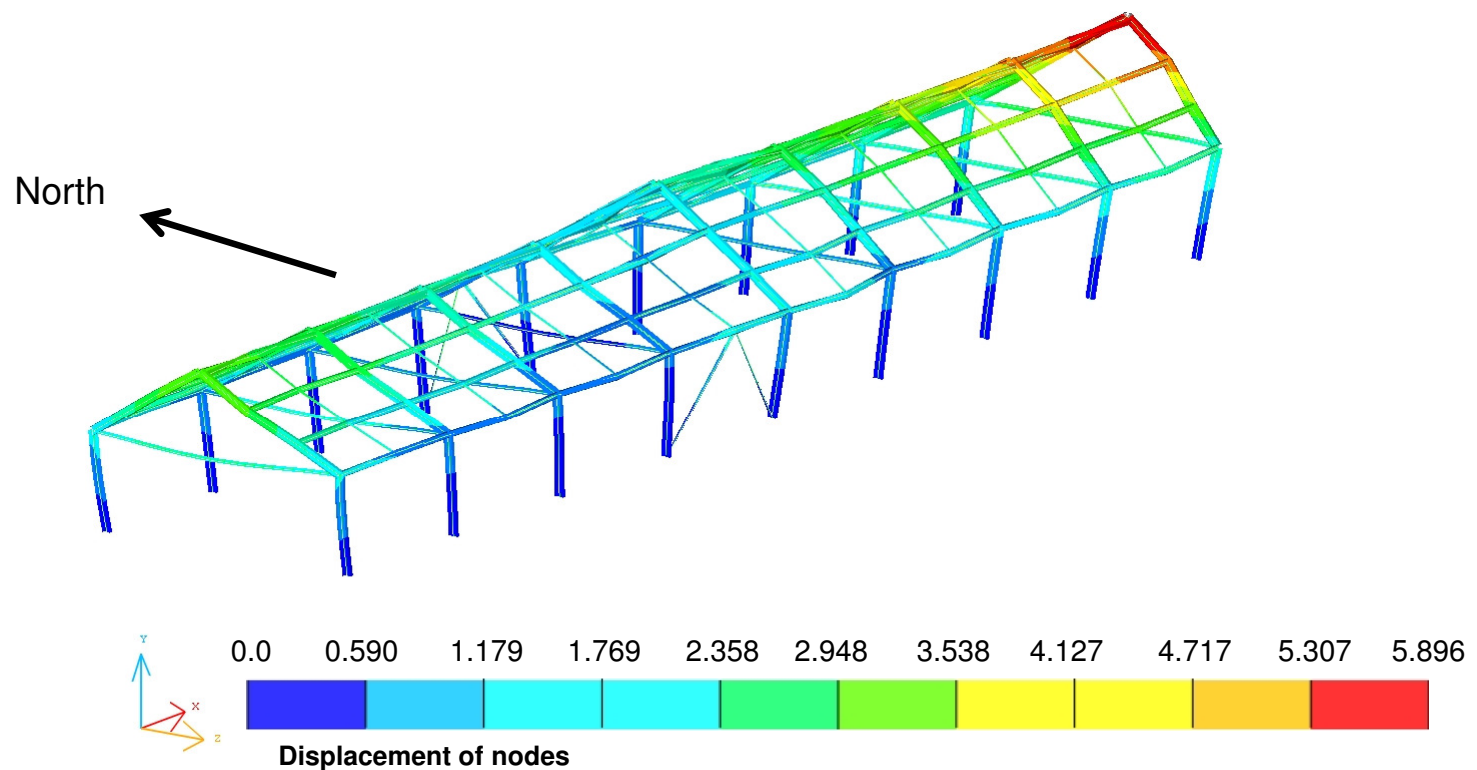
## 2<sup>nd</sup> part: Thermal solicitations and behavior of the structure



### Behavior of steel structure

- Behavior at  $t = 17$  mn (maximum temperature)

→ Distorted shape (cm)



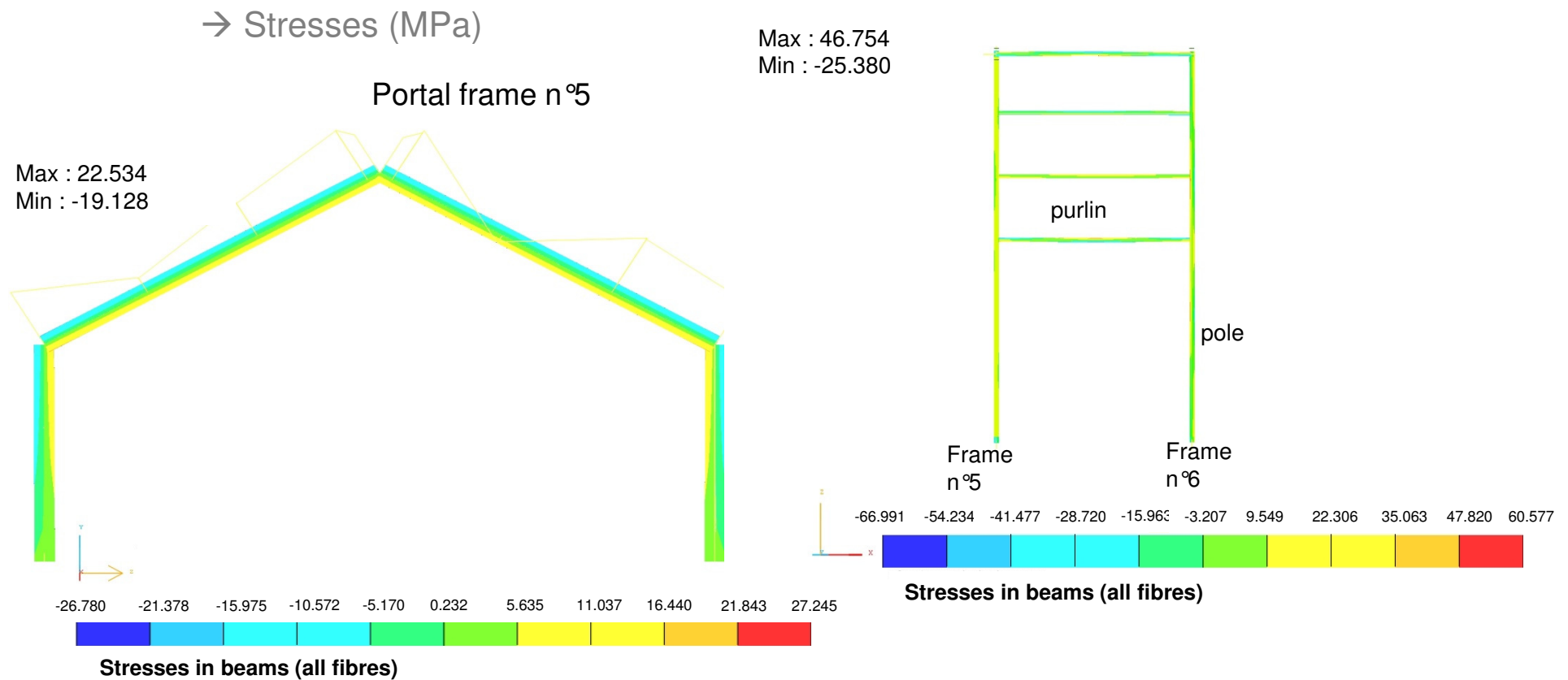
KMP – Fire modeling of the winterized roads

## 2<sup>nd</sup> part: Thermal solicitations and behavior of the structure



### Behavior of steel structure

- Behavior at t= 17 mn (maximum temperature)



KMP – Fire modeling of the winterized roads



### **Behavior of steel structure**

- Conclusions:
  - Structure is stable until the 12<sup>th</sup> minute of fire development
  - At t=12 mn : buckling on the tie beam next to the fire center (local instability)
    - No consequences on the general stability





# Conclusion

KMP – Fire modeling of the winterized roads



- **Fire safety engineering:**
  - Evolution of the structural geometry of the winterized roads with fire development
  - Use of temperature data from the fire modeling to assess the structural behavior
- **Impacts of the study:**
  - Results guarantee the good design of the winterized roads
  - Beginning of building work after these favorable results → Respect of  
schedule and cost

KMP – Fire modeling of the winterized roads

# THANK YOU - QUESTIONS?



**setec**  
Central Seine  
42 - 52, quai de la Rapée  
CS 71230  
75583 Paris cedex 12

Anne-Charlotte COUPIER  
[anne-charlotte.coupier@tpi.setec.fr](mailto:anne-charlotte.coupier@tpi.setec.fr)

[www.setec.fr](http://www.setec.fr)