LOCAFI+

Temperature assessment of a vertical member subjected to LOCAlised FIre
Dissemination

Grant Agreement n° 754072

3. Experimental tests and CFD calibration

3. Experimental tests and CFD calibration

Tests performed at the University of Liège

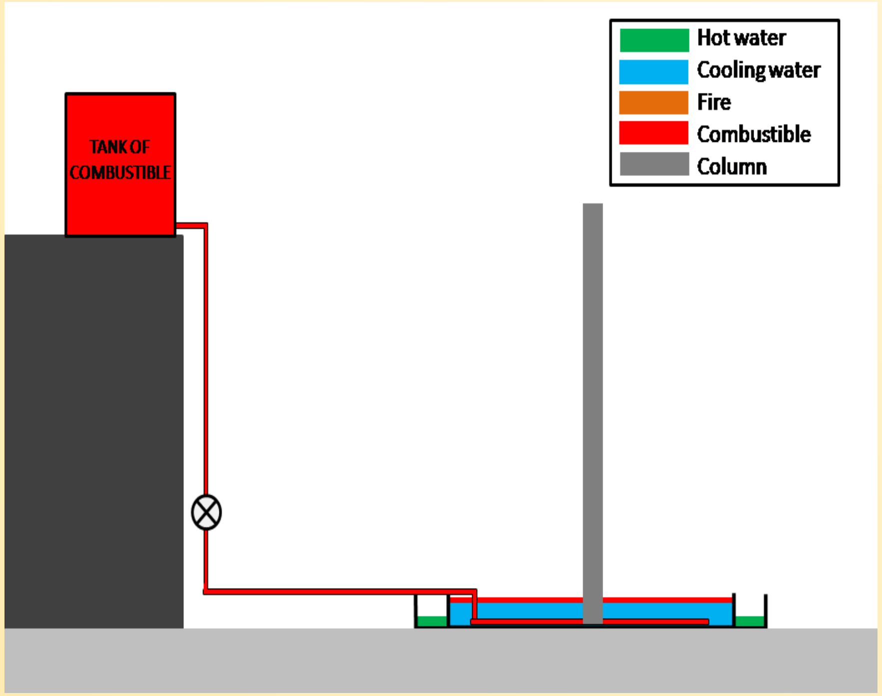
Characterisation of heat fluxes received by elements engulfed into the fire

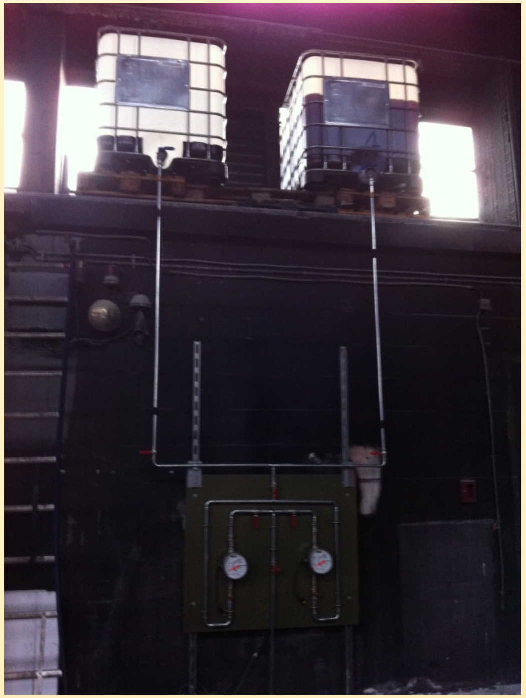
- 24 tests have been performed by the University of Liège varying:
  - The diameter of the fire (*5 diameters : 0.6m, 1.0m, 1.4m, 1.8m and 2.2m*)
  - The type of combustible (*2 different combustible liquids (diesel and N-heptane) + 1 cellulosic fire load*)
  - The presence of a column engulfed into the fire
- For each diameter and for the two combustible liquids:
  - One test without column into the fire
  - One test with a column at the centre of the fire source

3. Experimental tests and CFD calibration

Tests performed at the University of Liège

General test set-up



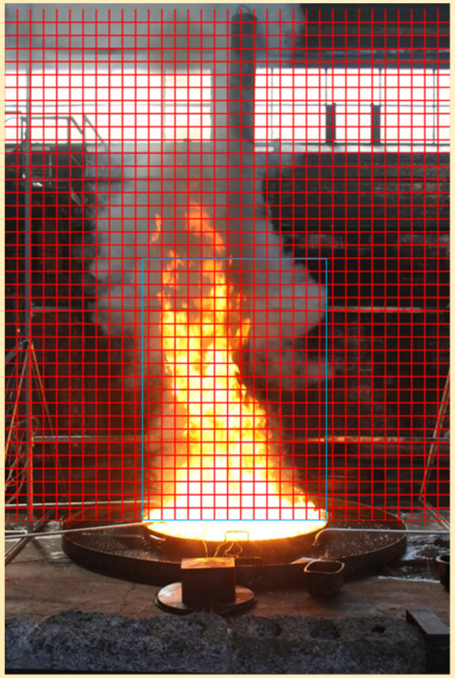


- Two tanks filled of heptane and diesel were placed at higher height than the floor to allow the fuel to flow by gravity ;
- The Rate of Heat Release of the pool fire was controlled by adjusting the flow of injected combustible by a simple manual valve ;
- The basin was continuously fed with cold water in order to cool down the layer underneath the burning fuel and, thus to provide a more stable steady burning regime by avoiding water ebullition.

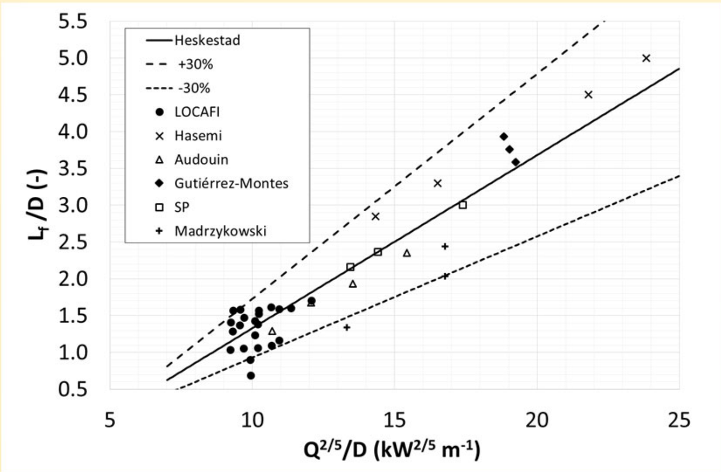
3. Experimental tests and CFD calibration

Tests performed at the University of Liège

Experimental measurements : flame length



The mean flame length L is the distance above the fire source where the intermittency has declined to 0.5, where intermittency I(z) is defined as the fraction of time the flame lies above the fire source. This assessment was made using digital image analysis.



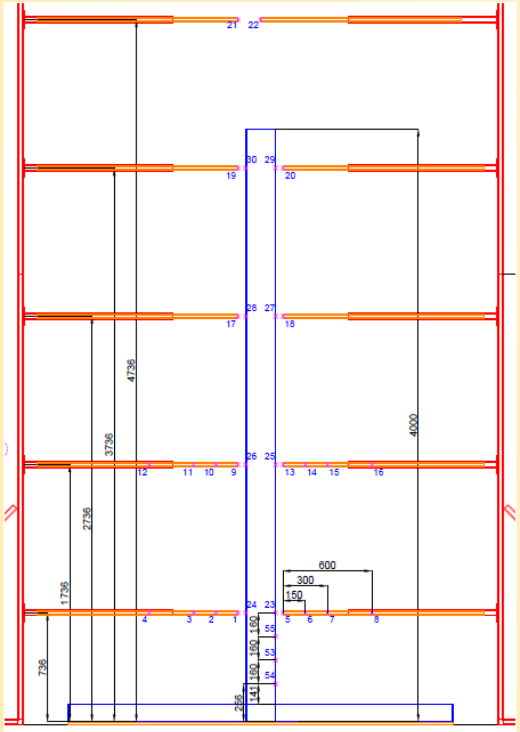
The difference between the experimental flame length and the flame length predicted by Heskestad is between +30% and -30% but this is in line with other pool fire investigations and mainly due to uncertainty about combustion efficiency and fuel density.

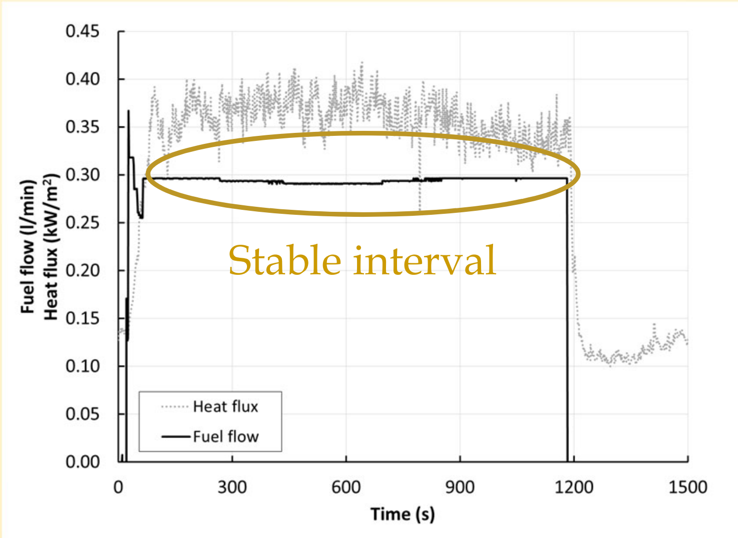
N. Tondini, J.M. Franssen, "Analysis of experimental hydrocarbon localised fires with and without engulfed steel members", Fire Safety Journal 92 (2017), 9-22

3. Experimental tests and CFD calibration

Tests performed at the University of Liège

Experimental measurements : temperature and fluxes



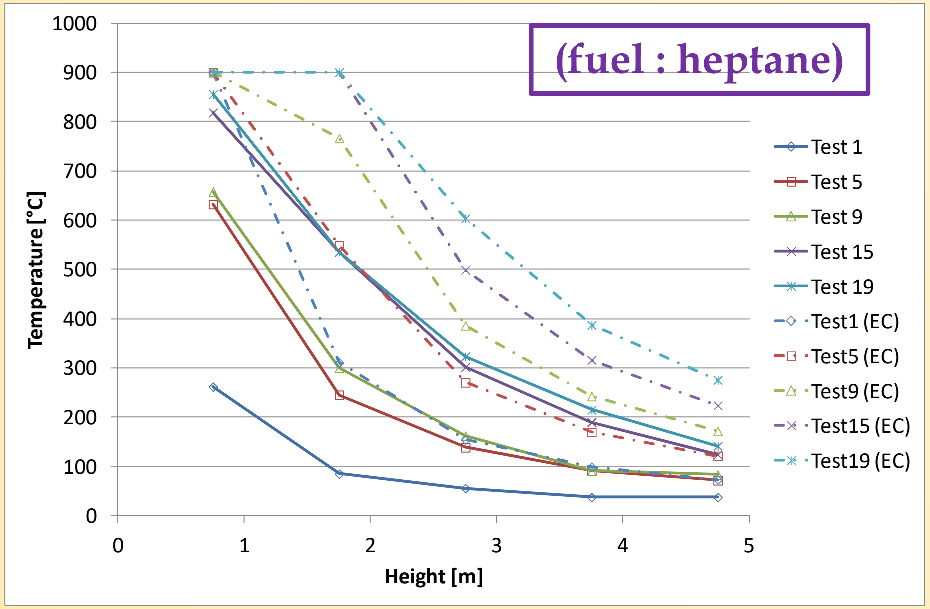


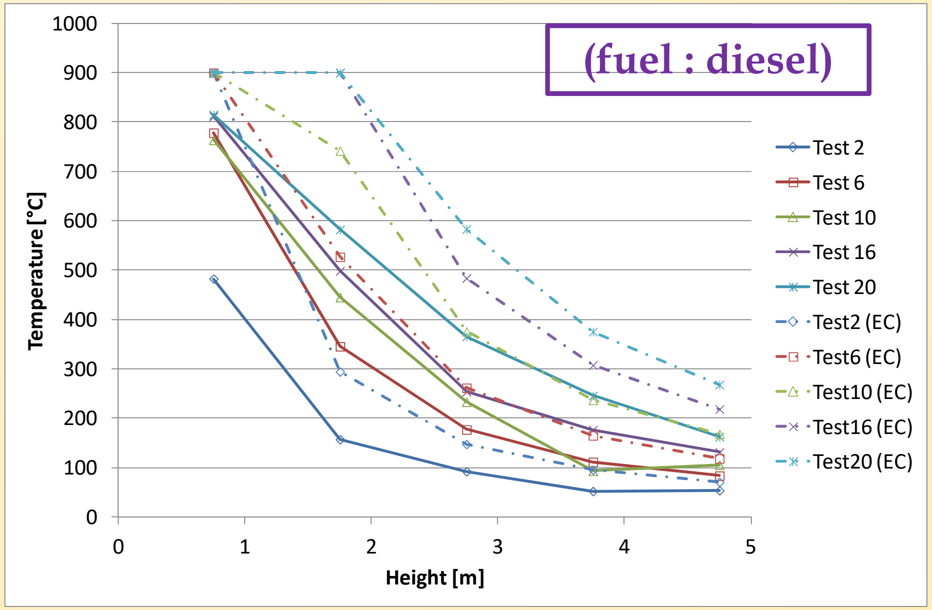
- Tests are performed until reached a steady-state configuration (measurements of gas temperature and radiative heat flux are stabilised) ;
- In configuration with steel columns, thermocouples also provide evolution of steel temperature.

3. Experimental tests and CFD calibration

Tests performed at the University of Liège

Experimental measurements : temperature and fluxes



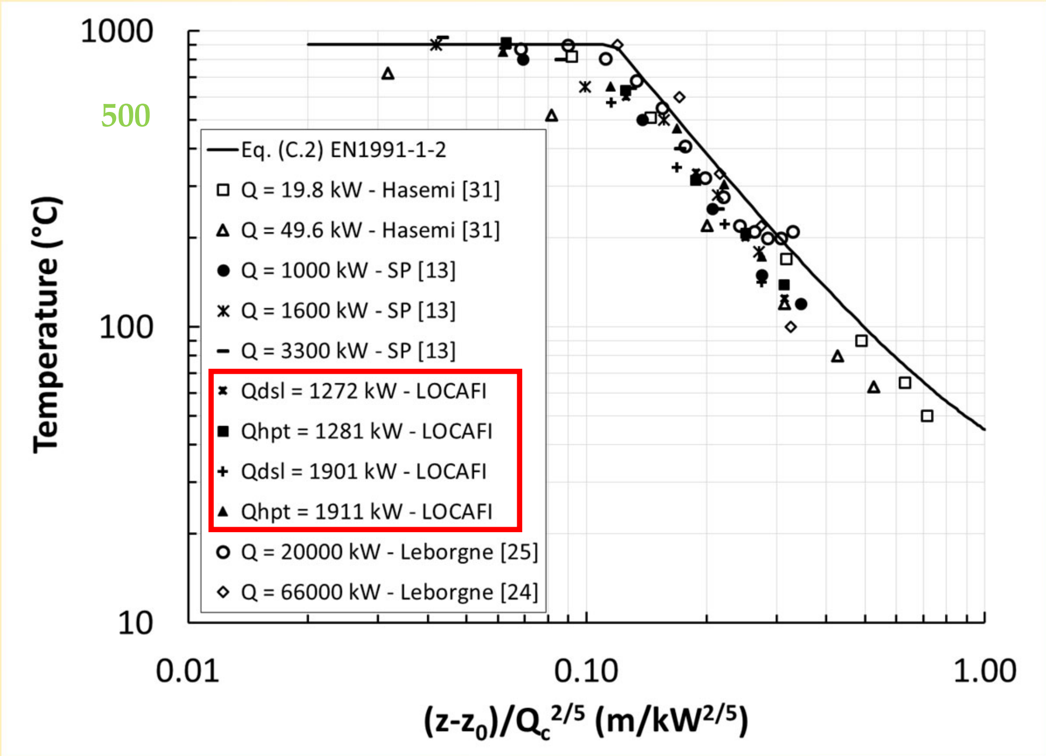


Heskestad correlation (EN 1991-1-2) over-estimates temperatures both in the flame ($\theta_g \geq 500°C$) and the plume ($\theta_g < 500°C$)

3. Experimental tests and CFD calibration

Tests performed at the University of Liège

Experimental measurements : temperature and fluxes

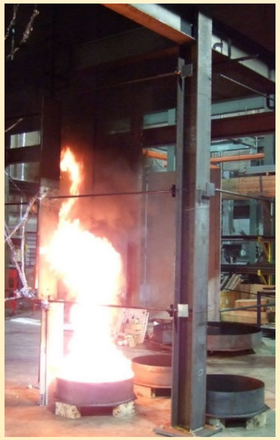


EN 1991-1-2 correlation provides a good assessment of temperatures both in the flame ($\theta_g \geq 500$°C) and the plume ($\theta_g < 500$°C).

3. Experimental tests and CFD calibration

Tests performed at the University of Ulster

Characterisation of heat fluxes received by elements outside the fire

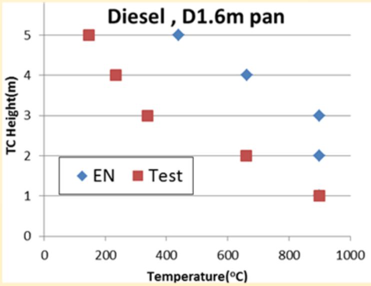

- 58 tests have been performed by the University of Ulster varying:
  - The presence or not of a ceiling (37 tests without / 21 tests with)
  - The number of pool fires (*from 1 to 4*) and diameter of these pools (*2 diameters : 0.7m and 1.6m*)
  - The type of combustible (*2 different combustible liquids (diesel and kerosene) + 1 cellulosic fire load*)
- The 9mx9m structure is composed of three types of columns (*I-section, H-section and O-section*)
- The HRR varied with time (not controlled) and was measured by a calorimeter hood
- Flame length is assessed using a camera and on the basis of the flame presence probability

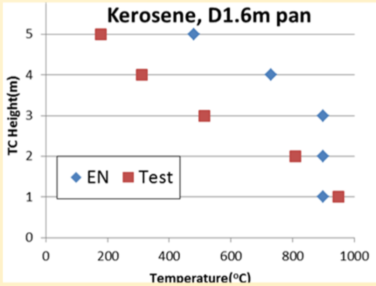
3. Experimental tests and CFD calibration

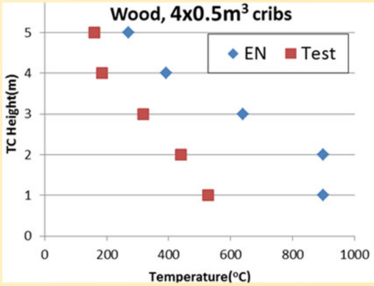
Tests performed at the University of Ulster

Experimental measurements : flame temperature

HEIGHT	TESTS O8, I9 (KEROSENE, D1.6M)		TEST O10 (DIESEL, D1.6M)		TESTS O1,O2 (KEROSENE, D0.7M)		TESTS O3,O4 (DIESEL, D0.7M)		TEST O14 (WOOD CRIBS)	
	EN	TEST	EN	TEST	EN	TEST	EN	TEST	EN	TEST
1M	900	949	900	899	900	686	900	652	900	527
2M	900	810	900	660	845	223	697	208	900	440
3M	900	515	900	339	381	90	325	89	640	317
4M	730	312	663	235	228	-	198	-	391	185
5M	479	179	440	146	157	-	139	-	271	159





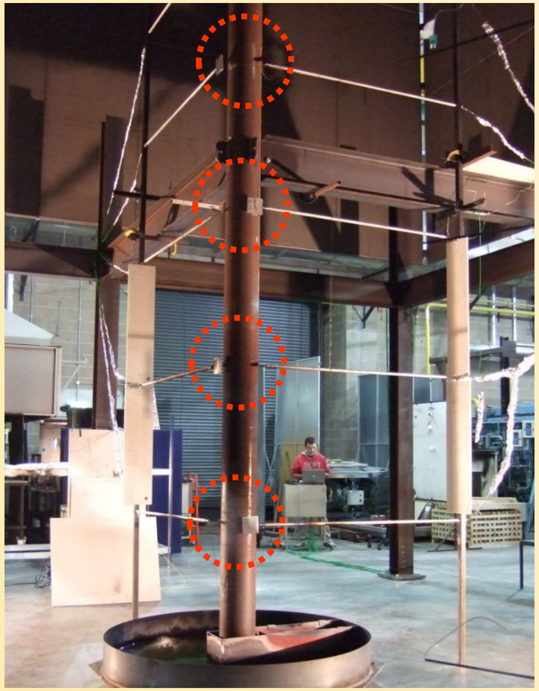


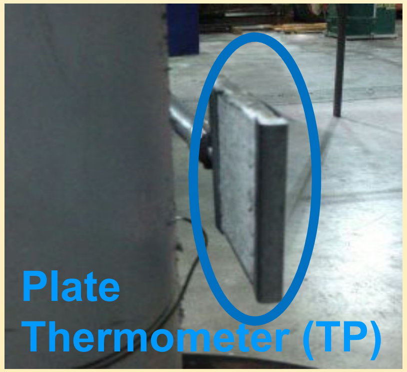
These tests confirm that Heskestad correlation (EN 1991-1-2) over-estimates temperatures in the flame ($\theta_g \geq 500$°C) and the plume ($\theta_g < 500$°C) domains.

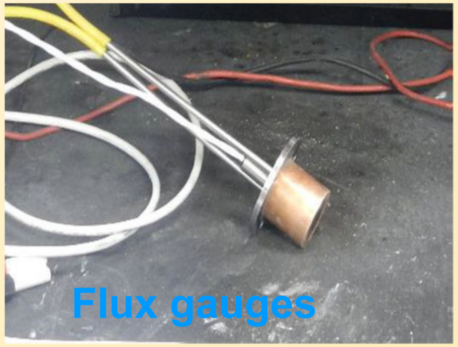
3. Experimental tests and CFD calibration

Tests performed at the University of Ulster

Experimental measurements : temperature and fluxes outside the fire





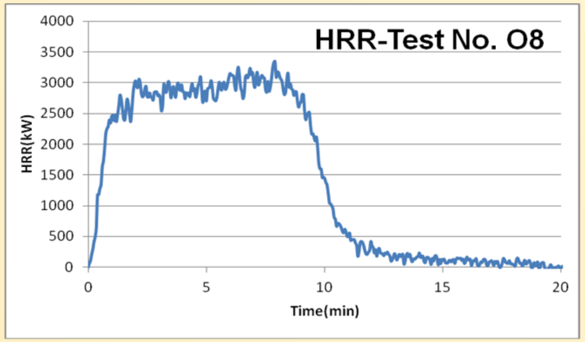


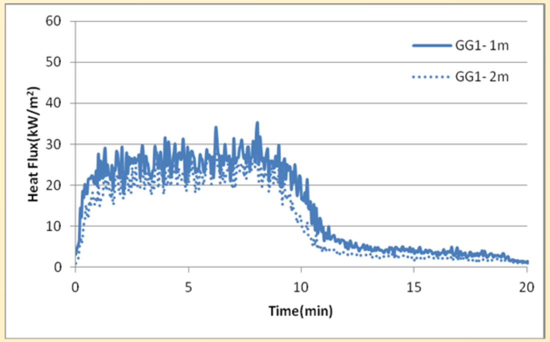
3. Experimental tests and CFD calibration

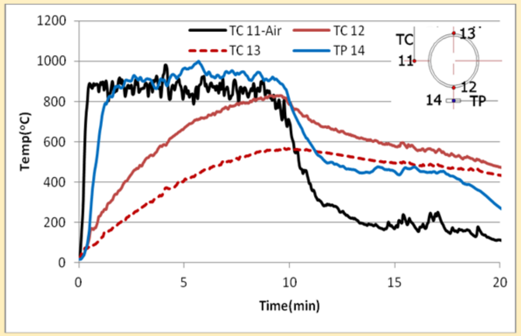
Tests performed at the University of Ulster

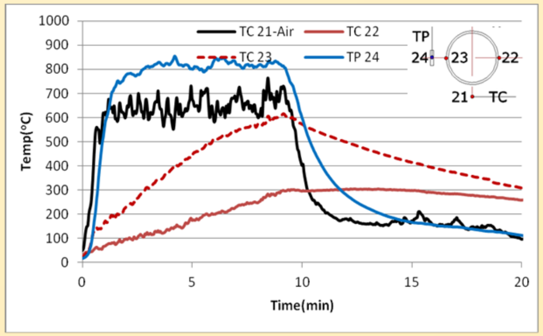
Experimental measurements : results obtained from O8 test

- Number of Pan(s) : 1
- Diameter of the pan : 1.6 m
- Fuel type : Kerosene
- Fuel quantity : 60 L
- Pool-column distance : 0 m
- Gauges-column distance : 1.5m
- No ceiling









3. Experimental tests and CFD calibration

Calibration of a CFD model using FDS software

Objectives

- The number of tests is limited and the measurements made during these tests are limited too.
- Due to the dimensions of the building/lab where the experimental tests have been undertaken, it was not possible to cover the full range of localised fires (Annex C of EN 1991-1-2 applies until D = 10 m and Q = 50 MW)

→ After validation of the model(s), CFD modelling is a cost-effective and powerful tool able to provide a very large set of results for further validation of analytical calculation methods

- FDS software is a free software, developed by NIST, and widely-used by the community of fire engineers

Calibration of FDS models was processes by reproducing a selection of 5 tests chosen on the basis of the following criteria

- Tests performed under constant and controlled conditions (Liège) and free conditions (Ulster)
- Tests exhibiting long stable and steady-state results
- Different types of fuels, small and large pool diameters, with and without ceiling,…

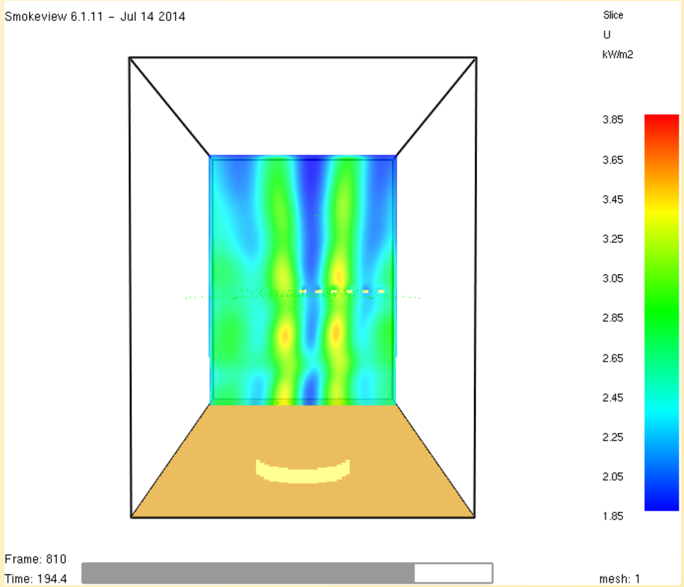
3. Experimental tests and CFD calibration

Calibration of a CFD model using FDS software

Calibration parameters

The most influencing parameters adjusted during the calibration process are :

- Turbulence model (Smagorinski, $C_s = 0.1$)
- Fuel properties, including soot yield, taken from literature (overventilated conditions)
- Number of Radiation Angles (200)
- Radiative loss fraction (range of 0.2-0.5, mainly depending on fuel type and fire diameter)
- Wind effects (based on measurements)
- Mesh grid dimensions (based on characteristic length and measure of turbulence resolution)



Example of flux variations due to an insufficient number of Radiation Angles

3. Experimental tests and CFD calibration

Calibration of a CFD model using FDS software

Test ULG 06 (D = 1m, Heptane, no column)

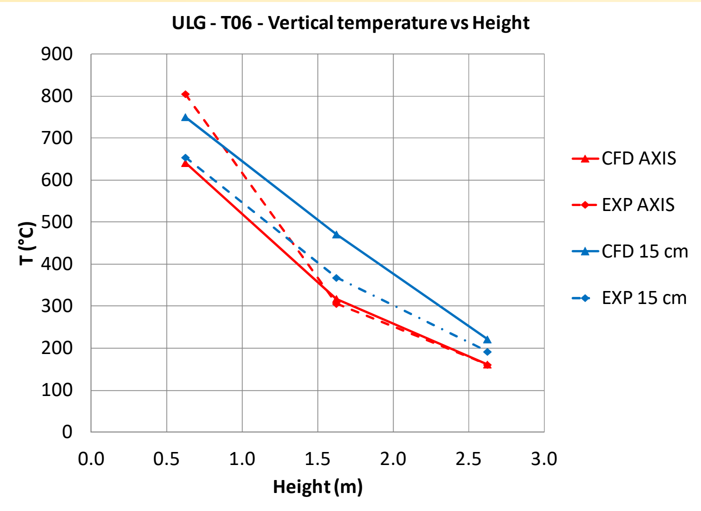
Average fuel flow q_{fuel}	0.98 l/min
Fuel density ρ	675 kg/m^3
Soot yield y_{soot}	0.037
Ideal heat of combustion $\Delta H_{c,ideal}$	44600 kJ/kg
Heat of combustion ΔH_c	41200 kJ/kg
RHR computed with $\Delta H_{c,ideal}$	491.7 kW (626.1 kW/m^2)

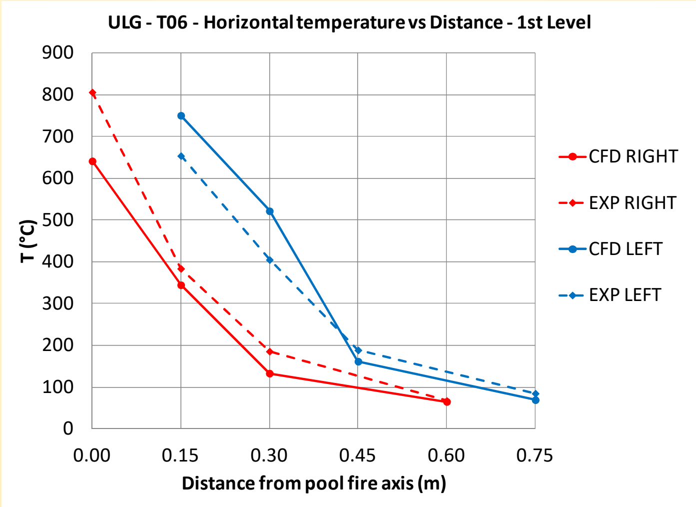
- Dimension of the CFD domain : 5.75m x 3m x 4m
- Grid size : 5cm x 5 cm x 5 cm
- Wind speed : 0.22 m/s
- Radiative loss fraction : 0.45 (SFPE)

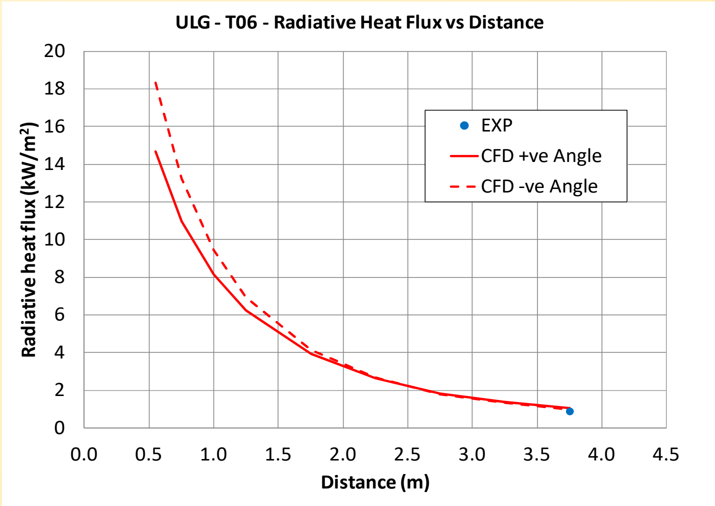
3. Experimental tests and CFD calibration

Calibration of a CFD model using FDS software

Test ULG 06 (D = 1m, Heptane, no column)







3. Experimental tests and CFD calibration

Calibration of a CFD model using FDS software

Test Ulster O29 (D = 0.7m, Diesel, with ceiling at 3.5m)

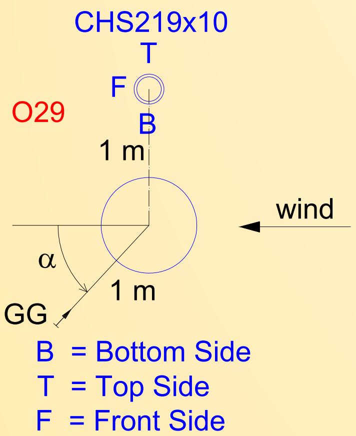
Fuel density ρ	**823 kg/m^3**
Soot yield y_{soot}	**0.10**
Ideal heat of combustion $\Delta H_{c,ideal}$	**44000 kJ/kg**
Heat of combustion ΔH_c	**41200 kJ/kg**
RHR computed with $\Delta H_{c,ideal}$	**491.5 kW (1277.1 kW/m^2)**

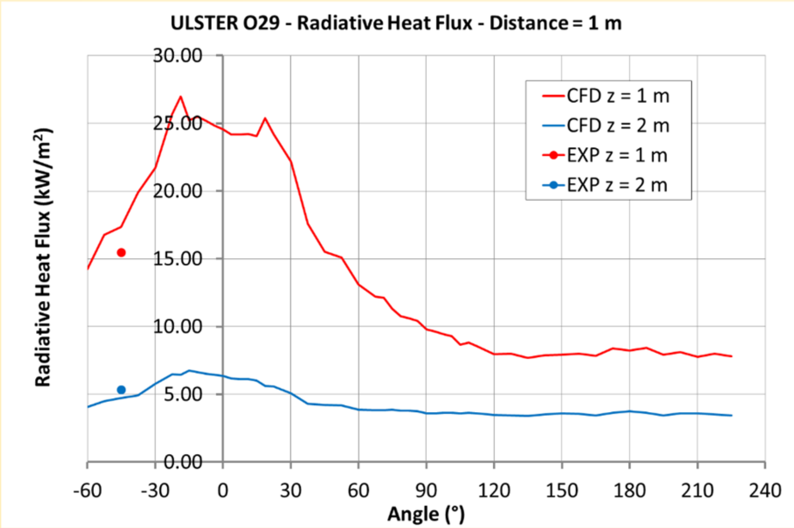
- Dimension of the CFD domain : 7m x 7m x 3.5m
- Grid size : 5cm x 5 cm x 5 cm
- Wind speed : 0.76 m/s
- Radiative loss fraction : 0.45 (SFPE)

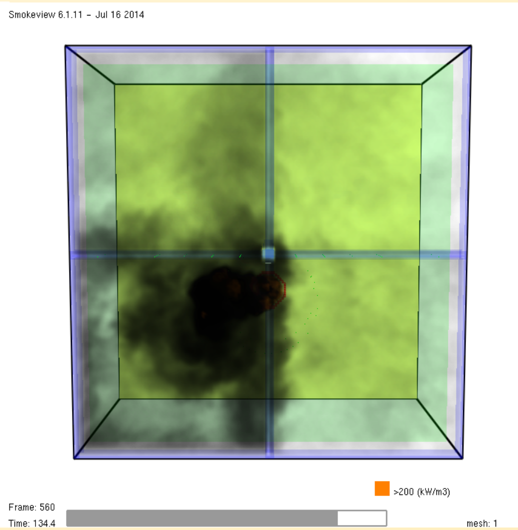
3. Experimental tests and CFD calibration

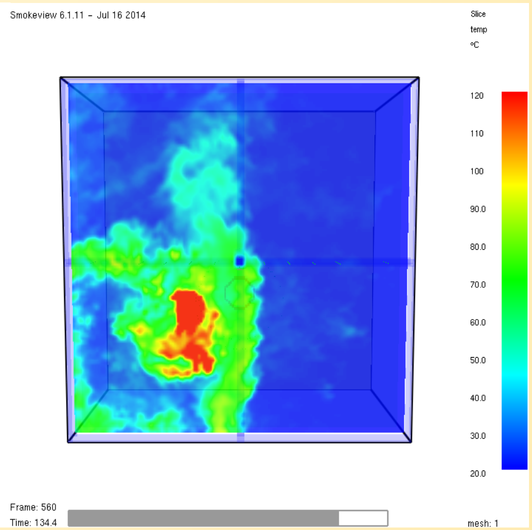
Calibration of a CFD model using FDS software

Test Ulster O29 (D = 0.7m, Diesel, with ceiling at 3.5m)









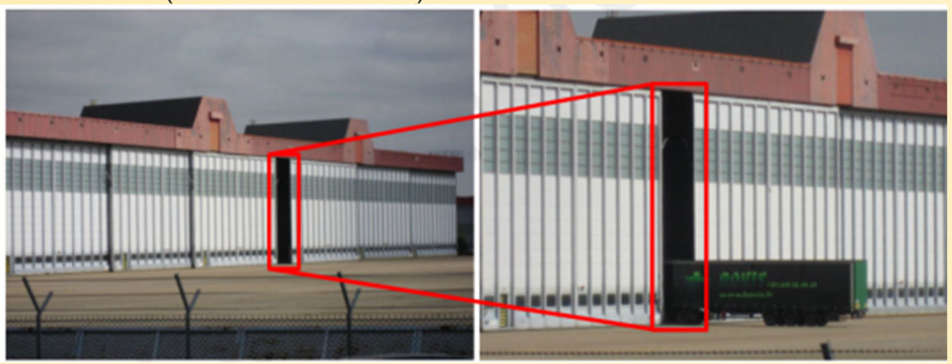
z (m)	CFD RHFG GG (kW/m²)	EXP GG (kW/m²)	Error (%)
1	17.35	15.45	12.3
2	4.71	5.32	-11.5

3. Experimental tests and CFD calibration

French tests (not in the scope of LOCAFI+)

Tests initiated by LCPP in a large volume :

- Main hall : 300 m x 50 x 17 m
- 2 kinds of combustibles : wood pallet / kerosen
- Fire tests repeated
- Highly instrumented : thermocouples, gauge heat flux, videos (IR and normal)



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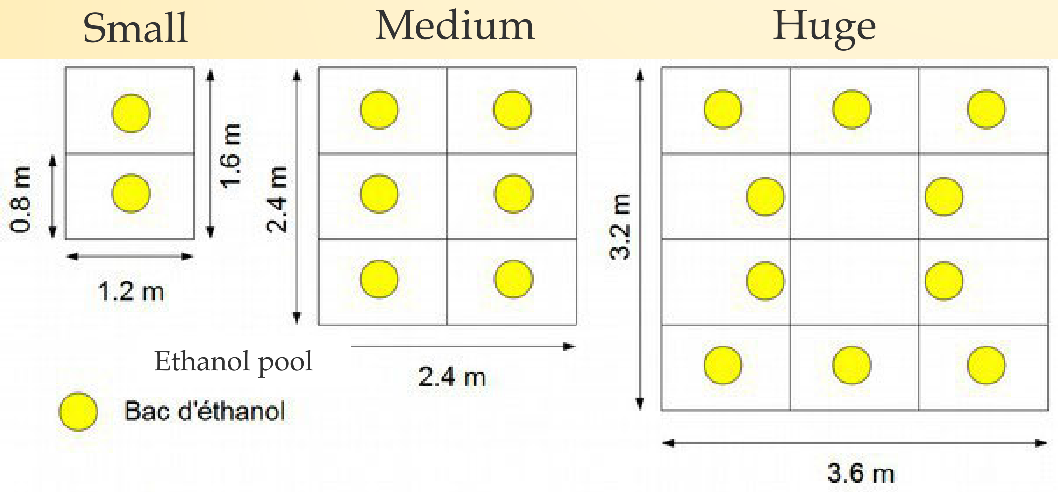
3. Experimental tests and CFD calibration



Small test : ~ 20 palets
Medium test : ~ 60 palets
Huge test : ~ 110 palets

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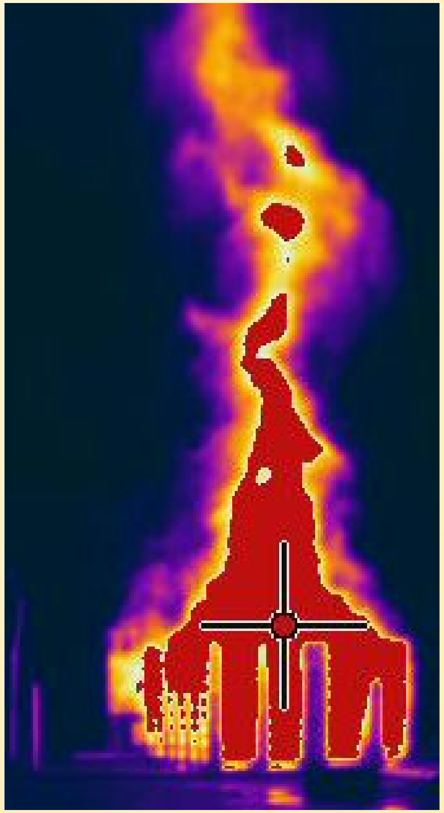
3. Experimental tests and CFD calibration

HRR ~ 30 MW



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