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# The Impact of Water-Based Fire Suppression Systems on Combustion Products

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*more info*  
<https://fric.no/en/news>

## Outline

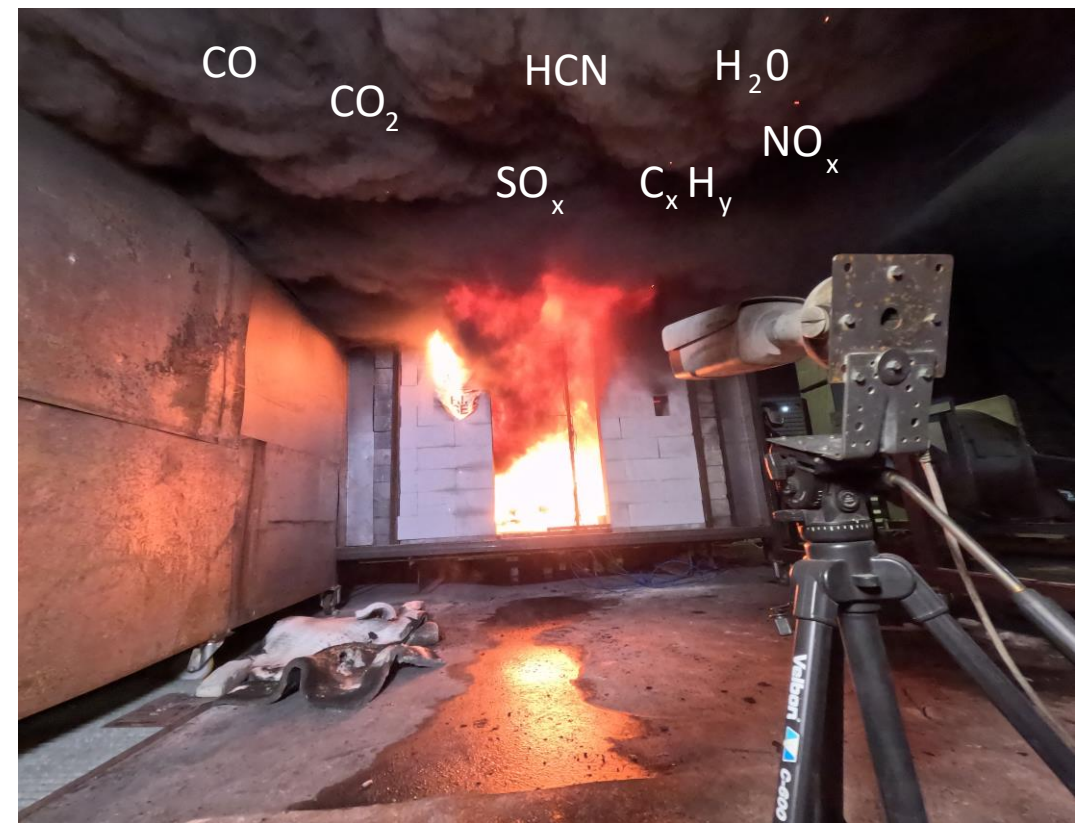
- Background
- Experimental Setup
  - Rig
  - Instrumentation
  - Test Matrix
- Results and Discussion
  - HRR and Total Heat Release
  - Gas temperatures
  - Gas analysis
- Conclusions



## Background

- The major lethal factors in uncontrolled fires are toxic gases, heat, and oxygen deficiency.
- According to the U.S. Fire Administration (USFA), smoke is the killer in **60% to 80%** of all fire deaths.

EHSToday – 7.09.2016

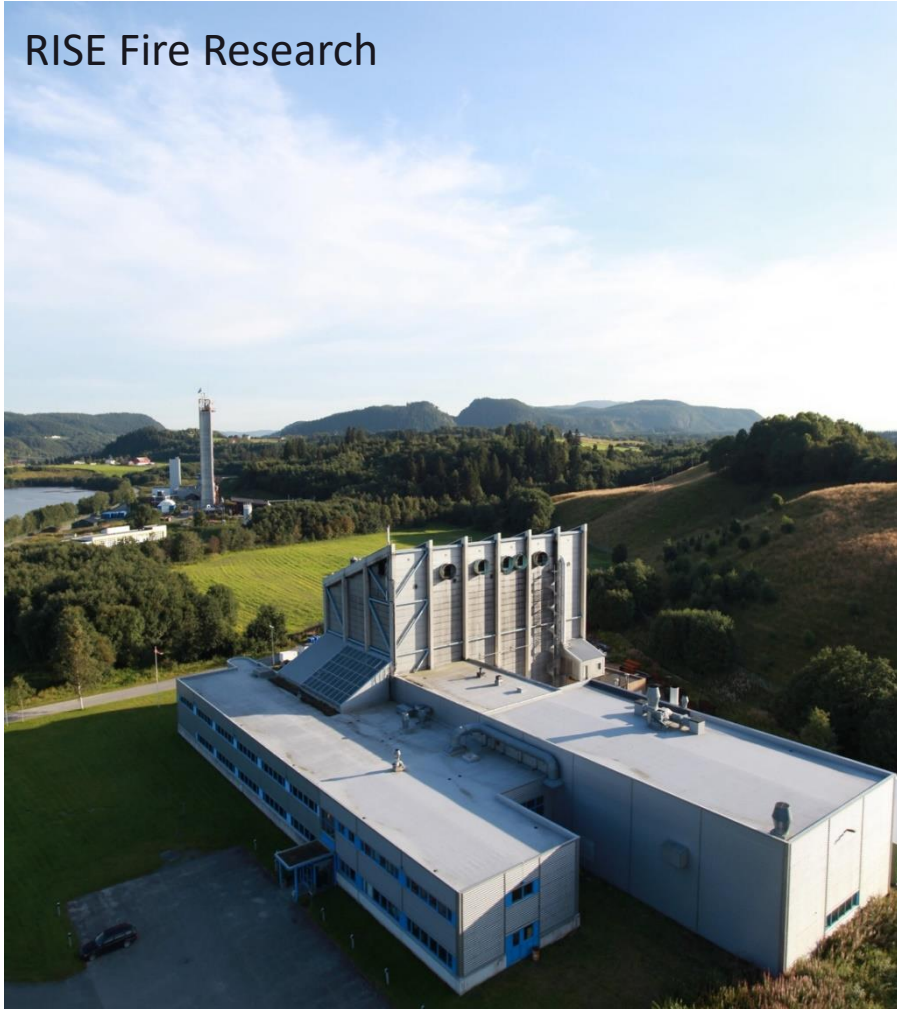


- Main species ( $10^3 \sim 10^5$  ppm):  $\text{CO}_2$ ,  $\text{H}_2\text{O}$ ,  $\text{O}_2$ , and  $\text{CO}$
- Moderate concentration species ( $10 \sim 10^3$  ppm):  $\text{CH}_4$ ,  $\text{C}_2\text{H}_4$ ,  $\text{HCN}$
- Low concentration species ( $1 \sim 10^2$  ppm):  $\text{NO}$ ,  $\text{NO}_2$ ,  $\text{C}_2\text{H}_6$ ,  $\text{C}_6\text{H}_{14}$
- Negligible species ( $< 10$  ppm):  $\text{N}_2\text{O}$ ,  $\text{SO}_2$ ,  $\text{NH}_3$ ,  $\text{HCl}$ ,  $\text{HF}$ ,  $\text{C}_3\text{H}_8$ ,  $\text{CHOH}$

Plenty of study on heat releases and temperatures, but limited knowledge on **gas toxicities with suppression.**

## Experimental Setup - Rig

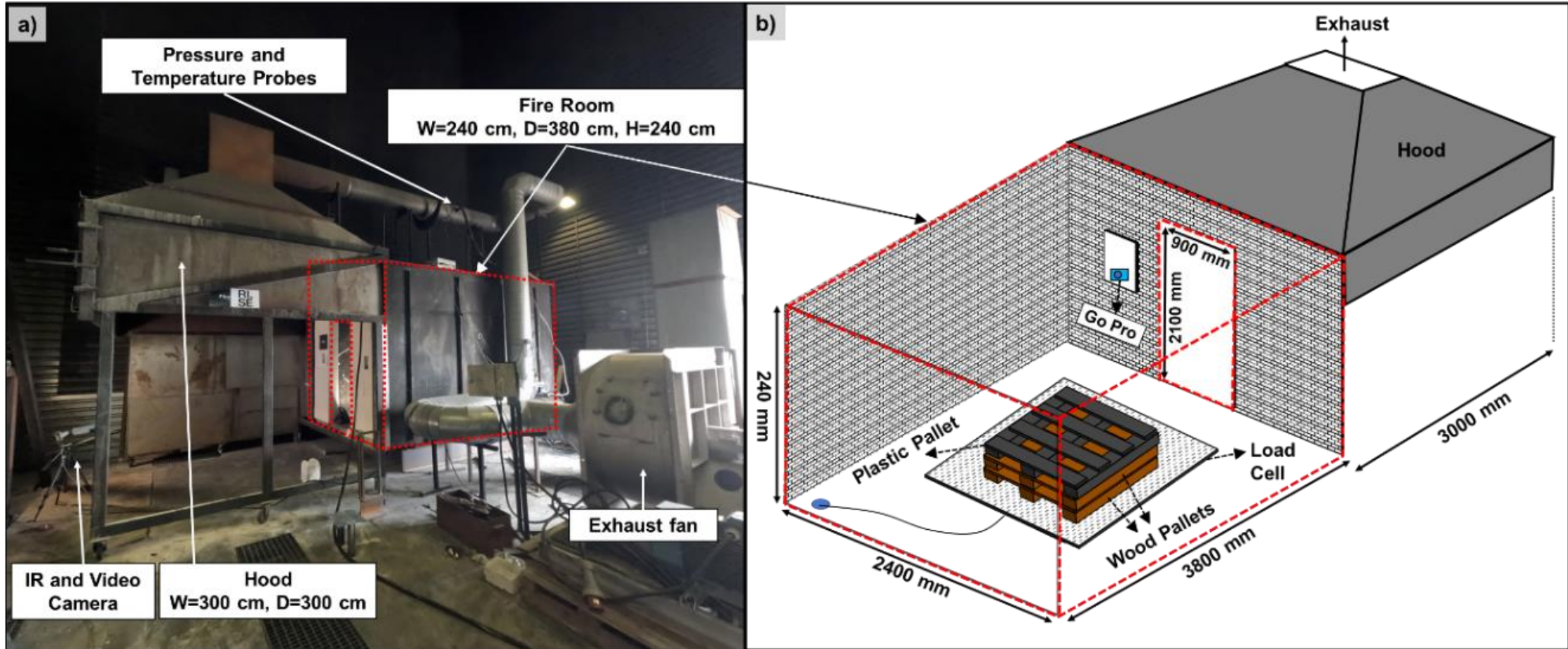
RISE Fire Research



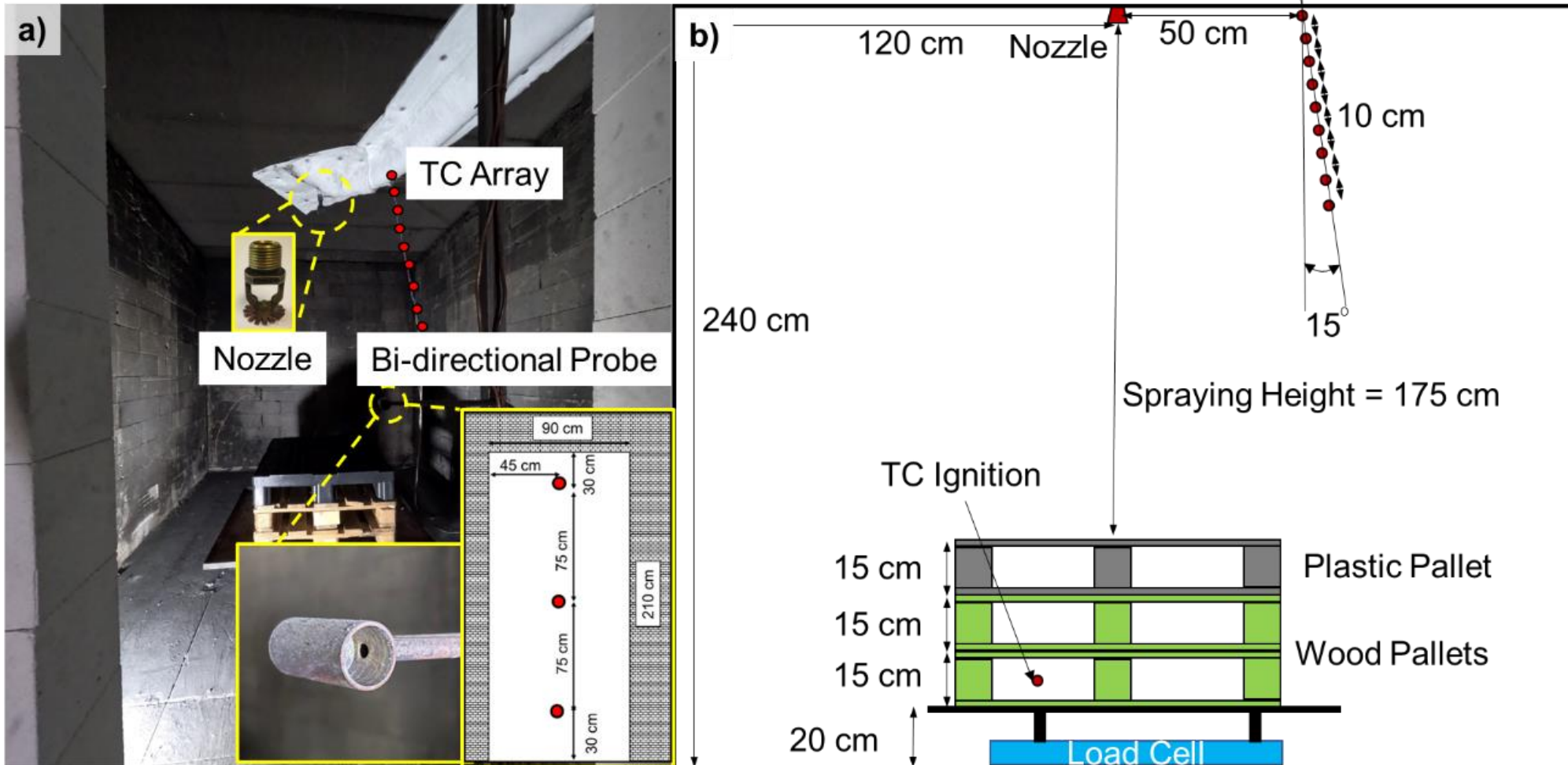
2.4 m x 3.8 m x 2.4 m fire room.  
ISO 9705 (door modified to 0.9 m x 2.0 m)



## Experimental Setup



## Experimental Setup-Instrumentation



Bulbs were removed from the nozzles. Manual activation.

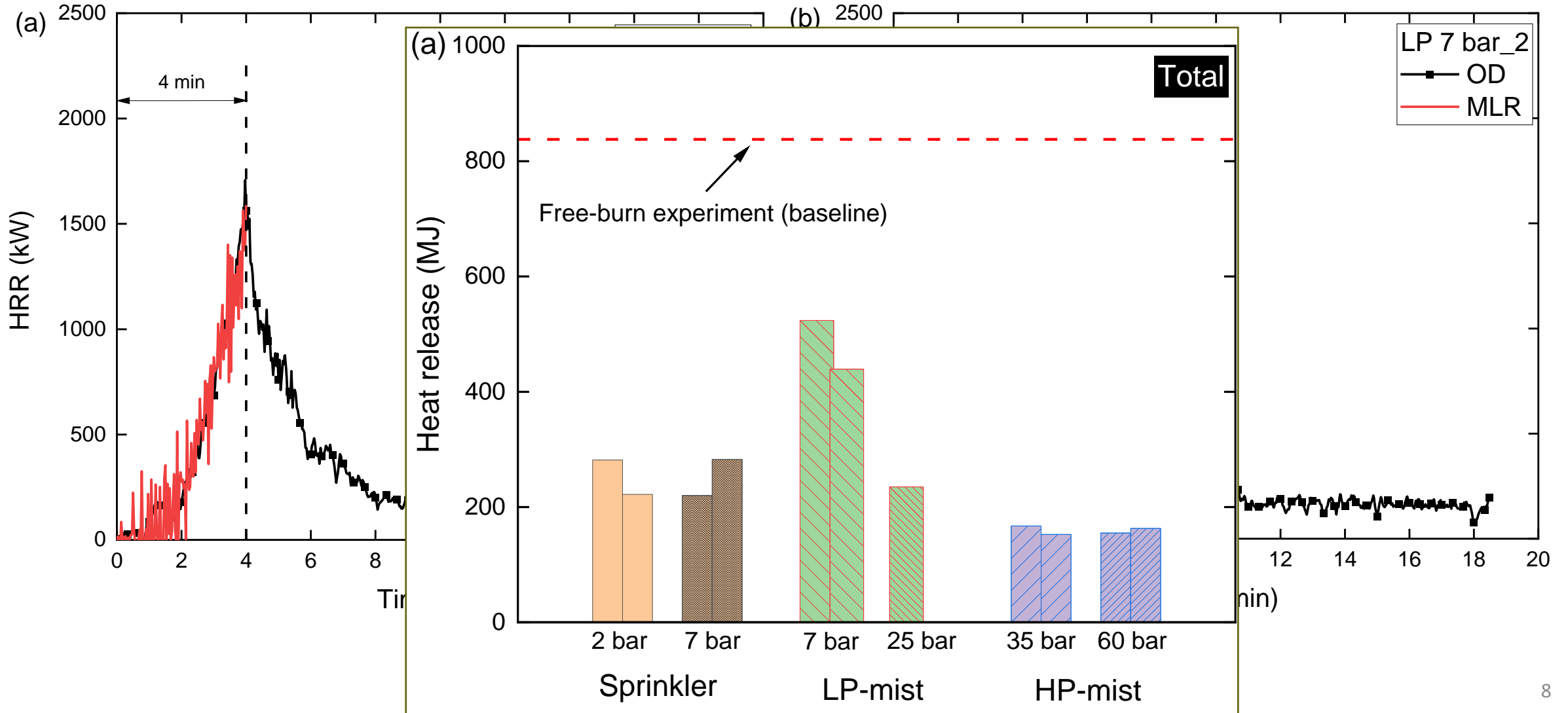


## Experimental Setup – Test Matrix

Experiment #	Suppression System	K-factor	Water Pressure (bar)	Water Flow Rate (L/min)	Average Wood Pallet Humidity (%)	Important Durations	
						Free Burn (min:sec)	Suppression (min:sec)
Baseline	No suppression	-	-	-	13.1	20:36	-
Sp2_1	Sprinkler (Sp)	78	2	110.3	14.2	4:00	02:00
Sp2_2				110.3	11.8		03:48*
Sp7_1			7	206.4	9.3		02:00
Sp7_2				206.4	13.7		02:00
LP7_1			Low-Pressure Water Mist (LP)	13.4	7		35.4
LP7_2	35.4	13.0					04:36*
LP25_1	25	67.0			12.4		02:00
LP25_2		67.0			14.5		02:00
HP35_1	High-Pressure Water Mist (HP)	2.91			35		17.2
HP35_2			17.2	13.0			05:59*
HP60_1			60	22.5	13.3	02:00	
HP60_2				22.5	13.0	02:00	

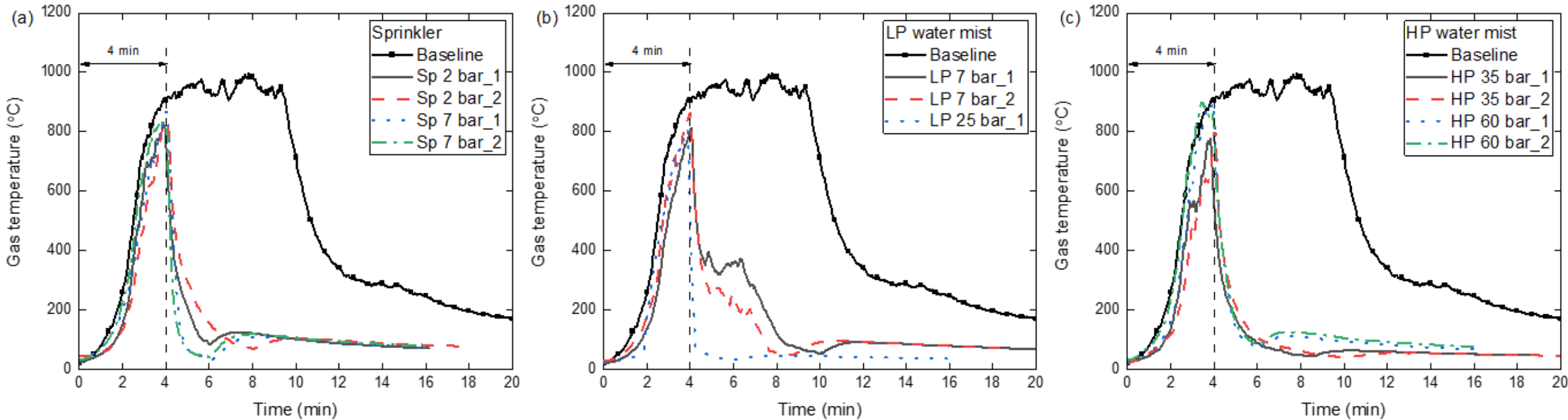
\* The suppression system could not extinguish the fire in 2 minutes, so water discharge was continued.

## Results and Discussion – Heat Release Rate Calculation and Total HRR



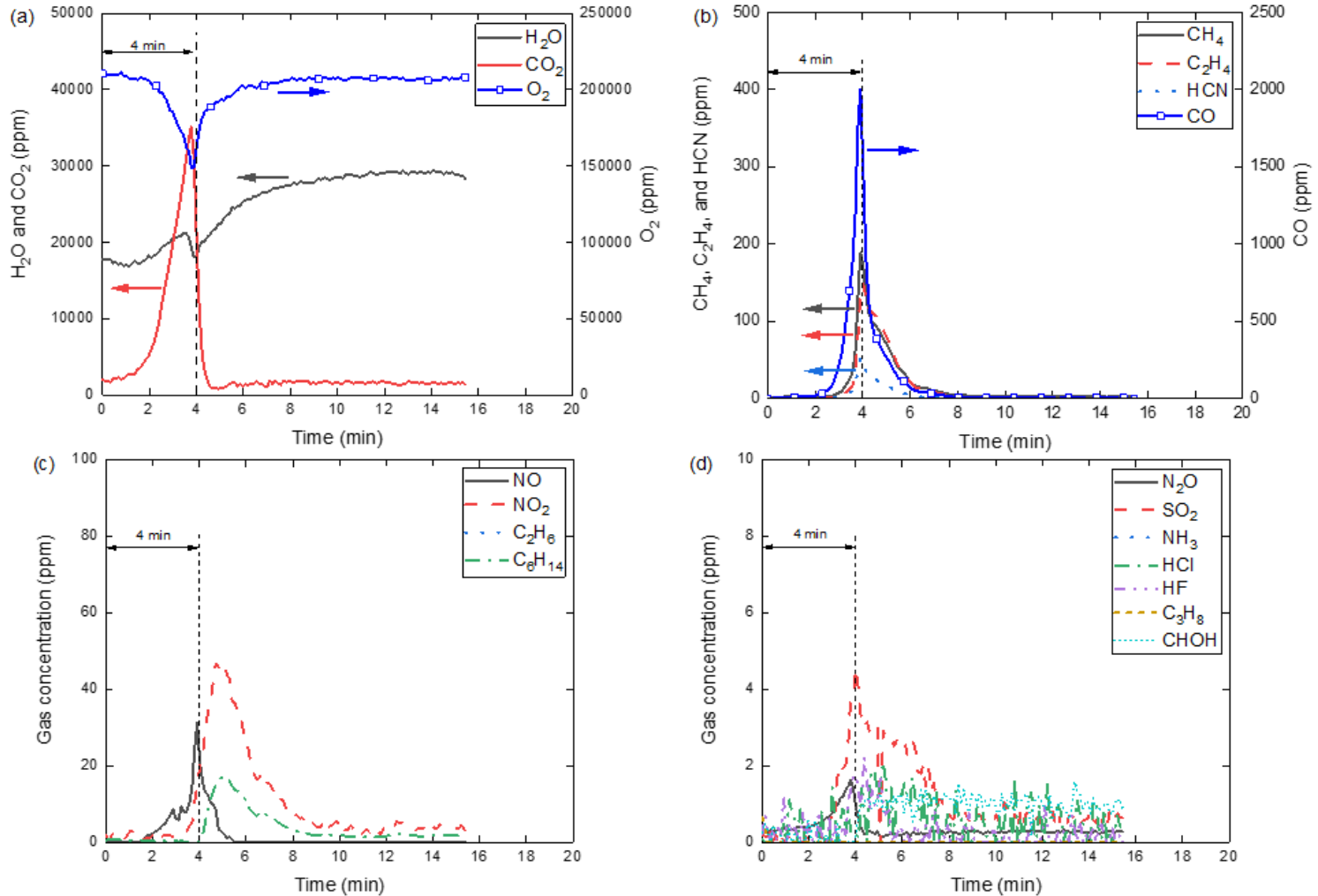


## Results and Discussion – Gas Temperatures at the Ceiling



The LP\_25 was the most efficient in cooling down the gas temperatures, while the LP\_7 was found to be the least efficient.

## Results and Discussion – Gas Analysis



Gas species measured in the experiment Sp7\_2

- Main species ( $10^3 \sim 10^5$  ppm): CO<sub>2</sub>, H<sub>2</sub>O, O<sub>2</sub>, and CO
- Moderate concentration species ( $10 \sim 10^3$  ppm): CH<sub>4</sub>, C<sub>2</sub>H<sub>4</sub>, HCN
- Low concentration species ( $1 \sim 10^2$  ppm): NO, NO<sub>2</sub>, C<sub>2</sub>H<sub>6</sub>, C<sub>6</sub>H<sub>14</sub>
- Negligible species (<10 ppm): N<sub>2</sub>O, SO<sub>2</sub>, NH<sub>3</sub>, HCl, HF, C<sub>3</sub>H<sub>8</sub>, CHOH

Dosage of exposure:

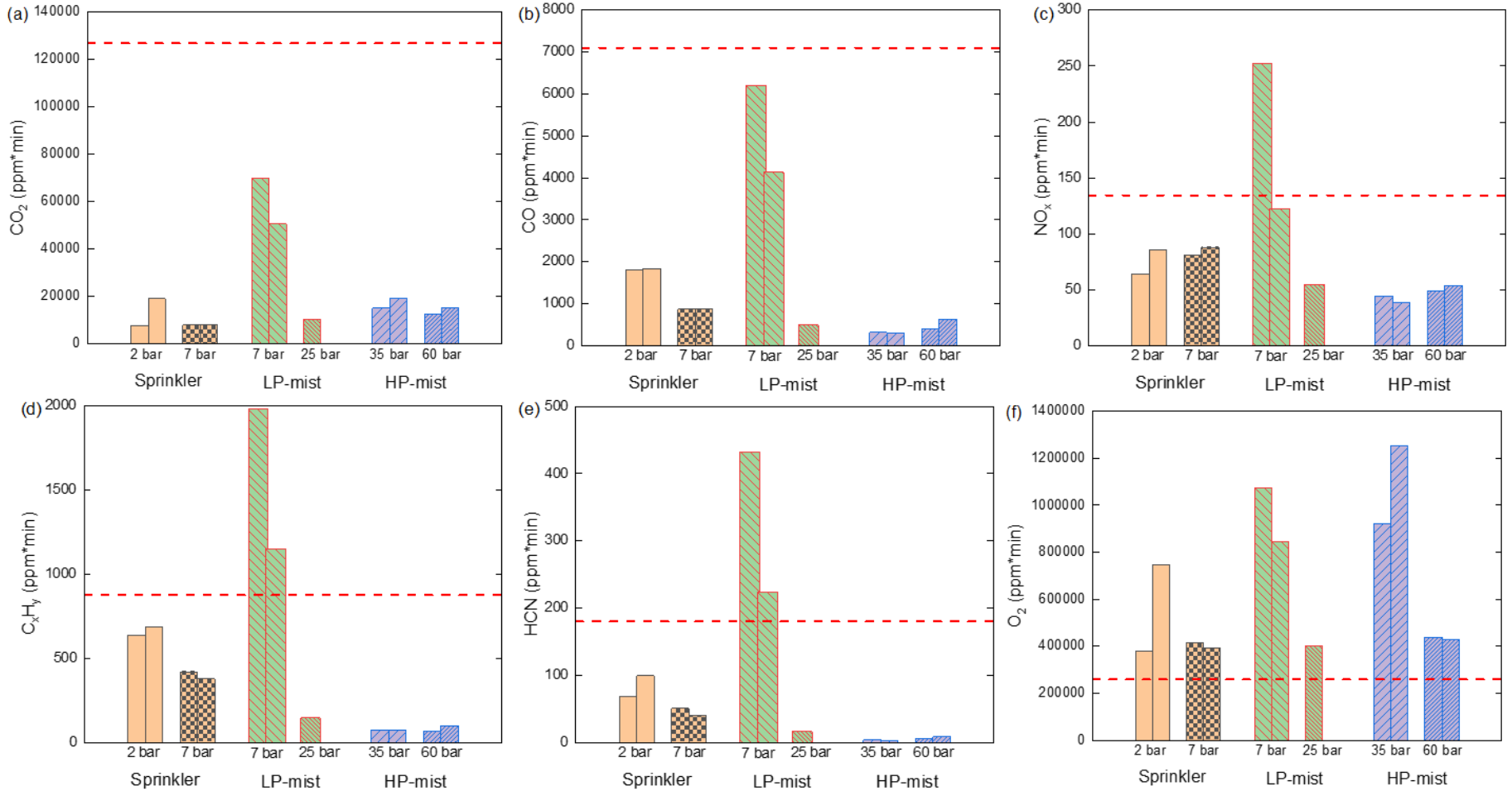
$$D = \int_0^T c(t) dt$$

Fractional Effective Doses (ISO 13571):

$$FED = \left[ \sum_{t_1}^{t_2} \frac{\varphi_{CO} \times \exp\left[\frac{\varphi_{CO_2}}{5}\right]}{35000} \Delta t + \sum_{t_1}^{t_2} \frac{\varphi_{HCN}^{2.36} \times \exp\left[\frac{\varphi_{CO_2}}{5}\right]}{1.2 \times 10^6} \Delta t \right]$$



## Results and Discussion – Gas Analysis at Suppression



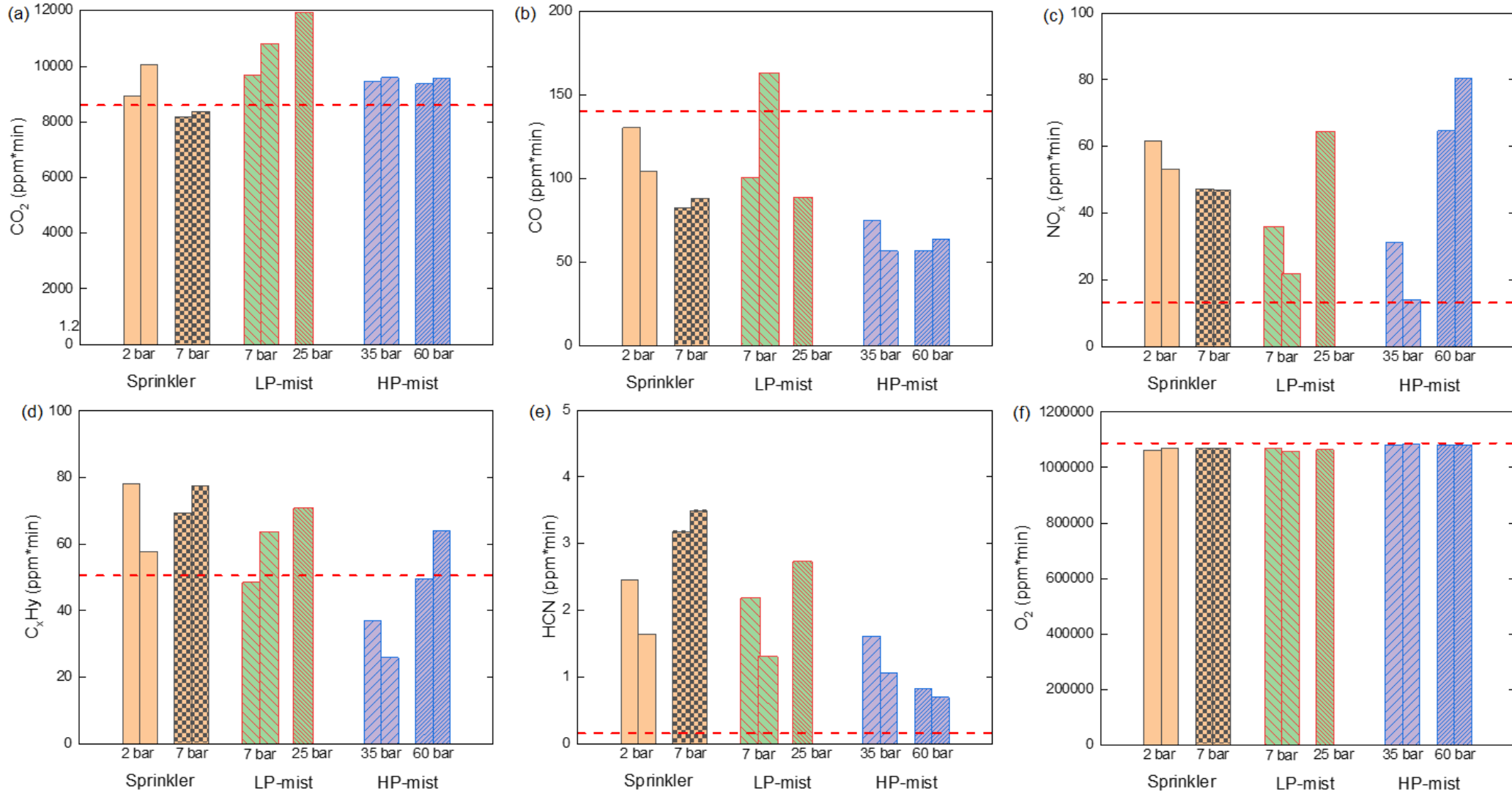
- HP system significantly reduced CO and HCN.
- LP7 system less effective, higher NO<sub>x</sub>, C<sub>x</sub>H<sub>y</sub>, and HCN than baseline (also not able to suppress the fire in 2 min)

## Results and Discussion – Gas Analysis at Suppression

Test #	CO			C <sub>x</sub> H <sub>y</sub>			HCN			FED
	Max. (ppm)	Mean (ppm)	D ratio	Max. (ppm)	Mean (ppm)	D ratio	Max. (ppm)	Mean (ppm)	D ratio	
Baseline	3763.5	3548.2	1	545.9	439.0	1	115.3	90.1	1	0.87
Sp2_1	3298.1	923.3	0.27	1109.8	328.1	0.76	121.4	34.7	0.39	0.09
Sp2_2	2238.7	484.6	0.16	809.3	180.4	0.56	118.1	26.1	0.44	0.10
Sp7_1	1570.6	416.6	0.12	656.3	203.4	0.48	87.1	24.5	0.28	0.04
Sp7_2	2003.3	448.7	0.13	374.1	194.3	0.45	52.8	20.6	0.23	0.03
LP7_1	2982.6	1045.1	0.46	1343.4	333.9	<b>1.47*</b>	228.0	72.9	<b>1.83*</b>	0.68
LP7_2	2969.5	897.9	0.33	1017.8	250.1	0.88	181.4	48.7	0.96	0.31
LP25_1	1326.0	250.2	0.07	163.2	74.5	0.17	25.3	8.3	0.09	0.02
HP35_1	349.0	71.8	0.03	43.4	17.0	0.06	5.1	0.9	0.02	0.01
HP35_2	150.6	48.5	0.02	26.2	12.2	0.05	1.5	0.4	0.01	0.01
HP60_1	937.1	188.8	0.06	100.0	32.8	0.08	16.6	3.1	0.04	0.01
HP60_2	1484.0	303.6	0.09	163.4	48.7	0.11	21.1	4.1	0.05	0.03



# Results and Discussion – Gas Analysis at Post-suppression Period



Low gas dosages during post-suppression

## Conclusions

- The effects of water suppression systems on heat releases, gas temperatures and combustion products of HDPE and wood pallets were studied.
- Three systems: Sprinkler (**Sp**), Low-Pressure (**LP**) water mist and High-Pressure (**HP**) water mist
  - Gas cooling assessment: LP7\_1 least efficient, LP\_25 most efficient
  - Heat releases reduced from 815 MJ to below 200 MJ, except LP7
  - Gas dosages (CO, HCN) reduced, except LP7
  - Low gas dosages during post-suppression
- LP25 and HP60 have better performance in terms of suppression time, reducing heat release, reducing gas dosages and FED.

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Suggestions or technical input for FRIC webinars?  
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