Experimental characterization and computer modelling of water mist systems

D. Alvear[1]; M. Lázaro[1]; J.I. Melgosa[2] and F. Arnáiz[2]
[1]GIDAI - UNIVERSITY OF CANTABRIA (Spain)
[2]RG Systems (Spain)

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Objetives

-Technological development and improvement of the components that make the water mist systems of RG Systems for optimum application in Cable Tunnels and Ducts.

-Selection and design of fire protection system components.

-Modeling and Validation (using full-scale tests) of the water mist system.

-Installation and launching of the fire protection system in a pilot Cable Tunnel.

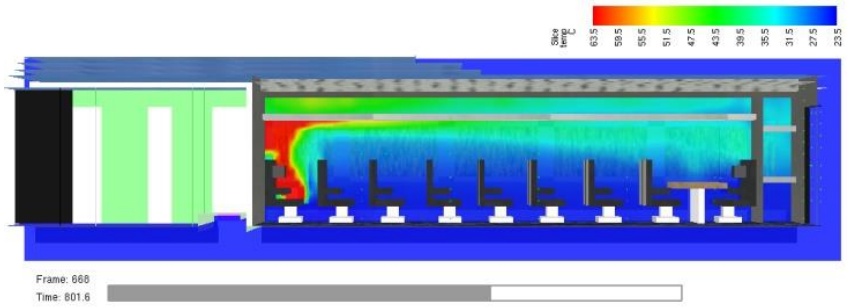
Previous collaboration projects

Small Scale Tests

GLOBAL PROJECT

Real-Scale Tests

Numerical Analysis



Water Mist System Analized

Nozzles:

-EMM 540856 (K-Factor: 2.04): Open nozzle for local application protected risks, with a k-factor of 2.04 and 5 micro-nozzles.

-EMM 20-760-845 (K-Factor: 4.62): Open nozzle for local application protected risks, with a k-factor of 4.62 and 20 holes.

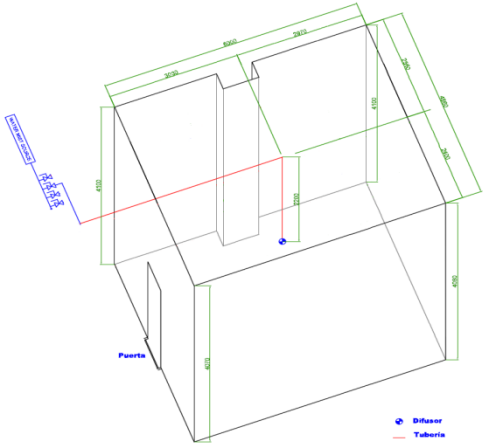
Full Scale Tests

Types of tests:

Collect data for the characterization of the nozzles and the validation activities in the fire computer model.

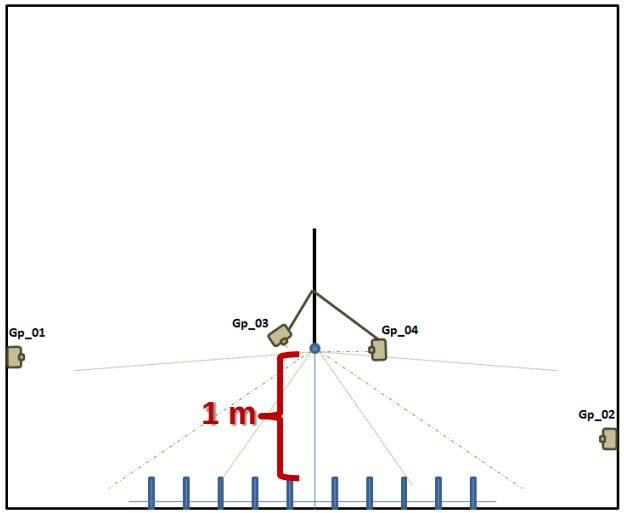
-Without ignition source: in order to have data without any element to disturb the droplet distribution, measuring output angles, flow distribution, etc.

-With ignition source: for the verification of the nozzle operation against two different sizes of pool fires.



Full Scale Tests

Without ignition source:



1	13	25	37	49	61	73	85	97	109	121	133
2	14	26	38	50	62	74	86	98	110	122	134
3	15	27	39	51	63	75	87	99	111	123	135
4	16	28	40	52	64	76	88	100	112	124	136
5	17	29	41	53	65	77	89	101	113	125	137
6	18	30	42	54	66	78	90	102	114	126	138
7	19	31	43	55	67	79	91	103	115	127	139
8	20	32	44	56	68	80	92	104	116	128	140
9	21	33	45	57	69	81	93	105	117	129	141
10	22	34	46	58	70	82	94	106	118	130	142
11	23	35	47	59	71	83	95	107	119	131	143
12	24	36	48	60	72	84	96	108	120	132	144

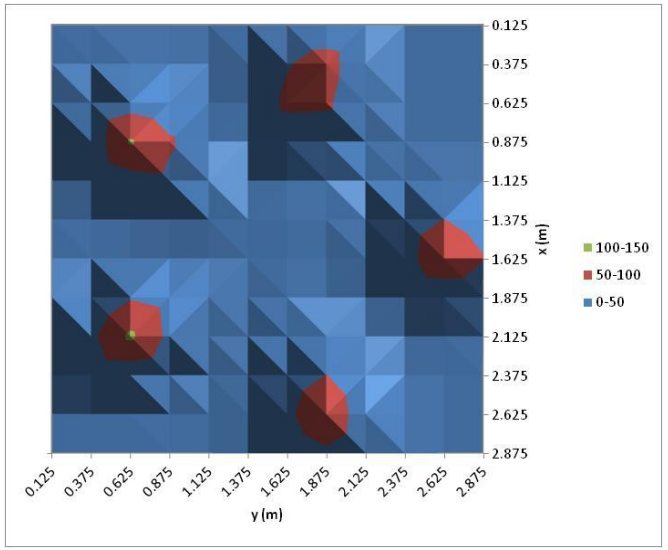
144 pipettes were placed at intervals of 25 cm covering a total area of 3m x 3m.

4 High-definition cameras to estimate angles.

Full Scale Tests

Without ignition source:

EMM 540856



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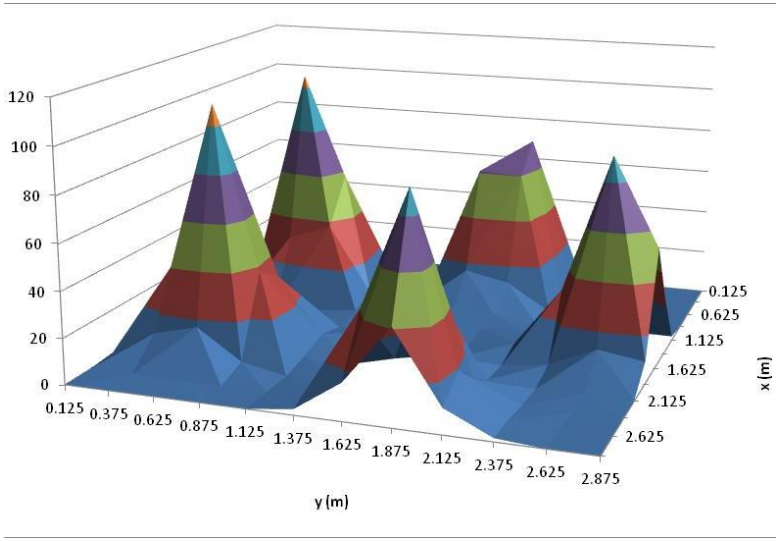
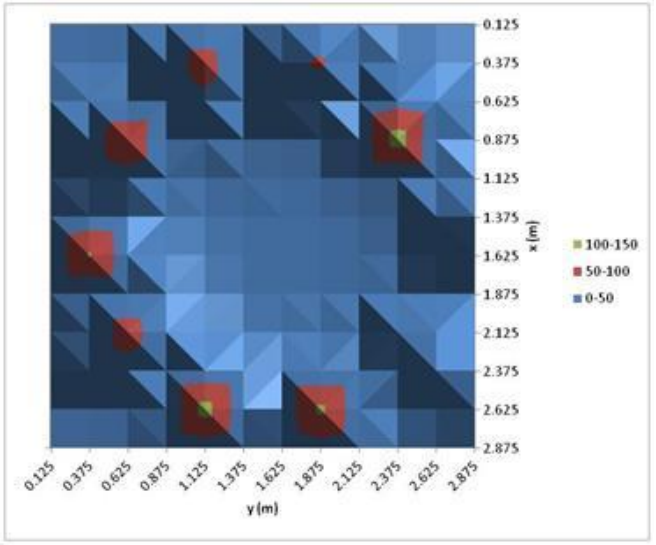


Units (ml)

Full Scale Tests

Without ignition source:

EMM 20-760-845



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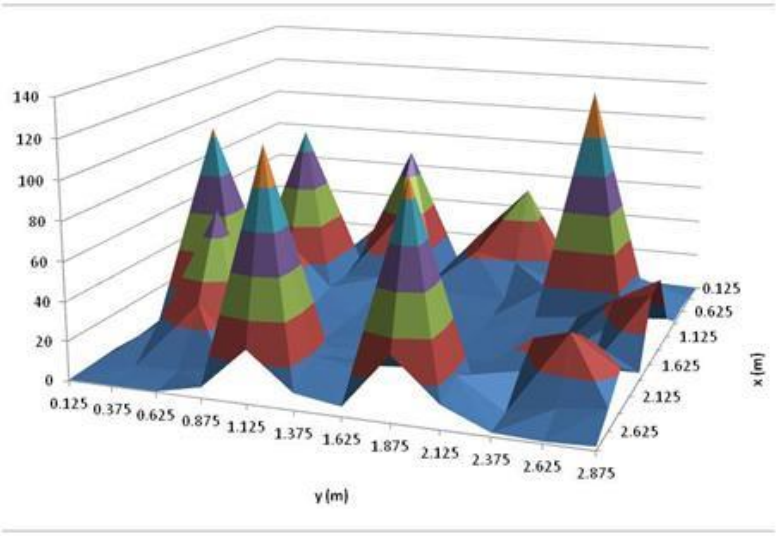
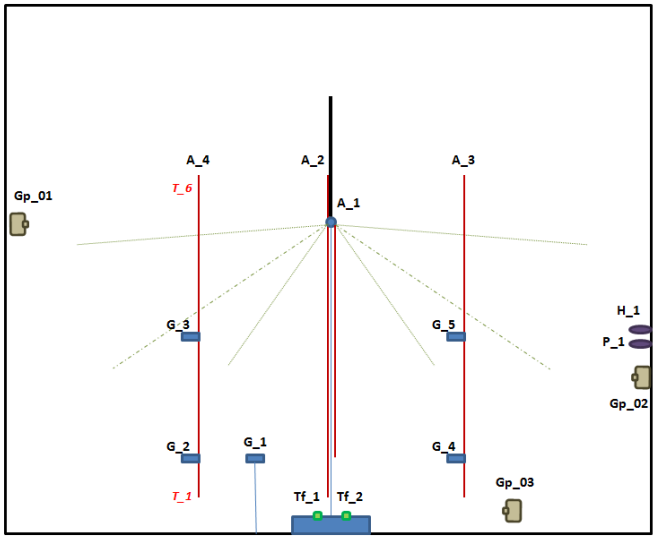
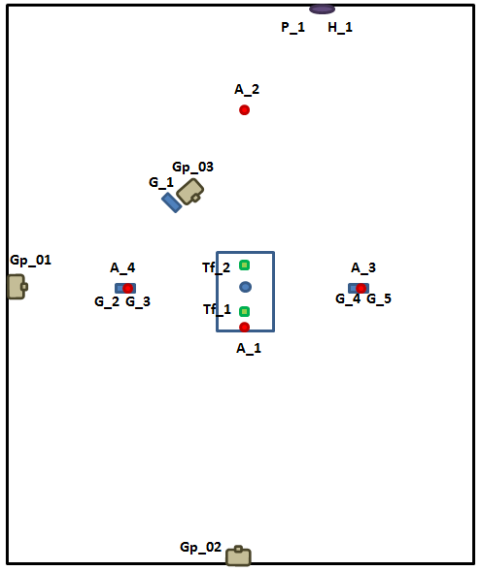


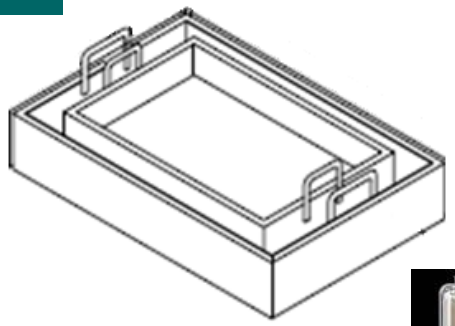
Units (ml)

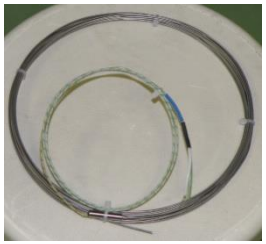
Full Scale Tests

With ignition source:





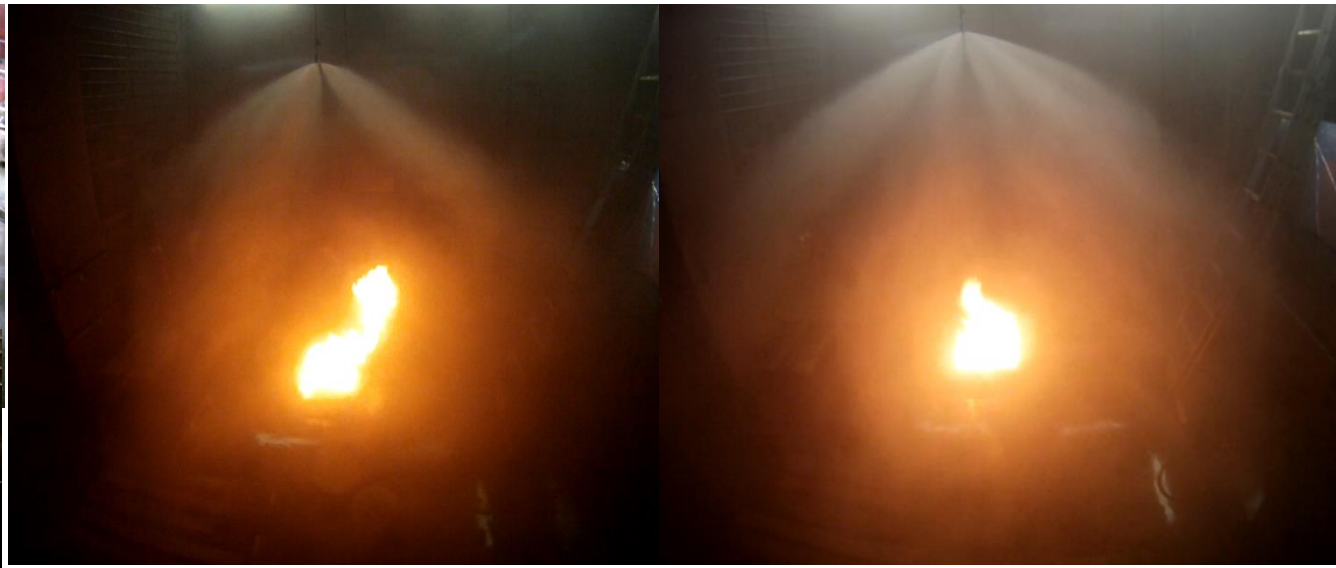




Pool fire dimensions	Area (m^2)	Fuel	Mass burning rate (kg/m^2 s)	Heat of combustión (kJ/kg)	Theorical HRR (kW)	Estimate HRR (kW)
A1 *(84.1 x 59.5 cm)*	0.5 ($5.38ft^2$)	Kerosene	0.039	43200	790 kW	480 kW
A2 *(59.4 x 42.0 cm)*	0.25 ($2.69ft^2$)	Kerosene	0.039	43200	363 kW	240 kW

Full Scale Tests

With ignition source:

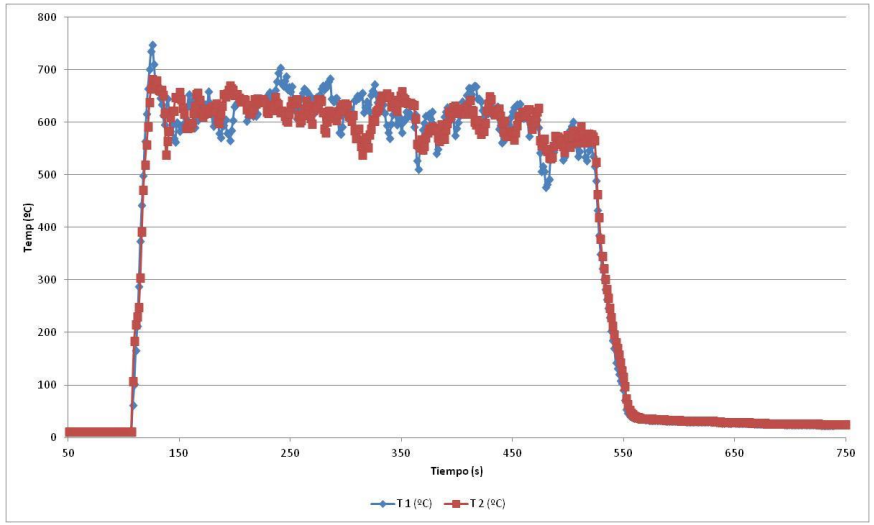


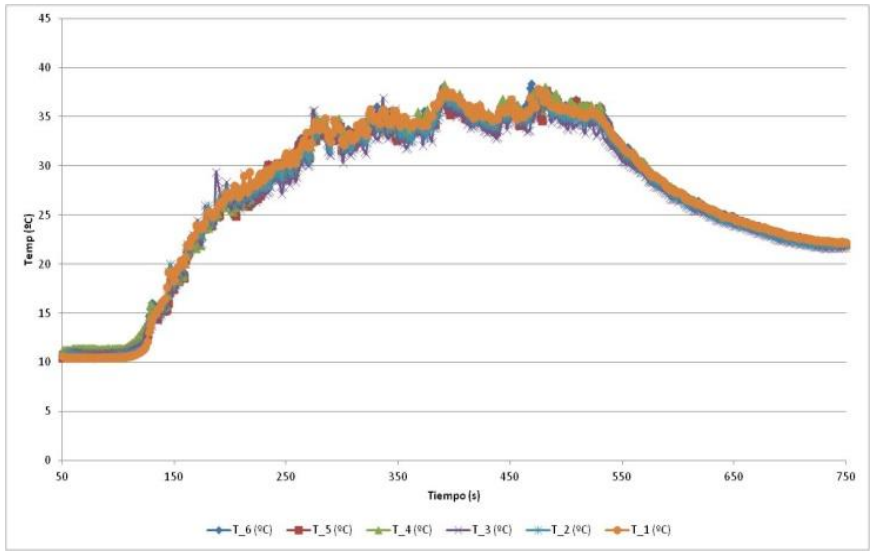
Full Scale Tests

With ignition source:

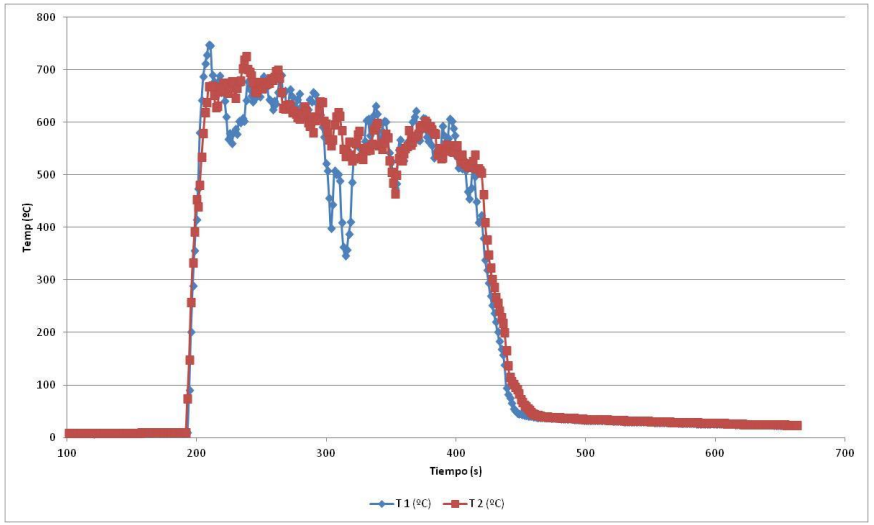
EMM 540856

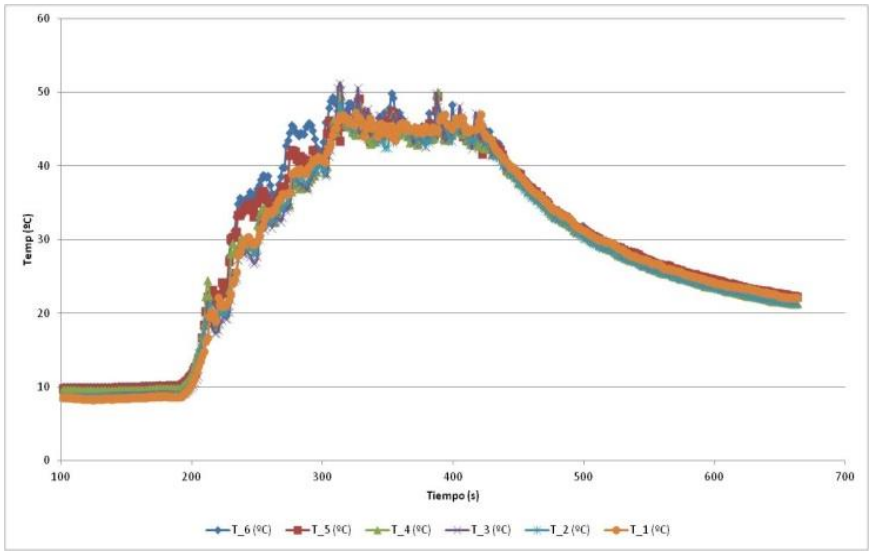
Pool fire – A2





Pool fire - A1



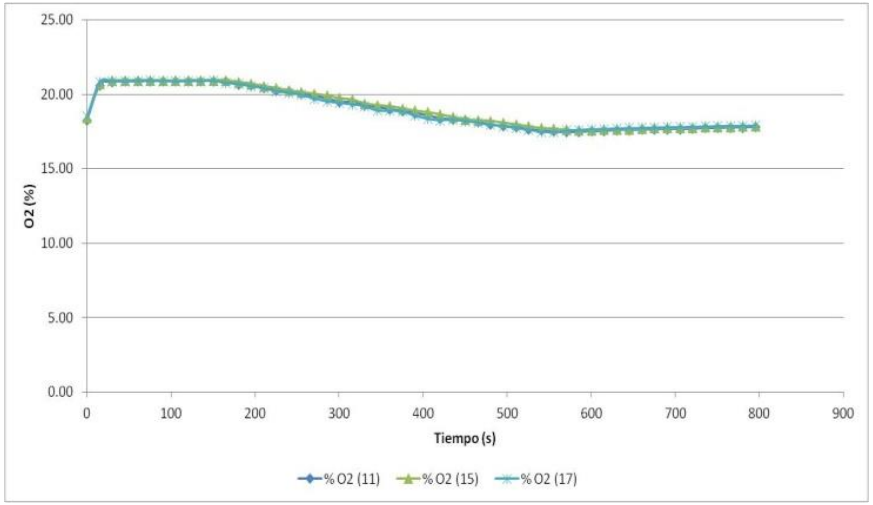


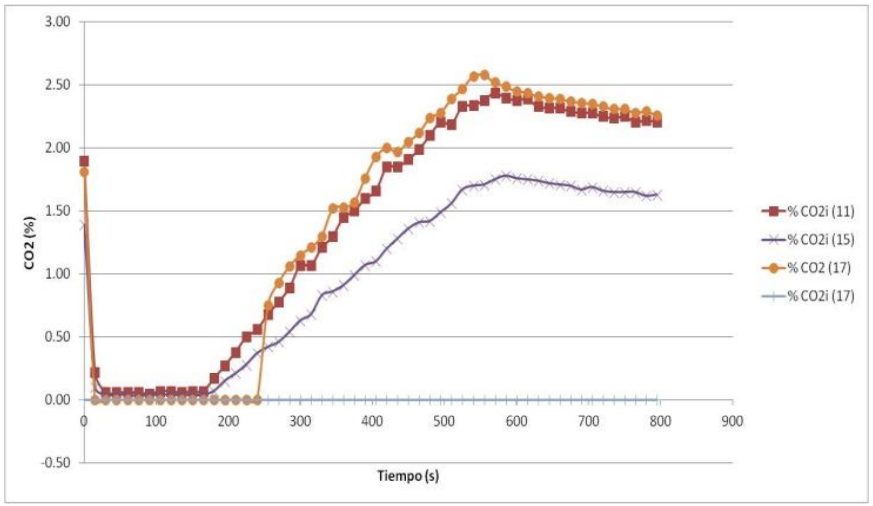
Full Scale Tests

With ignition source:

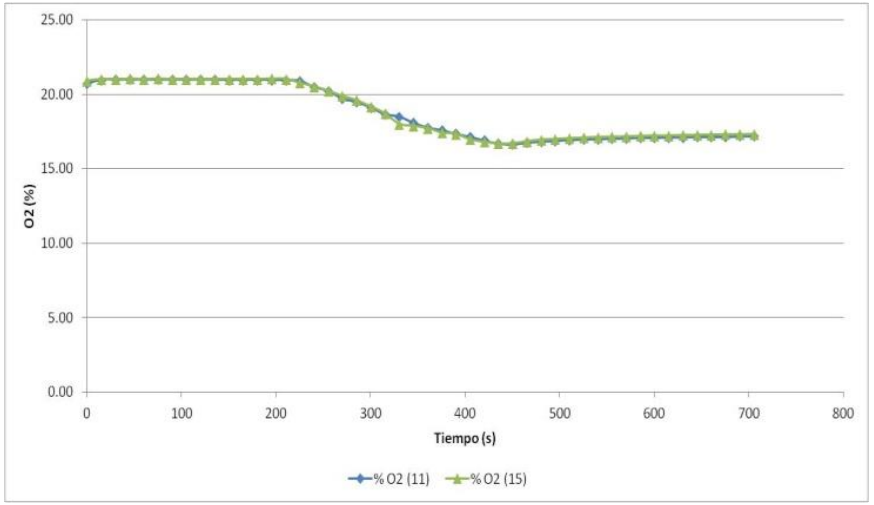
EMM 540856

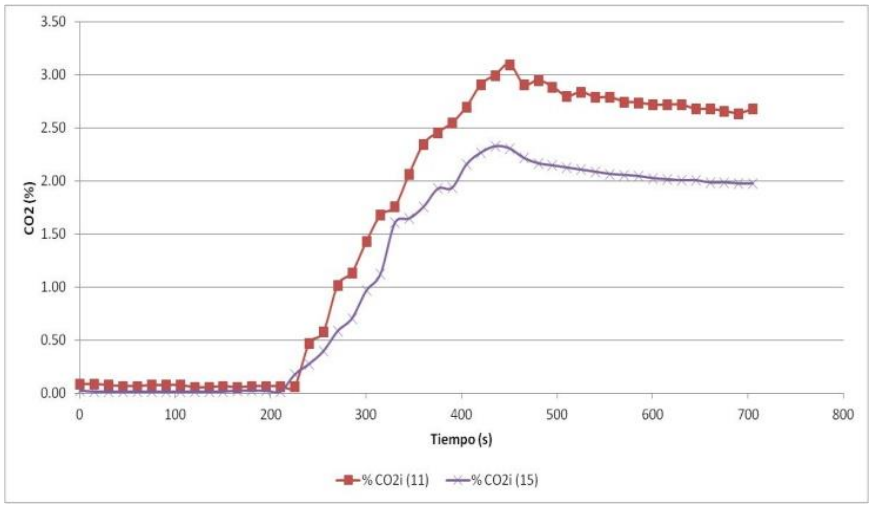
Pool fire – A2





Pool fire - A1



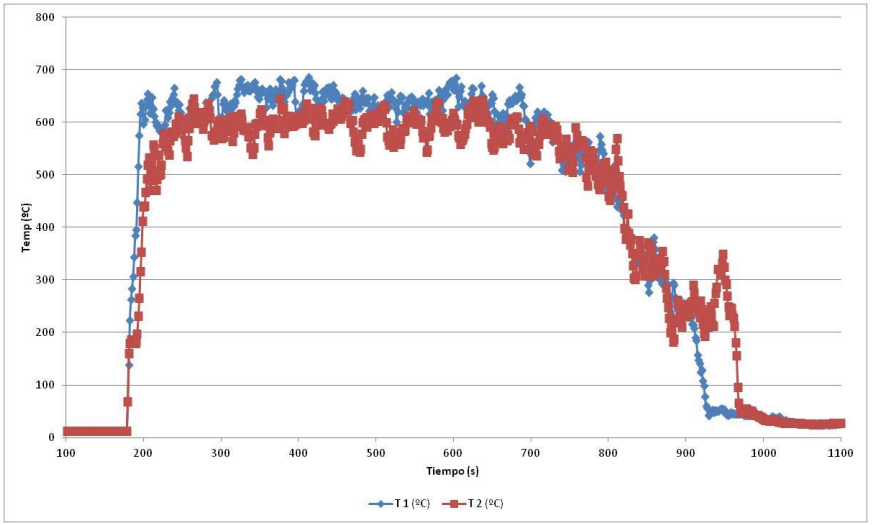


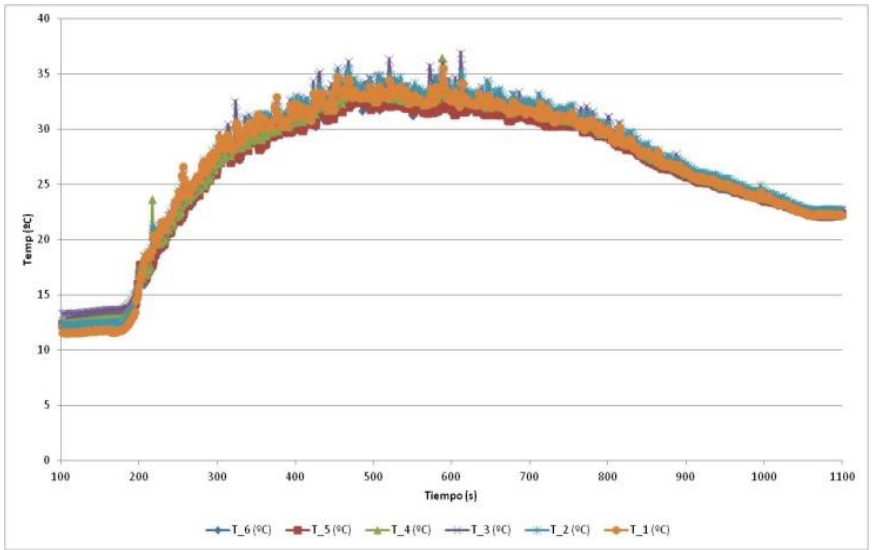
Full Scale Tests

With ignition source:

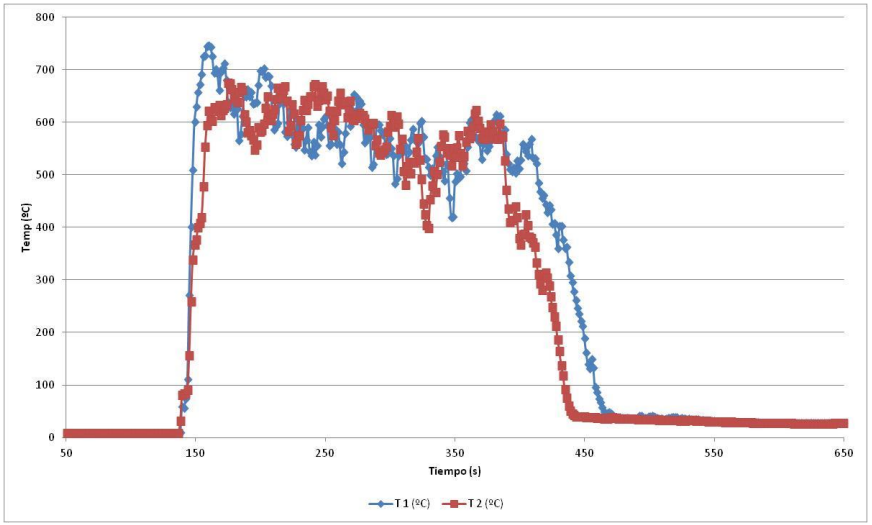
EMM 20-760-845

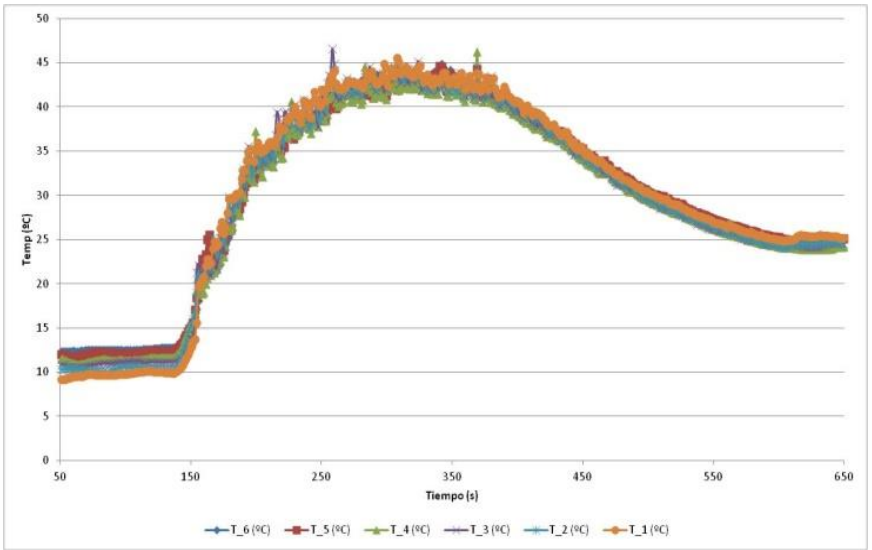
Pool fire – A2





Pool fire - A1



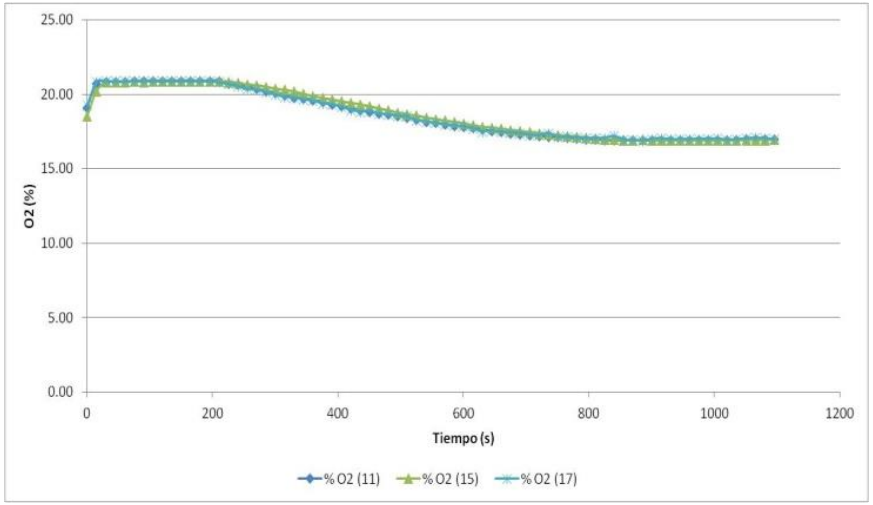


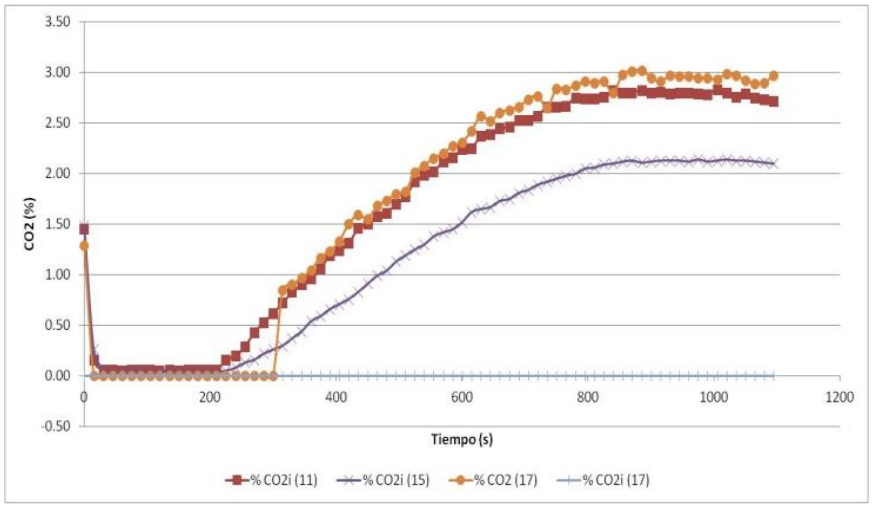
Full Scale Tests

With ignition source:

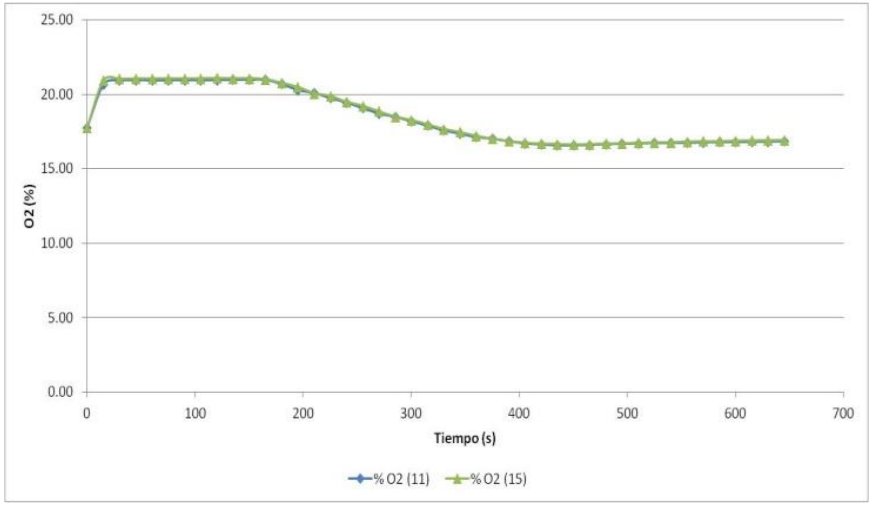
EMM 20-760-845

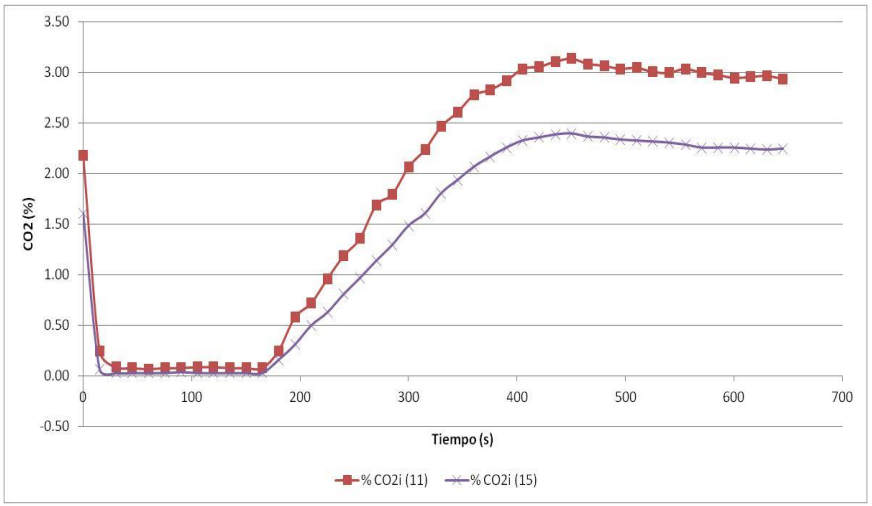
Pool fire – A2





Pool fire - A1

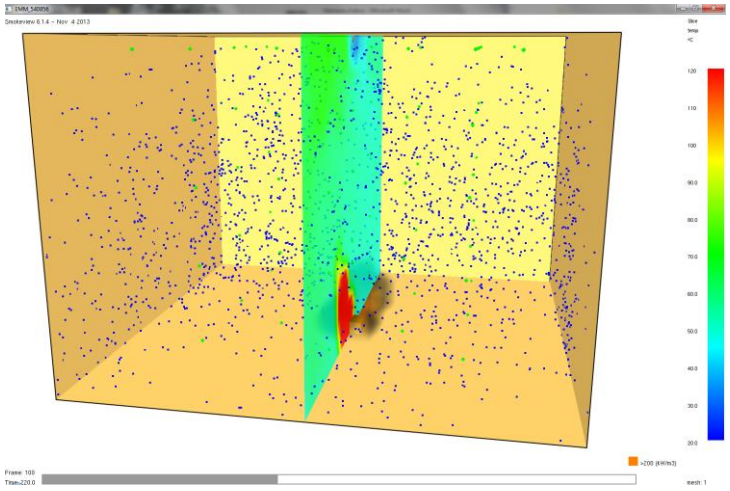


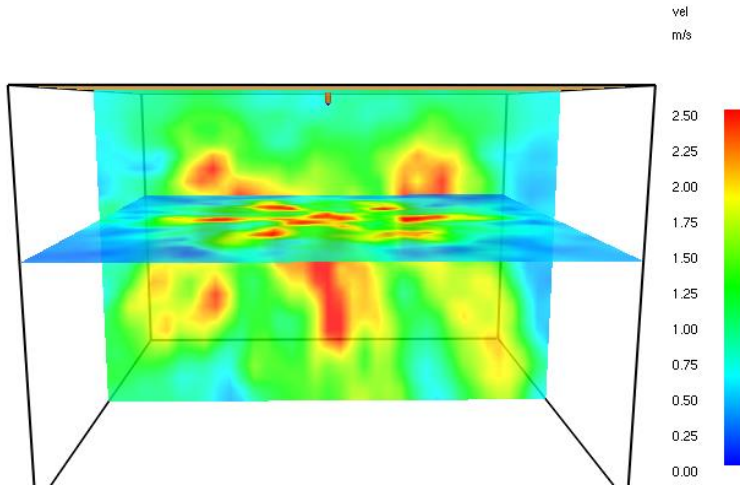


‘Fire Dynamics Simulator (FDS)’ v6:

-Developed by the National Institute of Standards and Technology (USA).

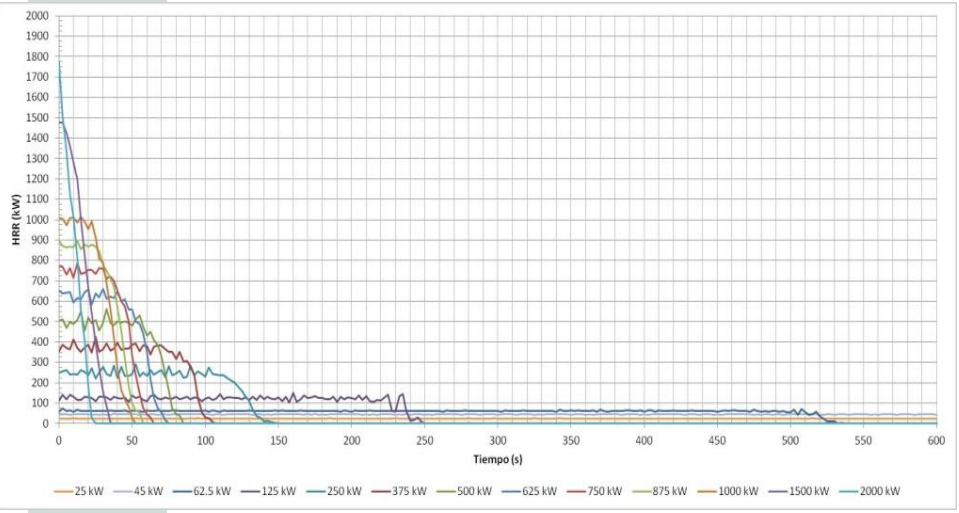
-Solves numerically a form of the ***Navier-Stokes equations*** appropriate for low-speed, thermally-driven flow with an emphasis on smoke and heat transport from fires.

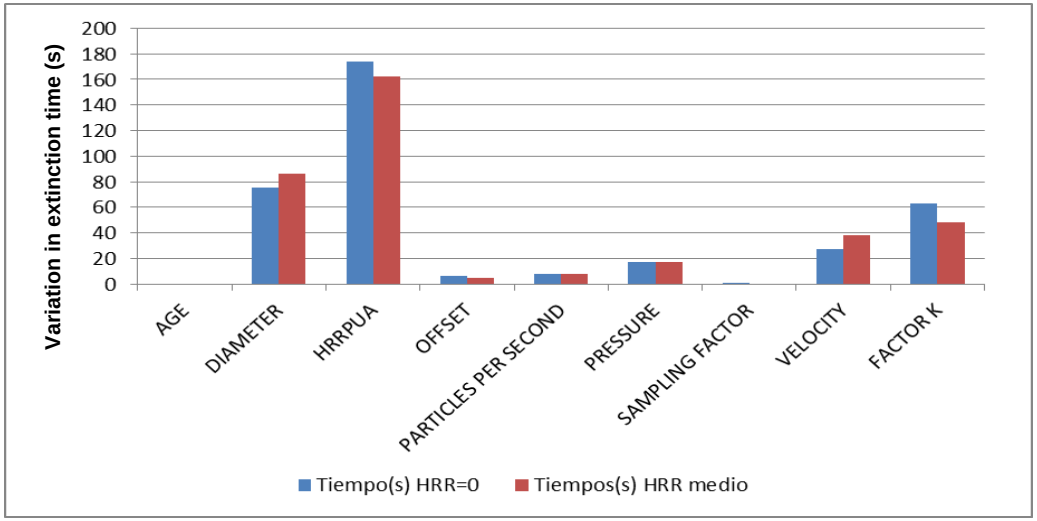


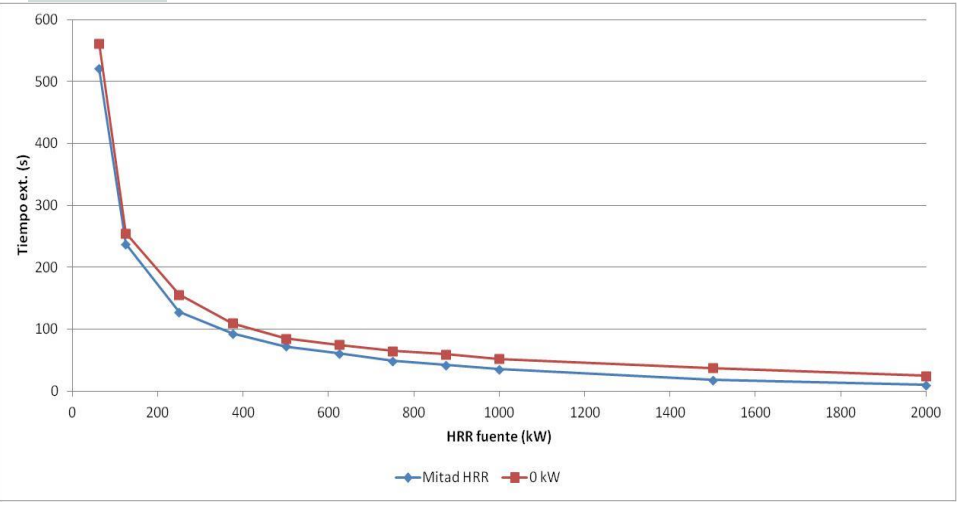


Computer Modeling

Sensitivity analysis:







	Range of values	Variation in extinction time (s) (HRR=0)	Variation in extinction time (s) (half of HRR)
AGE	10 - 100 (s)	0	0
DIAMETER	100 – 1000 (μm)	75	86
HRRPUA	125 - 2000 (kW)	174	162
OFFSET	0,05 - 0,3 (m)	6	5
PARTICLES PER SECOND	1000-50000	8	8
OPERATING PRESSURE	25 - 400 (bar)	17	17
SAMPLING FACTOR	1 - 51	1	0
PARTICLES VELOCITY	10 - 160 (m/s)	27	38
FACTOR K	0,1 - 10 (l/min bar$^{1/2}$)	63	48
ANGLES	0 – 170 (º)	65	68

Computer Modeling

Initial parameters:

EMM 540856

General Characteristics:

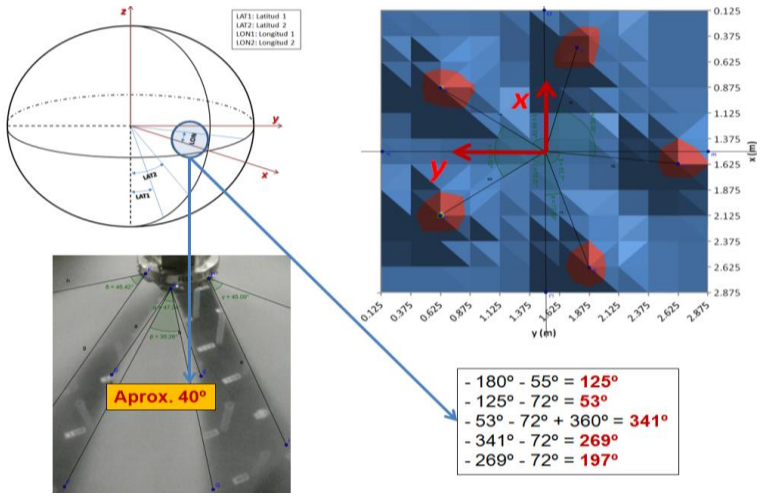
K-Factor (l/min·bar$^{1/2}$)	2.04
Micro-nozzle diameter (mm)	1.14

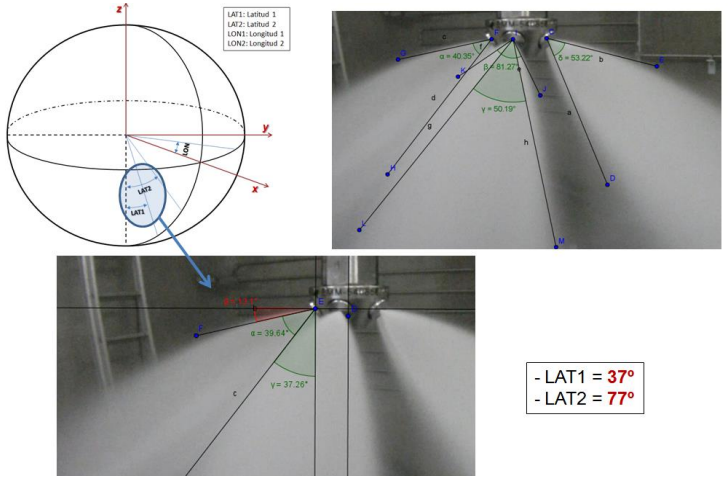
Specific test data:

Operation pressure (bar)	100
Initial velocity (m/s)	66.62

Assumptions:

Droplet Diameter (µm)	450
Offset (m)	0.2
Age (s)	30
Sampling factor	1
Particles per second	20000

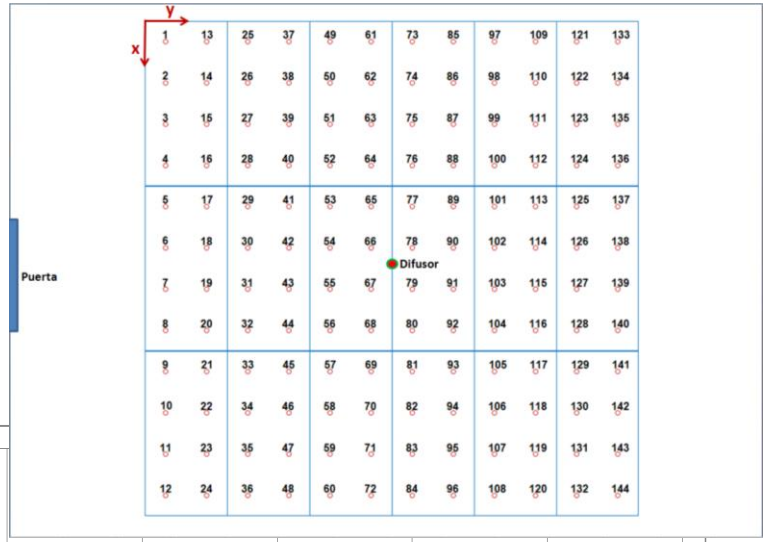


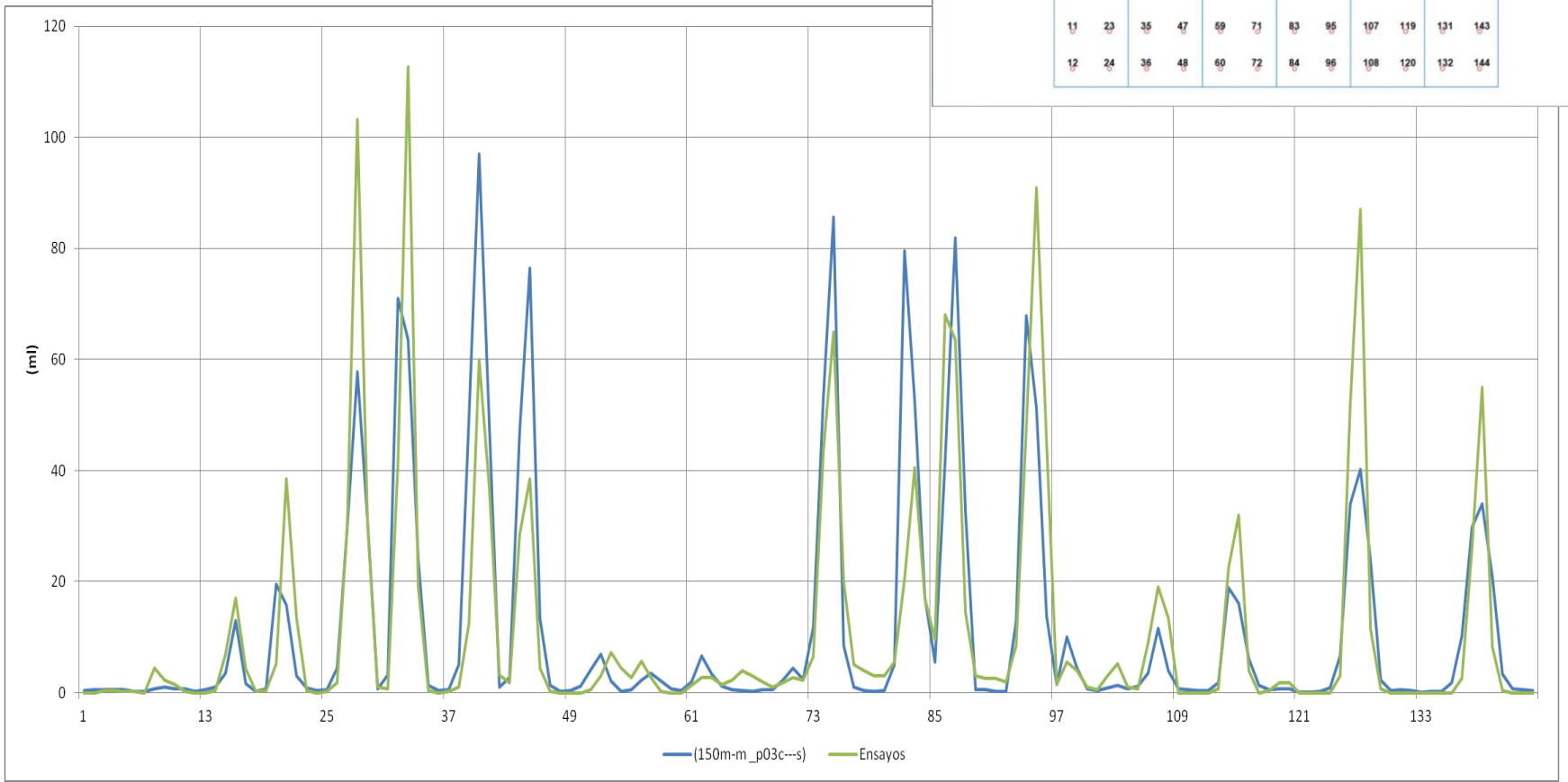


Computer Modeling

Results without fire:

EMM 540856

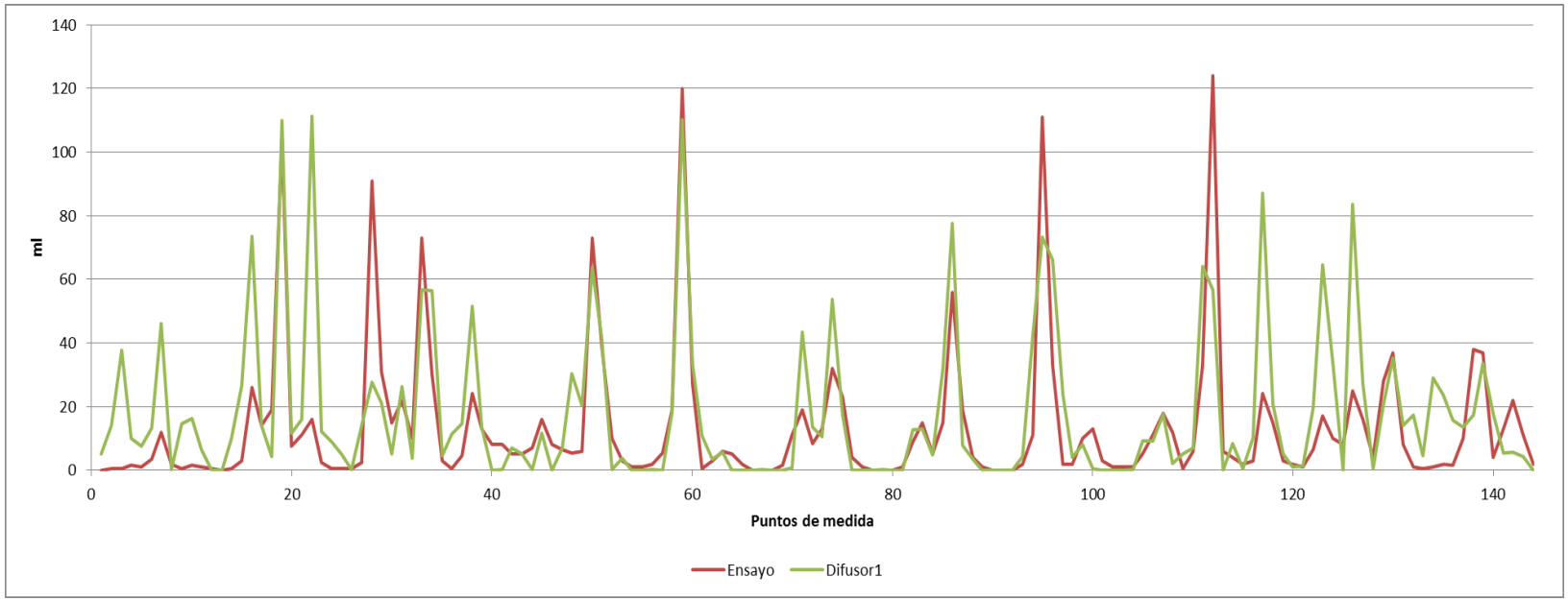


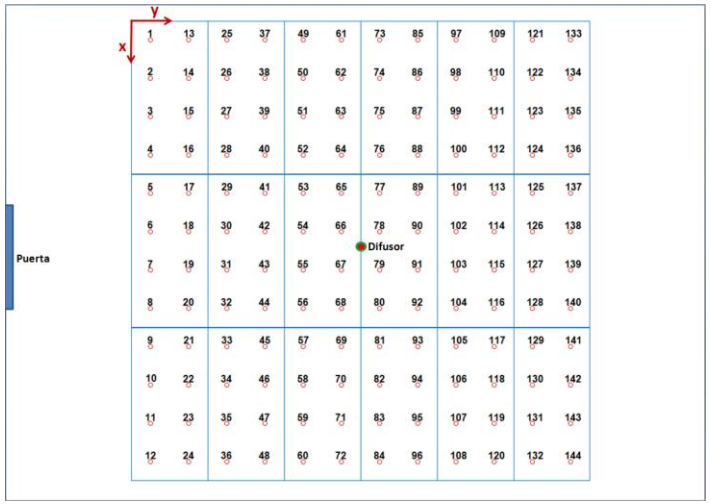


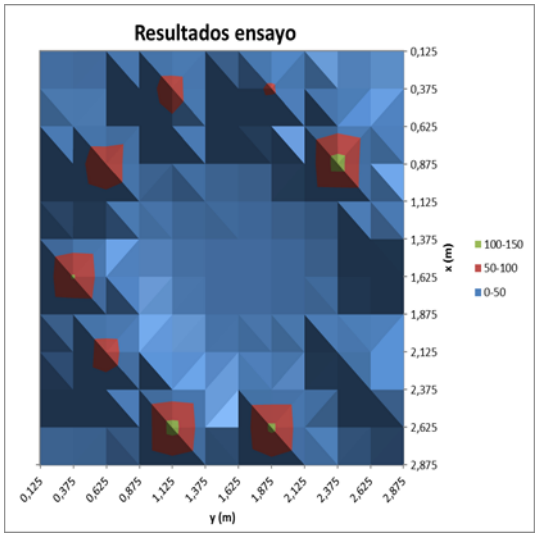
Computer Modeling

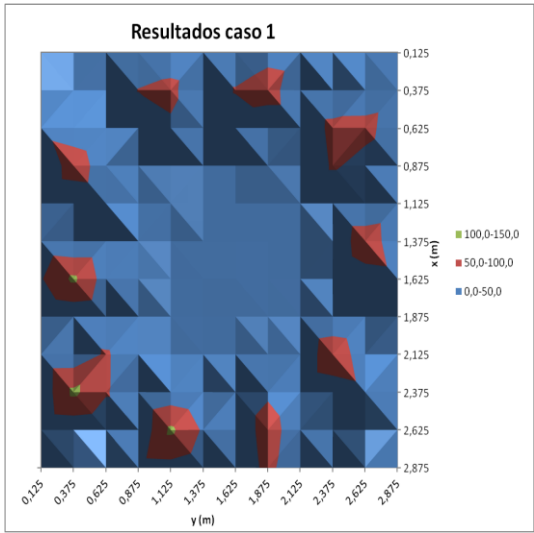
Results without fire:

EMM 20-760-845







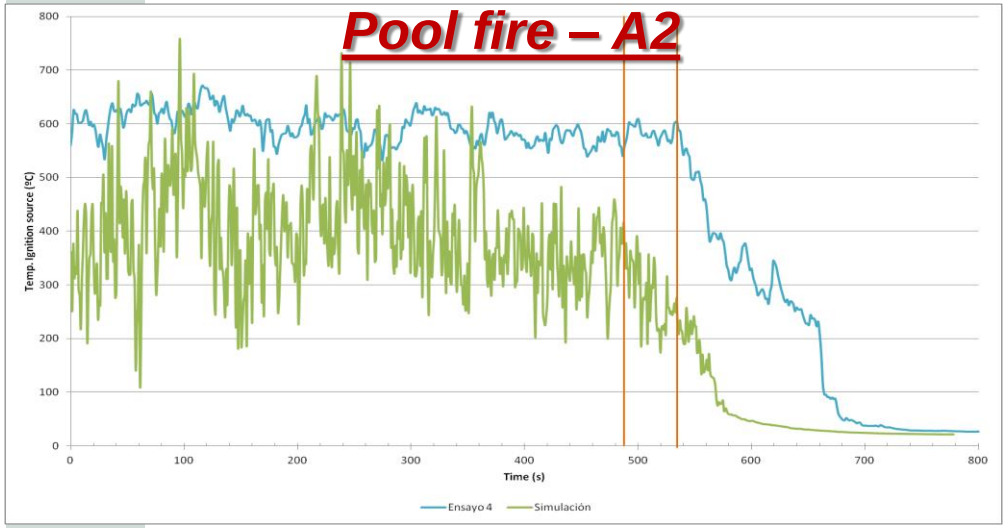


Computer Modeling

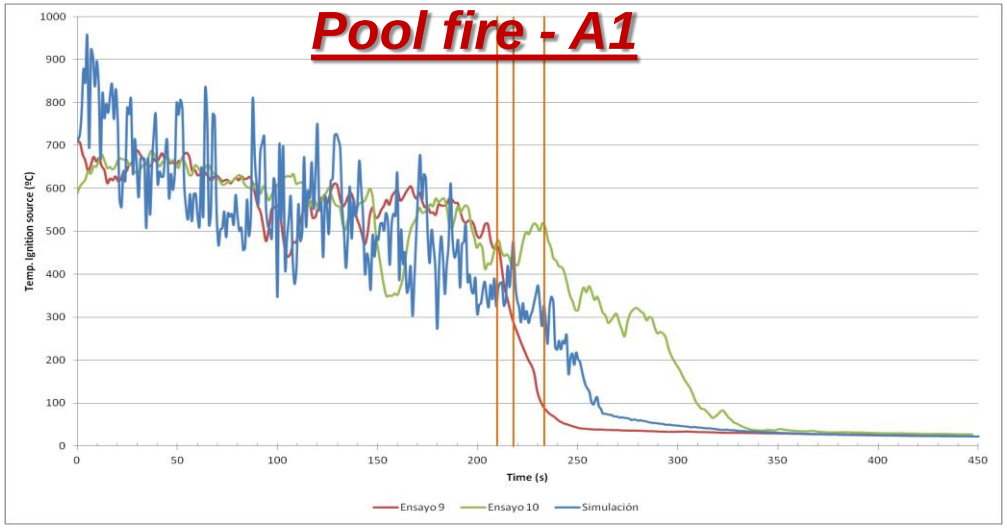
Results with fire:

EMM 540856

Pool fire – A2



Pool fire - A1



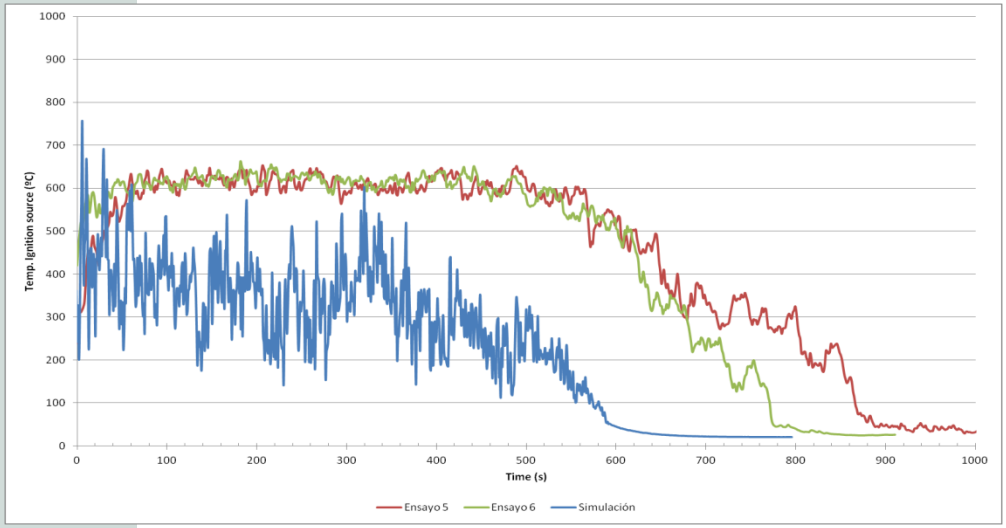
		Extintion time (s)	
		(No flame)	(Ignition source temp= 40º)
Pool fire A2 (240 kW)	Simulation	580 s	612 s
	Test 4	725 s	697 s
Pool fire A1 (480 kW)	Simulation	264 s	317 s
	Mean value Tests 9-10	293 s	294 s

Computer Modeling

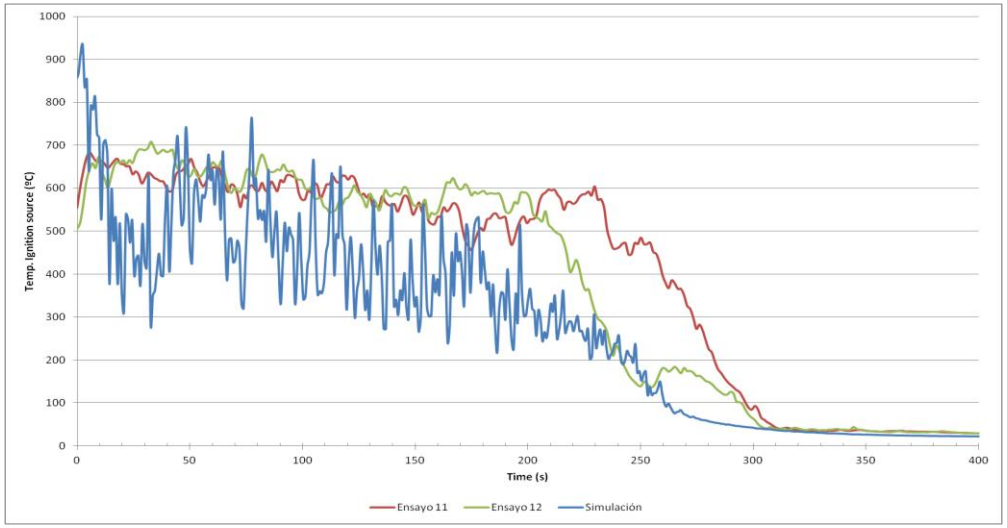
Results with fire:

EMM 20-760-845

Pool fire – A2

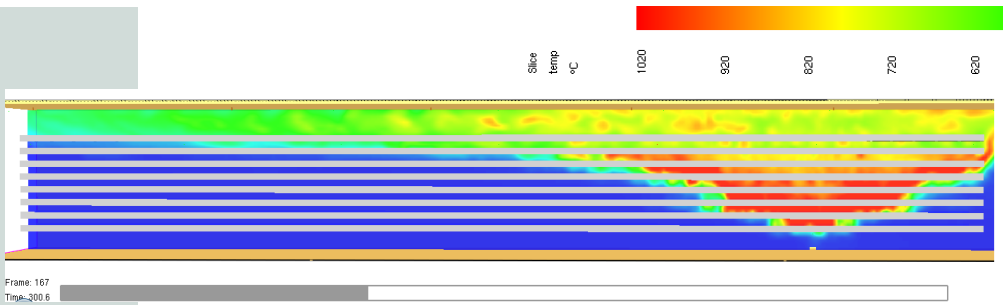


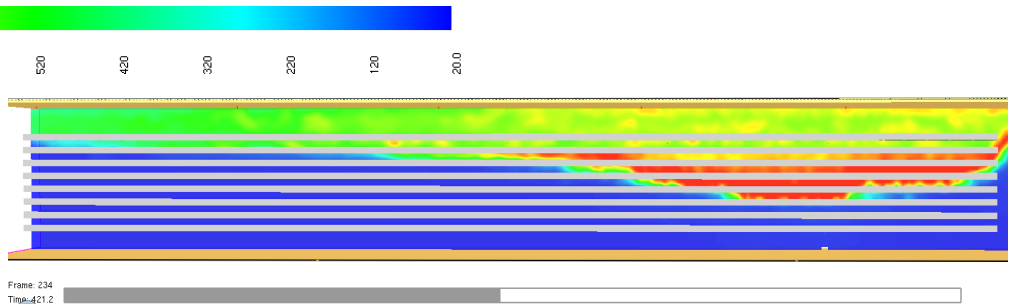
Pool fire - A1



		Extintion time (s)	
		(No flame)	(Ignition source temp= 40º)
Pool fire A2 (240 kW)	Simulation	591 s	608 s
	Mean value tests 5-6	929 s	857 s
Pool fire A1 (480 kW)	Simulation	275 s	304 s
	Mean value tests 11-12	387 s	310 s

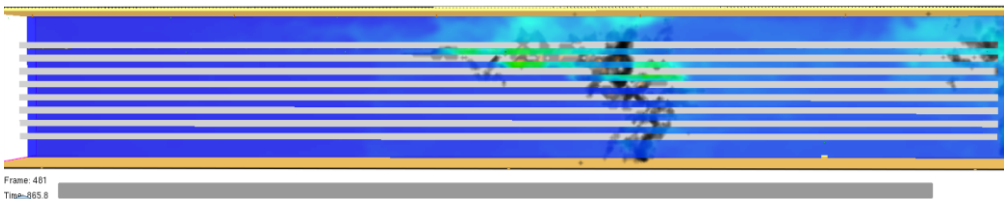
Computer Modeling: Cable Tunnels Fire Test





Ignition source turned off

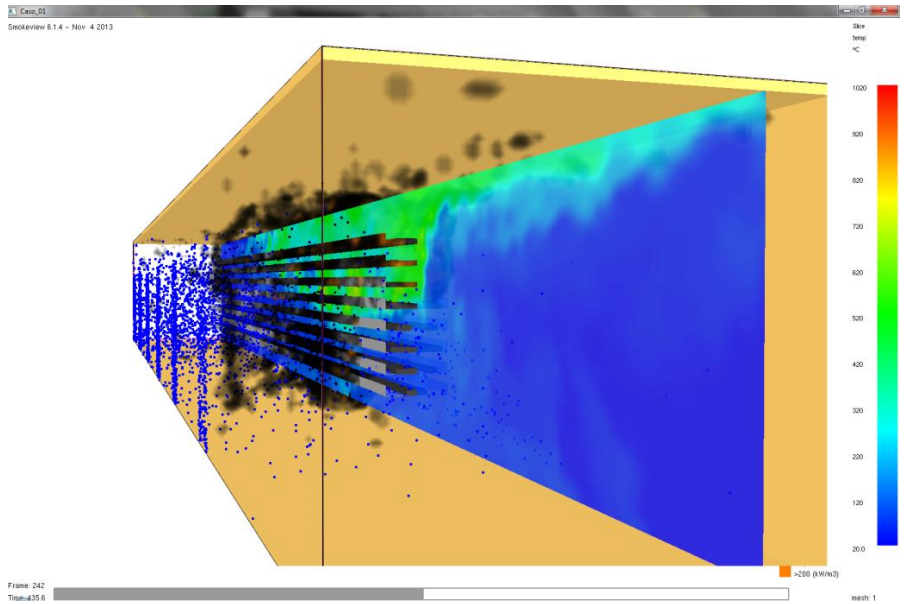
Water mist system turned on



445 s after activation of water mist system

	15	14.5	14	13.5	13	12.5	12	11.5	11	10.5	10	9.5	9	8.5	8	7.5	7	6.5	6	5.5	5	4.5	4	3.5	3	2.5	2	1.5	1	0.5	0	-0.5	
Tray 1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			Tray 1
Tray 2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			Tray 2
Tray 3	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			Tray 3
Tray 4	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0			Tray 4
Tray 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0			Tray 5
Tray 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0			Tray 6
Tray 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0			Tray 7
Tray 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0			Tray 8

Water mist system activated during about 960 s



Conclusions

-It has been sensed a high potential of these techniques for study and development of water mist systems.

-It has developed a methodology for the characterization of water mist systems.

-The use of validated fire computer models will allow to continue with the development of the system, include improvements, and performing an optimized system.

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