

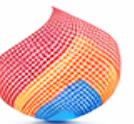
*25th International Water Mist Conference - IWMA
October 7 - 8, 2026 – Prague, Czech Republic*

Water Mist Performance for Electric Vehicle Fires in Parking Garages: A CFD-Based Assessment

The logo for MAPA FIRE features a stylized, colorful, teardrop-shaped graphic composed of a grid of dots in red, orange, and blue. Below this graphic, the words "MAPA" and "FIRE" are written in a bold, orange, sans-serif font, separated by a horizontal line.

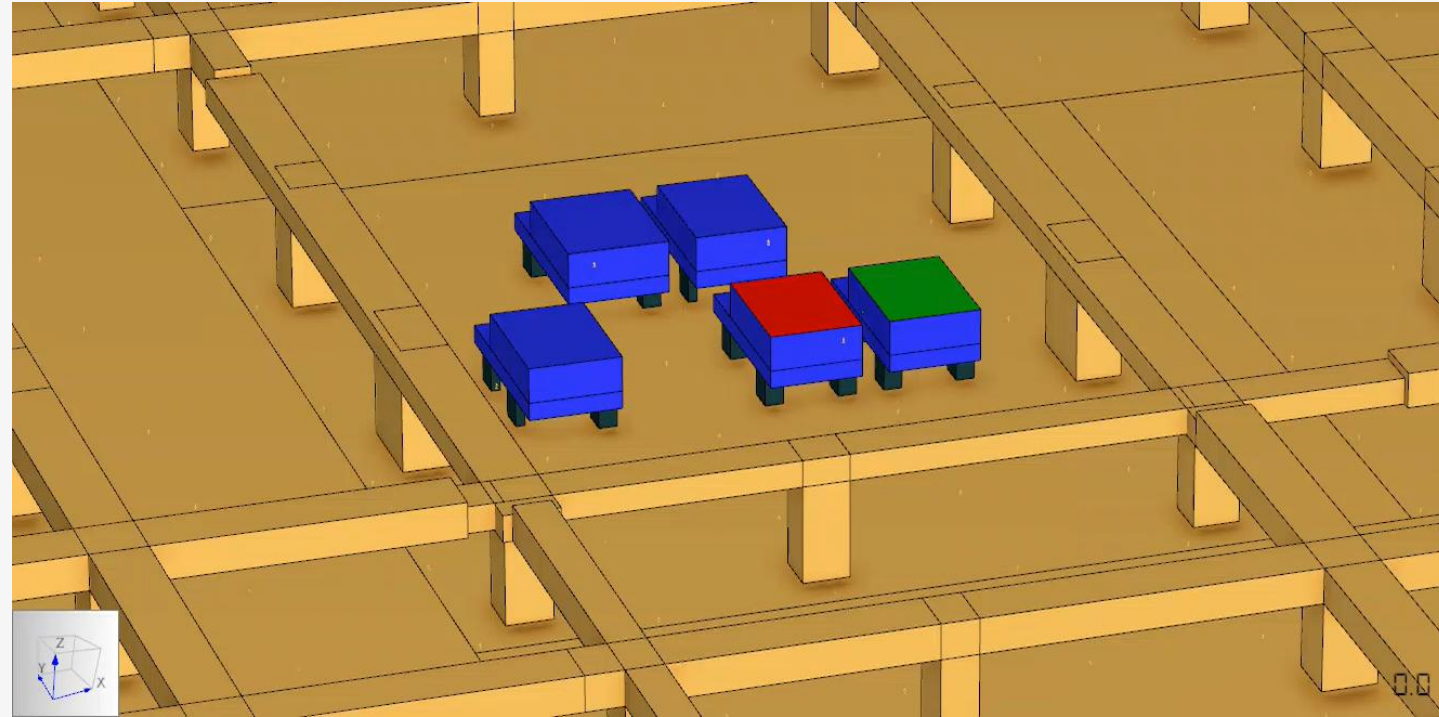
**MAPA
— FIRE —**

MAPA Fire – Chile
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0. OUTLINE

- INTRODUCTION
- METHODOLOGY
- SCOPE
- GOALS/OBJECTIVES
- PERFORMANCE CRITERIA
- FIRE SCENARIOS
- TRIAL DESIGNS
- EVALUATIONS OF TRIAL DESIGNS
- CONCLUSIONS

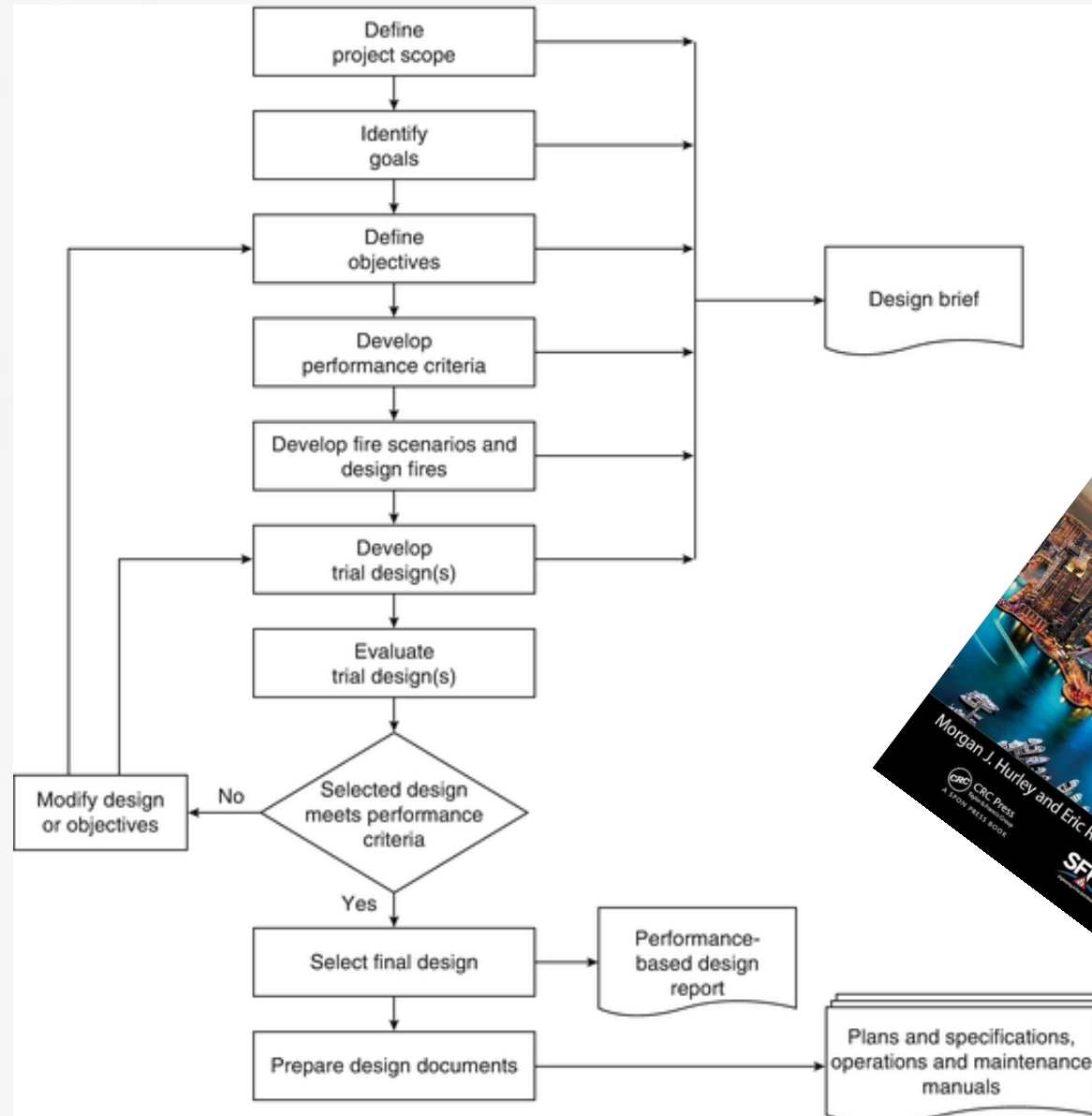


1. INTRODUCTION

- The rapid increase in the use of electric vehicles (EVs) has intensified the need for public parking facilities equipped with charging points. As a result, many existing car parks have begun **adapting their infrastructure to meet this growing demand.**
- These adaptations typically focus on electrical and operational requirements associated with EV charging; however, the fire safety implications of introducing EVs and charging systems have not been adequately considered.
- In parallel, there is a significant lack of knowledge among building owners, architects, facility operators, and local fire services regarding the specific **fire hazards associated with EVs.** This knowledge gap—combined with building regulations that have not yet been updated to reflect EV-related risks—creates a **potentially hazardous condition.**
- Recognizing this situation, the owners and managers of a car park currently undergoing adaptation for EV parking and charging wish to evaluate the **impact of a potential EV fire** on the existing infrastructure and to assess how a **fixed fire suppression system could mitigate its consequences.**

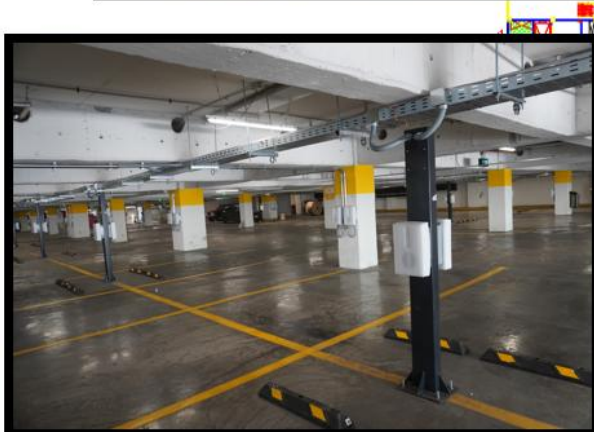
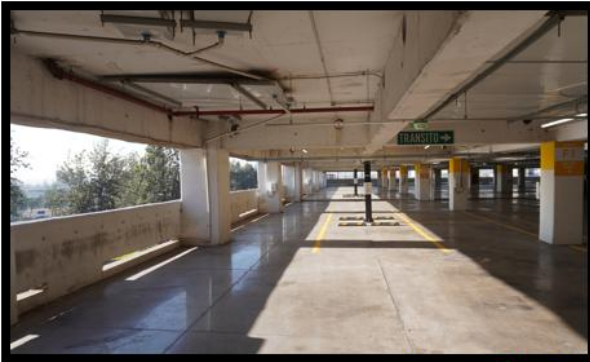
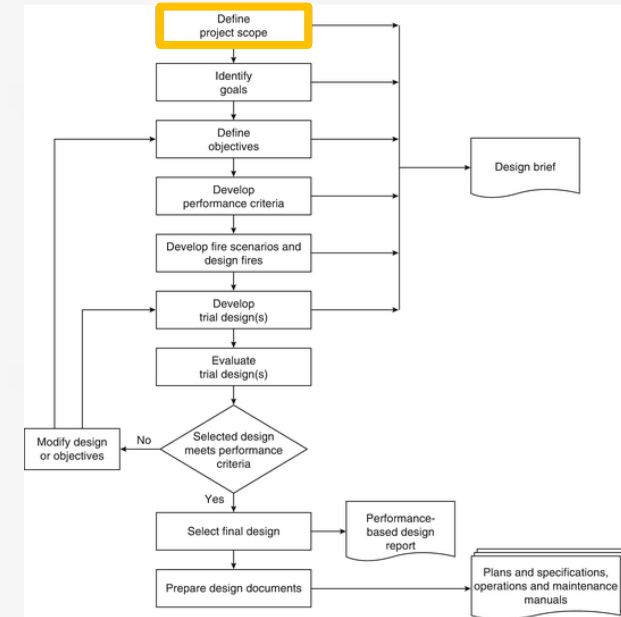


2. METHODOLOGY



3. SCOPE

- Existing Car Park
- No active/passive fire protection
- Allowing the parking and charging of EV
- Located on a third floor



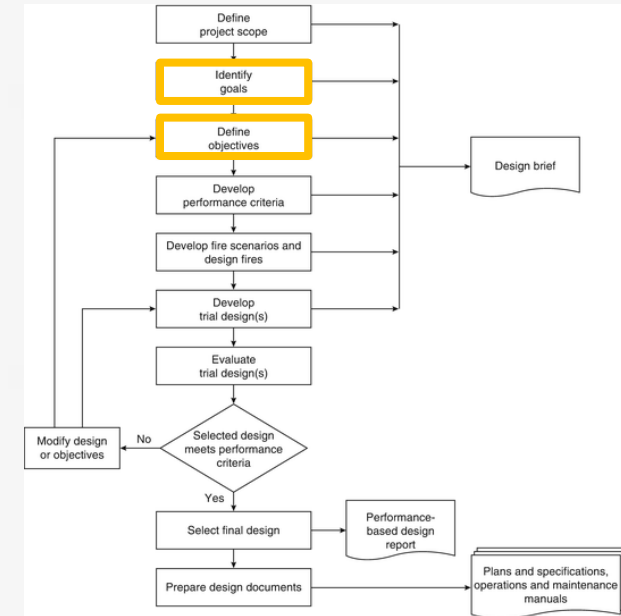
4/5. GOALS & OBJECTIVE

• Goals

- Provide an **environment reasonably safe from fire for occupants that are not closely related to the initial development of the fire and improve the survival capacity of the occupants closely related to the initial development of the fire.**
- Provide an environment reasonably **safe for firefighter** interventions.
- Provide an environment for **the protection of property** and operational continuity in the event of a fire, considering **minimal environmental impact**, especially related to water contamination and containment.

• Objectives

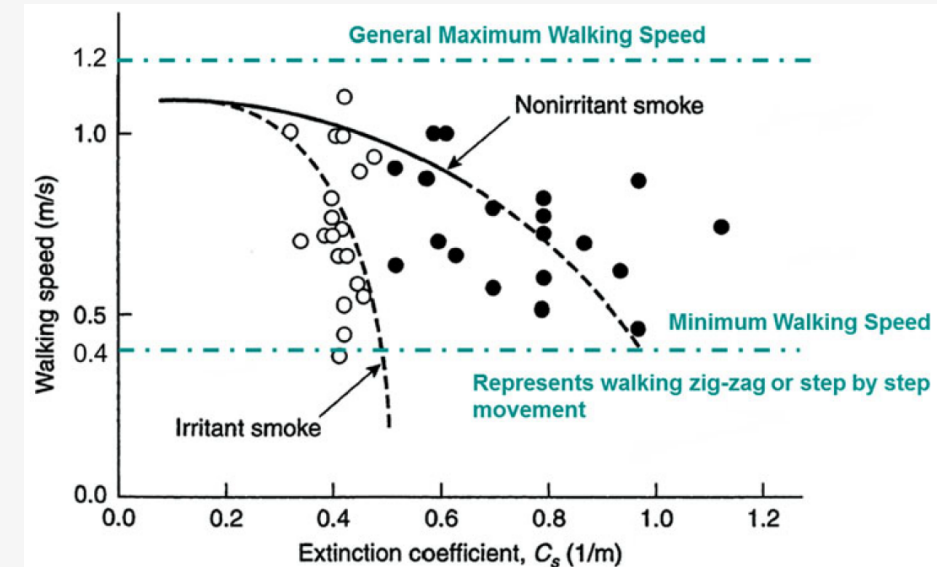
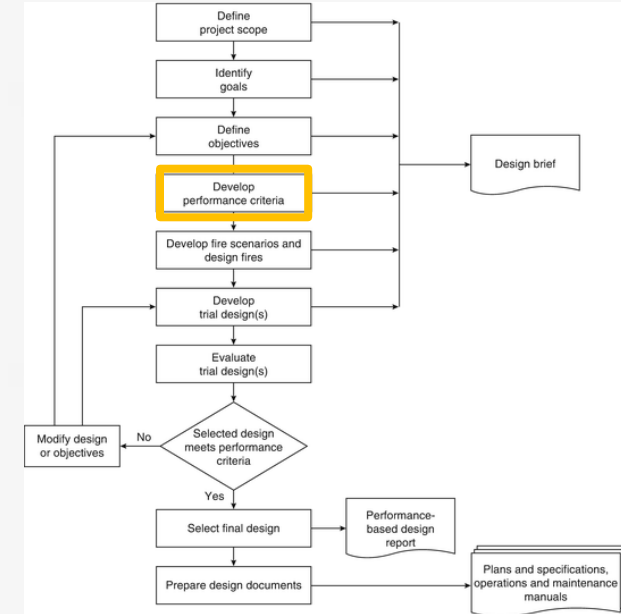
- **Protection of the occupants**: evaluate a fire protection system that protects the occupants who are not familiar with the initial development of the fire during the time necessary to evacuate. Allow occupants who are closely related to the fire to evacuate in sustainable conditions for life safety.
- **Operational continuity**: Evaluate a fire protection system that minimizes the impact of fire in the facilities, considering the fire propagation, heat release rate, among others.
- **Minimize the water discharge**: evaluate a fire protection system that allows compliance with objectives before mentioned and that also fulfils the environmental requirements of minimize the water containment.



6. PERFORMANCE CRITERIA

- **Extinction Coefficient & Visibility**
- **Fire spread and Hot Gases**
- Time to Control and Extinguish the Fire.
- Water discharged.
- Most flammable materials in a car will ignite upon exposure to a heat flux of 25 kW/m^2 .
- Flammable vehicle exterior materials found a critical heat flux range of $11\text{--}18.5 \text{ kW/m}^2$
- An upper-layer temperature of $500\text{--}600^\circ\text{C}$ is typically associated with the $20\text{--}25 \text{ kW/m}^2$ heat flux levels at which most ordinary flammable materials ignite.

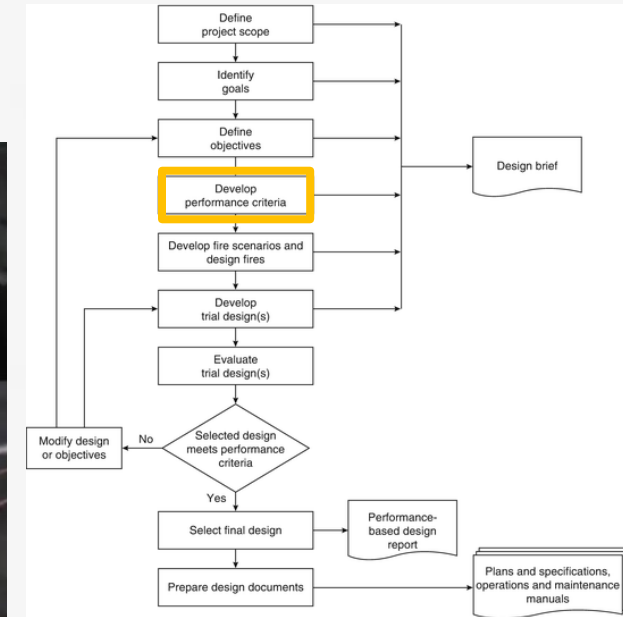
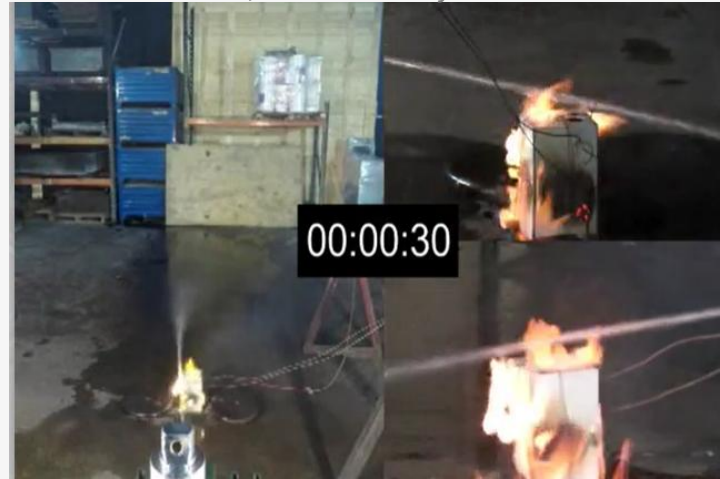
Degree of familiarity with inside the building	Smoke density (extinction coefficient)	Visibility
Unfamiliar	0.15 1/m	13m
Familiar	0.5 1/m	4m



6. PERFORMANCE CRITERIA

- Extinction Coefficient & Visibility
- Fire spread and Hot Gases
- **Time to Control and Extinguish the Fire.**
- Water discharged.
- Complex variable due to the external fixed protection systems are not capable of extinguish the fire, just control it and therefore, contain the HRR.
- NFPA 88A → NFPA 13: density of 0.2 gpm/ft^2 over an area of $1,500 \text{ ft}^2$ (140 m^2). Aprox. 12 sprinklers $K=8.0$ @ 11 PSI discharging 99 lpm (26 gpm)
- Watermist system: Projects are designed for water supply over 144 m^2 area of operation considering 9 upright nozzles.
- Water Pressure: 116 PSI (8 Bar), K-factor metric: 19 (l/min 1bar) and Flow rate: 53.74 lpm.

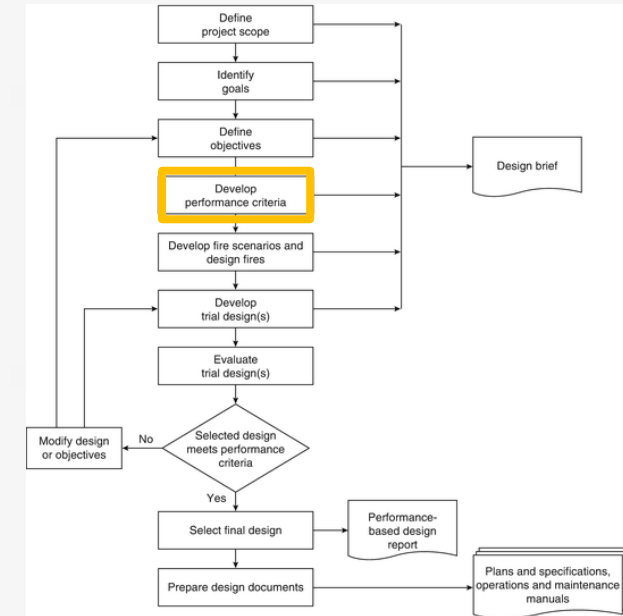
The Science of Fire and Explosion Hazards from Lithium-Ion Batteries, UL Fire Safety Research Institutes



RISE Report 8P03983-03 Fire Suppression Tests for Vehicle Battery Pack

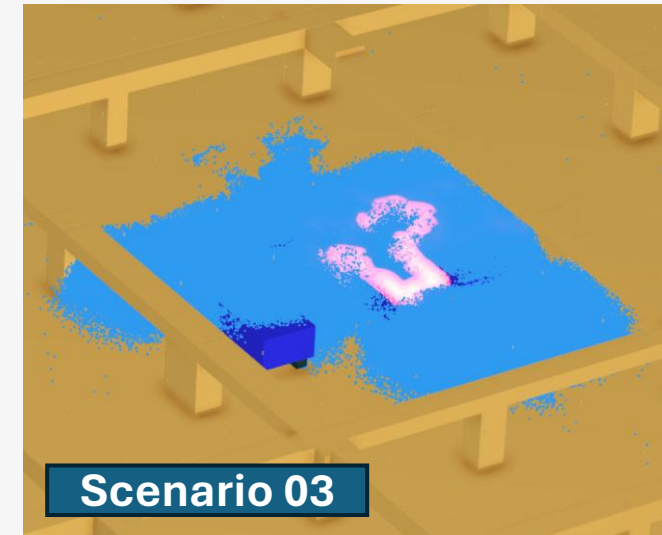
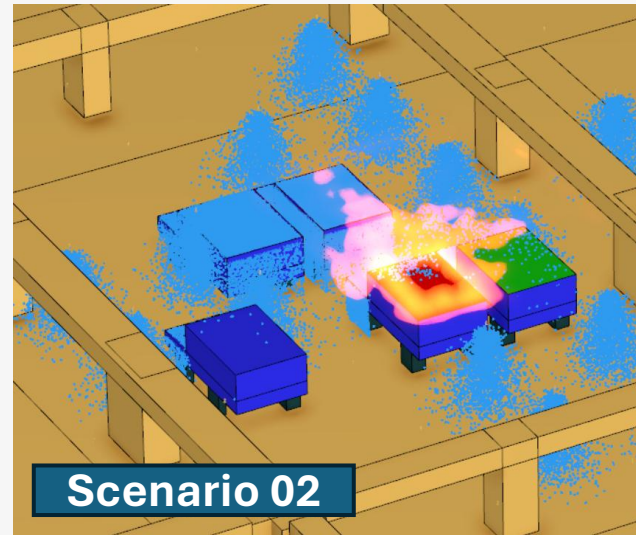
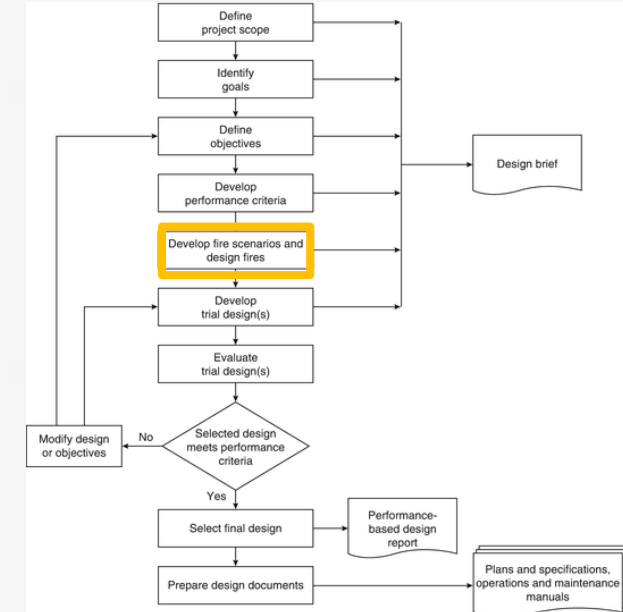
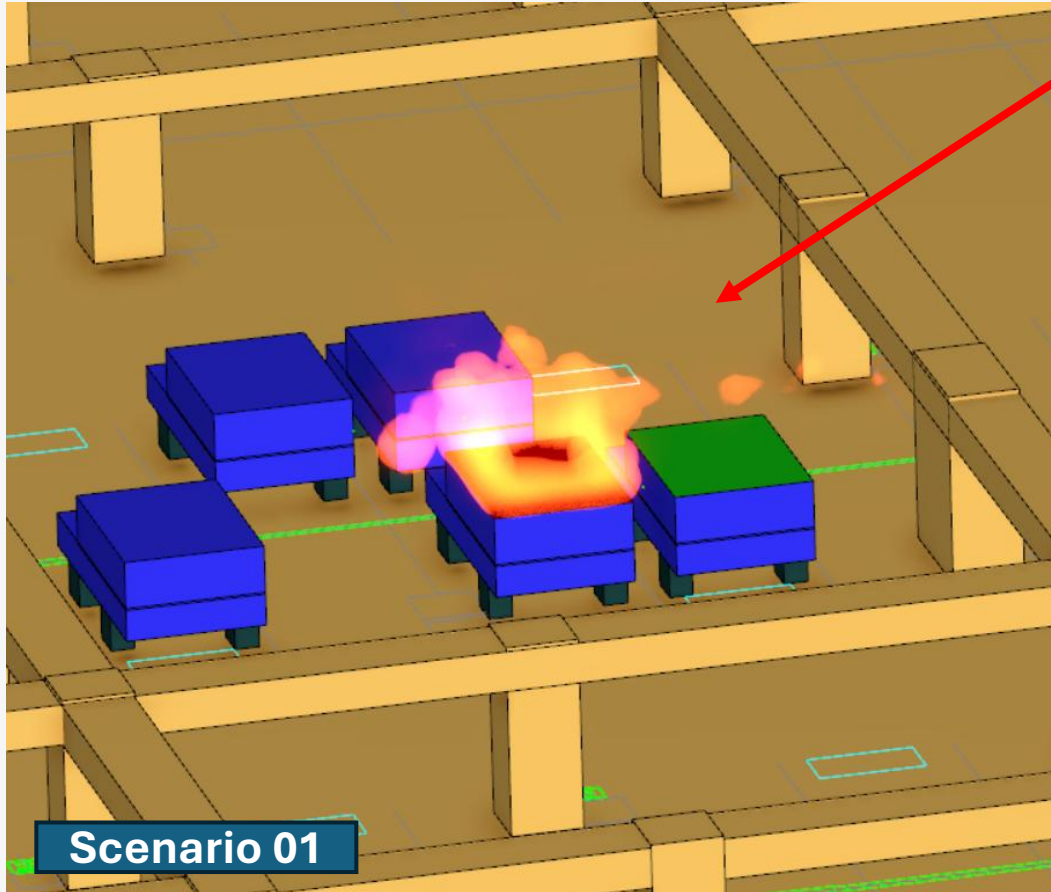
6. PERFORMANCE CRITERIA

- Extinction Coefficient & Visibility
- Fire spread and Hot Gases
- Time to Control and Extinguish the Fire.
- **Water discharged.**
- Numerous studies (RISE 2023:22, RISE 2020:90, among others) show that **fire-extinguishing water from BEVs** contains significantly **higher concentrations of contaminants** compared to that from conventional vehicles (ICEVs).
- **Fluorides** (dissolved HF, fluoride salts): very high levels resulting from the decomposition of the electrolyte (LiPF_6). These fluorides are highly toxic to aquatic organisms, even at low concentrations.
- **Heavy and transition metals**: Ni, Co, Mn, Li, Cu, Al, Fe, Zn, among others, released from both cells and structural components.
- **Solids**: fragments of charred electrolyte, plastics, and metal particles. RISE (2023:22) found that fire-extinguishing water from BEVs had significantly higher concentrations of metals and fluoride than that from ICEVs, with measurable toxicity to aquatic species.



7. FIRE SCENARIOS

- **Scenario 01 – Current Facility**
- **Scenario 02 – Sprinklers Protection**
- **Scenario 03 – Water mist Protection**

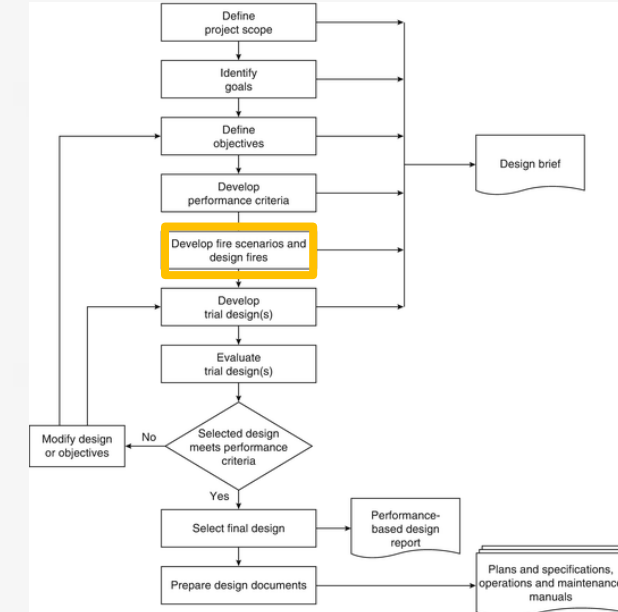


7. FIRE SCENARIOS

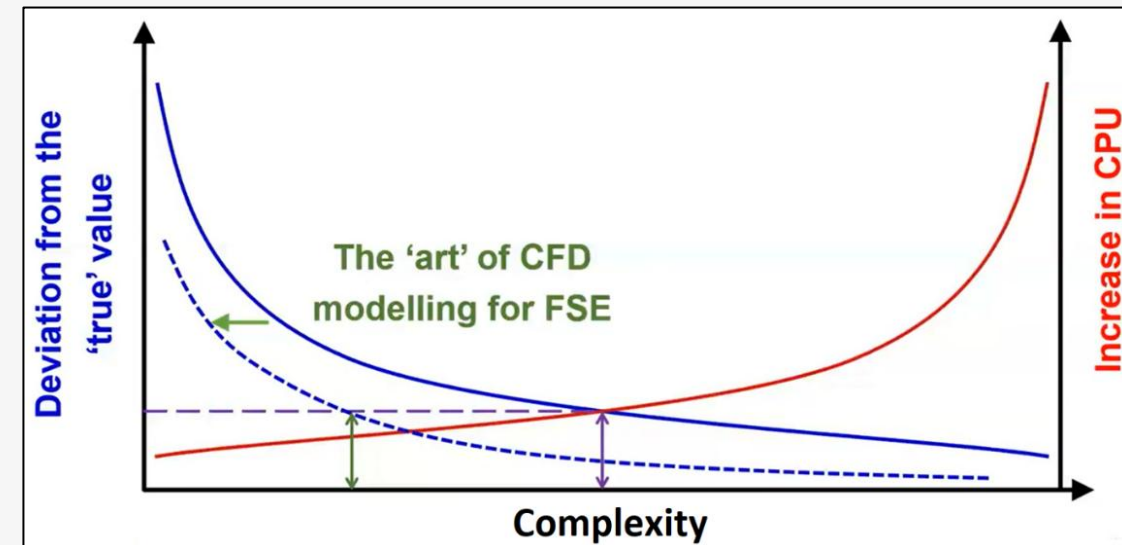
- General Considerations



Progress with LI-ION Battery Fire Safety: Engineering Solutions to Mobility and Storage Hazards, SFPE 2024 Engineering Symposium - FSRI Experimental Investigation of EV Fires Nathaniel Sauer, PhD SFPE Engineering Solutions Symposium Progress with Li-Ion Battery Fire Safety Phoenix, Arizona



Dr. Ir. Tarek Beji – University of Ghent



7. FIRE SCENARIOS

- **Ignition;** the car is considered already on fire.
- **Combustible:** representation according real fire scale tests

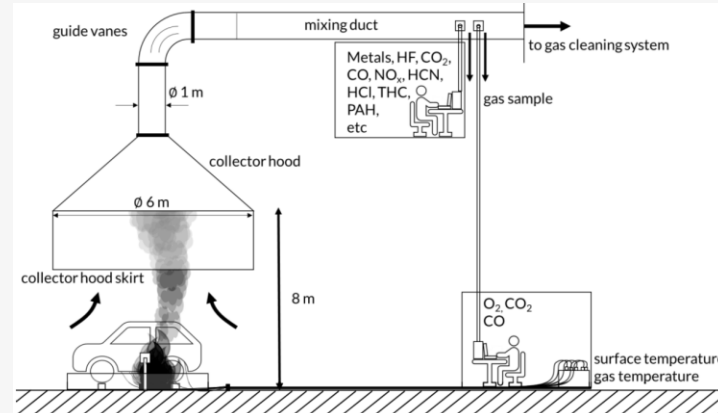
Likelihood of fire claims/car/year (%)	Type of car
0.001	EV
0.003	PHEV/REEV
0.007	Petrol
0.011	Diesel

T0194 – Covered car parks – fire safety guidance for electric vehicles, ARUP, July 2023.

Hazard Comparison: EV vs ICE

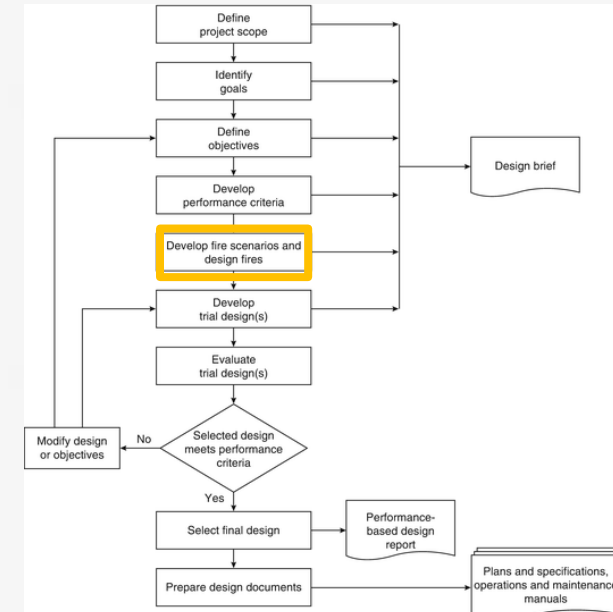
	EV	ICE
Fuel Source	Lithium-ion Batteries	Gasoline
Fire Causes	Puncture, overheating, overcharging, over-discharging	Fuel or oil leak, overheating, worn out parts, loose electrical components
Likelihood	** 25.1 fires/100,000 cars sold **	1,529.9 fires/100,000 cars sold
Suppression Time	~ 60 – 90+ min	~ 30 min
Water Usage	Reports of up to thousands of gallons; Sustained water supply needed	~500 gallons
Reignition Potential	Likely, and very common	Rare
Fire Size	Can be large if propagation occurs, Avg HRR: 1.5 – 8+ MW Avg THR: 5.9 GJ	Typically limited to 1 vehicle; propagation is less common Avg HRR: 6.5 MW – 8 MW Avg THR: 5.9GJ

** not based on national statistical data



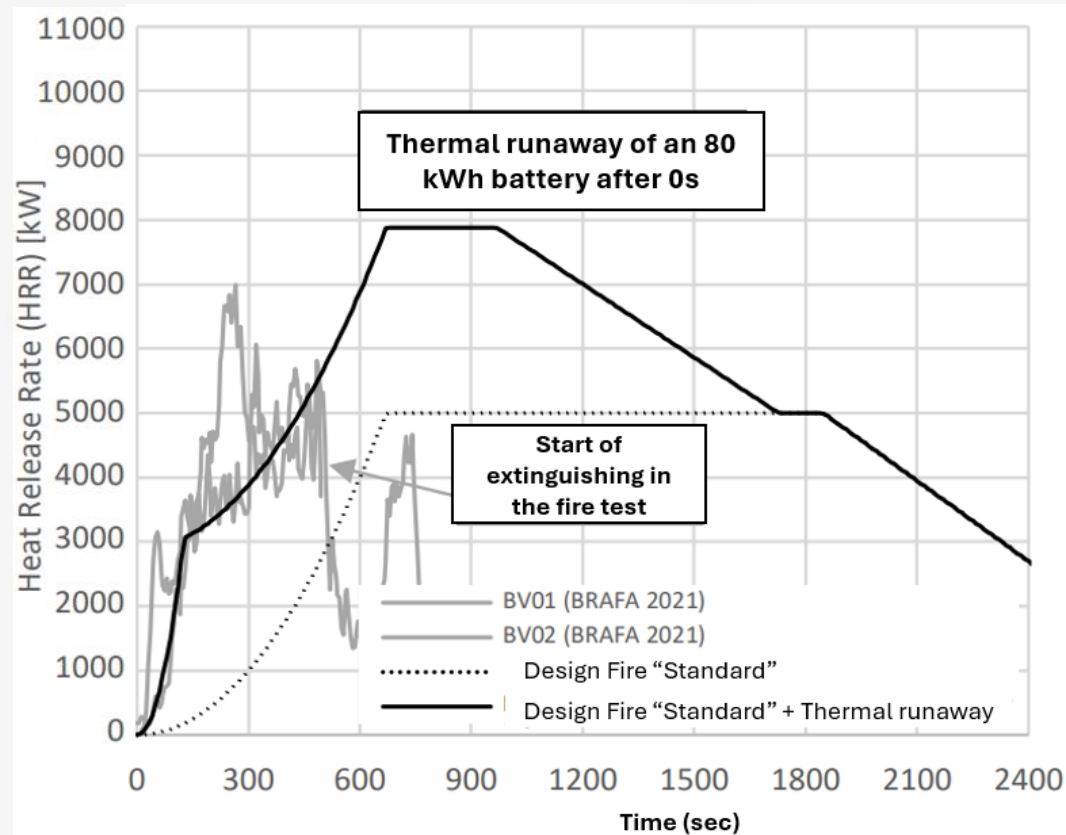
Toxic Gases from Fire in Electric Vehicles - Ola Willstrand, Roeland Bisschop, Per Blomqvist, Alastair Temple, Johan Anderson - RISE Report 2020:90

Gas measurements	ICEV A	BEV A	BEV B
CO ₂ , [kg] / [g/lost g]	344 / (1.4)	335 / (1.4)	438 / (1.1)
CO, [g] / [mg/lost g]	6 420 / (25.5)	7 790 / (31.5)	9 510 / (23.8)
THC, [g] / [mg/lost g]	2 370 / (9.4)	3 130 / (12.7)	2750 / (6.9)
HF, [g] / [mg/lost g]	11 / (0.04)	573 / (2.3)	859 / (2.1)
HCl, [g] / [mg/lost g]	1100 / (4.4)	1590 / (6.4)	1800 / (4.5)
HBr, [g] / [mg/lost g]	18 / (0.1)	115 / (0.5)	88 / (0.2)
HCN, [g] / [mg/lost g]	-	-	155 / (0.4)
SO ₂ , [g] / [mg/lost g]	479 / (1.9)	575 / (2.3)	645 / (1.6)
NO, [g] / [mg/lost g]	452 / (1.8)	371 / (1.5)	617 / (1.5)
NO ₂ , [g] / [mg/lost g]	44 / (0.2)	25 / (0.1)	76 / (0.2)
PAH, [g] / [mg/lost g]	112 / (0.4)	29 / (0.1)	334 / (0.8)



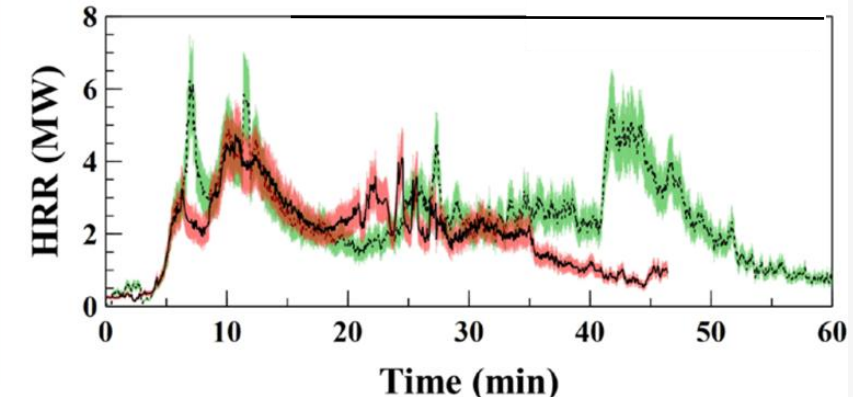
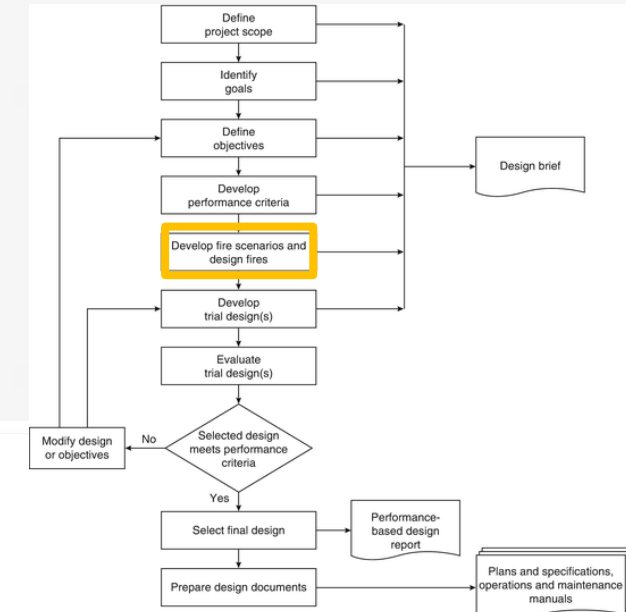
7. FIRE SCENARIOS

- HRR



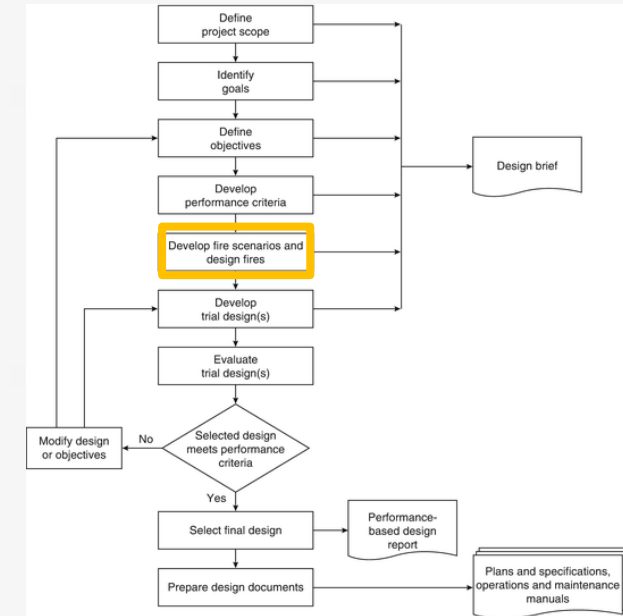
Brandszenarien bei E-PKW Stand der Wissenschaft, Dr.-Ing. Matthias Siemon Moritz Rupp, M. Eng.

Progress with LI-ION Battery Fire Safety: Engineering Solutions to Mobility and Storage Hazards, SFPE 2024 Engineering Symposium - FSRI Experimental Investigation of EV Fires Nathaniel Sauer, PhD SFPE Engineering Solutions Symposium Progress with Li-Ion Battery Fire Safety Phoenix, Arizona



7. FIRE SCENARIOS

- **HRR**
- **In FDS, a prescribed HRR (e.g., via HRRPUA or HRRPUV) cannot be extinguished because it bypasses the combustion and pyrolysis models.** Thus, an user-defined HRR does not decrease when water is applied, since it bypasses the combustion and pyrolysis models
- To represent **realistic EV fire behavior**, the HRR must therefore be **controlled rather than imposed**
- **A logical freeze function is implemented in FDS:** once the number of sprinklers or water-mist nozzles required to control an EV fire (according to applicable codes or manufacturer specifications) has activated, the HRR is held constant.
- This approach **prevents the artificial increase of HRR** and **prevent an excessive operation** of Sprinklers/Nozzles

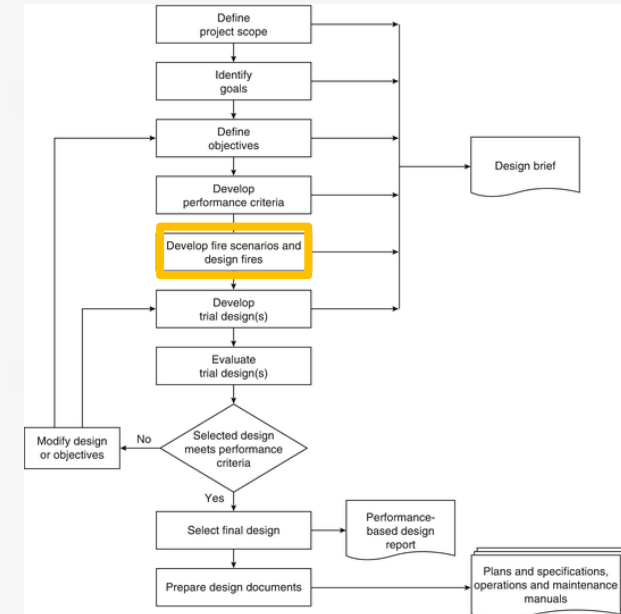
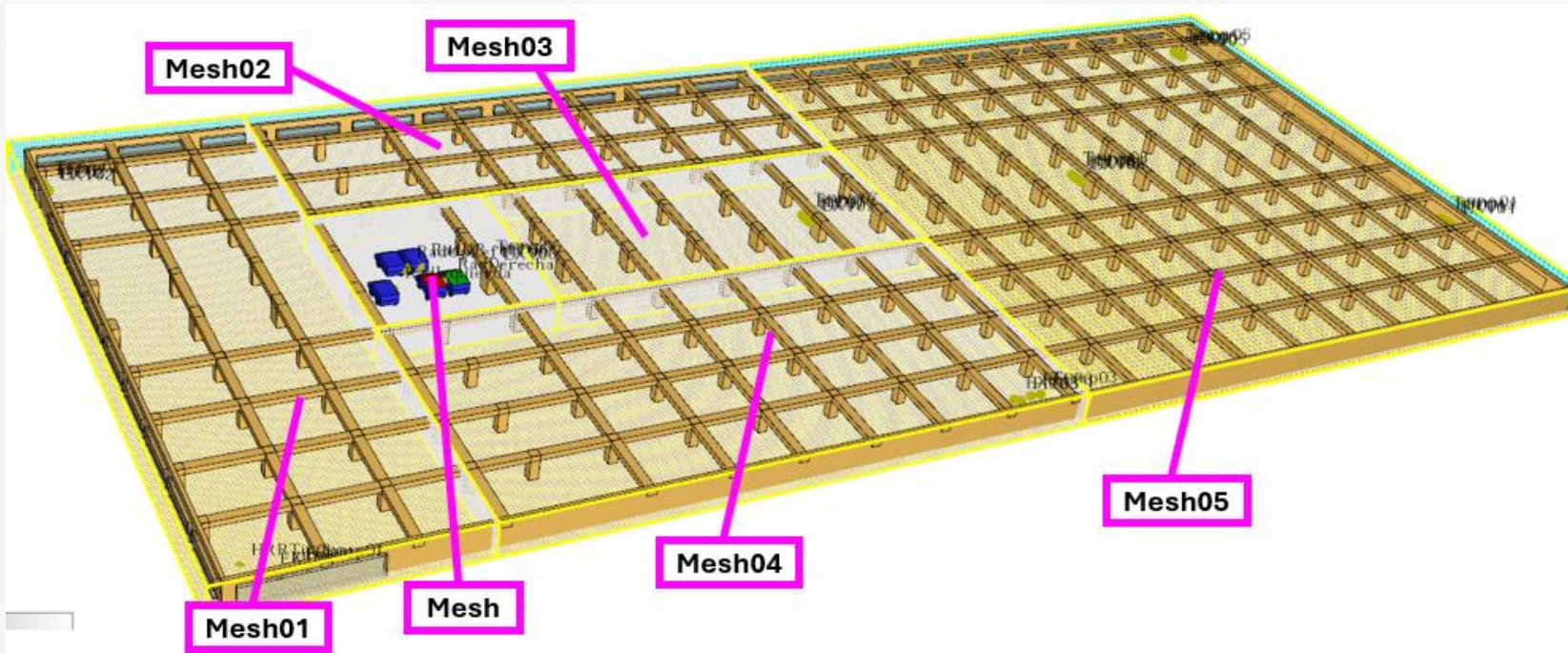


7. FIRE SCENARIOS

- Mesh Cell Size

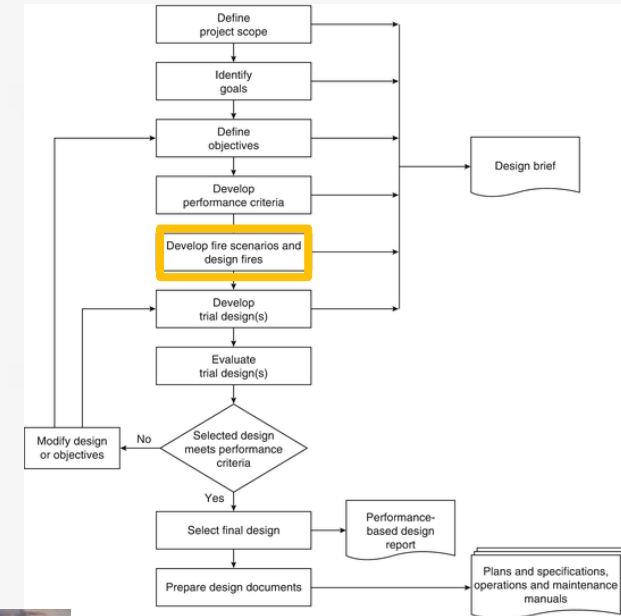
$$D^* = \left(\frac{Q}{\rho C T \sqrt{g}} \right)^{\frac{2}{5}} \quad 4 < \frac{D^*}{\delta x} < 16$$

Scenario	HRR		D*	Cellsize (m)	D*/Cellsize
01 - No System	8000	kW	1.4001	0.20	7
02 - Sprinkler System	4000	kW	1.0611	0.20	5
03 - WM System	4000	kW	1.0611	0.20	5



7. FIRE SCENARIOS

- **Jet Fires:** In EVs, venting flame jets can occur, but their reach and duration are typically limited compared to other jets (e.g., from CNG tanks), according to observations by RISE. Thus, this phenomena its not considered within the modelling.
- **Explosions:** A cloud of flammable vapors and gases may accumulate inside the vehicle. Flammable vapor clouds occurred in only 5% of the incidents. Thus, this phenomena its not considered within the modelling.

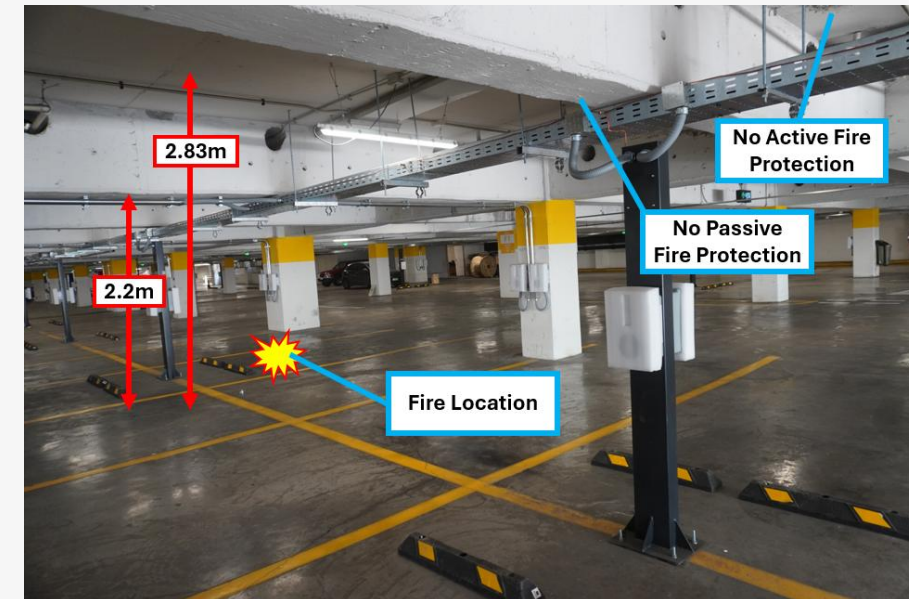
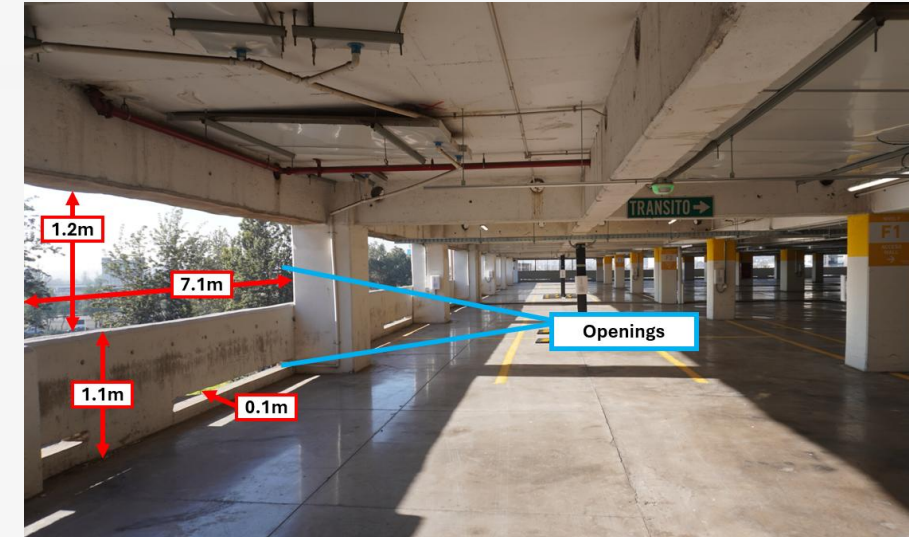
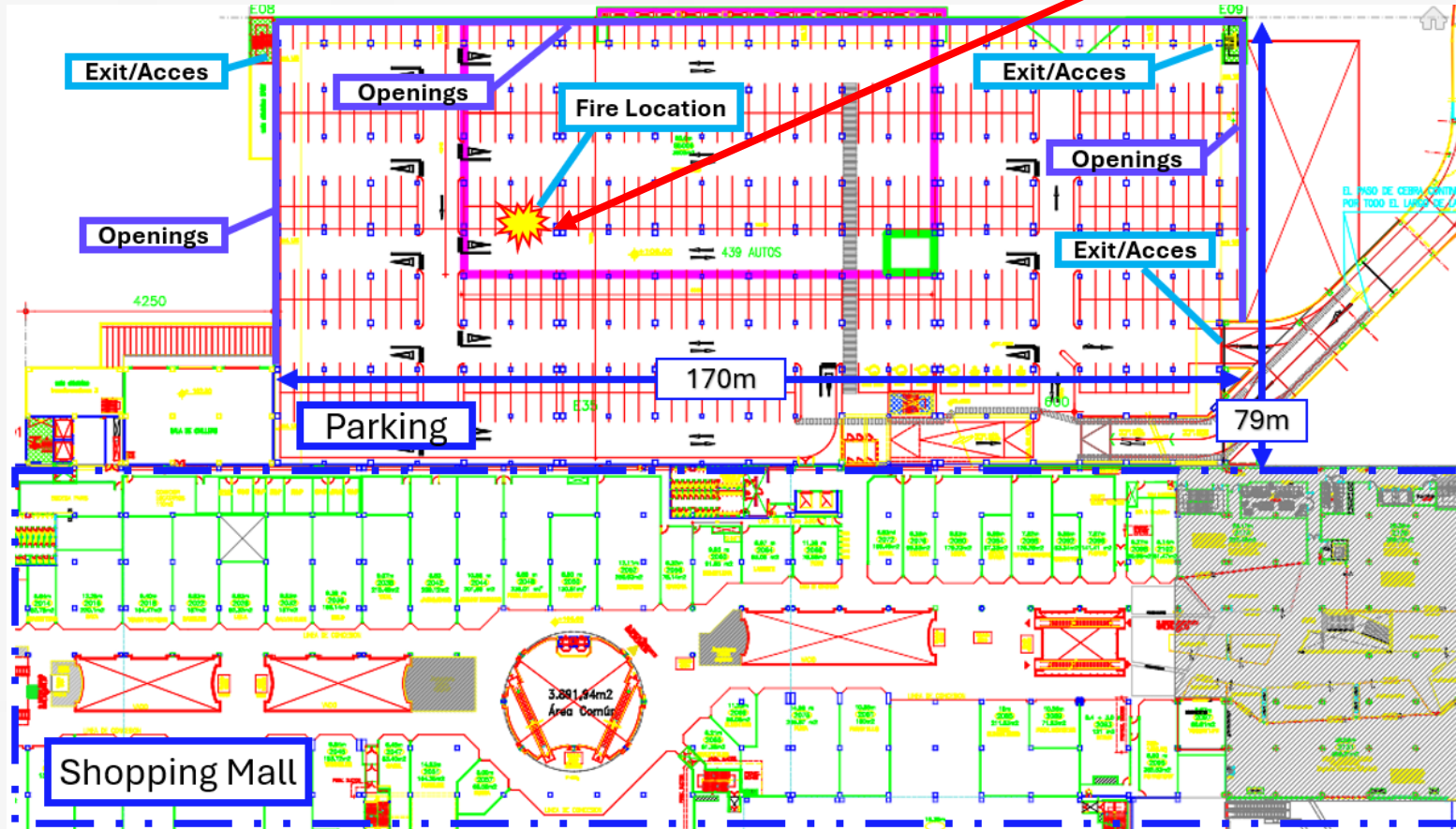
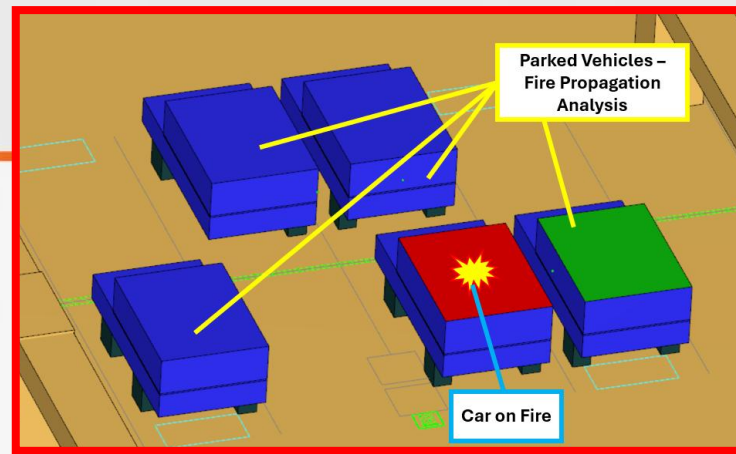


SFPE (Progress with LI-ION Battery Fire Safety: Engineering Solutions to Mobility and Storage Hazard) titled "Electric Vehicle & Micro-mobility Firefighting Considerations - Patrick Durham



7. FIRE SCENARIOS

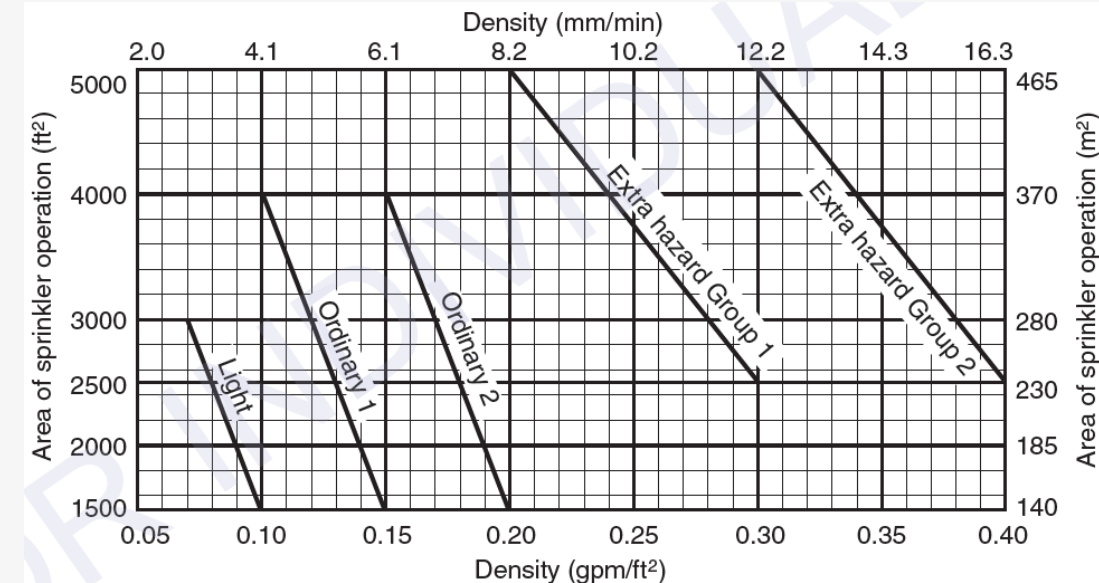
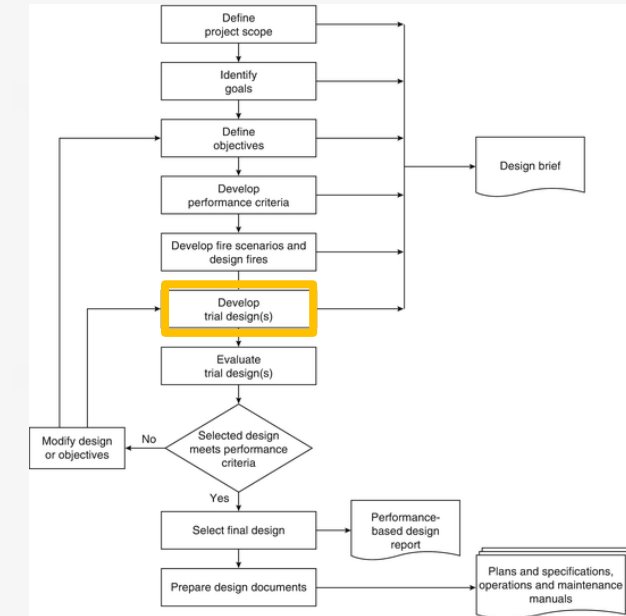
- Geometry & Fire Location



8. DEVELOP TRIAL DESIGN(S)

Scenario 02 – Sprinkler System

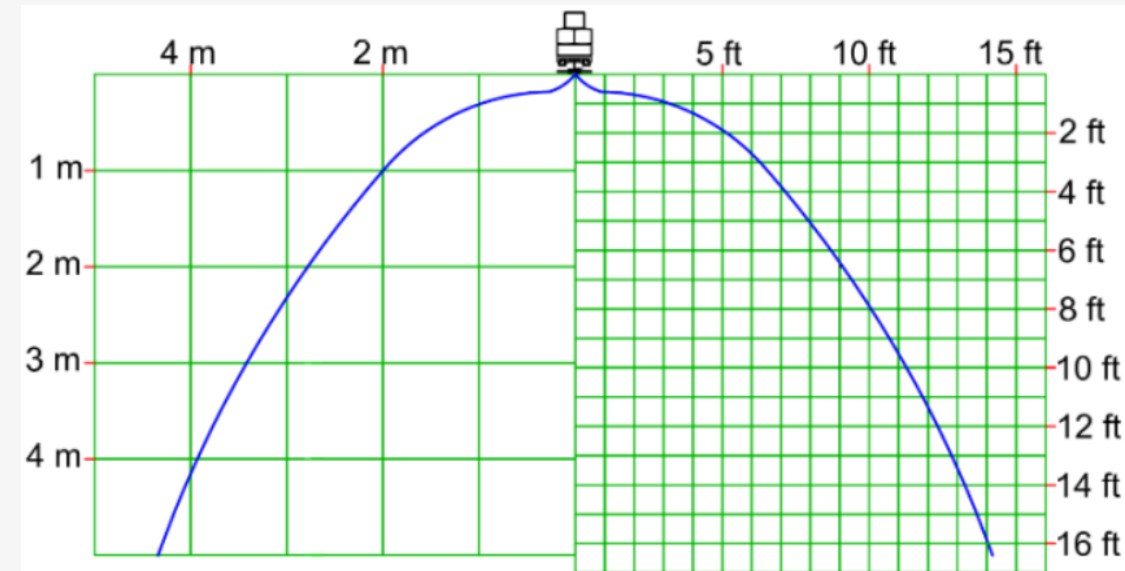
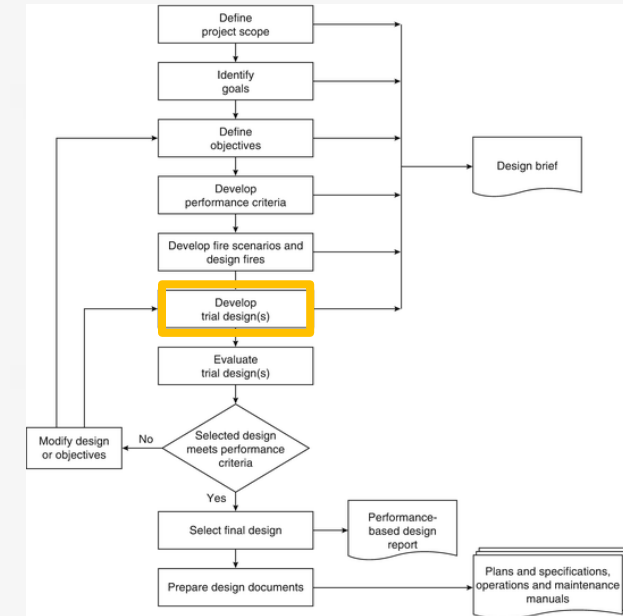
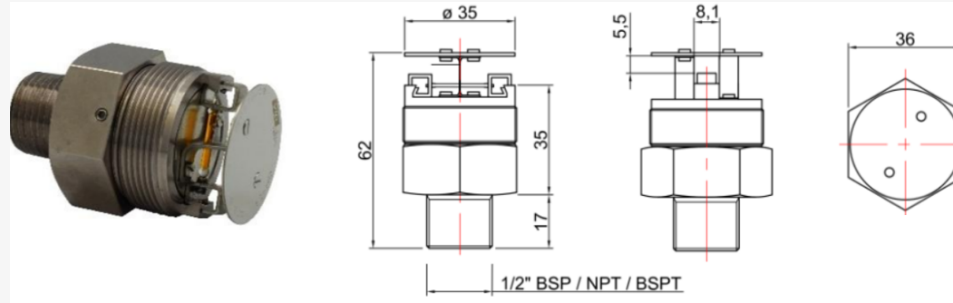
- **NFPA 88A** → open parking space (No sprinklers installation), total area of openings on each level 20% of the total wall area around that level (among other requirements)
- Current facility does not fulfill the NFPA opening requirement → **sprinkler system must be installed**
- Sprinklers FM approved - K factor of 8.0 (115) and a temperature rating of 68°C.
- System Flow: 300 gpm (**1134 lpm**), spkr flow 26 gpm (**99 lpm**)
- Operating pressure = 11 PSI.
- The RTI: 100 m^{1/2}*s^{1/2}
- N° Droplets: 5000
- Dv50: 2558um



8. DEVELOP TRIAL DESIGN(S)

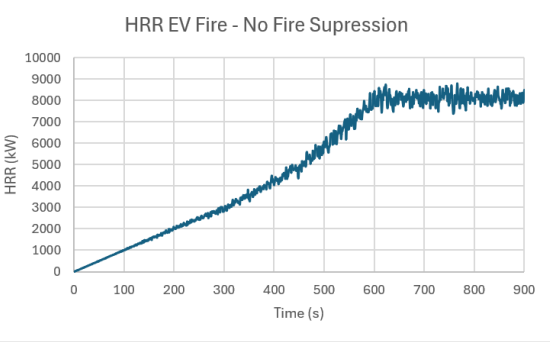
Scenario 03 – Water mist System

- Activation Temperature: 57°C
- Water Pressure: 116 PSI (8 Bar)
- K-factor metric: 19 (l/min 1bar)
- Flow rate: 53.74 lpm
- RTI: <50 (Fast Response)
- Drop Size DV50: <260µm
- N° Droplets: 100.000
- Spray pattern, offset, among others.
- The montage will be pendent at 0.15m under the roof
- Maximum distance of 3,60 m between the nozzles and a maximum of 1,80 m to any walls
- Minimum distance between nozzles, 2,45 meters



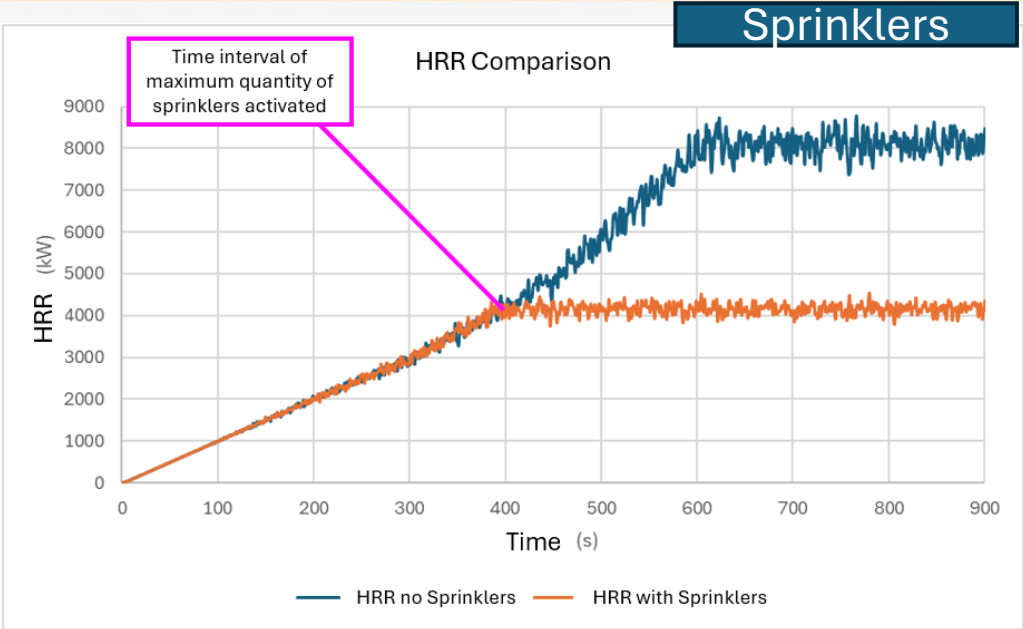
9. EVALUATE TRIAL DESIGN(S)

Time to Control the Fire



No Protection

	HRR (kW)		
	No System	Spkr	WM
Average @ 600 s	3323	2733	2607
Max. Peak	8781	4540	4354

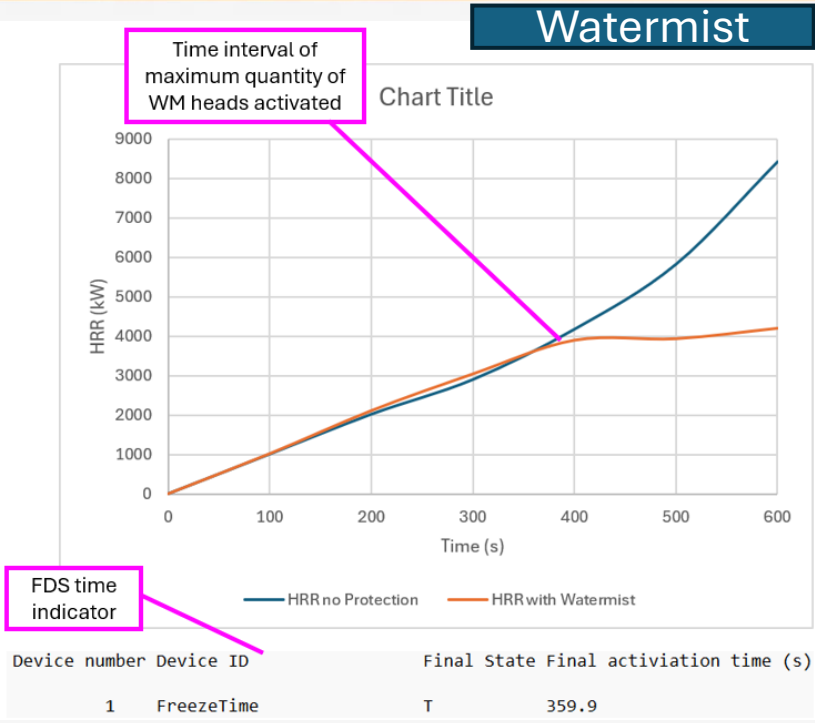


FDS time indicator	CONTROL Activation Times	
1	FreezeTime	T 386.6 s

DEVICE Activation Times		
37	SPK1	99.2 s
38	SPK2	89.8 s
39	SPK3	119.4 s
40	SPK4	121.6 s
41	SPK01	290.1 s
42	SPK02	392.2 s
43	SPK03	322.3 s
44	SPK04	355.3 s
55	SPK15	184.4 s
56	SPK16	245.9 s
57	SPK17	297.5 s
58	SPK18	343.6 s
151	SPK111	307.0 s
152	SPK112	350.8 s
153	SPK113	361.1 s
154	SPK114	391.0 s
76	SPK36	346.5 s
77	SPK37	386.6 s
78	SPK38	245.5 s
79	SPK39	285.6 s
82	SPK42	575.7 s
97	SPK57	521.9 s

22 Sprinklers

Sprinklers



FDS time indicator	Device number	Device ID	Final State	Final activation time (s)
1	FreezeTime	T	359.9	

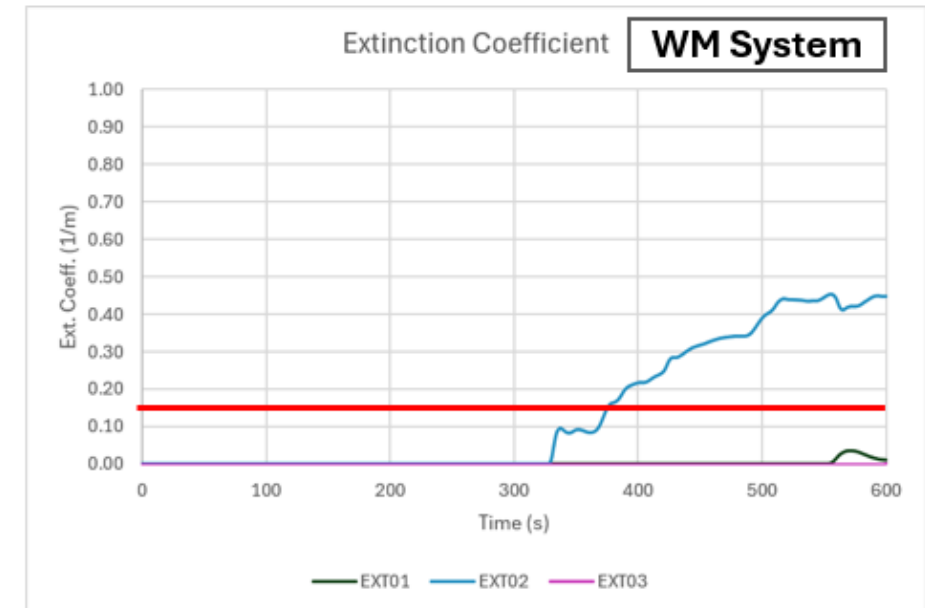
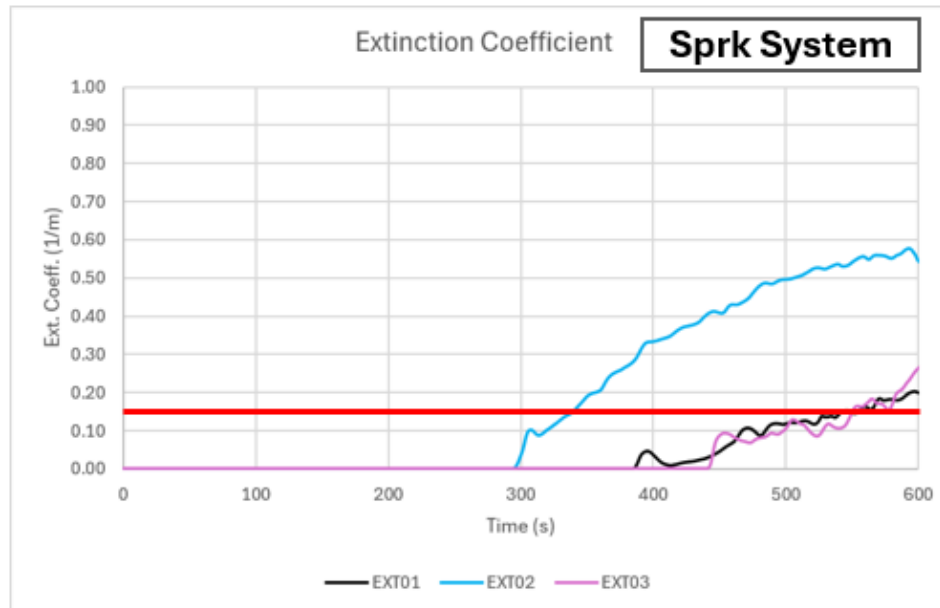
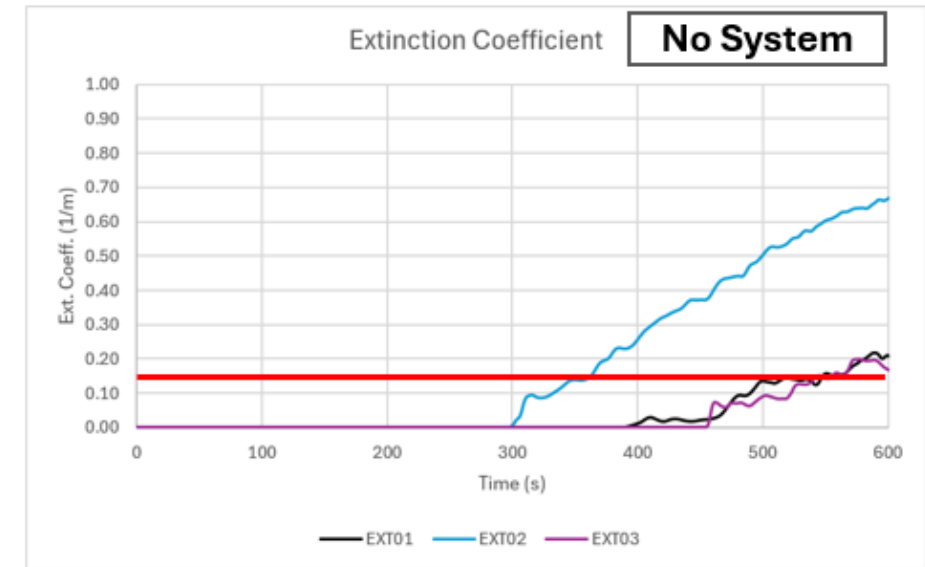
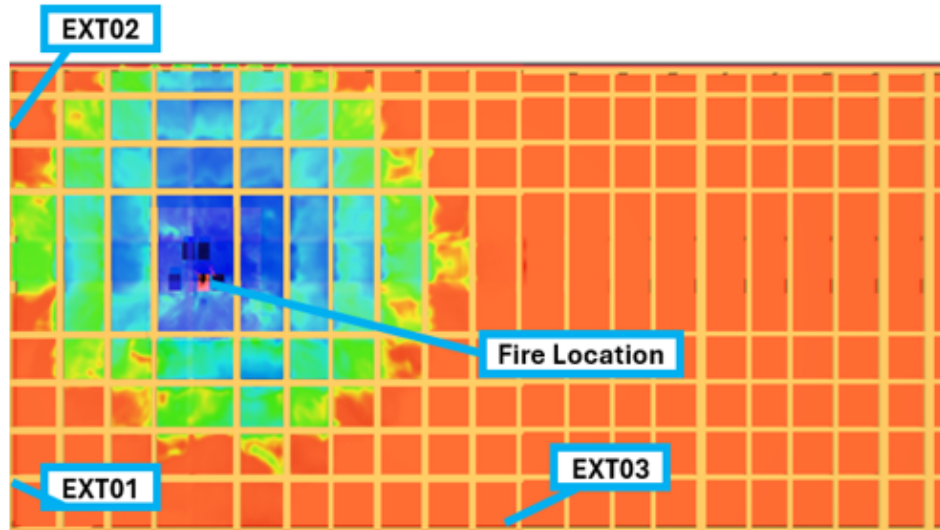
DEVICE Activation Times			
37	SPK1	T	150.6
38	SPK2	T	31.524
39	SPK3	T	265.4
40	SPK4	T	98.487
41	SPK01	T	441.3
55	SPK15	T	174.3
56	SPK16	F	No Activation
57	SPK17	T	359.9
76	SPK36	T	343.8
77	SPK37	F	No Activation
78	SPK38	T	353.3
79	SPK39	T	316.4

10 Nozzles

Watermist

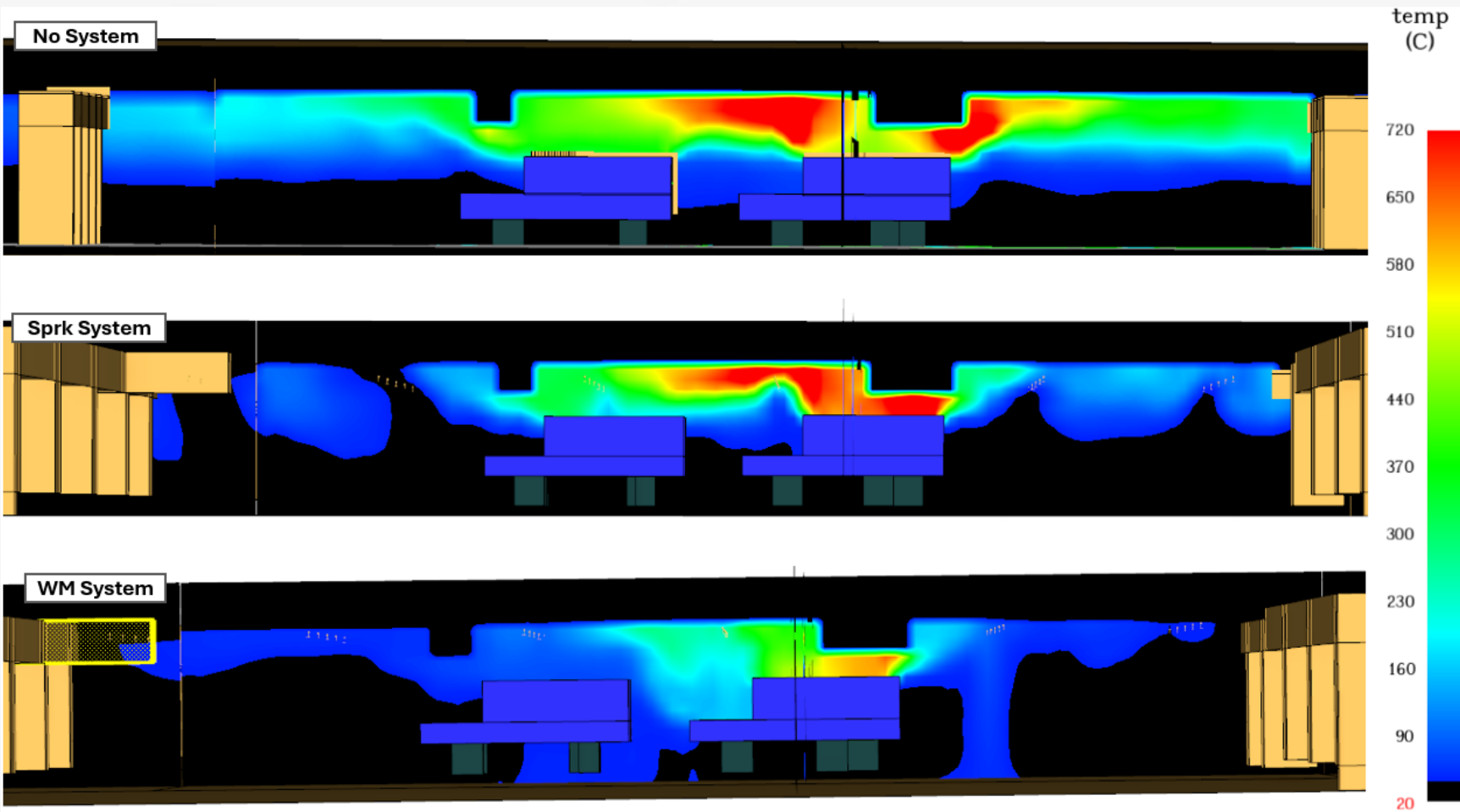
9. EVALUATE TRIAL DESIGN(S)

Extinction Coefficient & Visibility

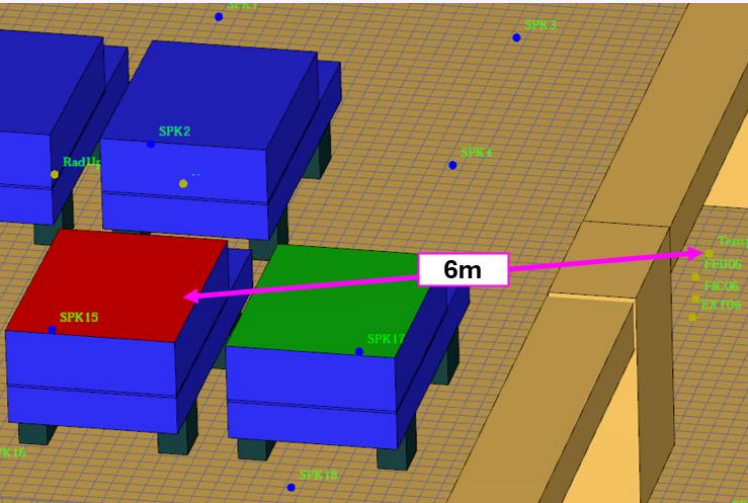
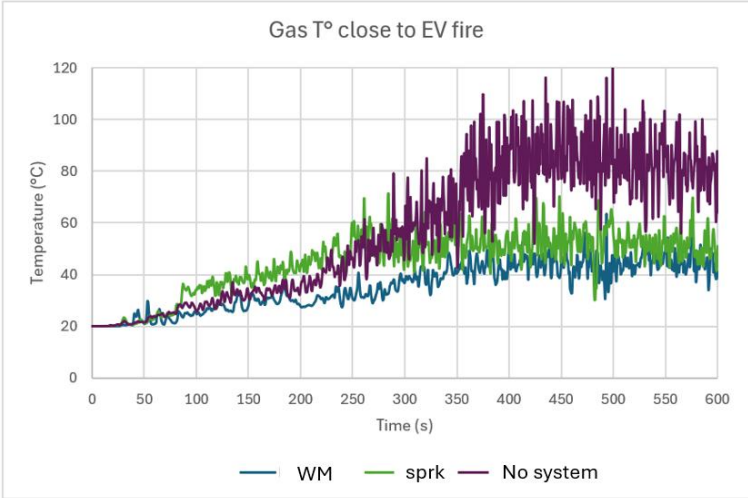


9. EVALUATE TRIAL DESIGN(S)

Hot Gases & Net Heat Flux

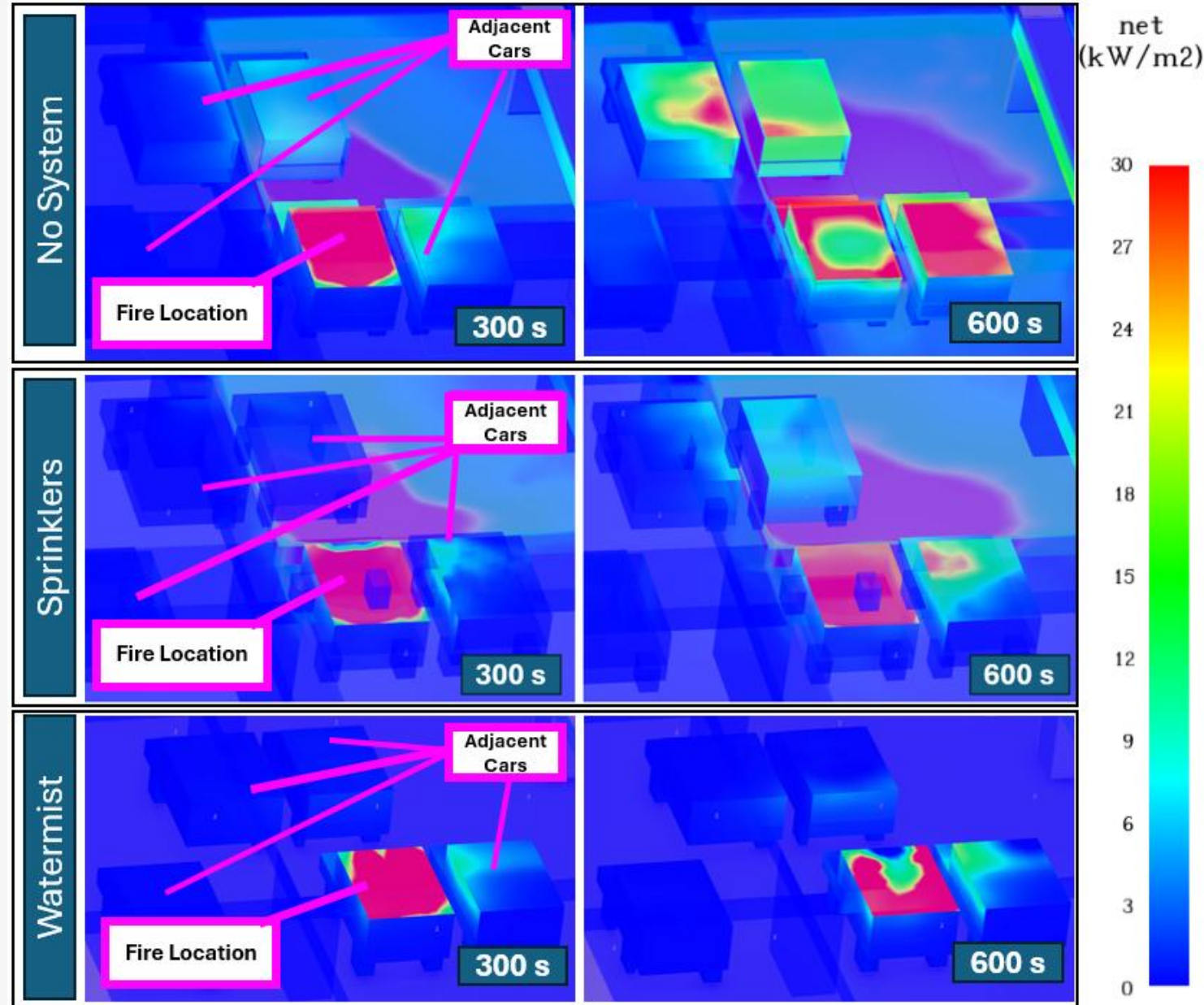
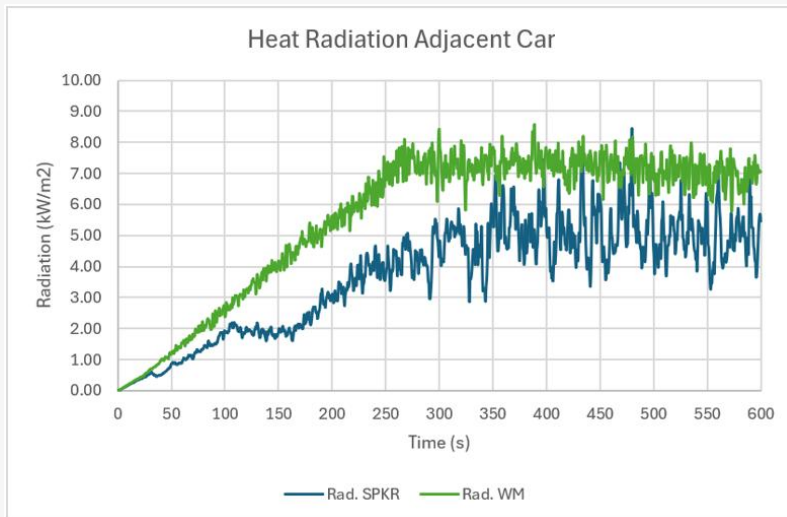
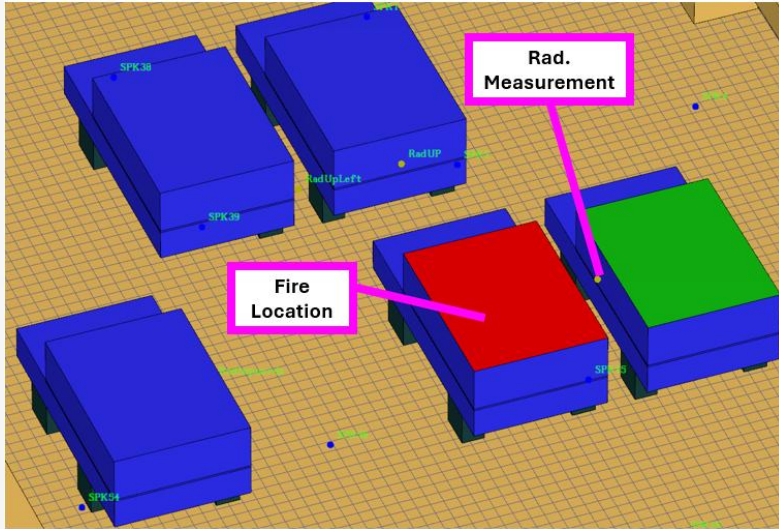


	Temperature (°C)		
	WM	Sprk	No System
Average	35.5	44.8	56.65
Max.	63.5	72.2	120.92



9. EVALUATE TRIAL DESIGN(S)

Hot Gases & Net Heat Flux

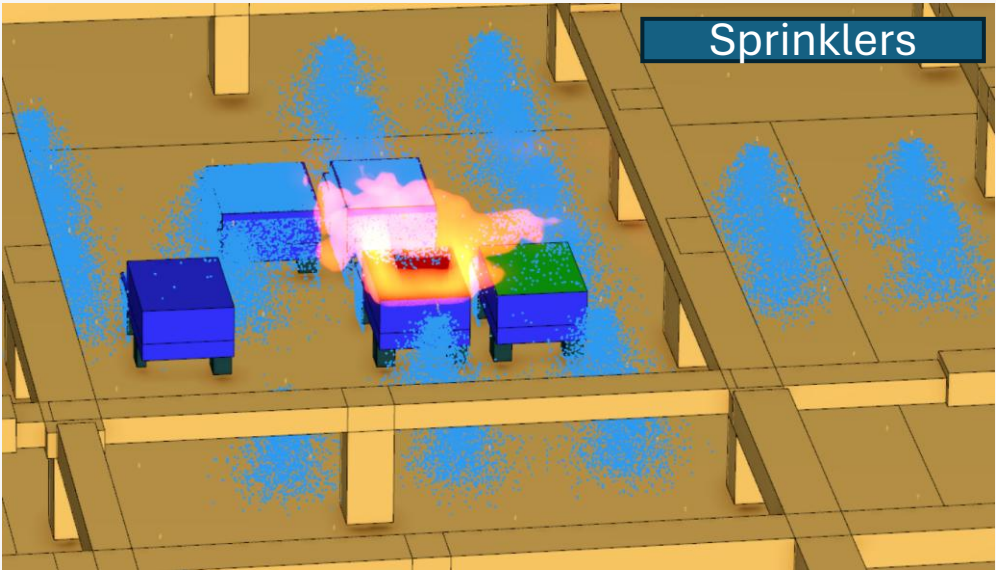


9. EVALUATE TRIAL DESIGN(S)

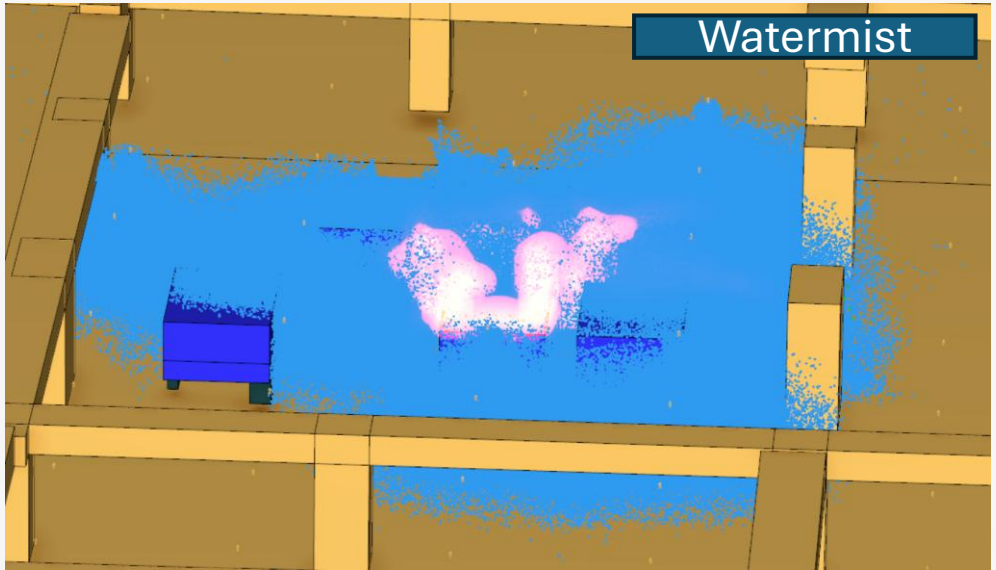
Water Discharged

Sprinklers System	
Operated Sprinklers	22
Flow per Sprinklers	99 lpm
Total Flow	2178 lpm
	575 gpm
Water Discharged	100 %
Aplication Time	60 min
Total Volume	130680 L
	130.68 m3

Water Mist System	
Operated Nozzles	10
Flow per Nozzle	53.74 lpm
Total Flow	537.4 lpm
	142 gpm
Water Discharged	24.67 %
Aplication Time	60 min
Total Volume	32244 L
	32.244 m3



Sprinklers



Watermist

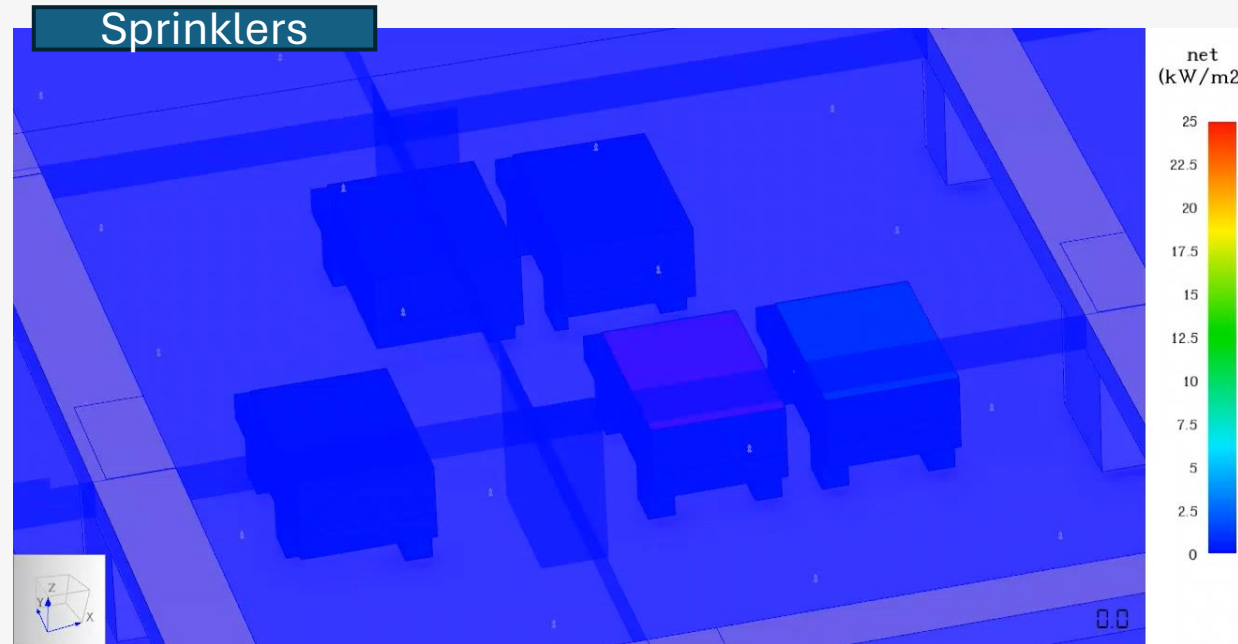
Hazard Comparison: EV vs ICE

	EV	ICE
Fuel Source	Lithium-ion Batteries	Gasoline
Fire Causes	Puncture, overheating, overcharging, over-discharging	Fuel or oil leak, overheating, worn out parts, loose electrical components
Likelihood	** 25.1 fires/100,000 cars sold **	1,529.9 fires/100,000 cars sold
Suppression Time	~ 60 – 90+ min	~ 30 min
Water Usage	Reports of up to thousands of gallons; Sustained water supply needed	~500 gallons
Reignition Potential	Likely, and very common	Rare
Fire Size	Can be large if propagation occurs, Avg HRR: 1.5 – 8+ MW Avg THR: 5.9 GJ	Typically limited to 1 vehicle; propagation is less common Avg HRR: 6.5 MW – 8 MW Avg THR: 5.9GJ

** not based on national statistical data

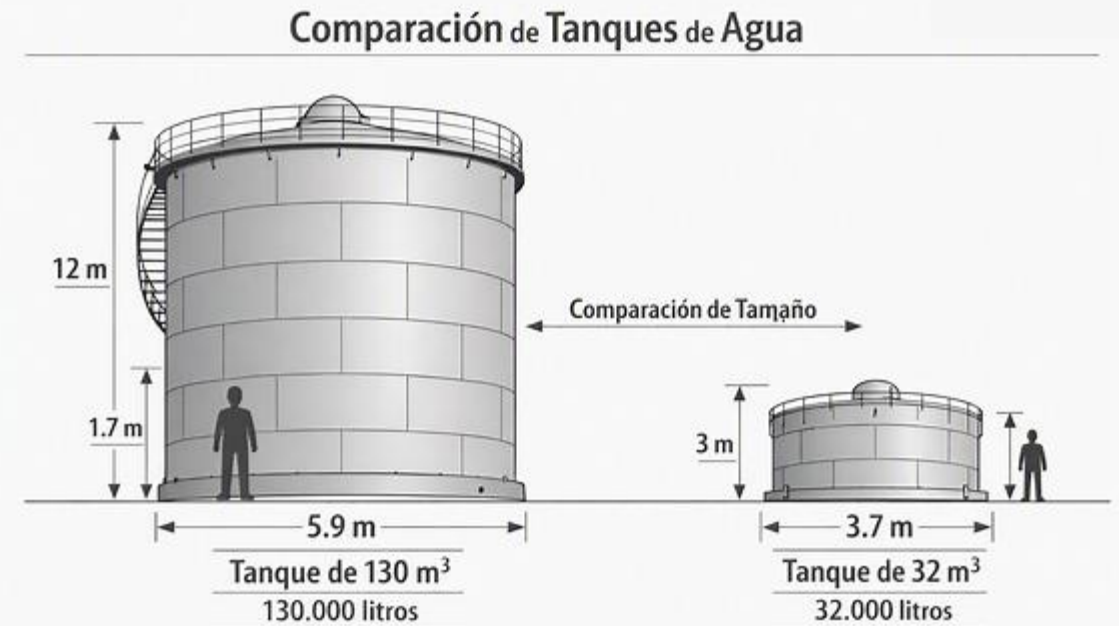
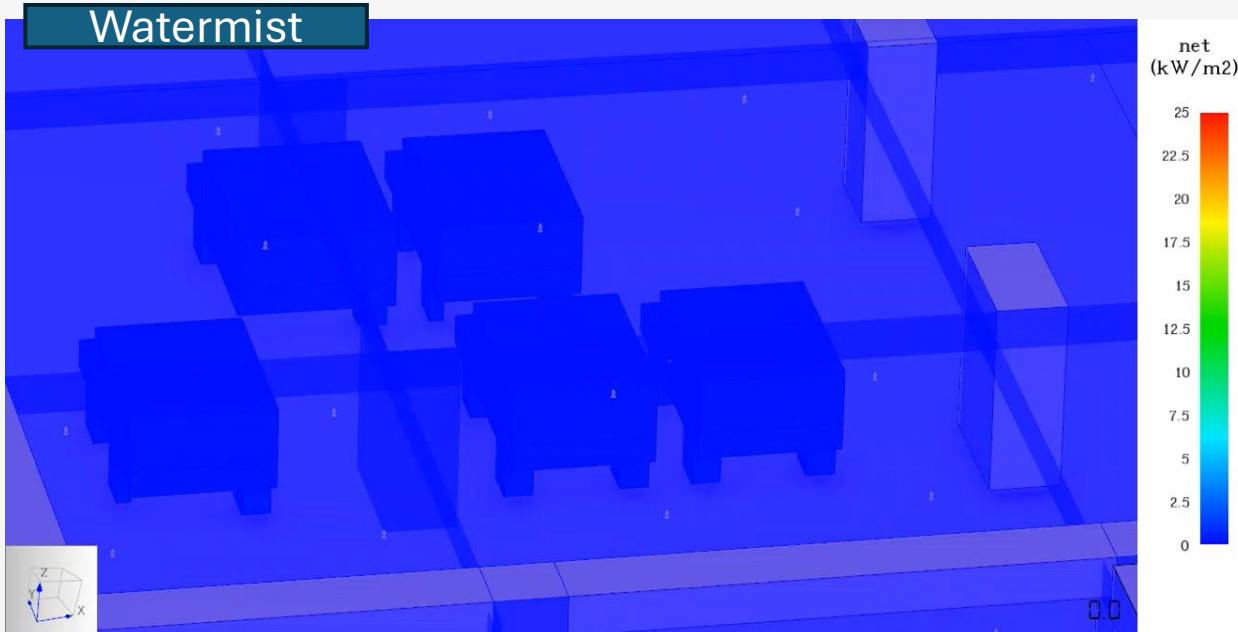
10. CONCLUSIONS

- EV fires exhibit larger generation of HF, SO₂, and other toxic gases associated with electrolyte decomposition.
- Both conventional sprinklers and the water mist system successfully control the EV fire.
- The probability of fire spread to adjacent vehicles is significantly reduced when either protection system is used, but water mist system demonstrate an even better performance than sprinklers system.



10. CONCLUSIONS

- Lower water discharge from the water mist system reduces the volume of contaminated firefighting water.
- The water mist system demonstrates superior efficiency in terms of water demand, achieving comparable levels of fire control with significantly less water than the sprinkler system.
- The lower water demand and effective thermal control of water mist system position it as an efficient and environmentally favorable solution.
- **REMEMBER: PBD it's a tool also used to quantify the levels of safety!**



*25th International Water Mist Conference - IWMA
October 7 - 8, 2026 – Prague, Czech Republic*

**Water Mist Performance for Electric Vehicle Fires in
Parking Garages: A CFD-Based Assessment**

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GRACIAS – THANK YOU

