30E JOURNÉES DU GDR FEUX

GENERATION OF CO AND SOOT PARTICLES DURING A CONFINED AND MECHANICALLY UNDER-VENTILATED FIRE

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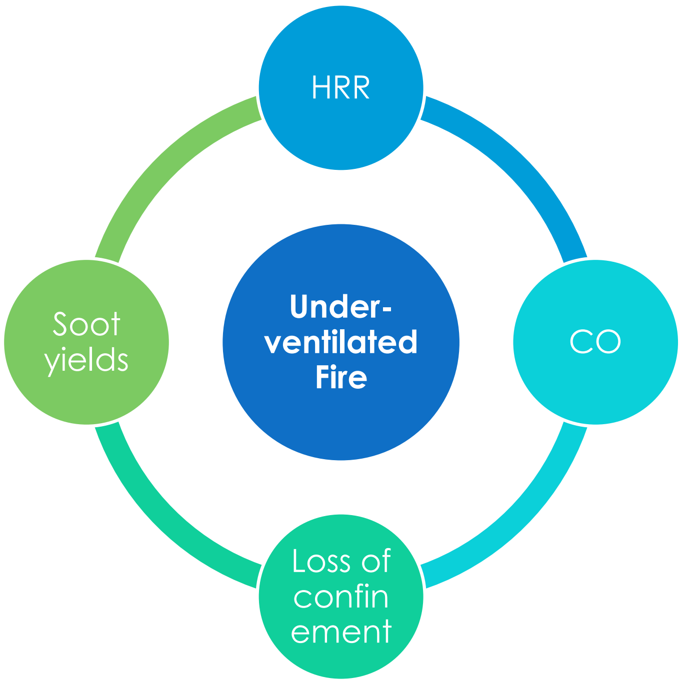
PLANNING

- General Context
- Experimental setup
- Operational Conditions
- Results
- Conclusion and Future Works

General Context

The problem of confined under-ventilated fires :



- The production of CO and soot particle in compartment fires can be affected by:
  - The ventilation
  - The vitiation

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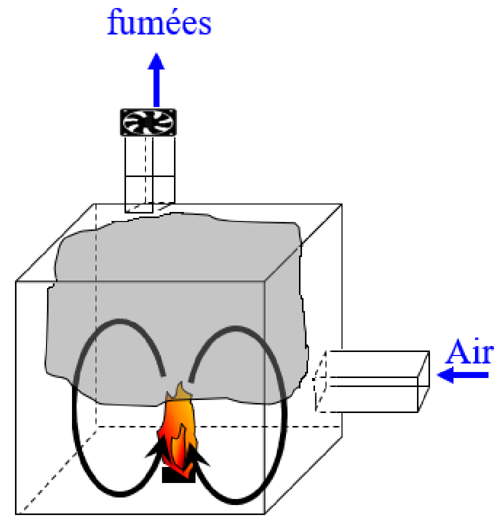
What is t[...]n the CO and soot CO [...]



Experimental setup – Confined and mechanically ventilated compartment

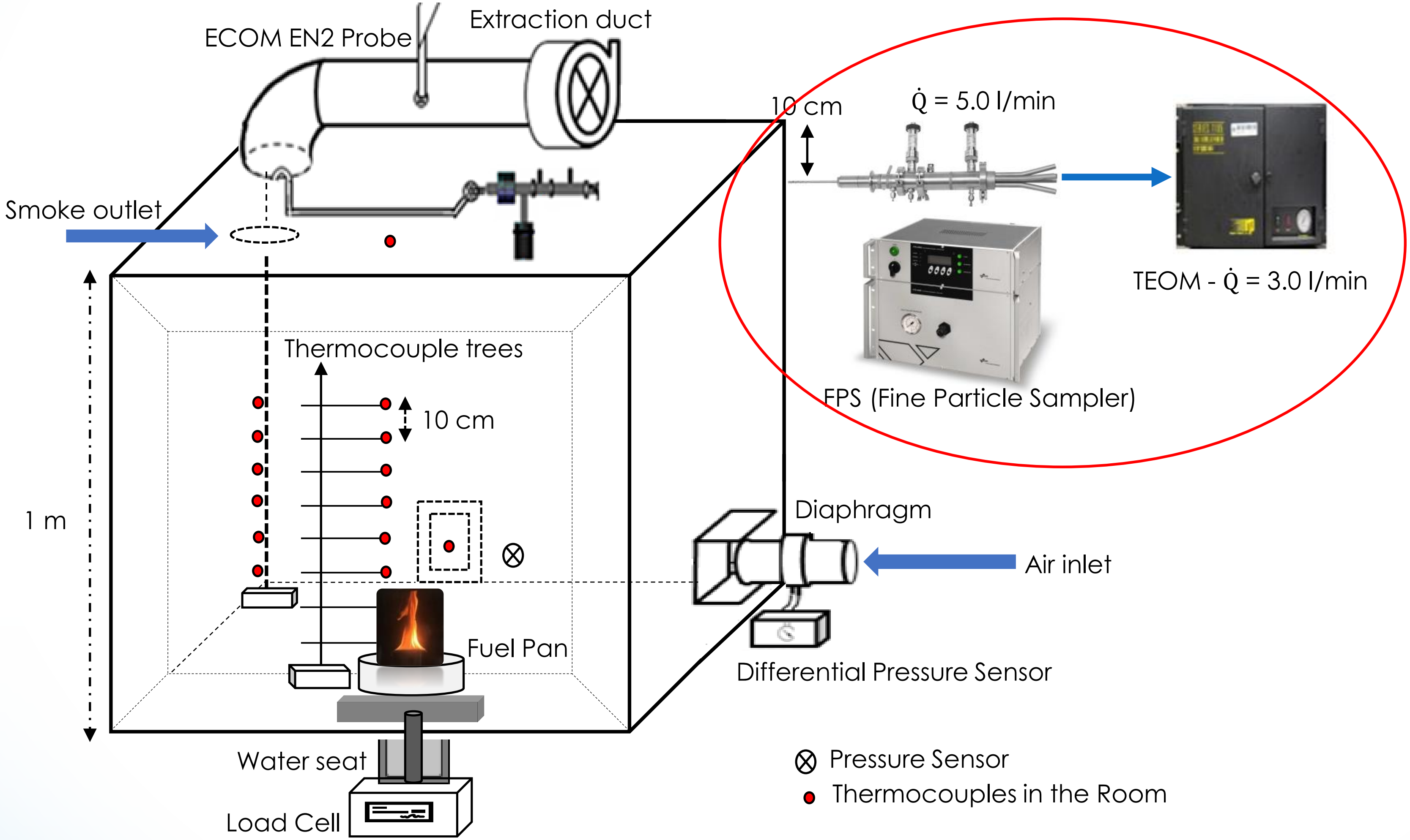


Fig. 1 - Operating diagram of the FPS probe

Fire scenarios - Operational Conditions

1 - Varying the fuel pan size

- **Variable parameter:**
  - Fuel Pan Diameter : 0.115; 0.140 and 0.190 m
- **Fixed parameters:**
  - Renewal Rate: 9.67 ACPH
  - Initial Mass: 266.6 g
- **Fuels:**
  - Pure n-Heptane - $\mathbf{C_7H_{16}}$
  - Technical Dodecane - $\mathbf{C_{12}H_{26}}$
- **Comparison between:**
  - Fuel Mass Los Rate (MLR)
  - Heat Release Rate (HRR)
  - Species Concentration in the extraction duct (O_2 and CO)
  - Mass concentration of soot particles.

2 - Varying ventilation flow rate

- **Variable parameter:**
  - Renewal Rate: 4.83 ; 9.67 and 17.8 ACPH
- **Fixed parameters:**
  - Fuel Pan Diameter: 0.190 m
  - Initial fuel height : 1.7 cm
- **Fuels:**
  - Pure n-Heptane - $\mathbf{C_7H_{16}}$
  - Technical Dodecane - $\mathbf{C_{12}H_{26}}$
- **Comparison between:**
  - Fuel Mass Los Rate (MLR)
  - Heat Release Rate (HRR)
  - Species Concentration in the extraction duct (O_2 and CO)
  - Mass concentration of soot particles.

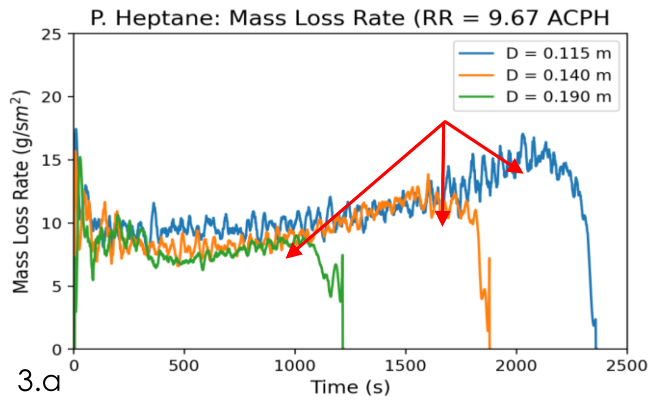
Fuel	Heat Combustion (kJ/g)	Heat Vaporization (kJ/g)	Flash Point (°C).	Boiling Temperature (°C)	Smoke point height (cm)
Pure n-Heptane	46.4	0.365	- 4	98	14.7
Technical Dodecane	49.9	0.361	71	170 - 195	13.7

Fire scenarios - Operational Conditions

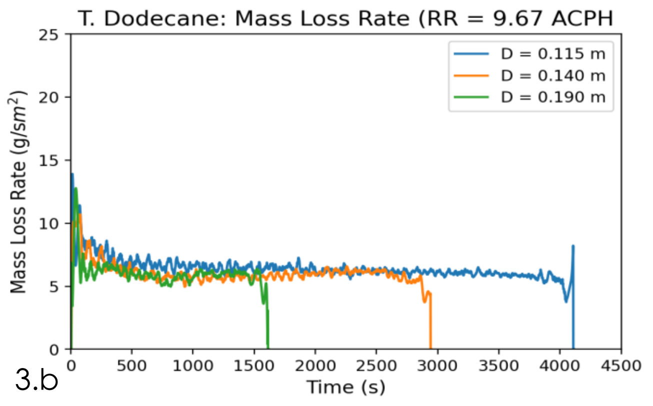
3 - Varying the fuel type

- **Variable parameter: Fuel**
  - Pure n-Heptane - $\mathbf{C_7H_{16}}$
  - Technical Dodecane - $\mathbf{C_{12}H_{26}}$
- **Fixed parameters:**
  - Renewal Rate: 4.83; 9.67 and 14.8 ACPH
  - Fuel Pan Diameter: 0.190 m
  - Initial Mass: 266.6 g
- **Comparison between:**
  - Mass Loss Rate (MLR)
  - Global Equivalence Ratio
  - Species Concentration in the extraction duct (CO)
  - Mass concentration of soot particles.

Effects of fuel pan size in confined and mechanically ventilated fires - MLR



3.a



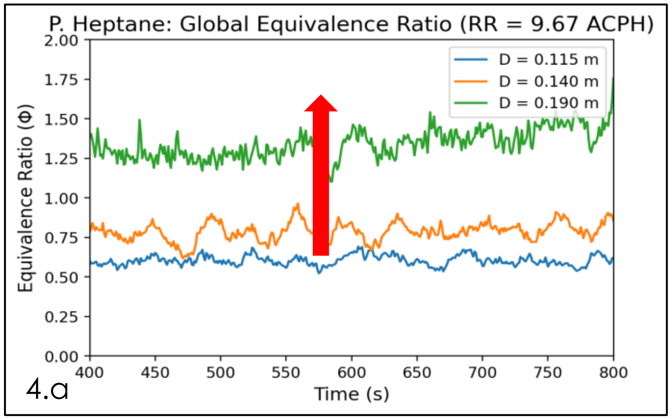
3.b

Fig.3 - Effects of the fuel pan size on the time variation of the Mass Los Rate at RR = 9.67 ACPH; (a) Pure n-Heptane; (b) Technical Dodecane.

- The confined and mechanically ventilated fire is developed in 4 stages:
  1. Ignition
  2. Propagation
  3. Steady state
  4. Extinction by lack of fuel

- Appearance of border effects before extinction for the fires with Pure n-Heptane

Effects of fuel pan size in confined and mechanically ventilated fires - GER



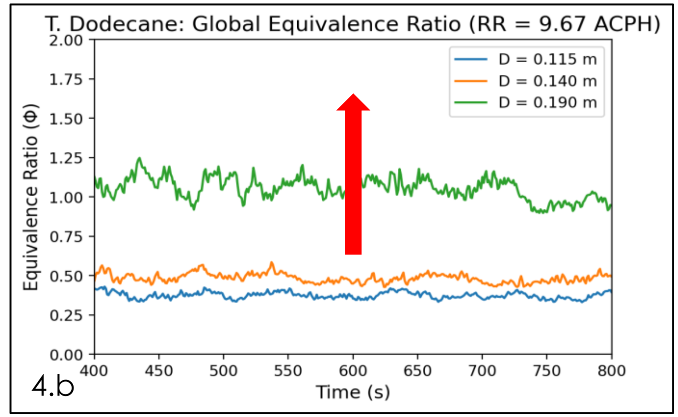


Fig.4 - Effects of the fuel pan size on the Global Equivalence Ratio at RR = 9.67 ACPH; (a) Pure n-Heptane; (b) Technical Dodecane.

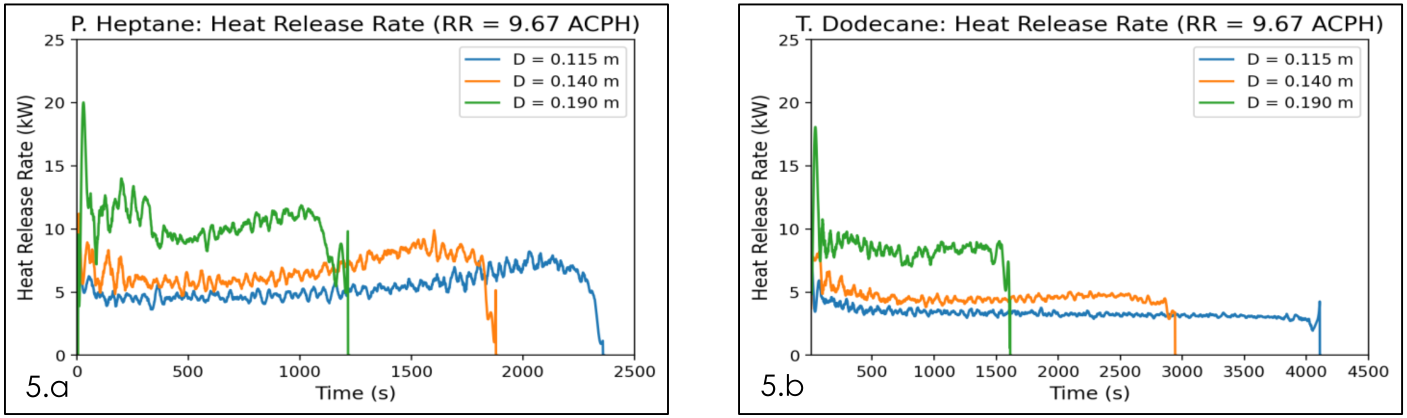
Global equivalence Ratio:

$$\mathrm{GER} = \frac{\dot{m}_{fuel}/\dot{m}_{Air}}{\left(\dot{m}_{fuel}/\dot{m}_{Air}\right)_{st}}$$

- $\dot{m}_{fuel}$: Fuel burning Rate (g/s)
- $\dot{m}_{Air}$: Air inlet flow rate (g/s)

- For fuel pan sizes greater than 0.190 m, the fire compartment is characterized by under-ventilation. (GER >1).

Effects of fuel pan size in confined and mechanically ventilated fires – HRR and gas temperature profile



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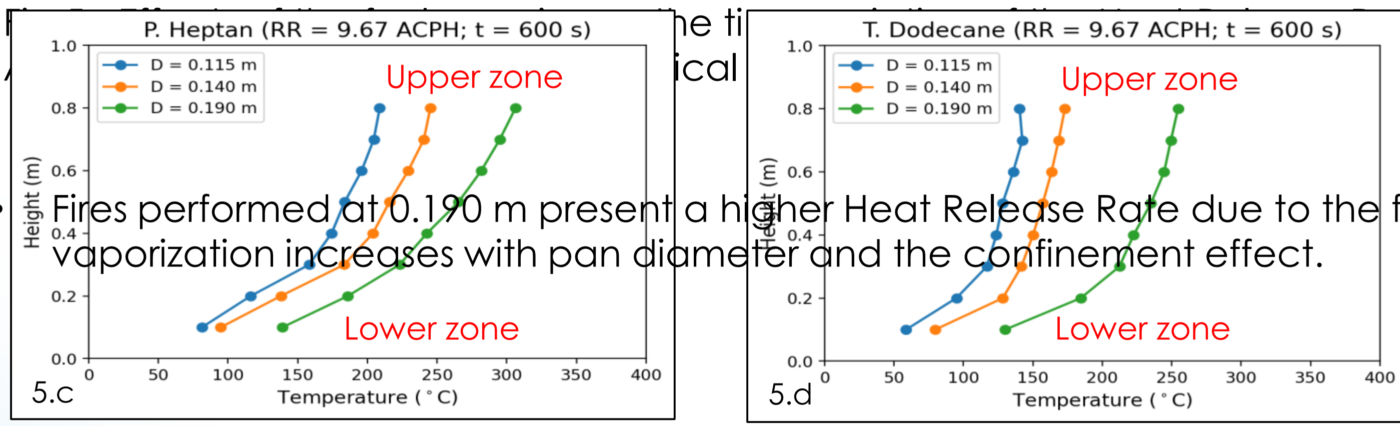
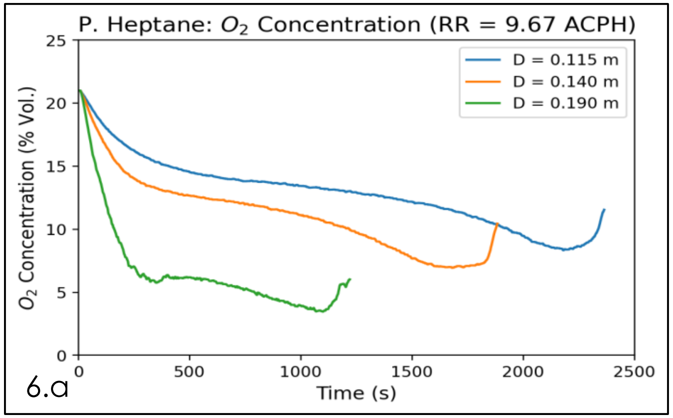


- Fires performed at 0.190 m present a higher Heat Release Rate due to the fact that fuel vaporization increases with pan diameter and the confinement effect.

- The gas temperature never reaches a steady state.

Effects of fuel pan size in confined and mechanically ventilated fires – [O_2]



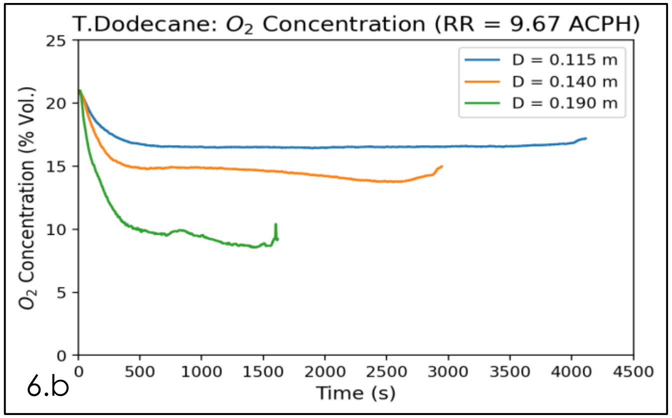


Fig.6 - Effects of the fuel pan size on the O_2 concentration at RR = 9.67 ACPH; (a) Pure n-Heptane; (b) Technical Dodecane.

- As the fuel pan size becomes important, the more O_2 is consumed.
- For the test performed with T. Dodecane, during the steady phase, the O_2 consumption seems to be stable until extinction.

Effects of fuel pan size in confined and mechanically ventilated fires – [CO] and [Soot]

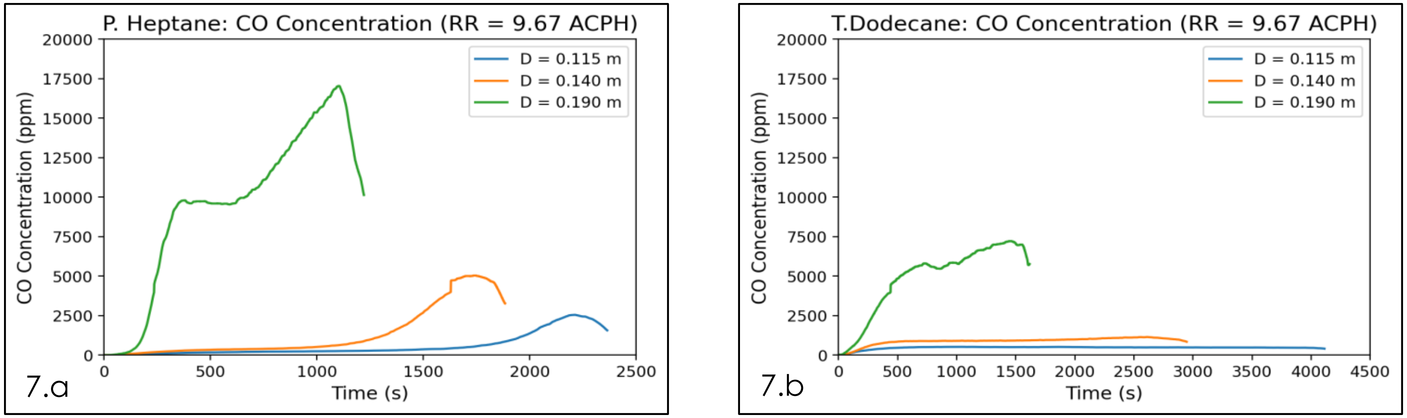
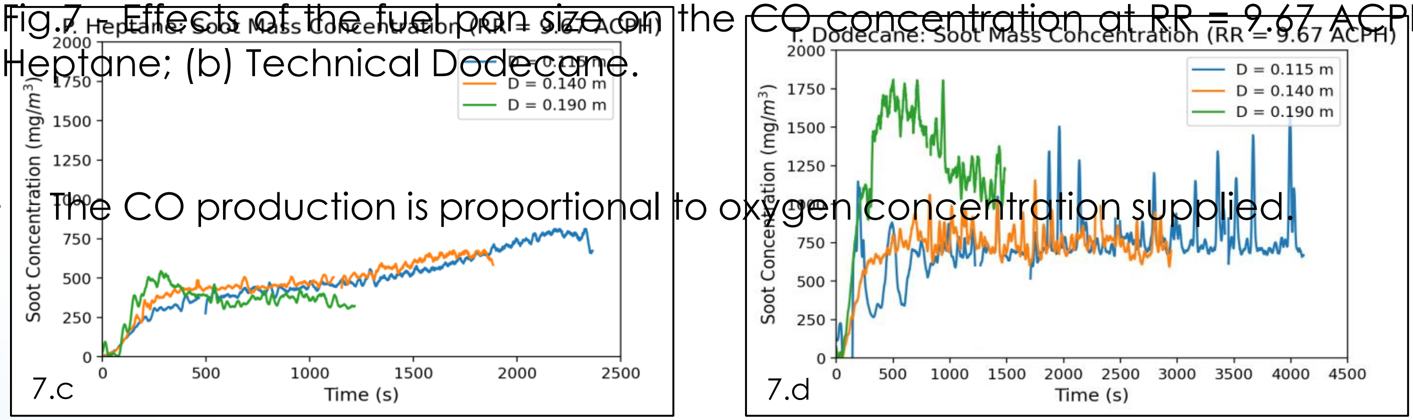
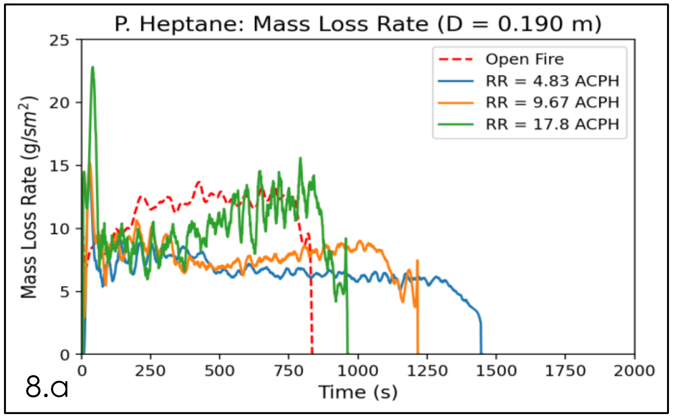


Fig.7 – Effects of the fuel pan size on the CO concentration at RR = 9.67 ACPH; (a) Pure n-Heptane; (b) Technical Dodecane.



- The CO production is proportional to oxygen concentration supplied.

Ventilation effects in confined and mechanically ventilated fires - MLR



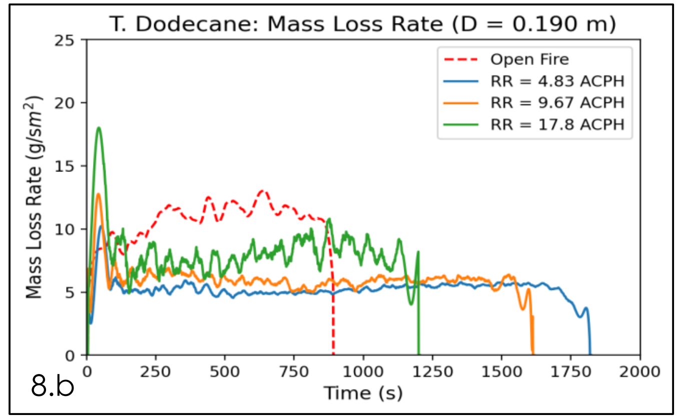
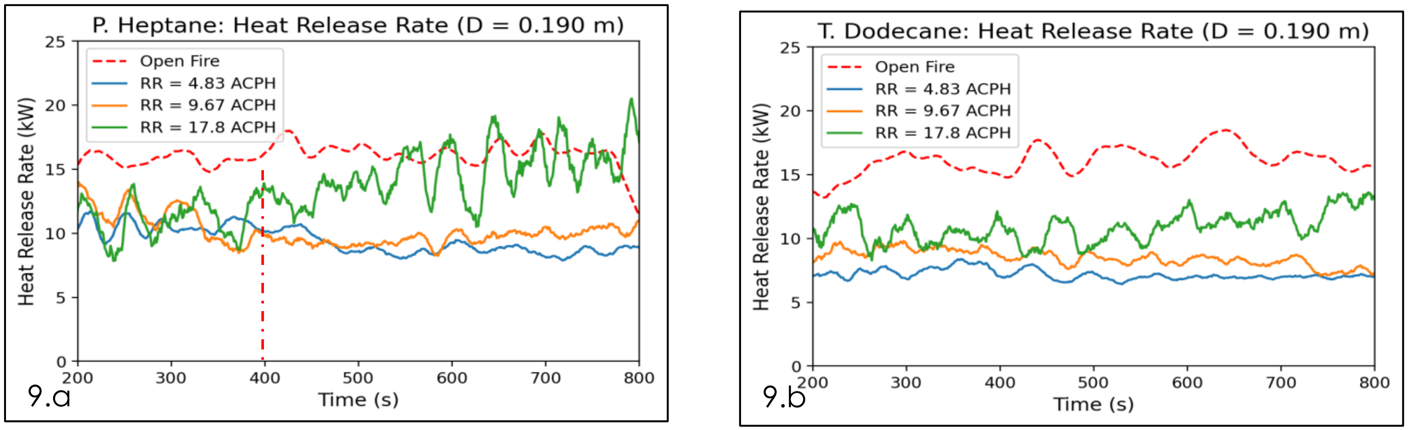


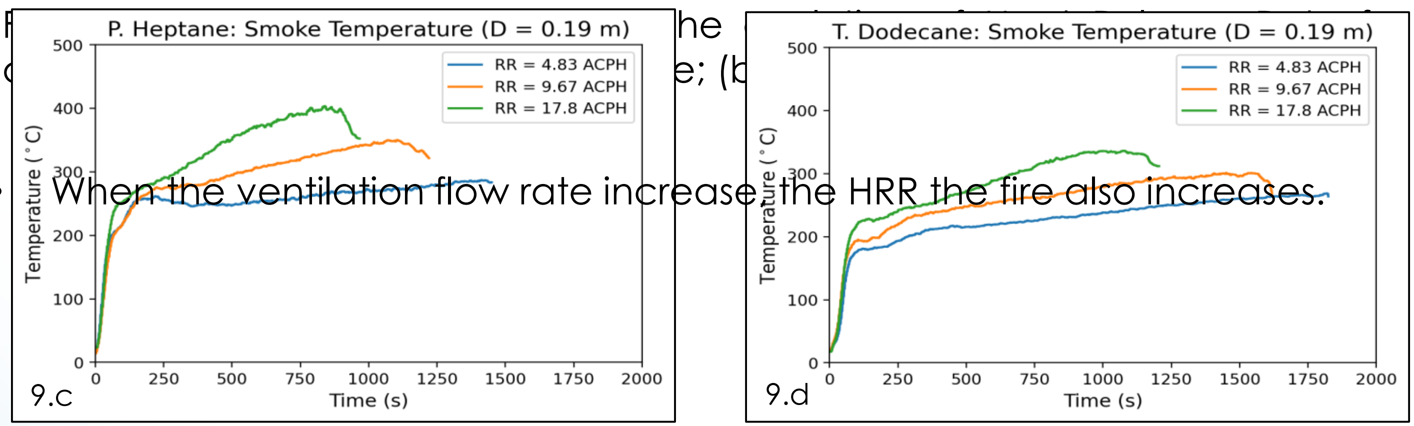
Fig.8 - Effect of Renewal Rate on the time variation of the Mass Loss rate for the 0.190 m diameter pool fire; Pure n-Heptane; (b) Technical Dodecane.

- The test performed with Pure n-Heptane at 17.8 ACPH showed strong fluctuations that create a pressure effect on the load cell.
- The fuel MLR of T. Dodecane followed the same pattern for the 4.83 ACPH and 9.67 ACPH ventilation rate.

Ventilation effects in confined and mechanically ventilated fires - HRR



the 0.190 m



- When the ventilation flow rate increase the HRR the fire also increases.
- Consequently increases the gas temperature and the fire risk in extraction duct.

Ventilation effects in confined and mechanically ventilated fires – [O_2]

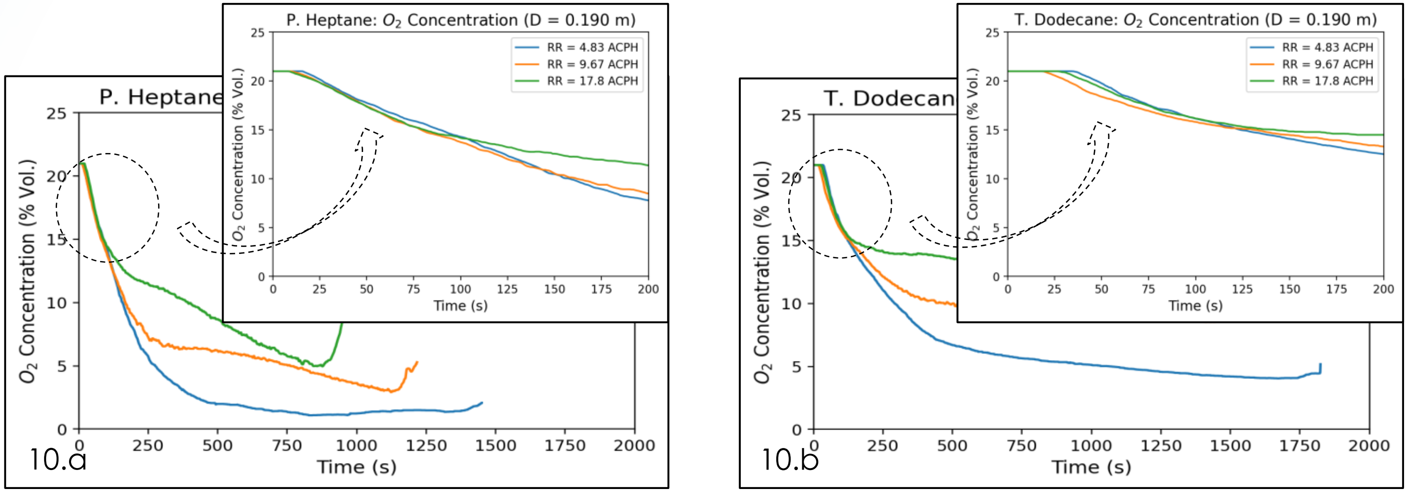
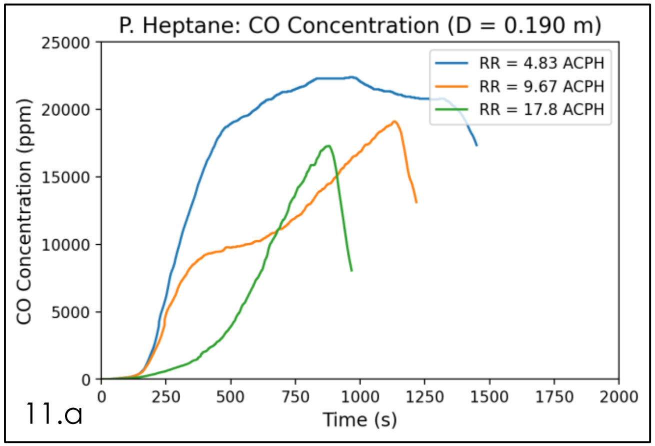


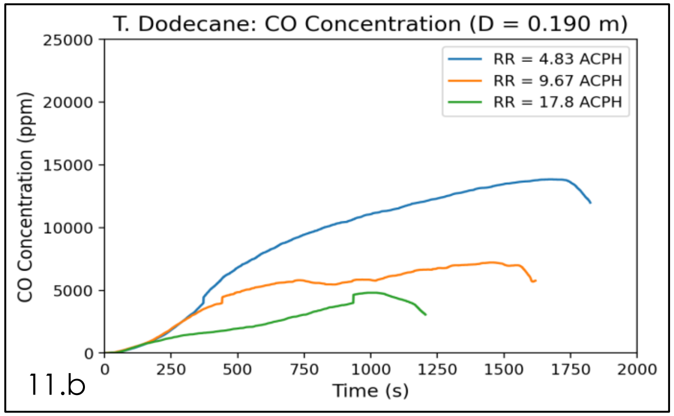
Fig.10 - Effect of Renewal Rate on the O_2 concentration for the 0.190 m diameter pool fire; (a) Pure n-Heptane; (b) Technical Dodecane.

- Fires performed at a low ventilation rate showed a higher oxygen consumption, after 500 s the O_2 reaches a quasi-steady state.
- The oxygen concentration within the enclosure rapidly starts decreasing due to the production of combustion products (mainly carbon dioxide and monoxide, and soot).

Ventilation effects in confined and mechanically ventilated fires –[CO] and[Soot]

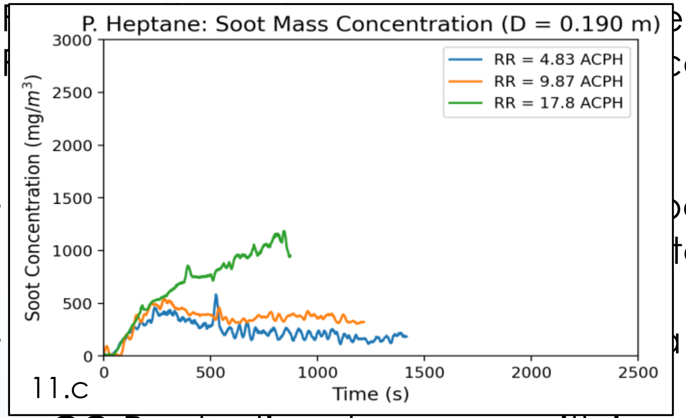


11.a

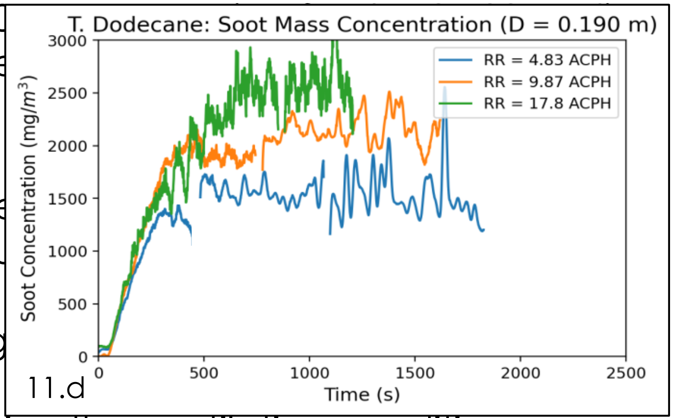


11.b

F... e CO... eter pool fire;
F... cane



11.c



11.d

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- ... a hig...
- CO Production decreases with increasing the ventilation condition.

Effects of fuel type in confined and mechanically ventilated fires

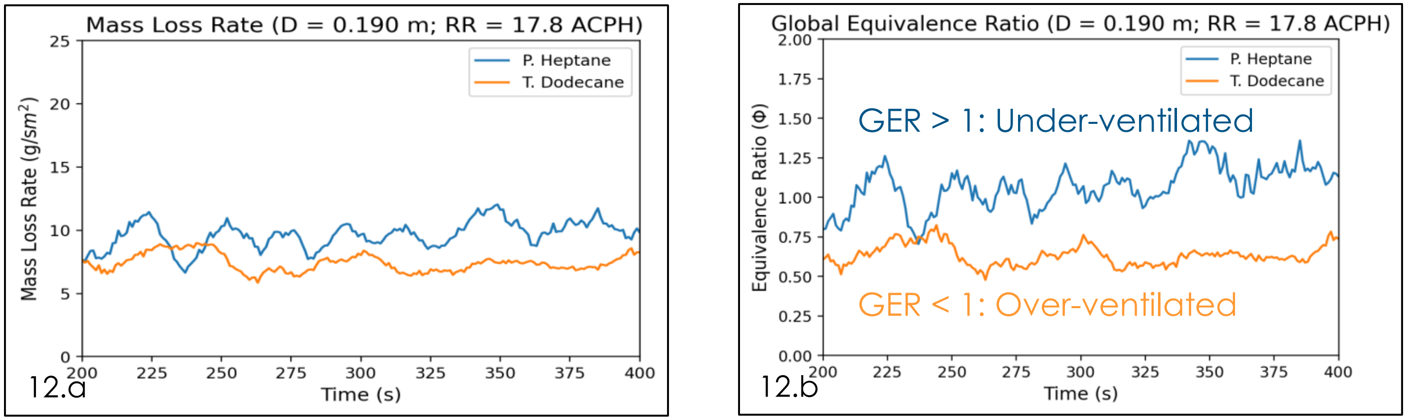
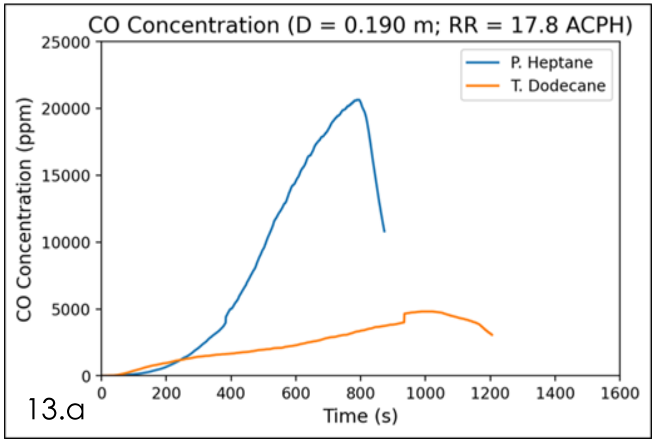


Fig.12 - Effects of the fuel type on the development of fire; (a) Time evolution of Mass Loss Rate; (b) Evolution of Global Equivalence Ratio for Pure n-Heptane and Technical Dodecane at RR = 17.8 ACPH.

- The MLR of Pure n-Heptane pool fire is slightly higher than that the T, Dodecane.
- For this condition, the Heptane fire is developed in a under-ventilated environment.

Effects of fuel type in confined and mechanically ventilated fires



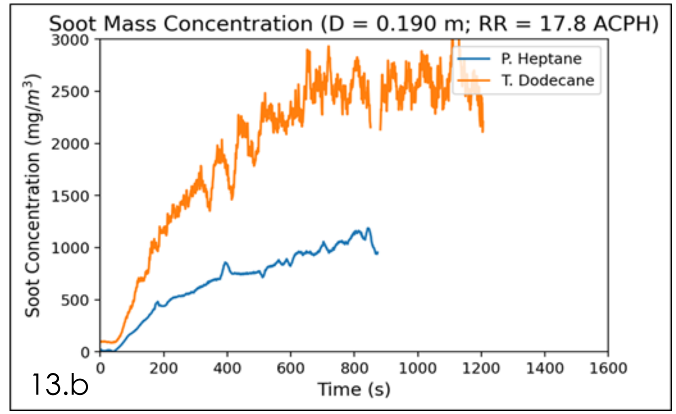
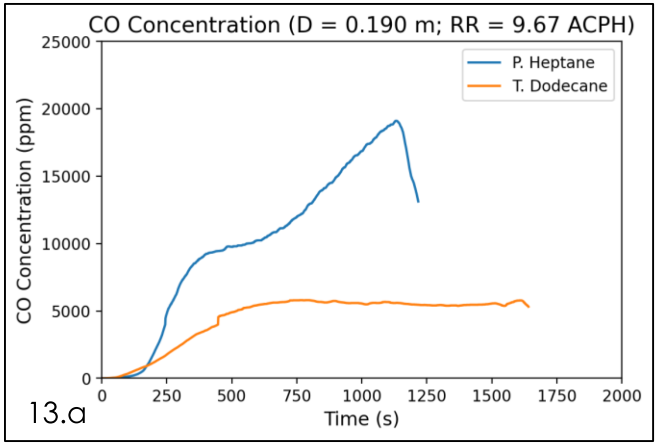


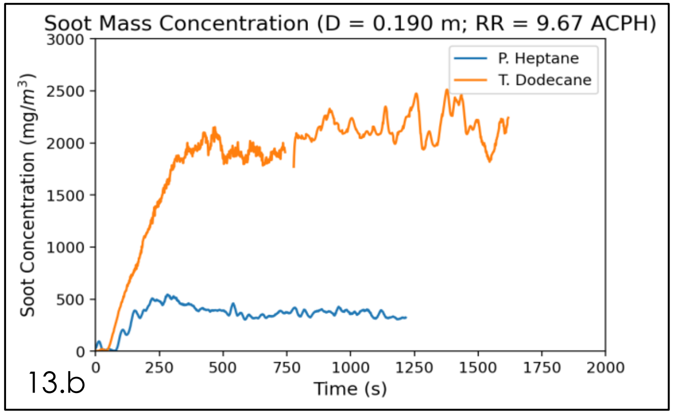
Fig.13 - Effects of the fuel type on the development of fire; (a) Time evolution of CO concentration; (b) Soot Mass concentration for Pure n-Heptane and Technical Dodecane at RR = 17.8 ACPH.

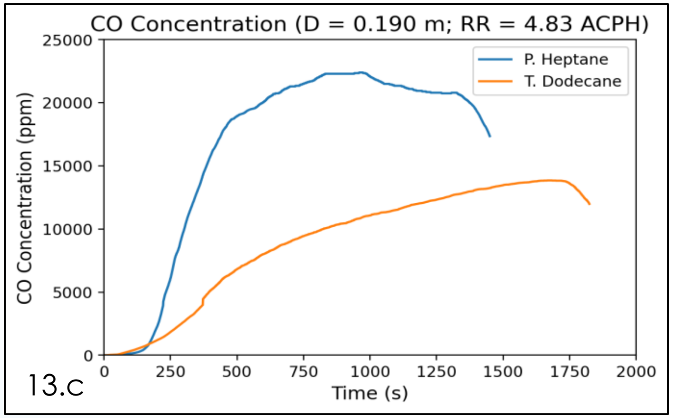
1- Pure n-Heptane fire produced the highest CO concentration.

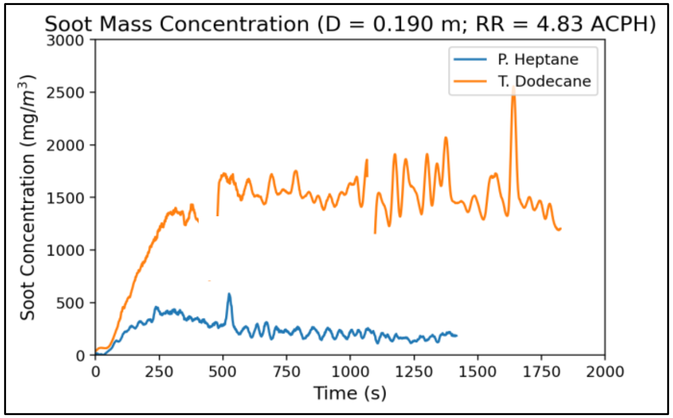
2- Technical-grade Dodecane produced the highest soot emissions.

Effects of fuel type in confined and mechanically ventilated fires









Conclusions and Future Works

- We can obtain under-ventilated fires by increasing the fuel pan size.
- The increase of fuel pan size (diameter) generates an increases in the HRR, consequence temperature of the gases stored in the compartment also increase. Similar behavior was observed with the ventilation flow rate.
- The increase of Renewal Rate (ACPH) reduces the fire extinction time.
- Carbon monoxide concentration depends strongly on the type of fuel (Pure n-Heptane > Technical dodecane).
- When a fire produces large amounts of CO, soot production is lower.
  - More volatile fuel produce higher concentrations of CO
  - Heavier fuel produce higher soot concentrations.

- Future Works
- Continue measurements with heavy fuels.
- Perform measurements by changing the position of the air intake.

THANKS FOR YOUR ATTENTION.