Large-Scale Fire Testing of Electric Vehicles in Tunnels

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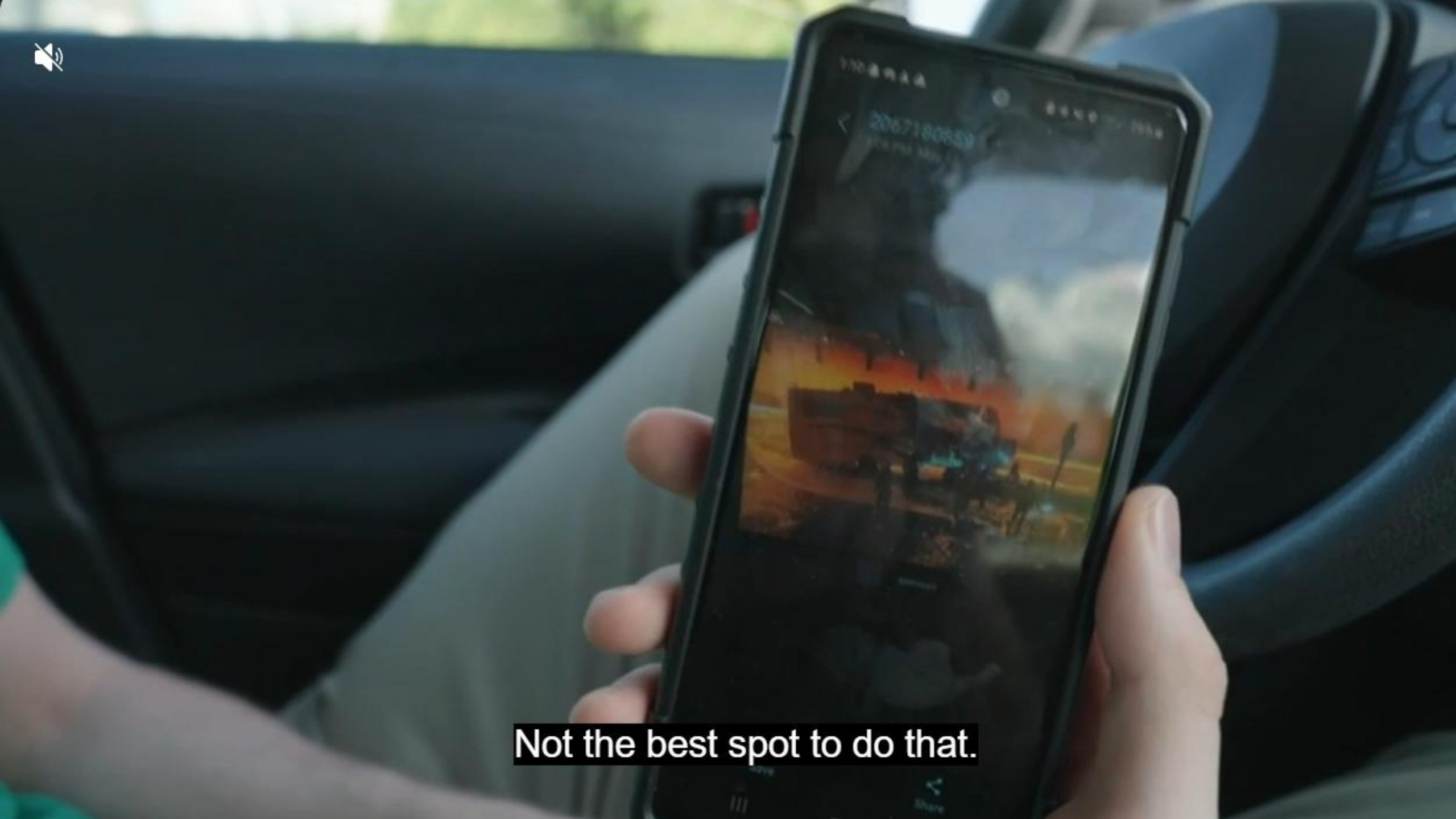
Not the best spot to do that.


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SPEED CAMERA
24 HOURS IN TUNNEL
VARIABLE SPEED
LIMIT ENFORCED

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MODEL TNL280 SPRAY NOZZLE

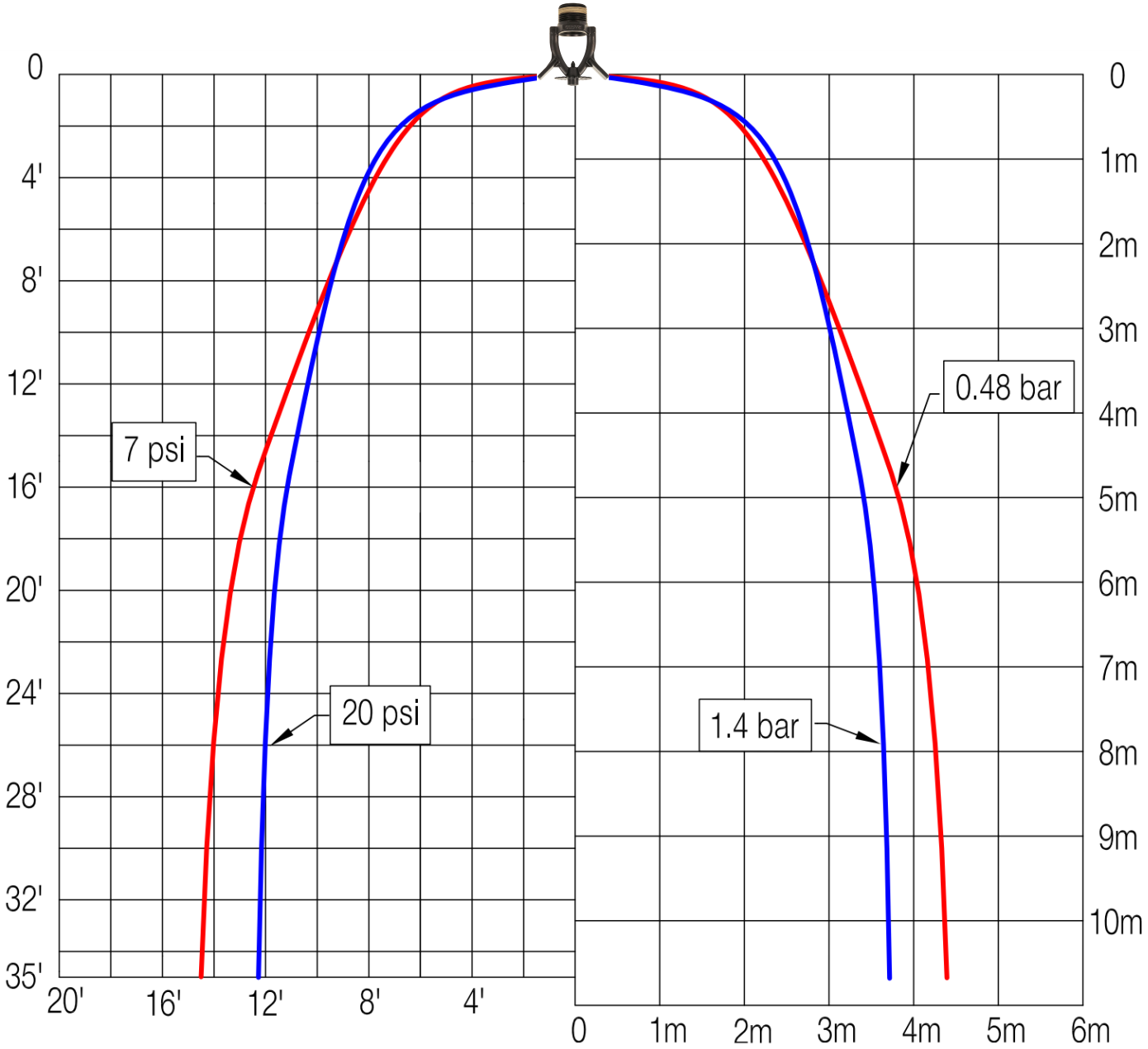
c UL us LISTED

Model TNL280 Spray Nozzle

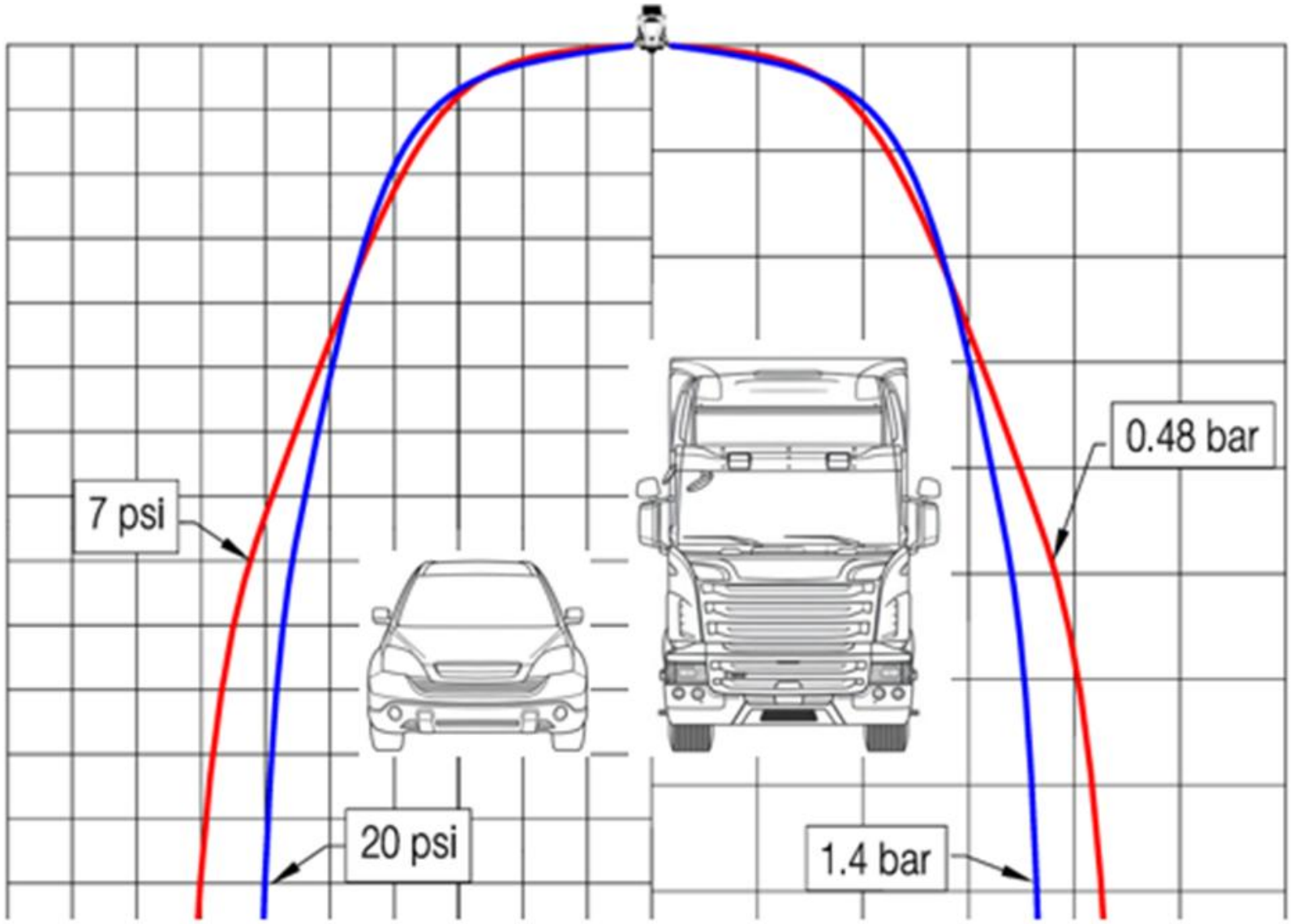
- Spray nozzle designed for tunnel fire protection
  - May be used in other applications
- Approvals:
  - cULus Listed
- Pressure rating:
  - 12 bar (175 psi)
- K-factor:
  - 400 (28.0)
- Coverage:
  - 5.5 m x 5.5 m (18 ft x 18 ft)
- Finish:
  - RASCO500 Ceramic Coating
    - cULus Listed corrosion resistant
- Installation wrench
  - W5
- Technical Bulletin 099

Model
TNL280

Model TNL280 Pendent Spray Pattern Graph



Model TNL280 Pendent Spray Pattern Graph



Model TNL280 Dimensions & Hydraulics

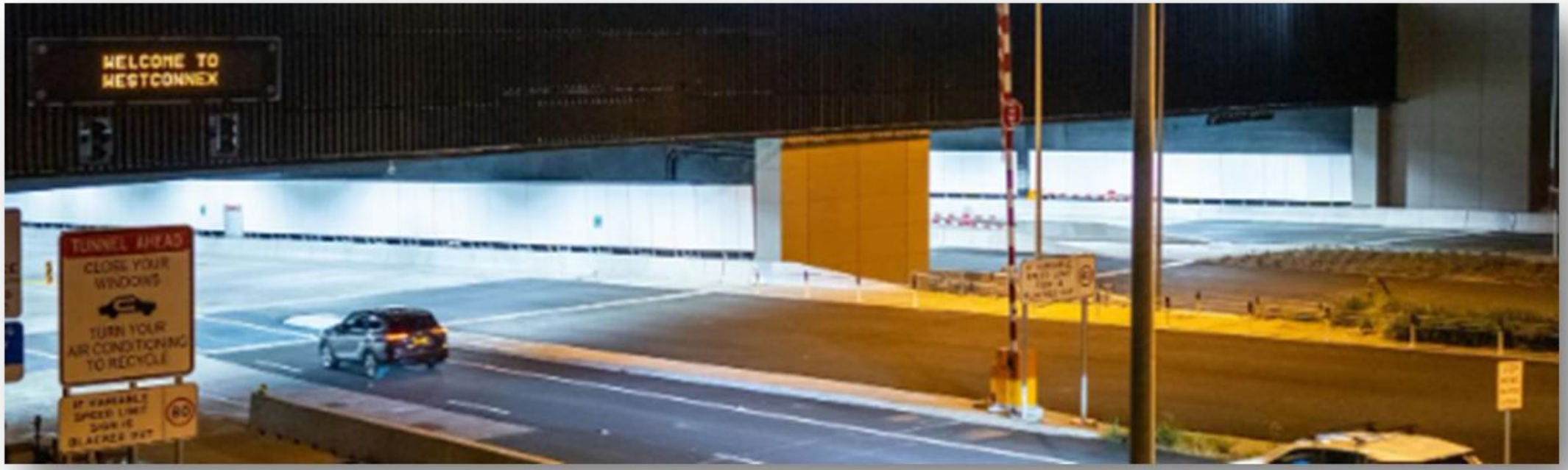
Listed Water Spray Density for Installation for Coverage Area of 18' x 18' (5.5m x 5.5m) **Table A**

Max. Nozzle Height Above Finished Floor ft (m)	Average Water Spray Density over the Coverage Area* gpm/ft² (mm/min)	Flow Rate gpm (L/min)	Operating Pressure psi (bar)
20 (6.1)	0.217 (8.8)	75 (285)	7 (0.5)
	0.37 (15.0)	125 (475)	20 (1.4)
35 (10.7)	0.176 (7.2)	75 (285)	7 (0.5)
	0.27 (11.0)	125 (475)	20 (1.4)

***Note:** Listed to provide +/- 15% of the Average Water Spray Density over the Coverage Area under test conditions specified in UL 2351.

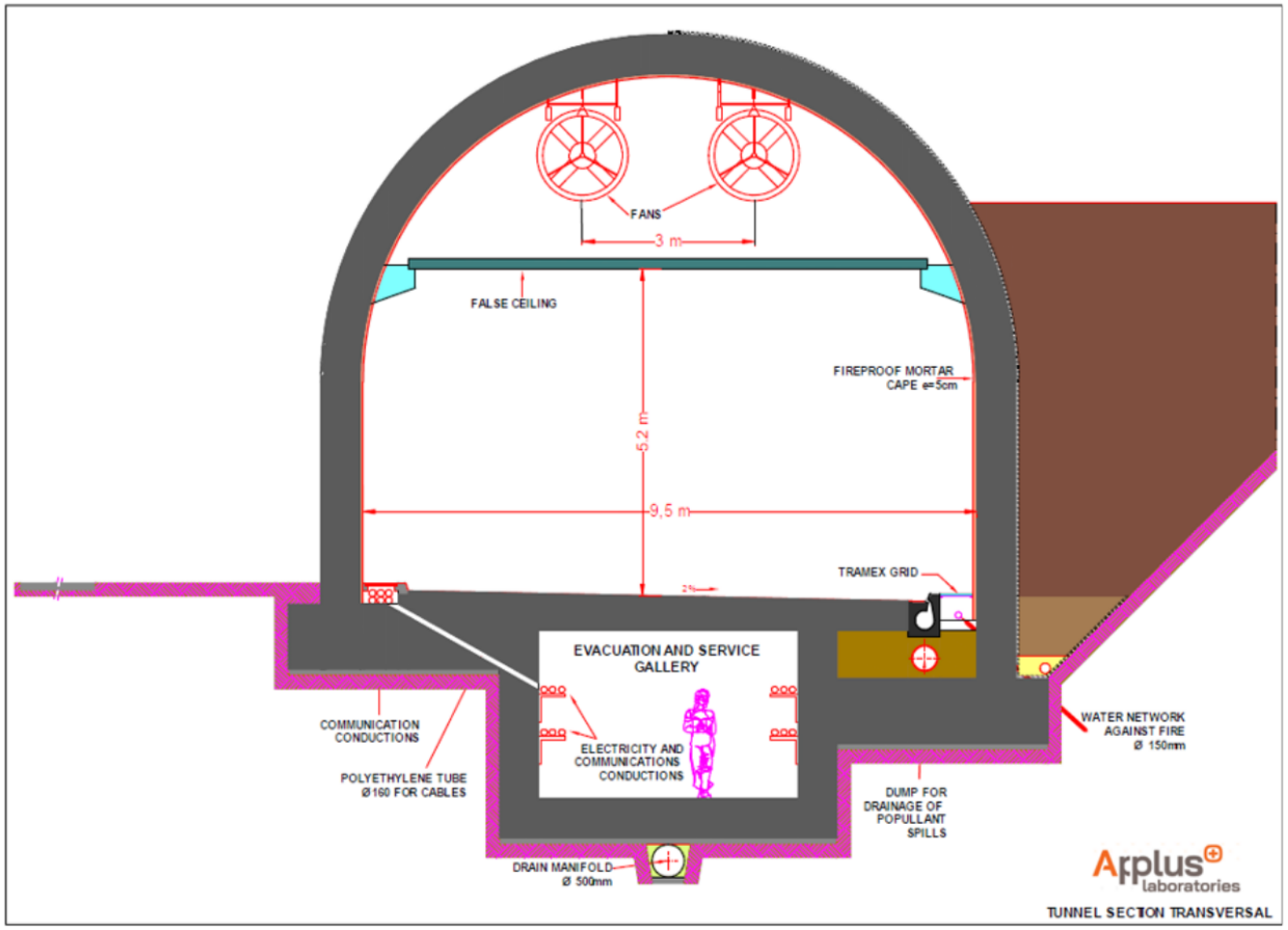
TNL280 Reference Projects

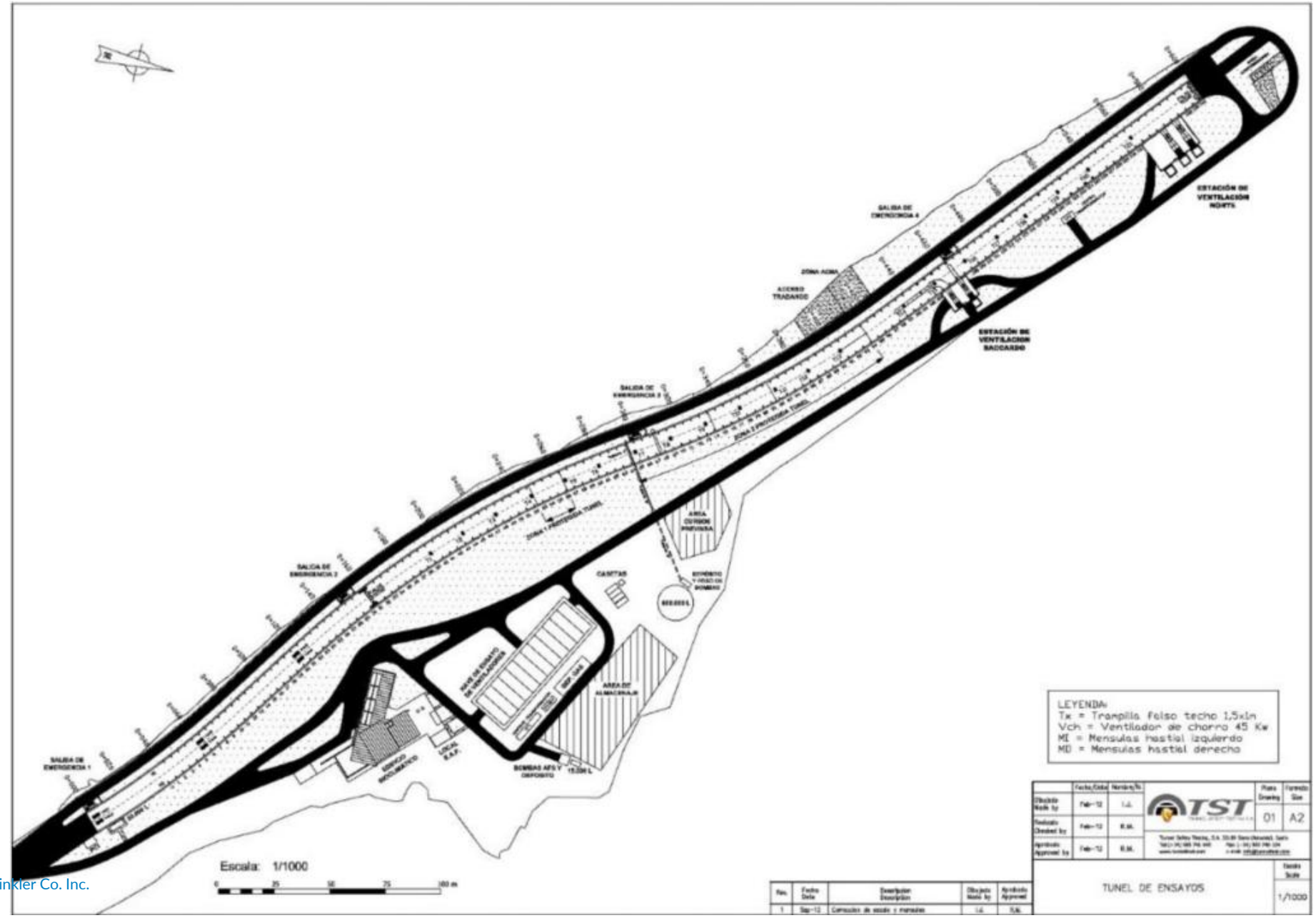
Project Name	TNL280's Installed
M5 Tunnel, Sydney	11,000
West Connex M4-M5 Link in Sydney	13,500
West Connex Rozelle Interchange in Sydney	10,200
M6 in Sydney	4,600
Qiddiya Resort Core Tunnel in Saudi Arabia	3,100



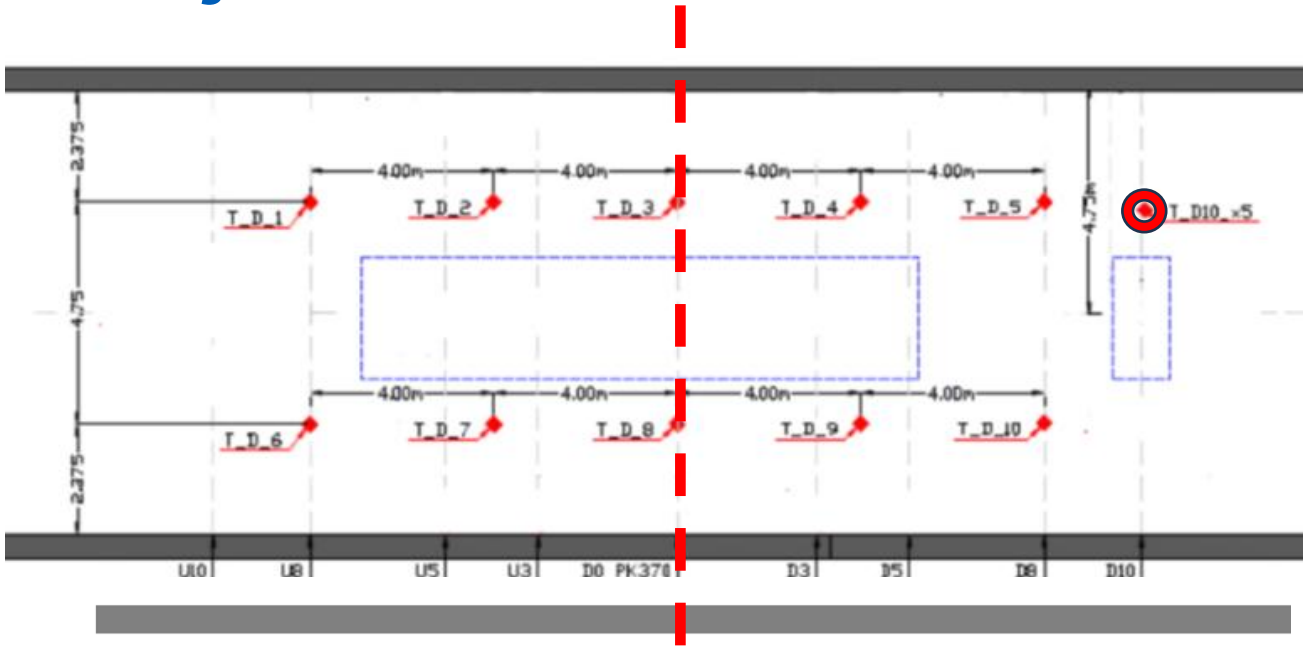
Fire Test Site

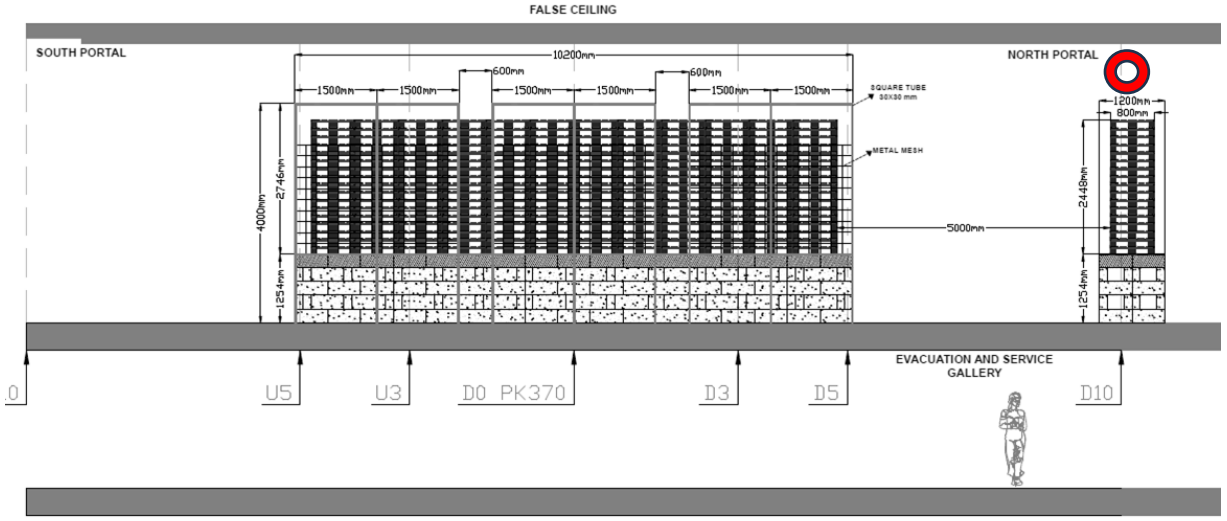
- Location:
  - Applus+TST Facility
    - San Pedro de Anes Asturias, Spain
- Tunnel length:
  - 600 m (1969 ft)
- Tunnel width:
  - 9.5 m (31 ft 2 in.)
- Tunnel height:
  - 5.2 m (17 ft)
- Fixed fire fighting system:
  - Deluge system
  - K400 (K28) Nozzles (Reliable Model TNL280)





Instrumentation Layout





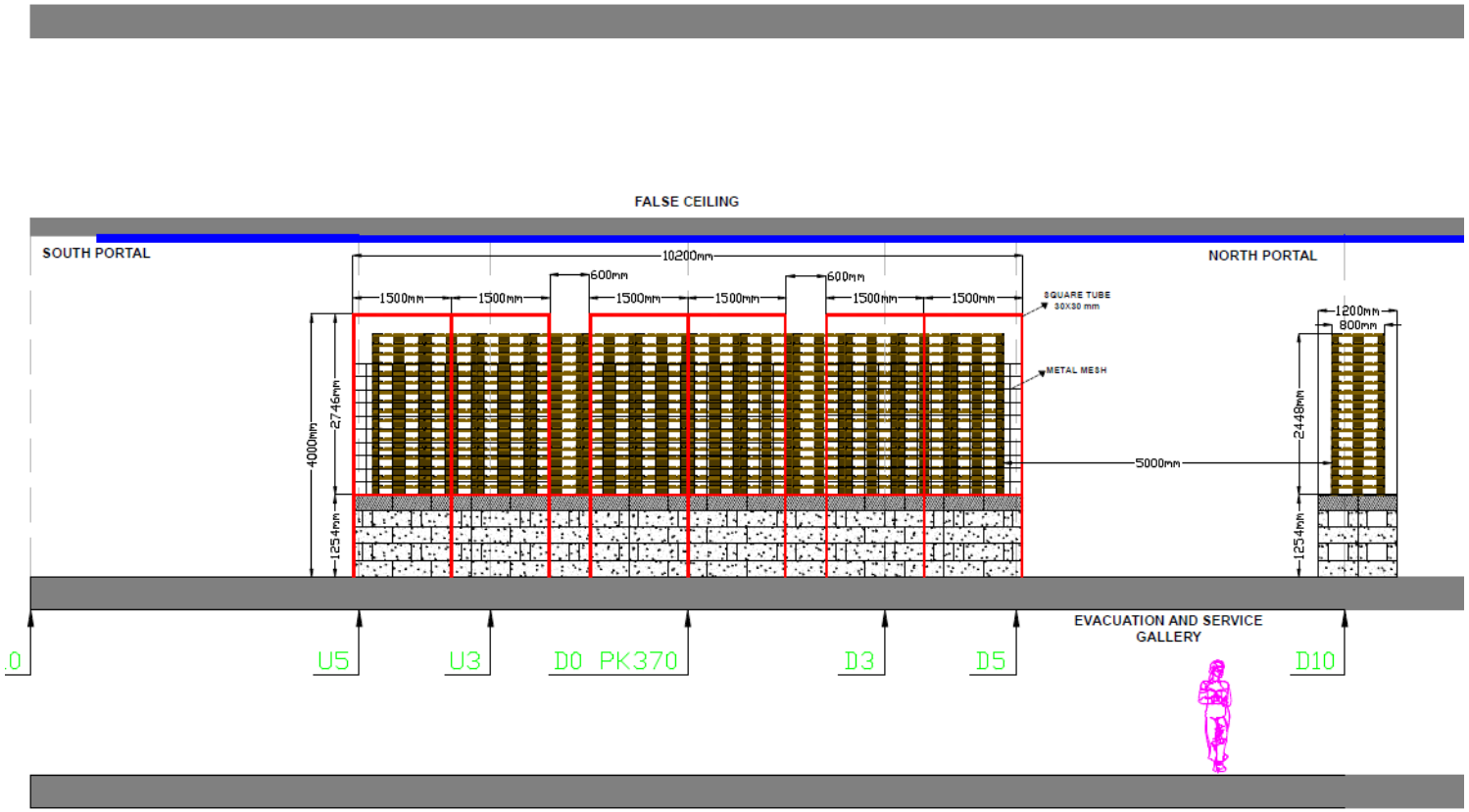
Performance Criteria

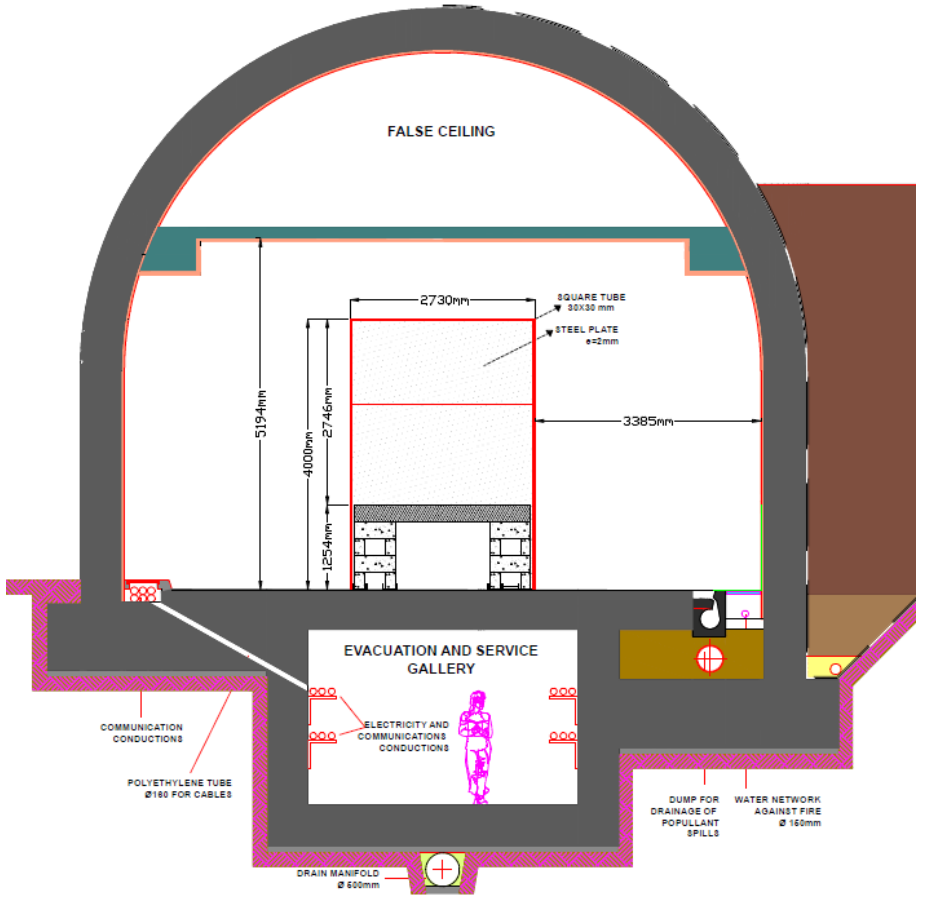
Criteria	Performance criteria
Criteria 1 - Temperature	Temperature at 1.8 m height upstream from U10 and downstream from D10 shall not exceed 60ºC during all the test, no later than 120 seconds after FFFS activation.
Criteria 2 – Heat flux	Heat flux at 1.8 m height upstream U15 and downstream D15 shall not exceed 5 kW/m^2 during all the test, no later than 120 seconds after FFFS activation.
Criteria 3 - Fire spread	Target 5 m from fire load shall be not ignited during all the test.

Summary of Tests

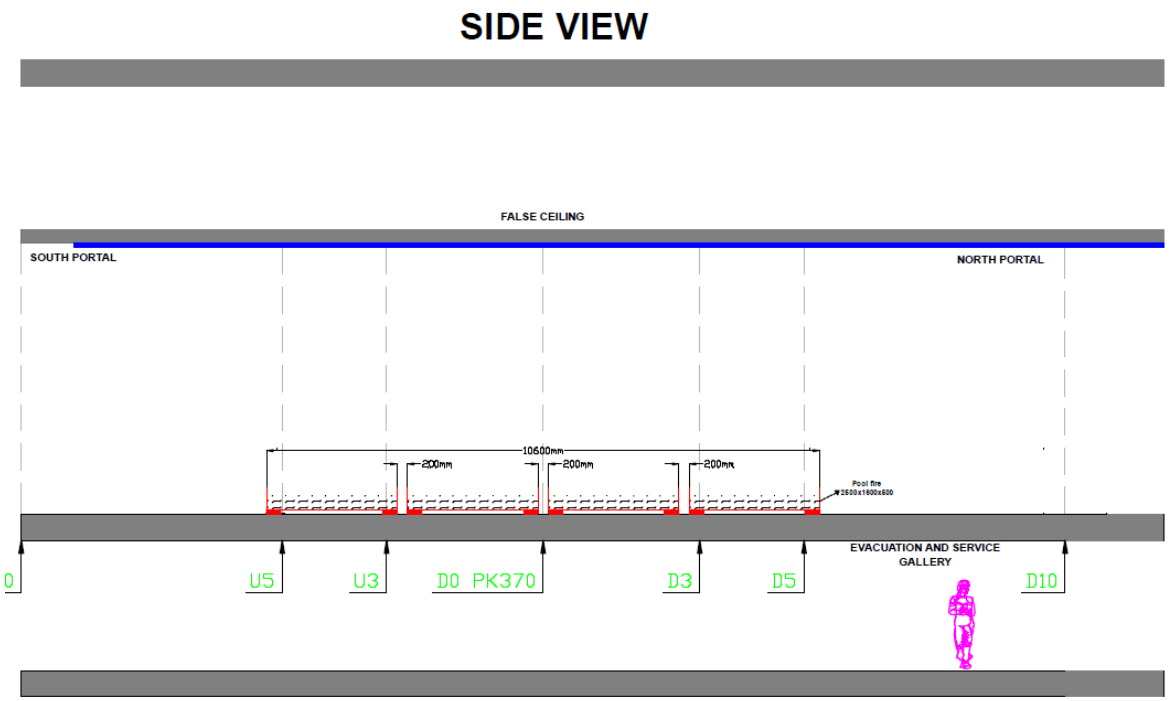
	Test Scenario	Ignition Location	Detection Temperature	Time from Ignition to Detection	Nominal Delay Time	Water Transport Time	Water Arrival After Detection	Air Velocity
Test 1	408 Wooden Pallets (150 MW)	Under 1 Line	**100 C**	2 min 48 s	2 min	22 s	2 min 28 s	3 m/s
Test 2	408 Wooden Pallets (150 MW)	Between 2 Lines	**100 C**	3 min 50 s	**3 min**	20 s	3 min 20 s	**4 m/s (4.7 m/s)***
Test 3	408 Wooden Pallets (150 MW)	Between 2 Lines	68 C	6 min 38 s	2 min	16 s	2 min 16 s	3 m/s
Test 4	Diesel Pool Fire (60 MW)	Between 2 Lines	68 C	29 s	2 min	5 m 16 s	7 m 16 s	3 m/s
Test 5	EV Test	Between 2 Lines	68 C	46 m 25 s	3 min	16 s	3 m 24 s	2 m/s

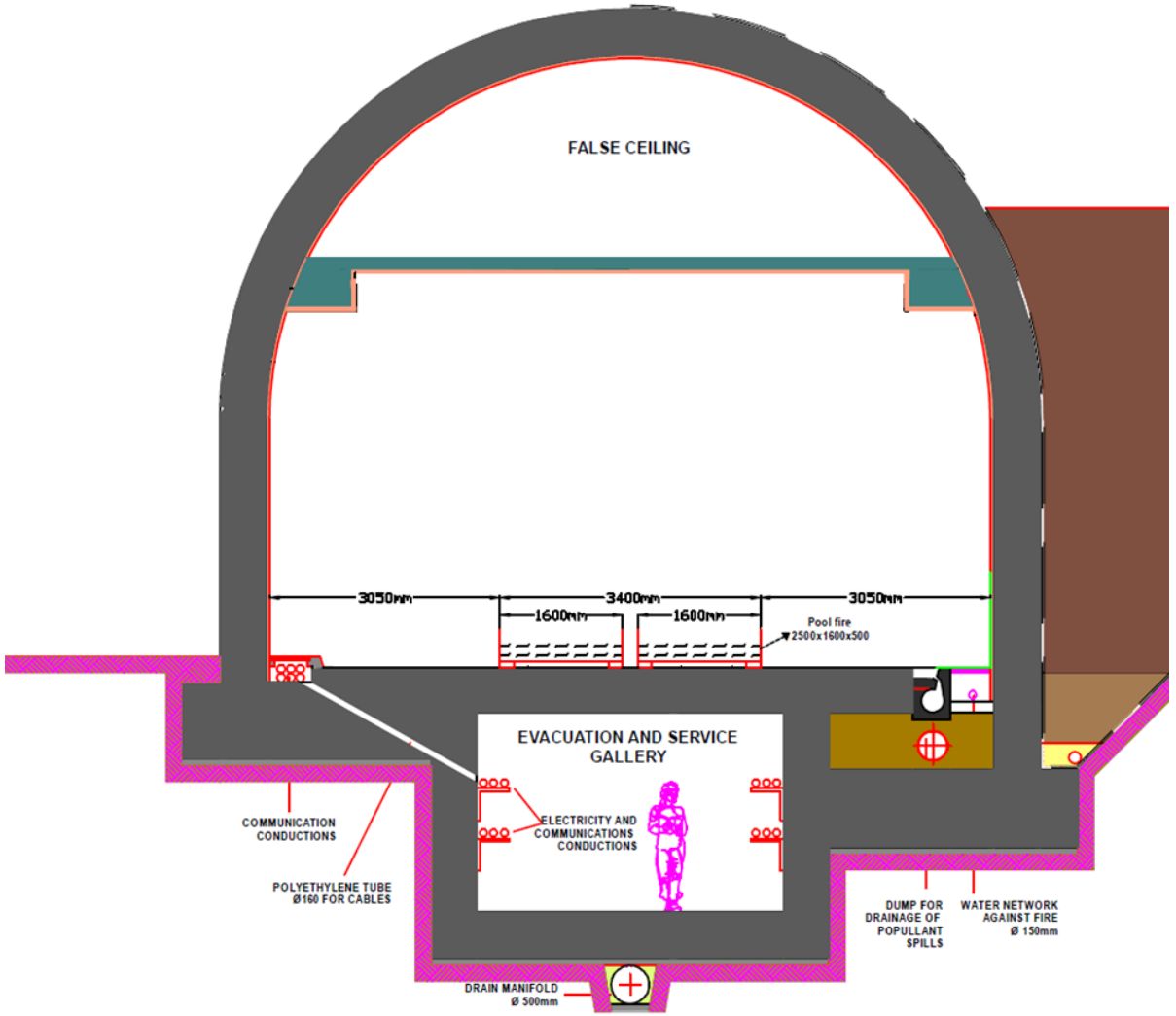
Class A Commodity





Class B Commodity



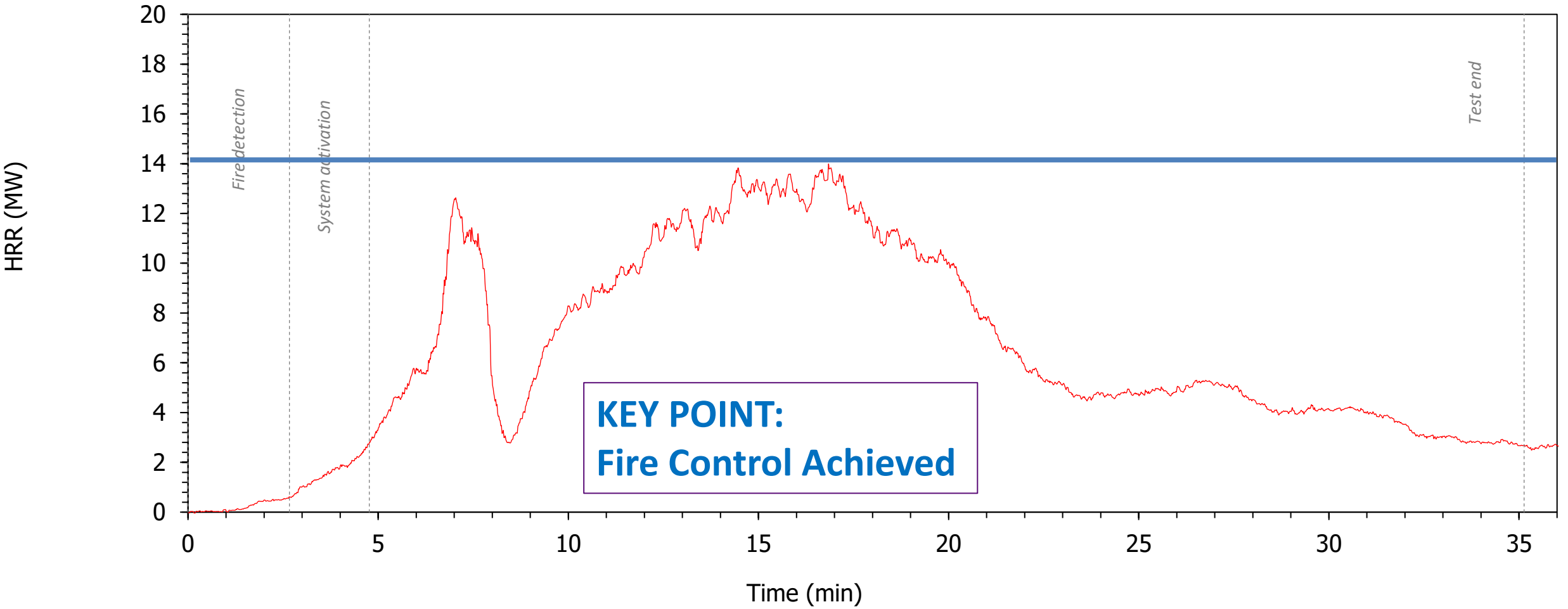


Test 1- Summary

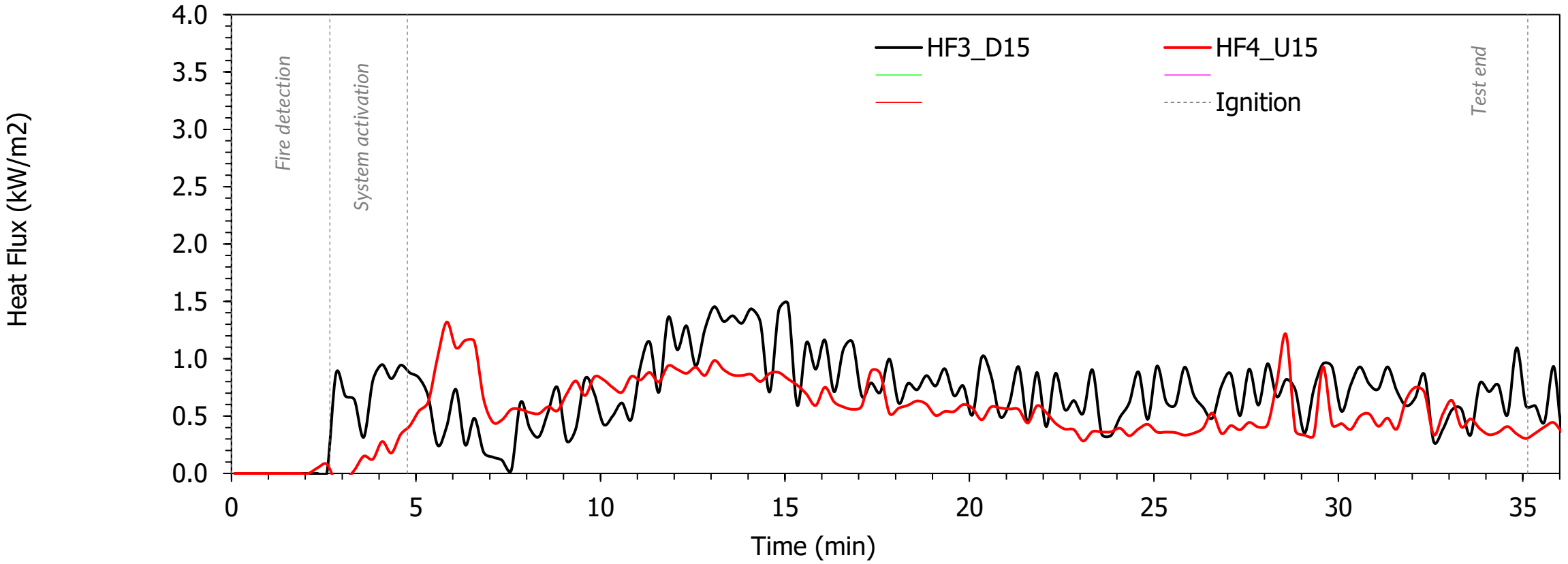
Test Conditions:

TNL280 Tunnel Nozzle:	K400 (K28)
Distance between nozzles:	5.5 m (18 ft) [max. allowed]
Nozzle pressure:	0.5 bar (7 psi) [min. allowed]
Activation Temperature:	100 C (212 F)
Time Delay:	2 min
Air Velocity	3 m/s (9.8 ft/s)
	10.8 km/h

Test 1 – Heat Release Rate (HRR)



Test 1- Heat Flux

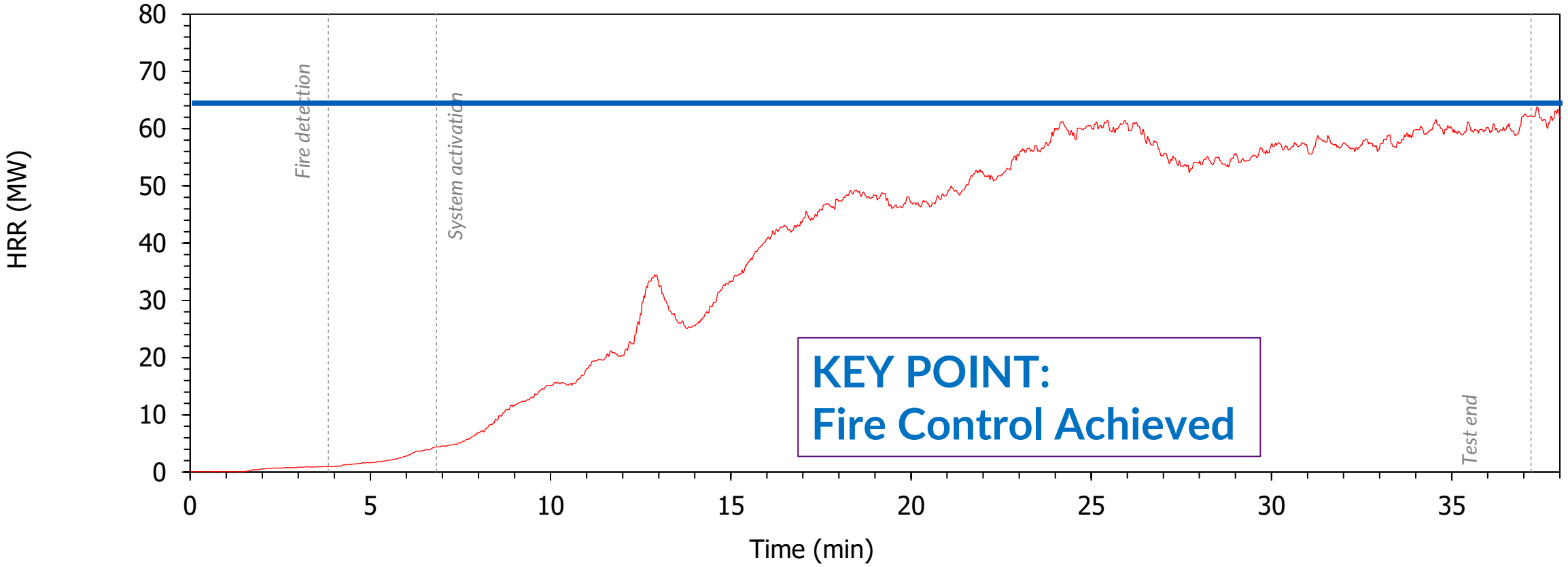


Test 2- Summary

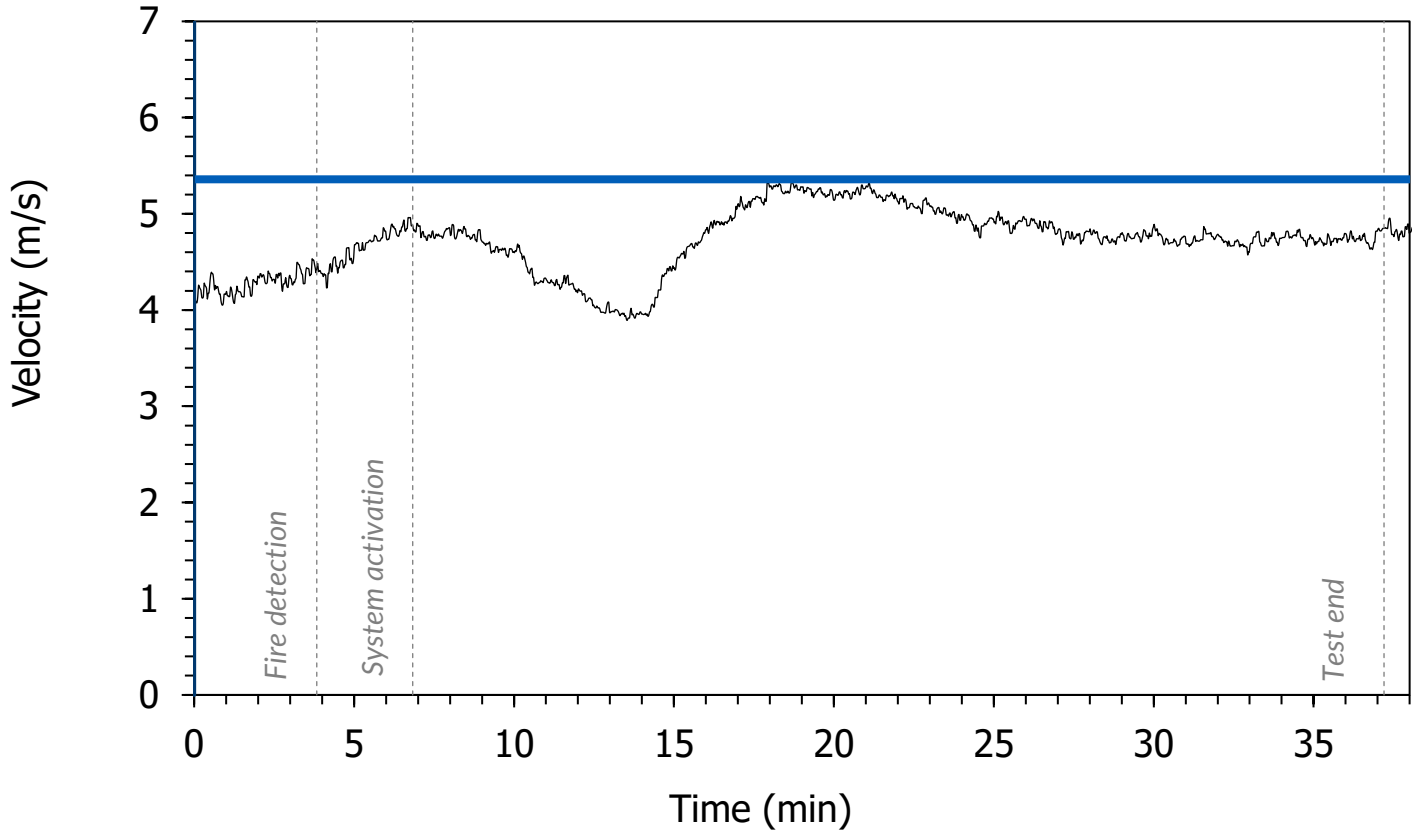
Test Conditions:

TNL280 Tunnel Nozzle:	K400 (K28)
Distance between nozzles:	5.5 m (18 ft)
Nozzle pressure:	0.5 bar (7 psi)
Activation Temperature:	100 C (212 F)
Time Delay:	3 min
Air Velocity	**4.7 m/s (15.4 ft/s)**
	16.9 km/h

Test 2- Heat Release Rate (HRR)

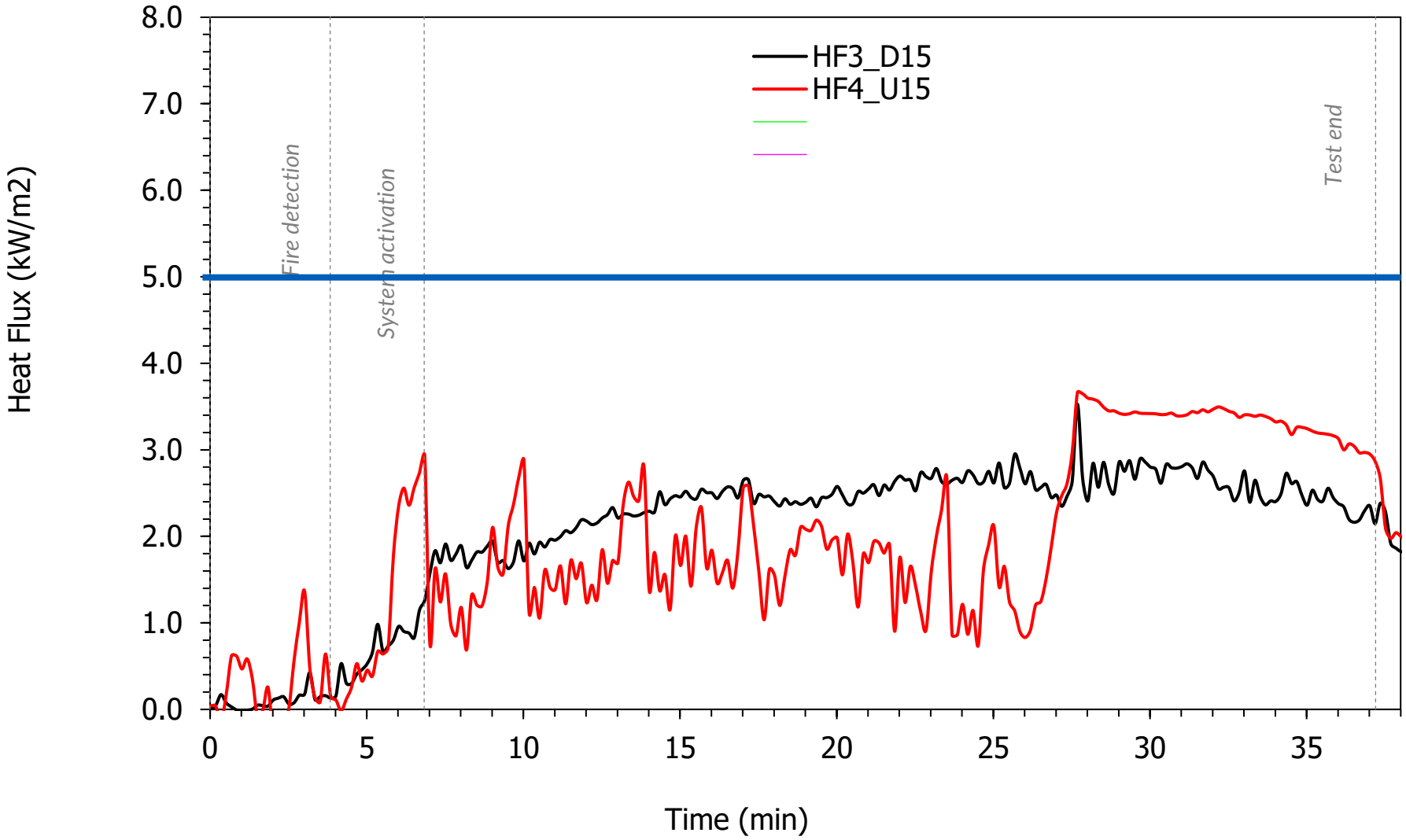


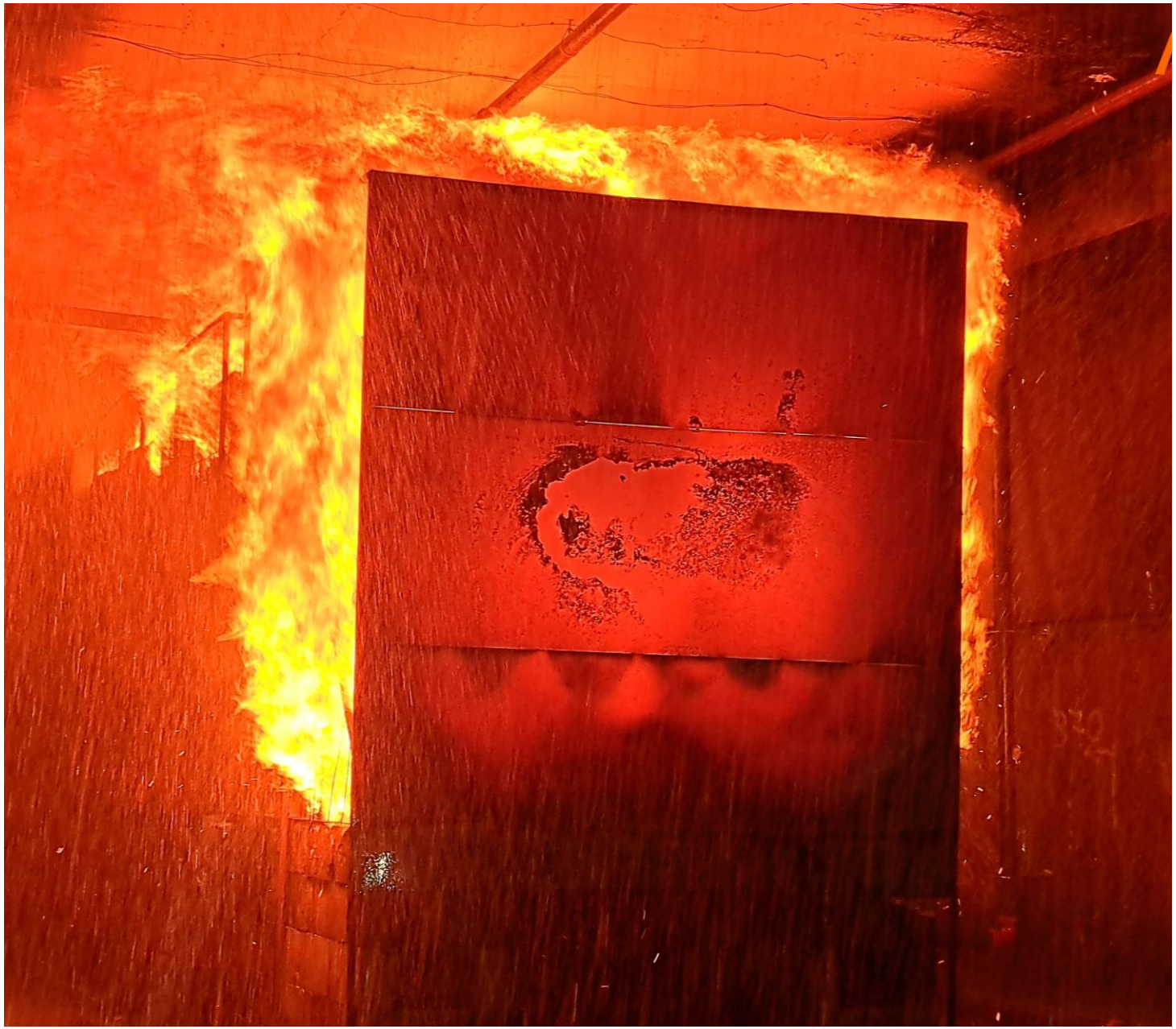
Test 2- Average Air Velocity



Average air velocity for this test was **4.7 m/s!**

Test 2- Heat Flux



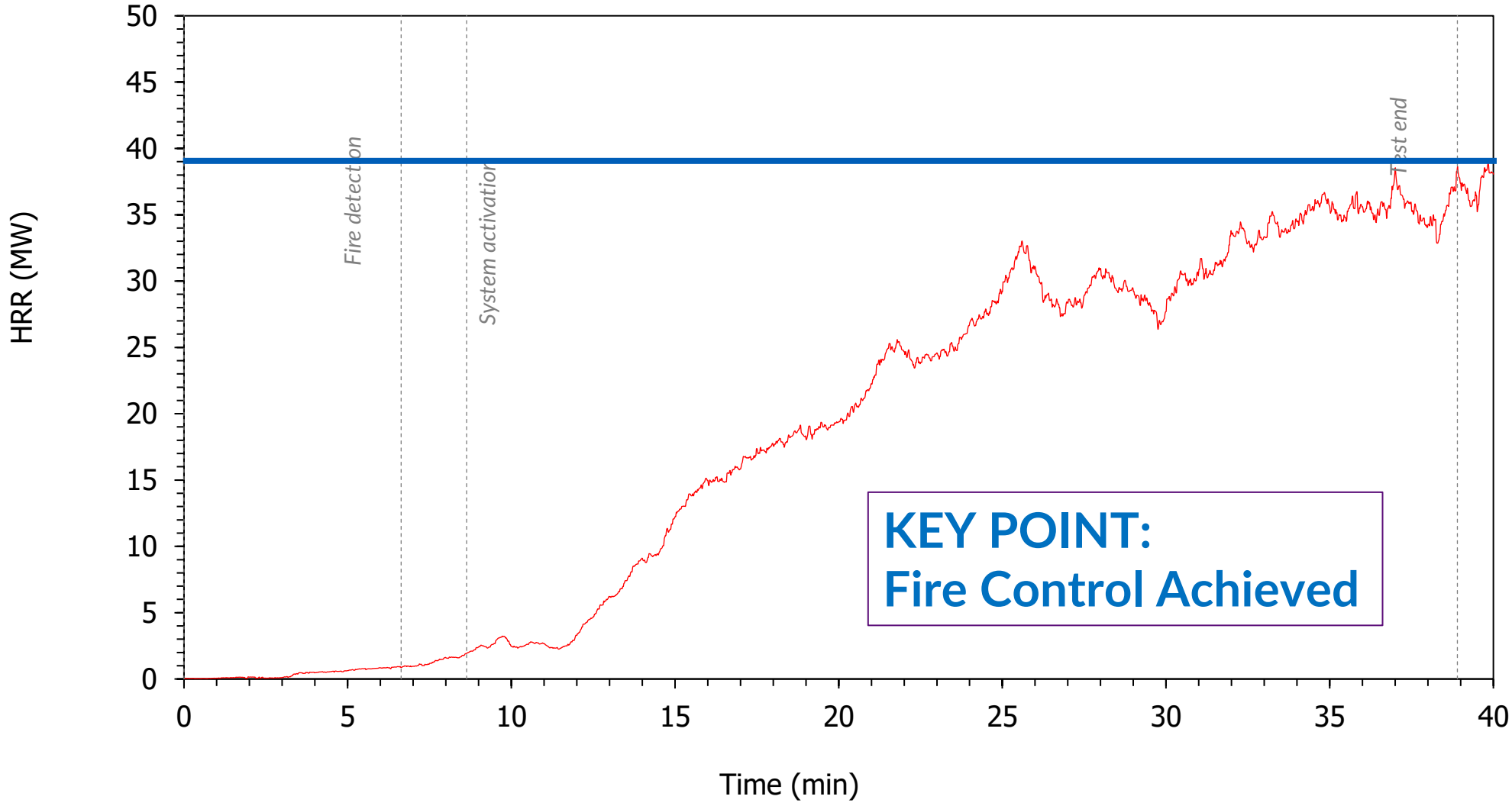


Test 3- Summary

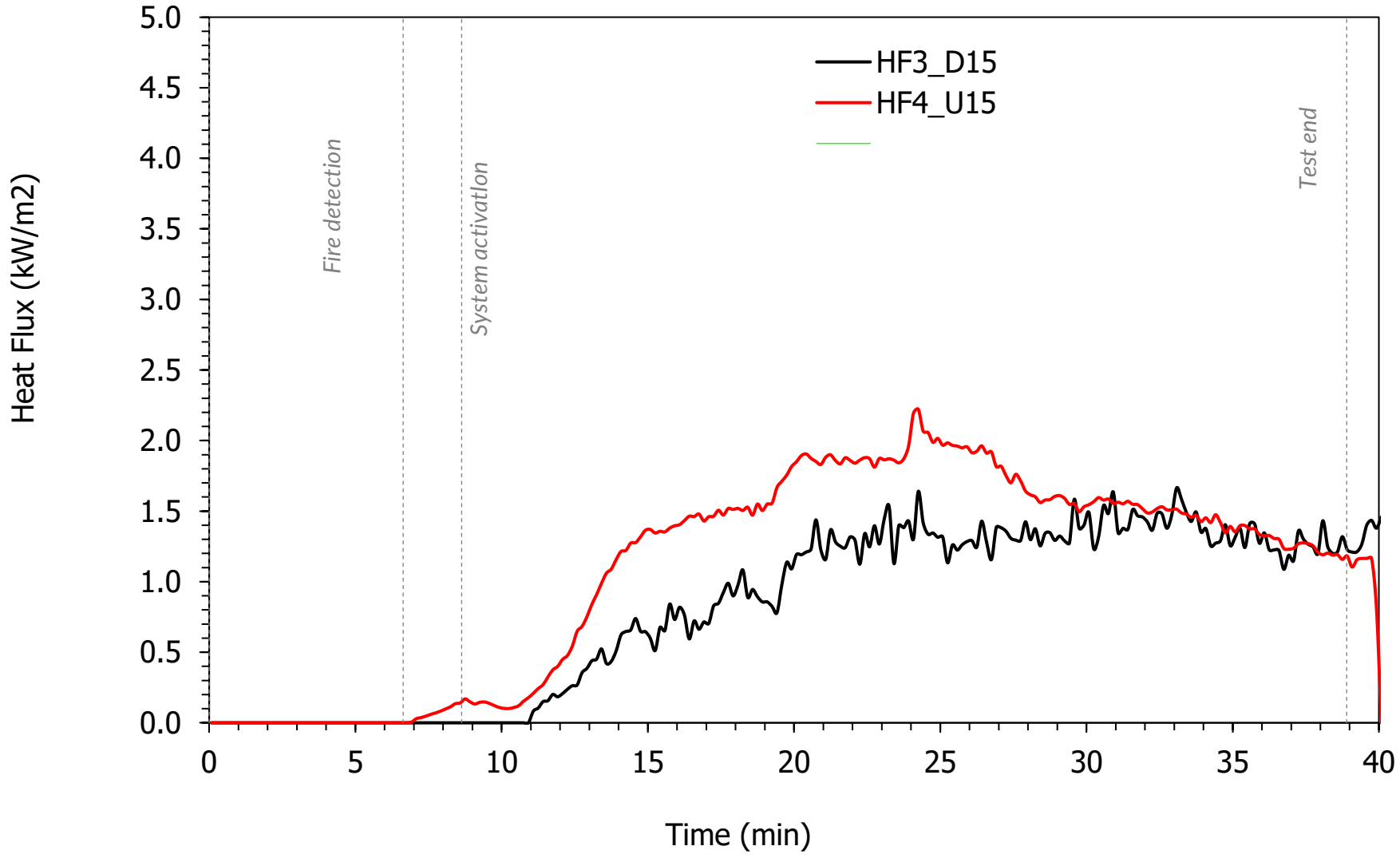
Test Conditions:

TNL280 Tunnel Nozzle:	K400 (K28)
Distance between nozzles:	5.5 m (18 ft)
Nozzle pressure:	0.5 bar (7 psi)
Activation Temperature:	68 C
Time Delay:	2 min
Air Velocity	3 m/s

Test 3- Heat Release Rate (HRR)



Test 3- Heat Flux



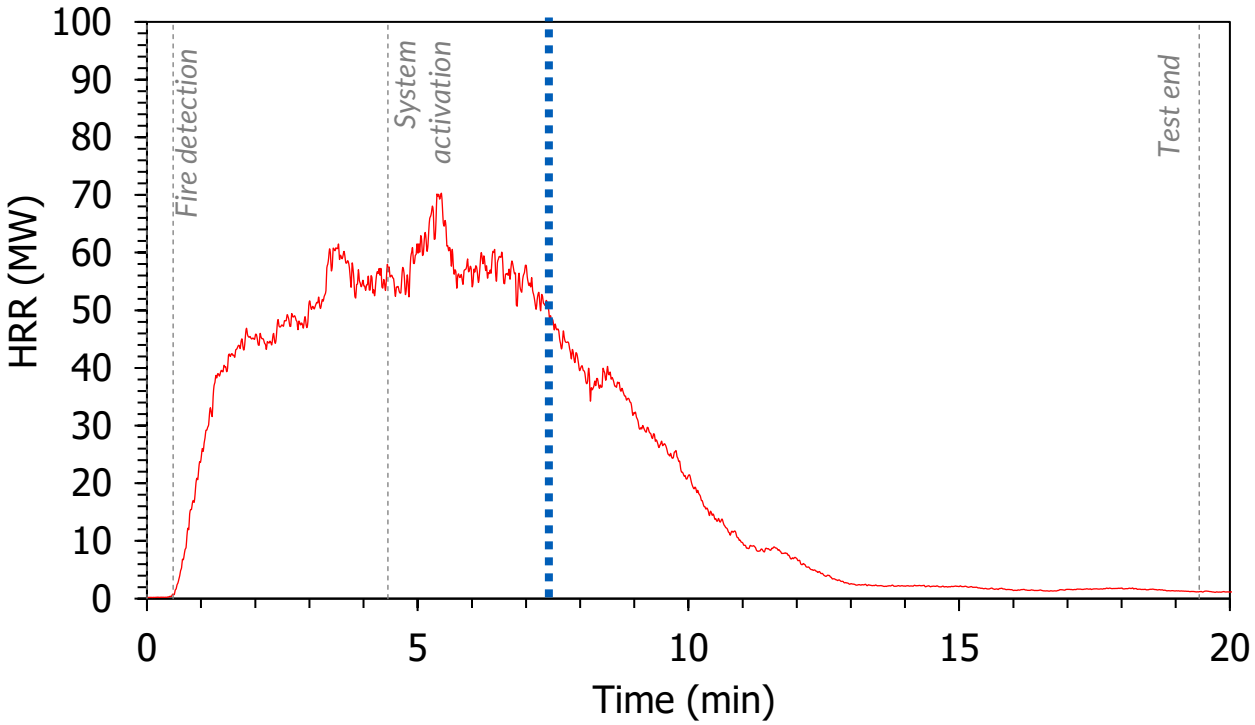
Test 4- Summary

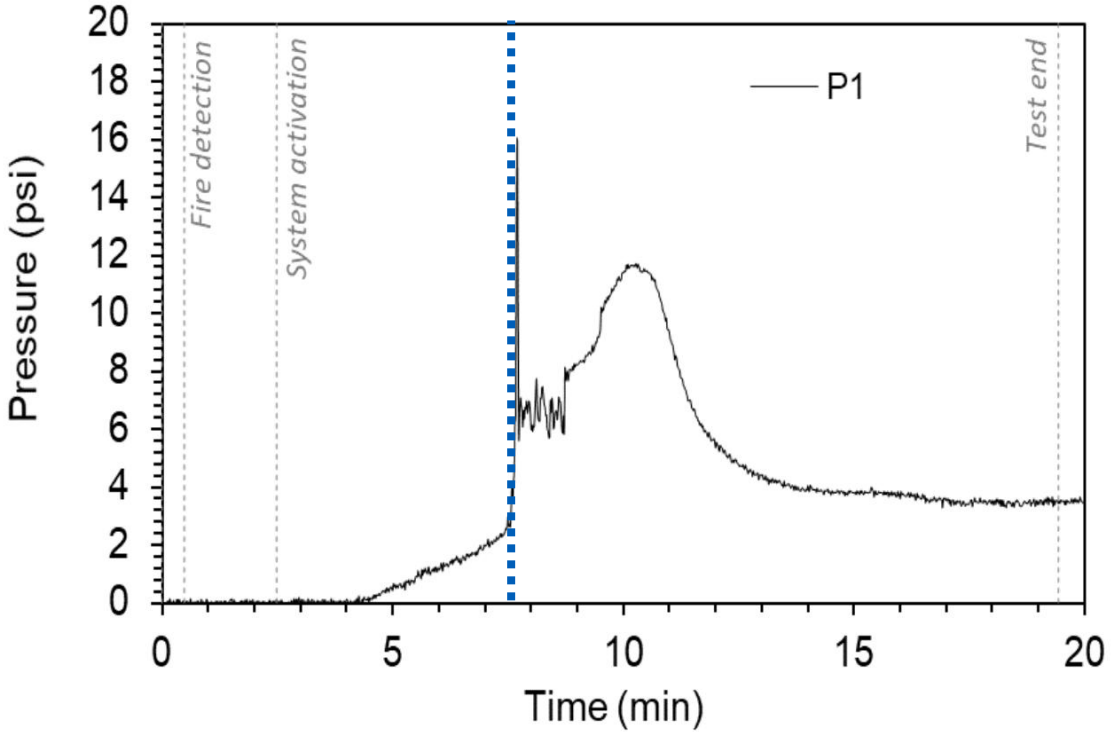
Test Conditions:

TNL280 Tunnel Nozzle:	K400 (K28)
Distance between nozzles:	5.5 m (18 ft)
Nozzle pressure:	0.5 bar (7 psi)
Activation Temperature:	68 C
Time Delay:	2 min
Air Velocity	3 m/s

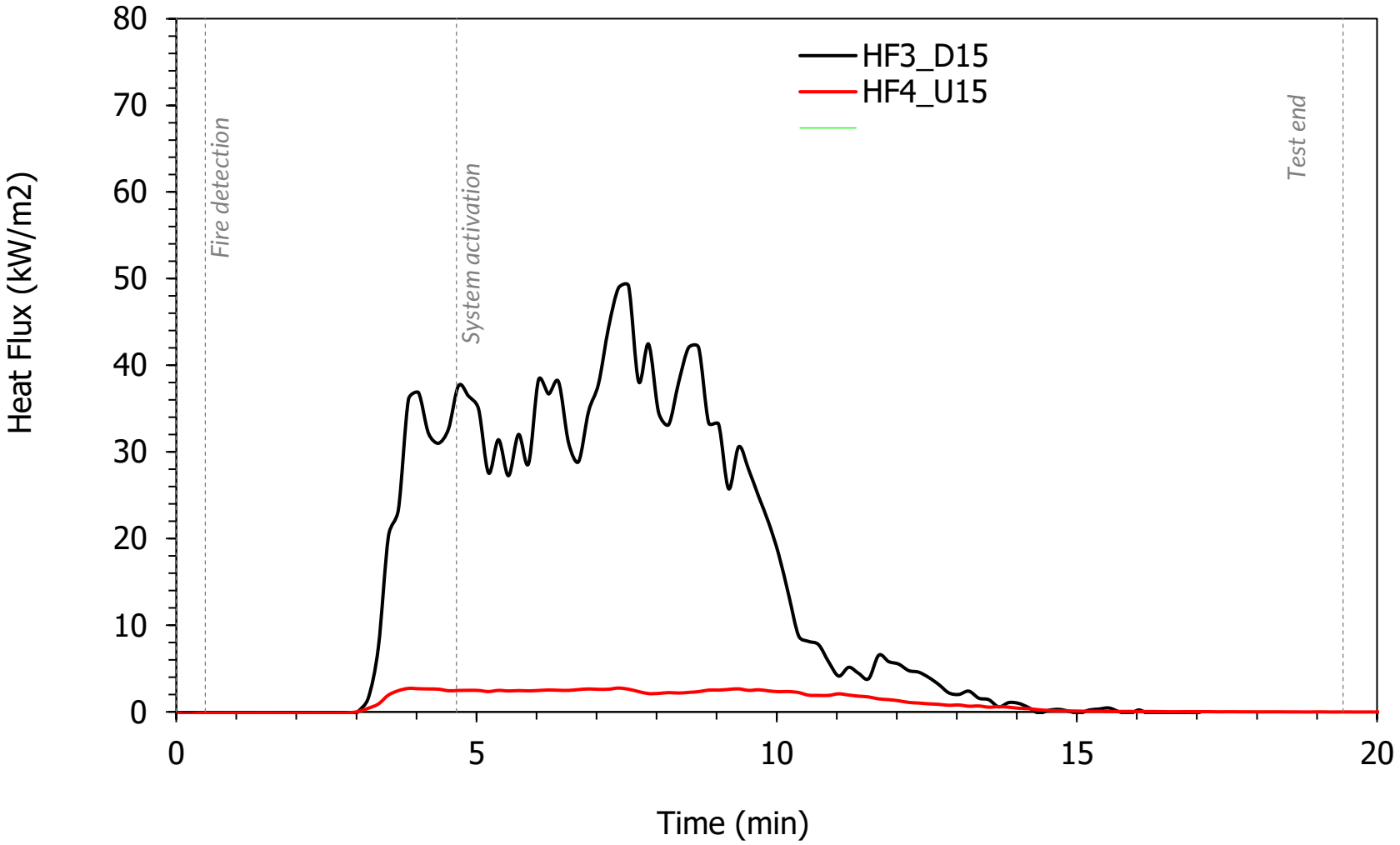
NO TEST

Test 4- HRR and System Pressure





Test 4- Heat Flux

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Test 5- EVs

Test Conditions:

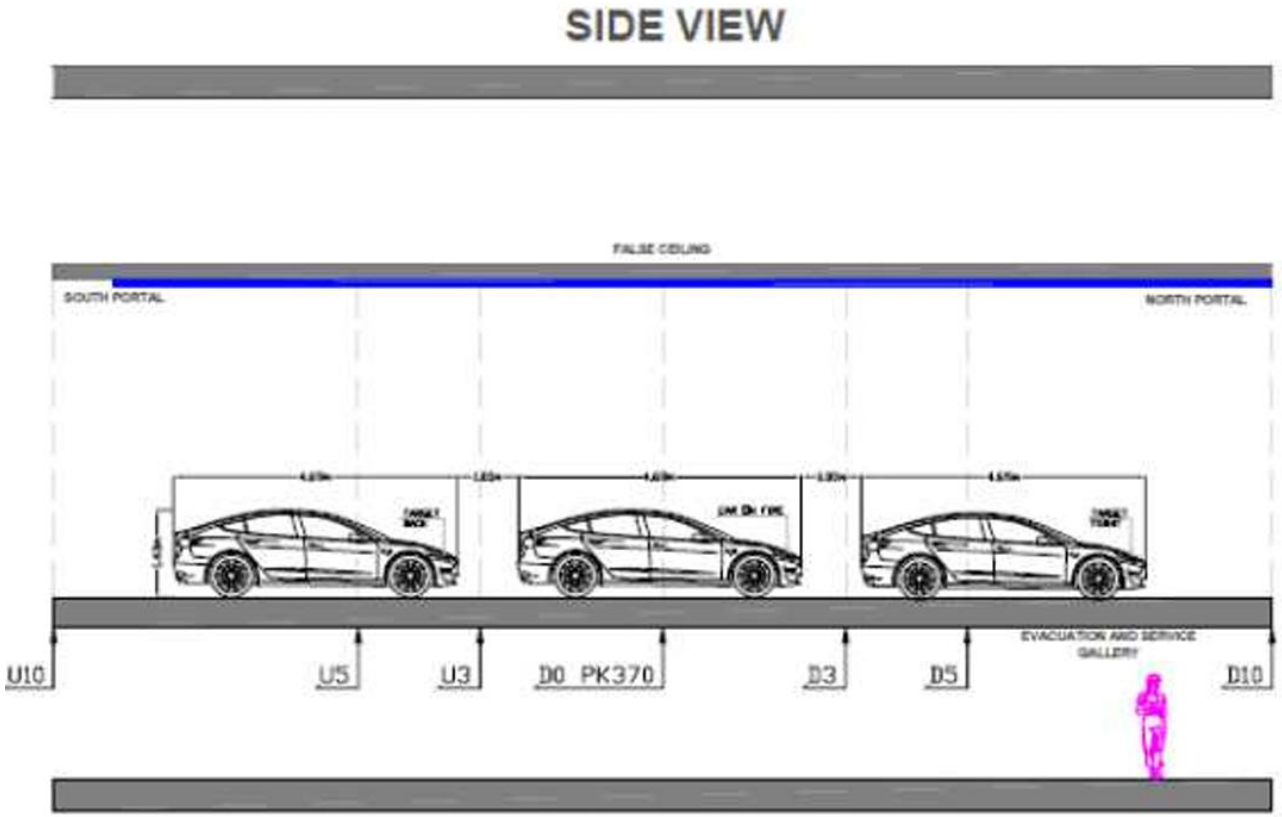
TNL280 Tunnel Nozzle:	K400 (K28)
Distance between nozzles:	5.5 m (18 ft)
Nozzle pressure:	0.5 bar (7 psi)

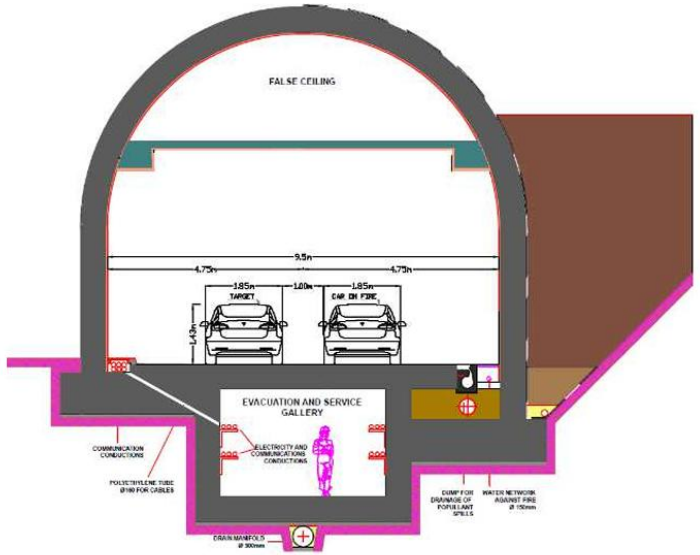
Vehicles:

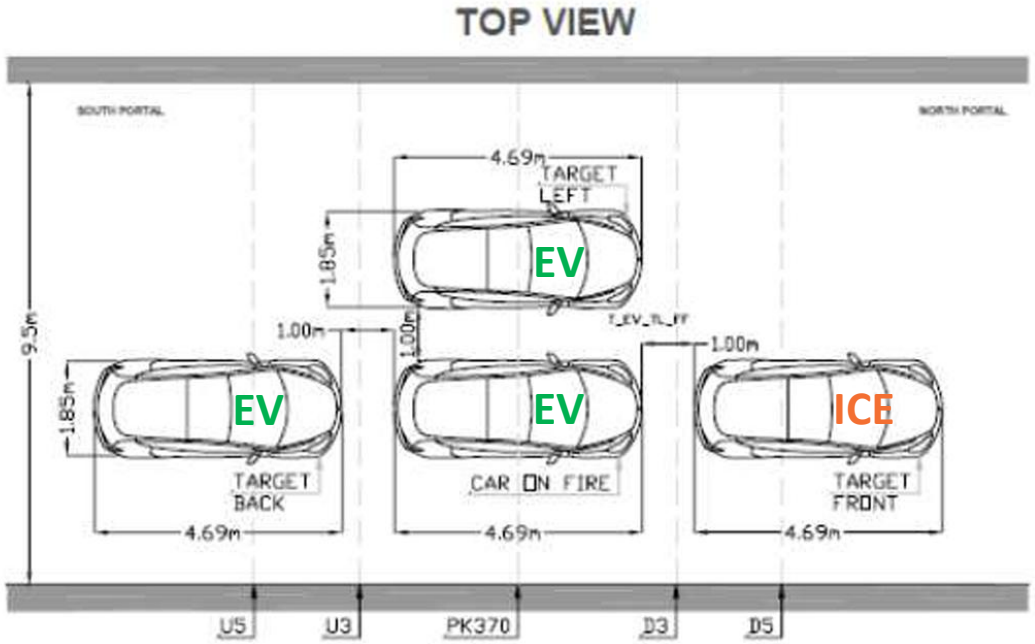
- Three (3) Tesla Model 3 EVs at 100% SOC
- One (1) ICE Vehicle

Test simulated a fire involving multiple vehicles in the tunnel. FFFS was not activated until after three of four vehicles were involved.

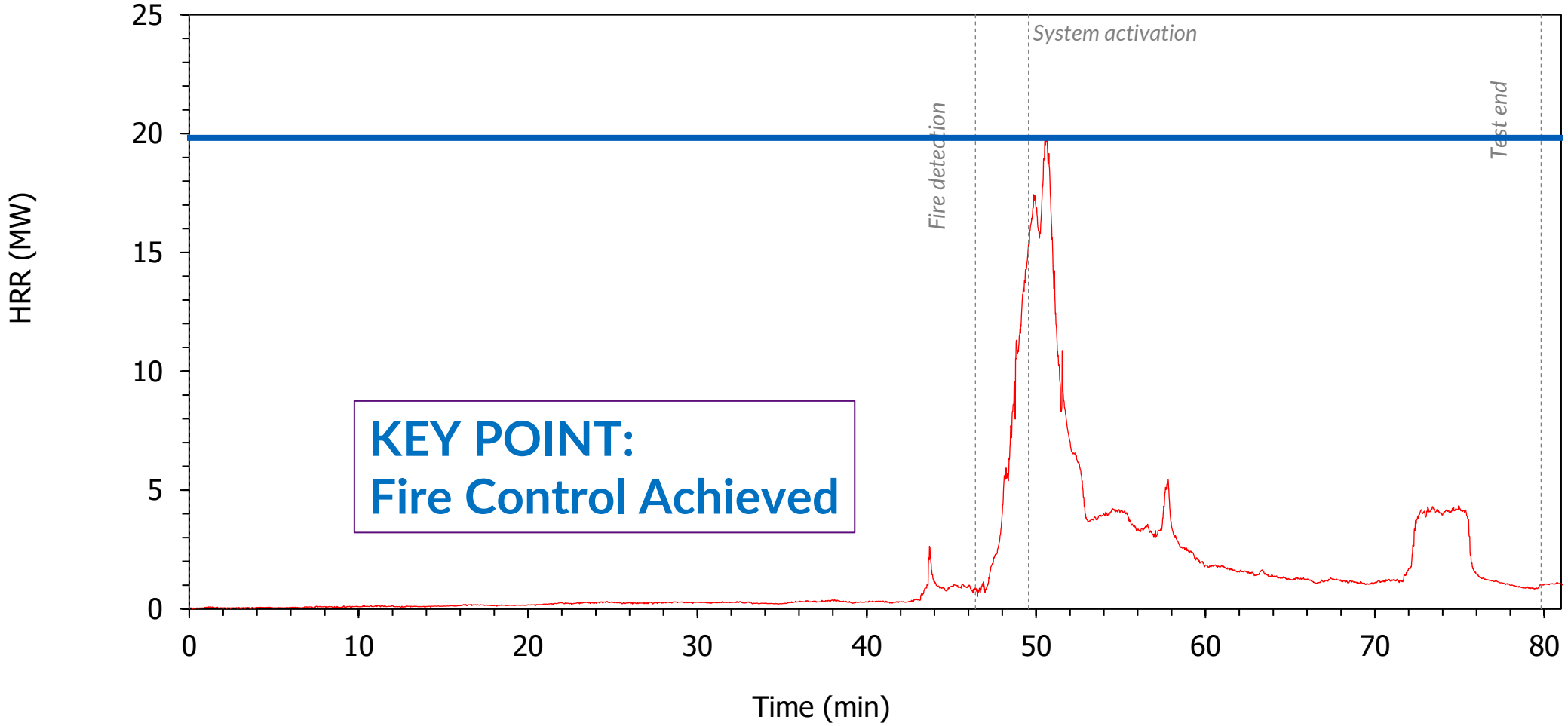
EV Test Layout



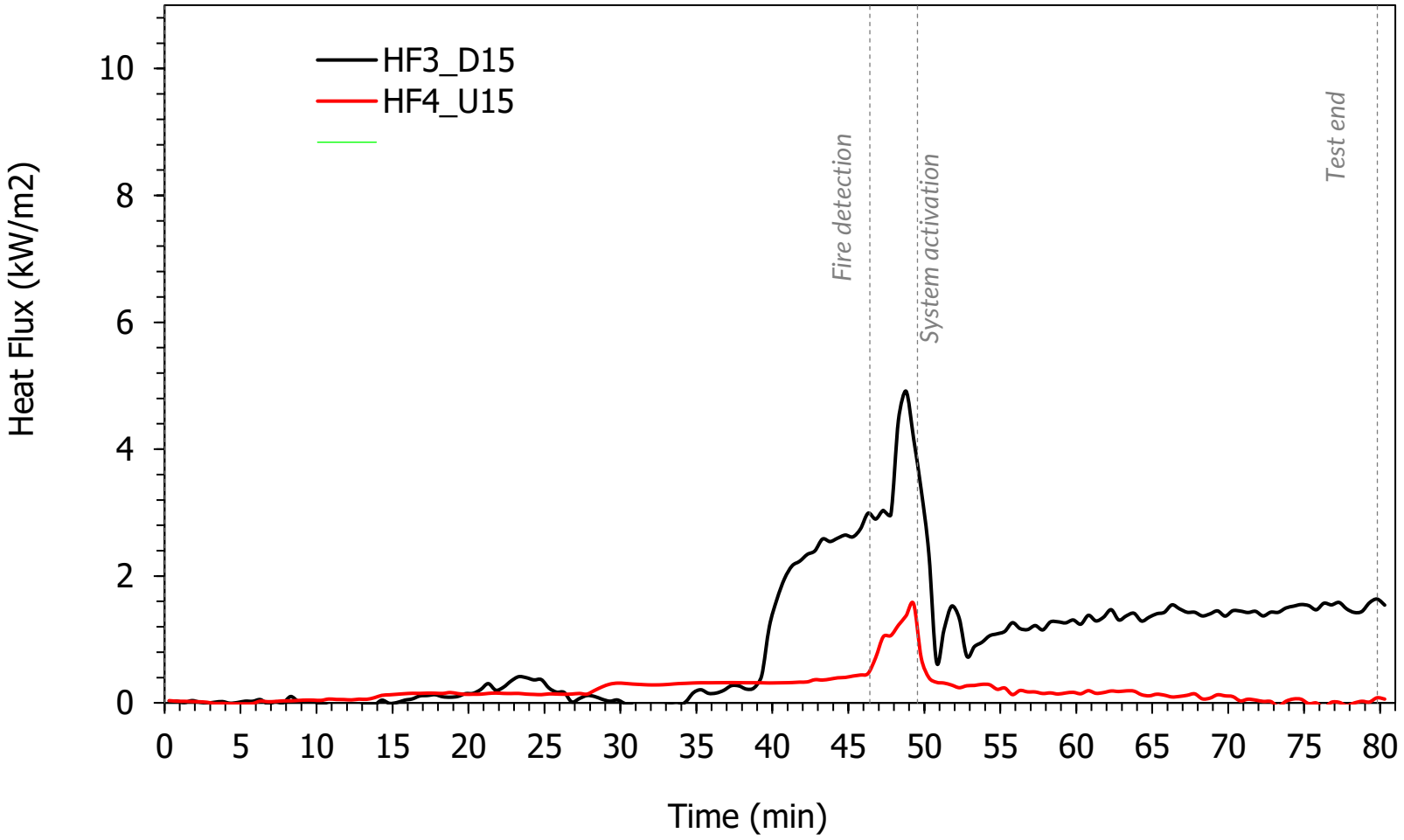




Test 5- Heat Release Rate (HRR)



Test 5- Heat Flux



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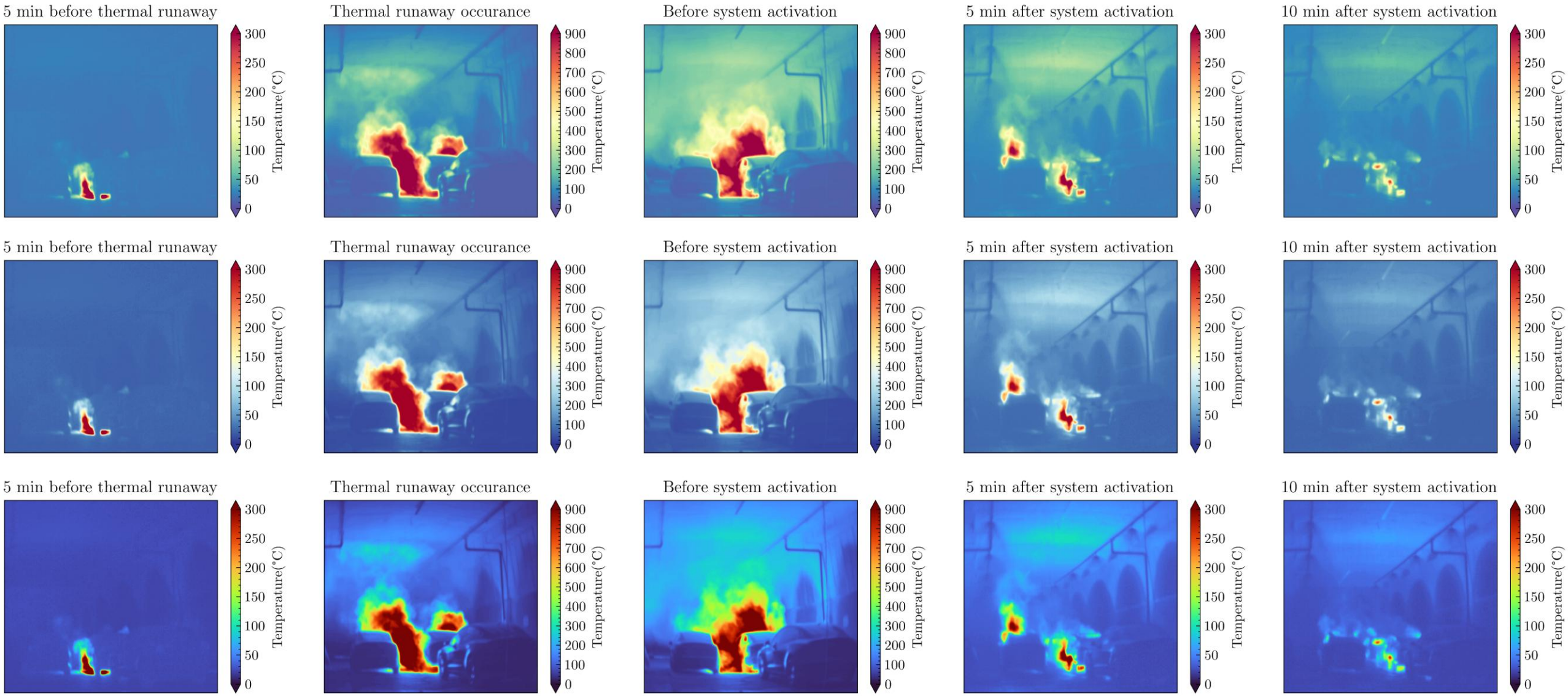
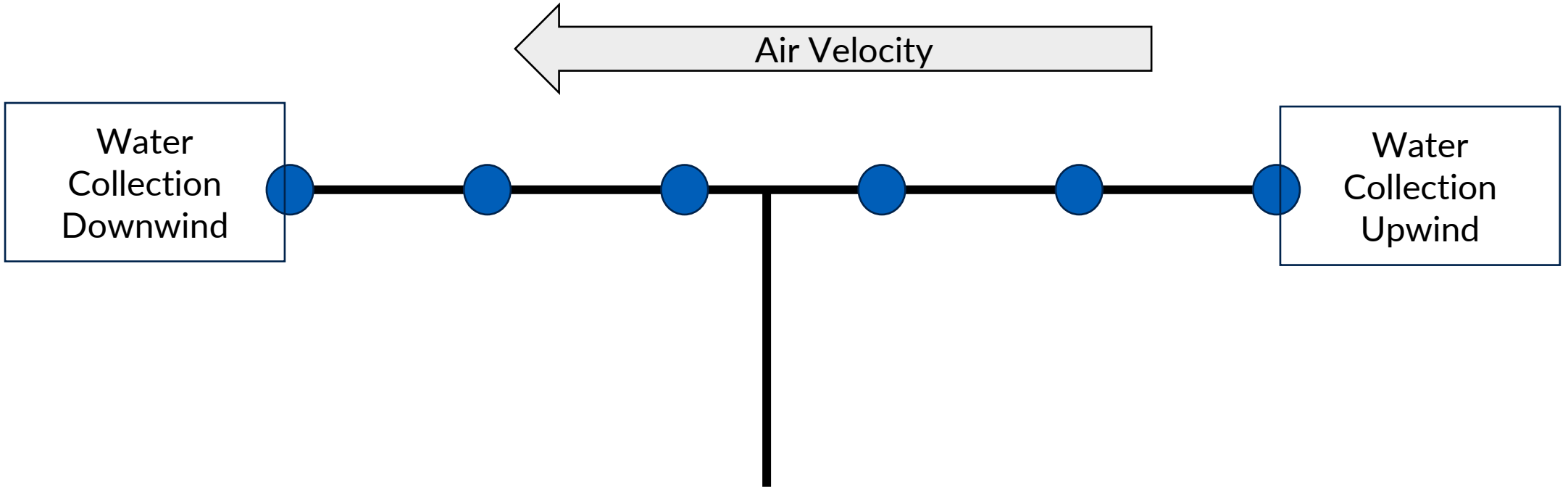
Test 5- Thermal Imagery



Credit: Jakub Bielawski

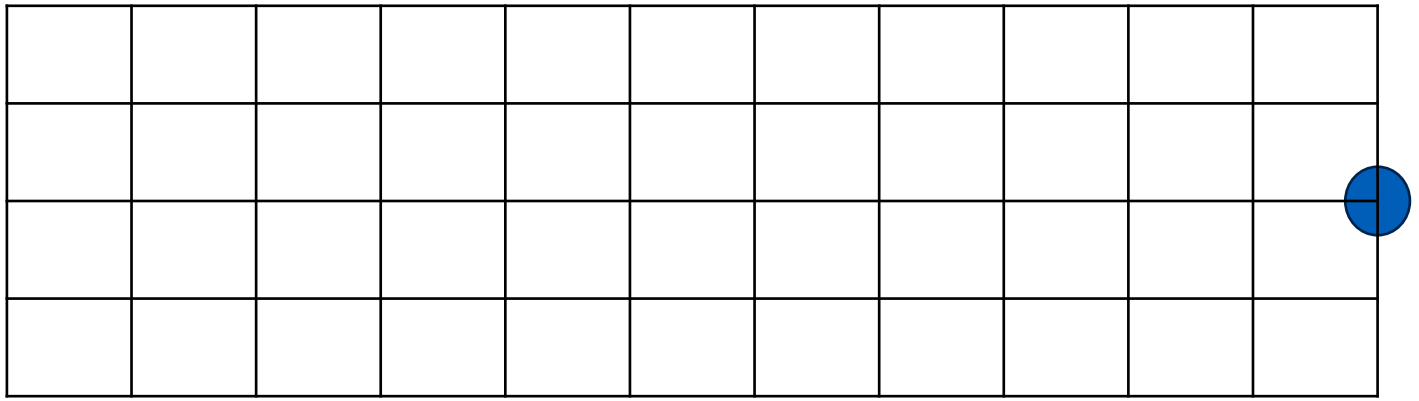
Air Velocity vs Discharge Pattern

Nozzle Arrangement

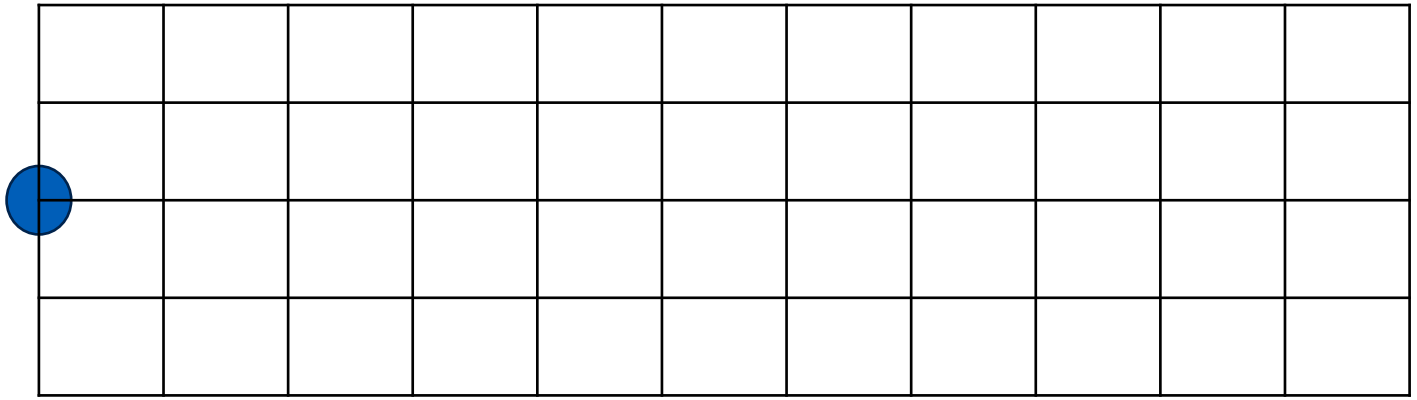


Collection Bucket Placement

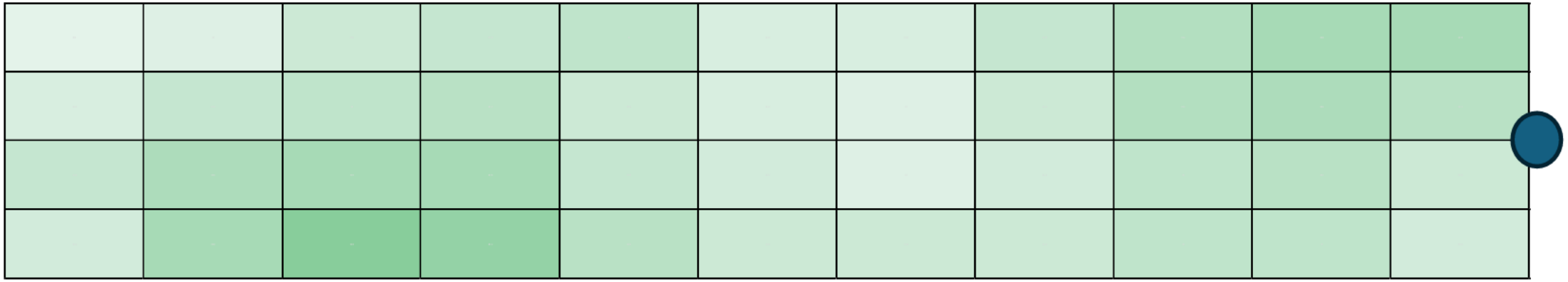
Water Collection Downwind



Water Collection Upwind

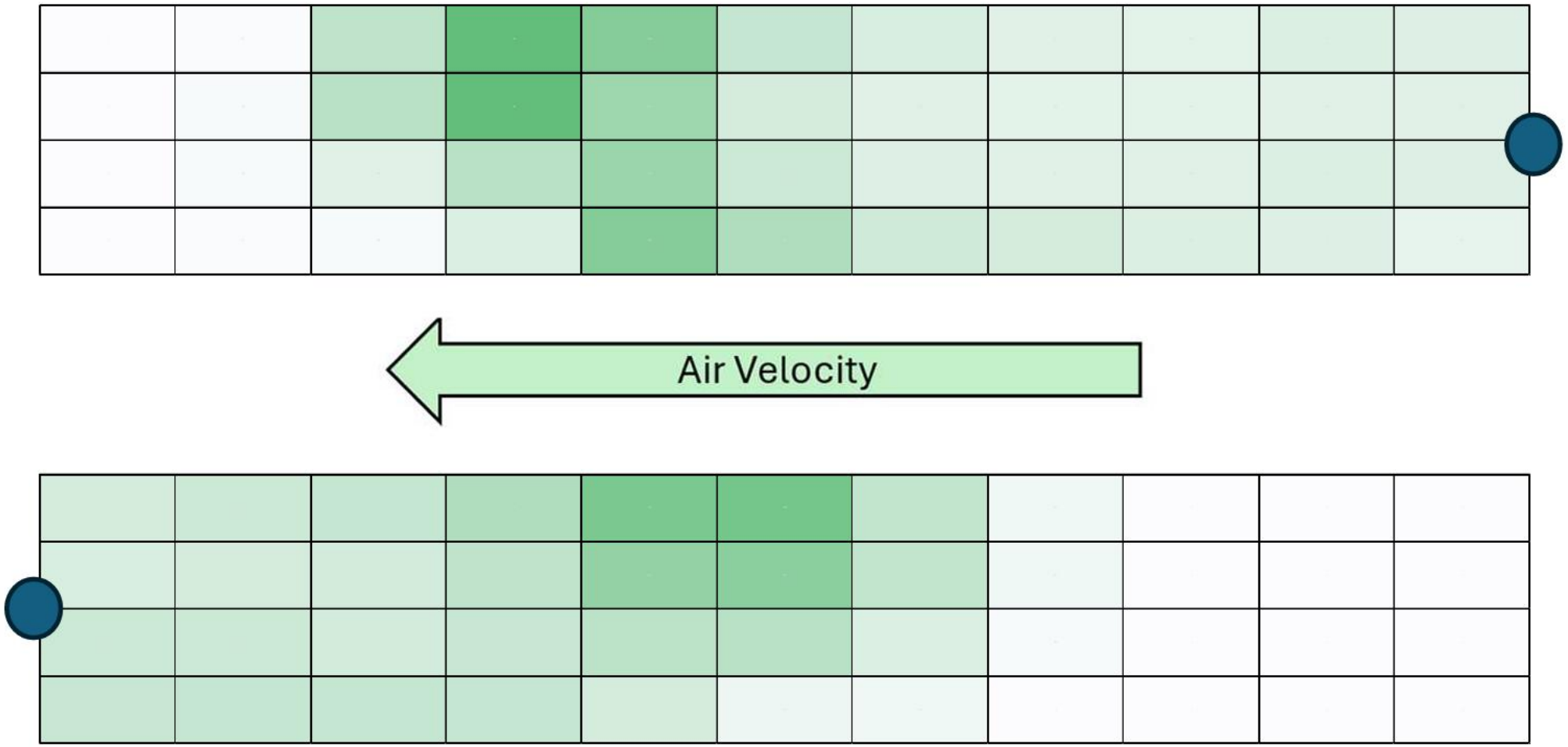


Control - No Forced Ventilation

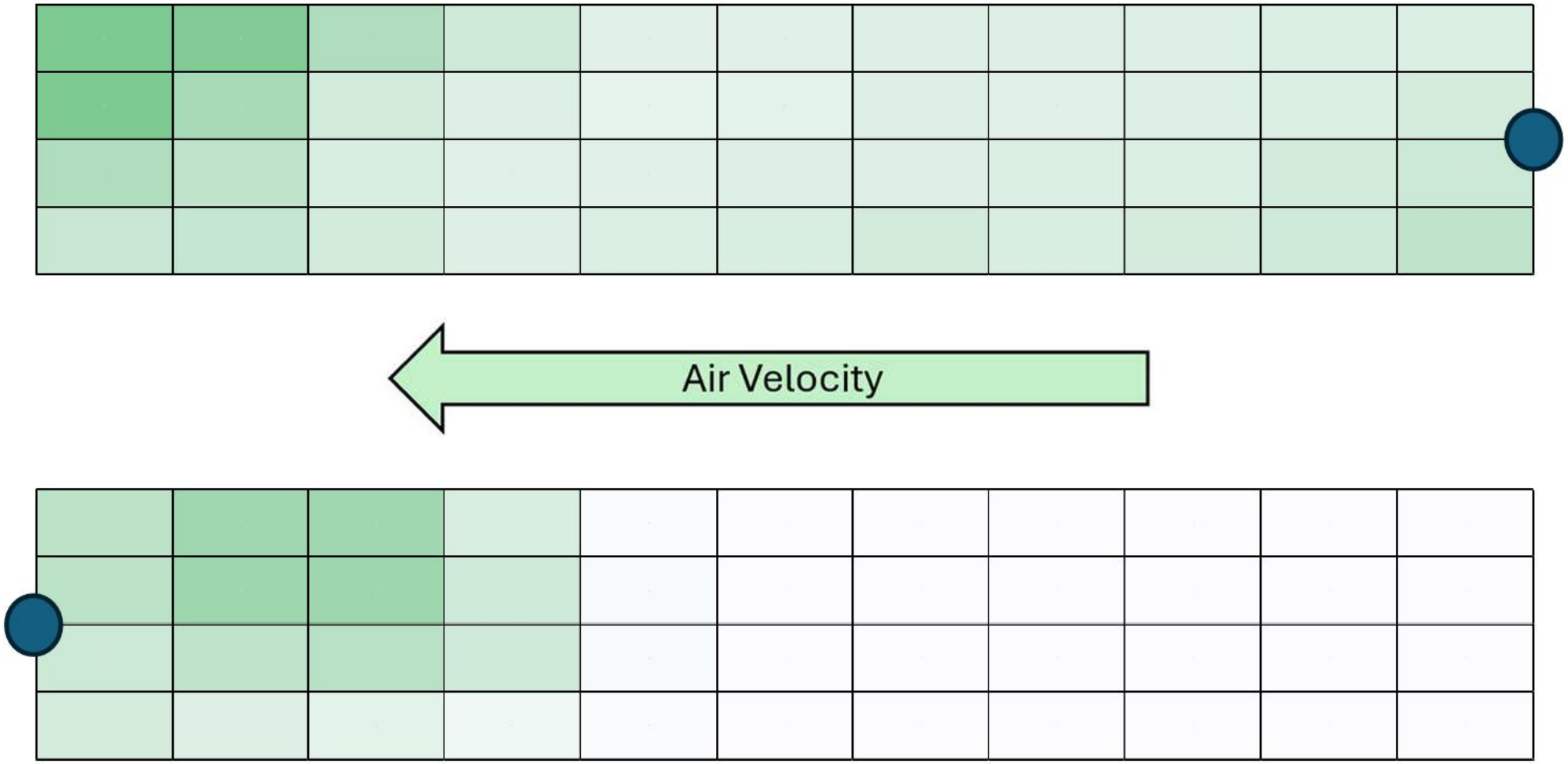


- Although ventilation was turned off around 1.4 m/s of natural ventilation could not be eliminated due to environmental conditions

3 m/s Forced Ventilation



4.5 m/s Forced Ventilation



Recommended Valving

- Depending on the tunnel application any of the Deluge Valve options could be used.
  - DDV Remote Resetting Pressure Reducing
  - DDV Remote Resetting
  - DDV Deluge
  - DDX Deluge
- Due to the length or elevation change associated with tunnel applications the **pressure reducing** function may be required.
- Also, in many large tunnel applications a remote command center is part of the fire protection plan. The **remote resetting** function is available in these cases.
- Depending on the width of the tunnel and the zone length, valves ranging from 4” (100 mm) -6” (150 mm) sizes are generally appropriate.

Solenoid Valve

- **Latching Style Solenoid Valve** - Latching style solenoid valves require an impulse to change state, accommodations must be made with the control panel
  - Burkert Latching Solenoid, 300 psi rated (for FM systems)
- **Non-Latching Style Solenoid Valve-** Non-latching style solenoid valves are normally closed and open upon energizing the 24 V circuit. Upon loss of power the solenoid will return to the closed state.
  - Skinner/Parker Non-latching Solenoid, 175 psi (for UL systems)
  - Skinner/Parker Non-latching Solenoid, 300 psi (for UL systems)

Acknowledgments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