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Water-mist systems for fire-protection of saunas

Paolo E. Santangelo[1], Luca Tarozzi[2], Massimiliano Bettati[2], Paolo Tartarini[1]

[1]**Dipartimento di Ingegneria "Enzo Ferrari"**
Università degli Studi di Modena e Reggio Emilia, Modena, Italy
[2]**Bettati Antincendio S.r.l., Reggio Emilia, Italy**

- Increasing popularity of saunas in the built environment (e.g., hotels, recreation centers, resorts)
- Fire hazards:
  - timber benches
  - fabric (e.g., linen, towels)
  - chemicals (e.g., detergents)
- Potentially high environmental temperatures (~ 90 °C), electrical heaters, incandescent stones
- Natural/forced ventilation that may emphasize fire evolution and spread
- Lack of knowledge about active fire-protection systems in the open literature
- Buildings already endowed with fire-protection systems vs. unprotected buildings (stand-alone solutions required)
- Support and inspiration from industry

from: www. starpool.com

from: www.burgoynes.com

Sources:

I. RC50. Fire Safety in the Construction and Use of Saunas, United Kingdom: Fire Protection Association (FPA) on behalf of RISC Authority, 2009

II. G. Howe, S. Lloyd, Application of water mist to saunas, *International Fire Professional*, October 2014, pp. 15-18.

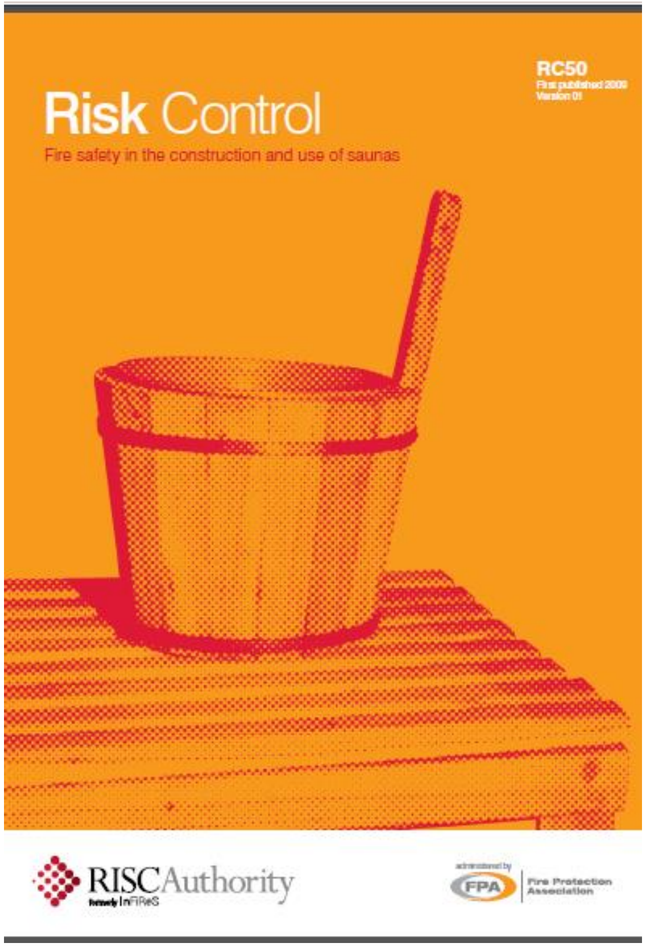
III. Zurich Insurance Group, Risk Topics, Fixed fire protection – Water mist – Saunas, 2015

from: www.flamefastusa.com

- Generic reference to standard NFPA 750 for water-mist systems
- Use of a wood crib and a heptane pool as the ignition source and accelerant respectively
- Pre-heated sauna mock-up with forced ventilation
- Comparison between a sprinkler and a water-mist supression system

from: Howe and Palle, IWMC 2014

Technical Recommendations



Active fire-protection systems as those based on water-mist technology are to be combined with:

- Suitable and adequate passive fire-protection measures (e.g., fire-rated separations)
- Fire alarms (e.g., heat and/or smoke detectors)
- Use of automatically-operated fire dampers in any ventilation duct
- Measures against excessive drying out of the timber linings
- Requirements for heating and electrical installations

Ostia: incendio in una palestra in via Mare dei Sargassi, lunga colonna di fumo

Un incendio di vaste dimensioni si è sviluppato all'alba in una nota palestra di Ostia, la Virgin, in via Mare dei Sargassi. L'area che sta bruciando sarebbe di circa 6000 metri

Redazione
25 GIUGNO 2012 09:48

In via Mare dei Sargassi, nelle vicinanze dell'ospedale G.B.Grassi, a Ostia è andata a fuoco nella notte una nota palestra: la Virgin.

I più letti di oggi

1. "Si stanno sparando", rinvenuti due bossoli in strada: indaga la polizia
2. Ostia: rapina alle Poste il giorno del pagamento delle pensioni, due arresti
3. Elezioni Ostia, veleni nel centrodestra: Meloni mette alla porta Alemanno e Storace
4. Immobilismo grillino sui Punti Verde Qualità: ferite sul territorio e concessionari danneggiati

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La sauna va a fuoco Danni ingenti nella spa

Gio, 27/07/2017 - 05:52

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PER APPROFONDIRE: incendio, sauna, Spa, soraga — Tempo di lettura: 1 minuto 16 secondi

Fiamme nel primo pomeriggio di ieri nel centro benessere dell'hotel Madonnina di Soraga.

To grasp the disaster:

https://www.youtube.com/watch?v=GQcF8MsI18g

Main scope:

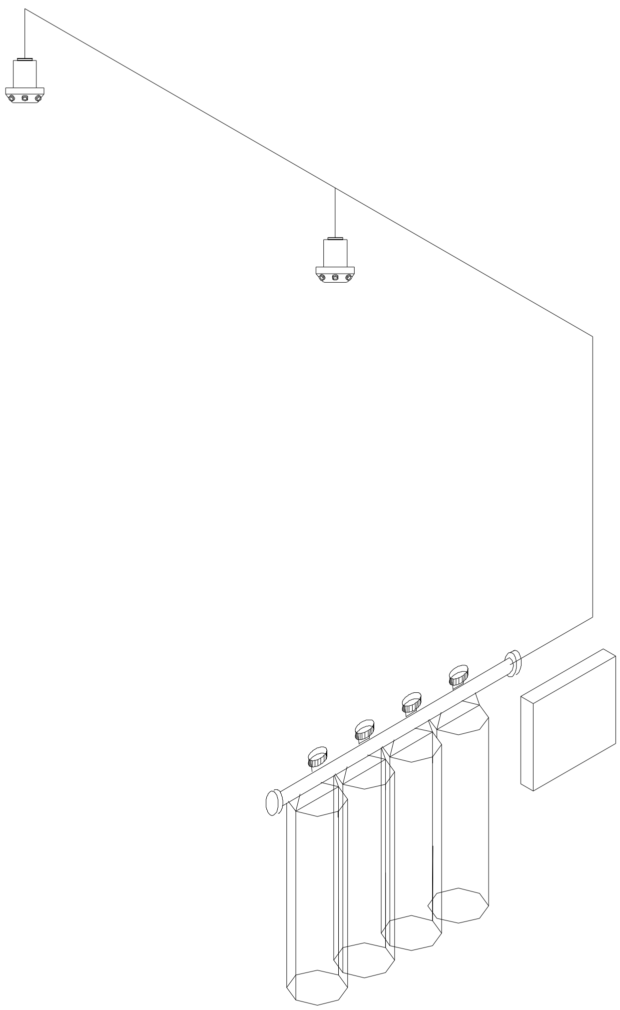
Development, design and implementation of a water-mist, stand-alone system dedicated to sauna fire protection

Objectives:

- Challenging a promising, discharge-based system against this fire scenario
- Identifying the main structural and physical mechanisms governing this fire configuration and water-mist control and suppression performance
- Development of a testing procedure to quantitatively evaluate suppression/extinction in sauna scenarios
- Evaluating water-mist capabilities within a real-scale facility and throughout an experimental test series towards a worst-case scenario

Challenge:

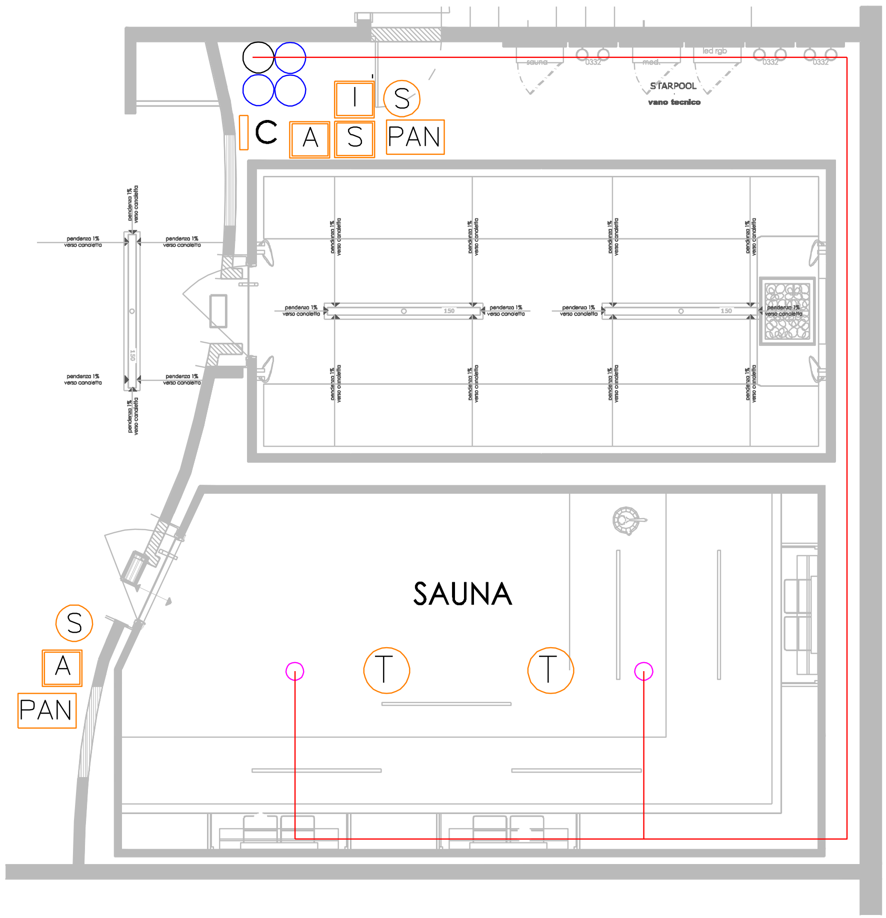
Need for consolidating a set of variable parameters – mainly related with geometric configuration and ignition – within a limited number of tests



An actual water-mist system for sauna fire protection consists of:

- High-pressure delivery unit that includes water-filled cylinders and inert gas cylinders to allow > 100 bar initial pressure
- Open water-mist nozzle set and stainless steel piping
- Detection system, notably heat detectors operating at fixed temperature threshold and connected to a control unit
- Fire alarm system including sounders and beacons
- Remote signaling of alarm, discharge and fault

Actual Installation



Moncalieri (Italy) Fitness center by Virgin Active

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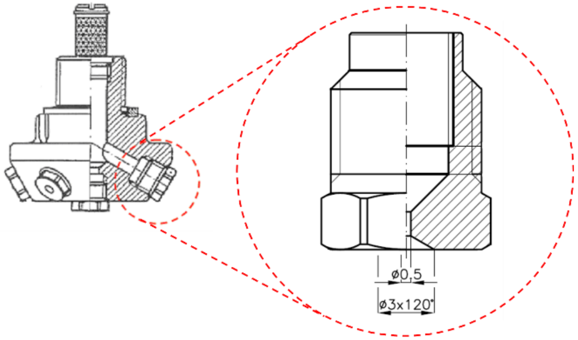


CODE:	NWMO014
MANUFACTURER:	Bettati Antincendio S.r.l.
K-FACTOR:	1.4 L min^{-1} $bar^{-0.5}$ (overall)
INJECTORS:	7 (6 peripheral, 1 central) pressure-swirl
AREA COVERAGE:	3.6 × 3.6 m (1.8 m from the wall)
INSTALLATION HEIGHT:	2.4 m
OPERATIVE PRESSURE:	150 bar descending (nitrogen-pressurized)
CAPACITY OF CYLINDERS:	80 L (each)
No. OF WATER CYLINDERS:	3
No. OF N_2 CYLINDERS:	1
MAX. COMPARTMENT AREA:	25 m^2
DISCHARGE TIME:	> 10 min

The released spray was previously characterized by Santangelo (*Exp Therm Fluid Sci* 34 (2010) 1353-66 and *J Therm Sci* 21 (2012) 539-48) in terms of **drop-size distribution**, **initial velocity field** and **cone angle**.

Standard CEN/TS 14972:2011

''Fixed firefighting systems – Watermist systems – Design and installation''

No specific guidance provided for sauna fires

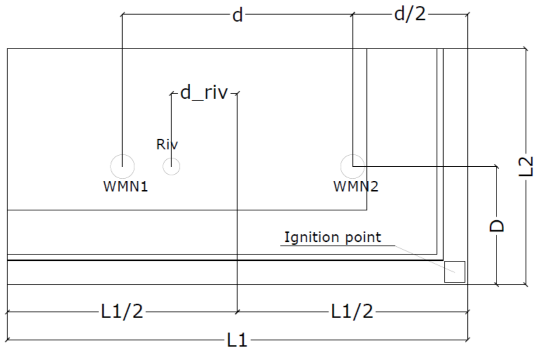
Annex B

'Guidelines for developing representative fire test procedures for watermist systems''

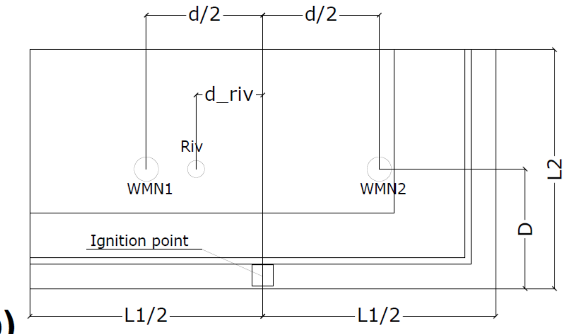
- Evaluation of fire hazard;
- Evaluation of the compartment conditions;
- Performance objectives;
- Anticipated worst-case scenario(s).

PASS/FAIL criterion:
SUPPRESSION

Experimental Facility



a)



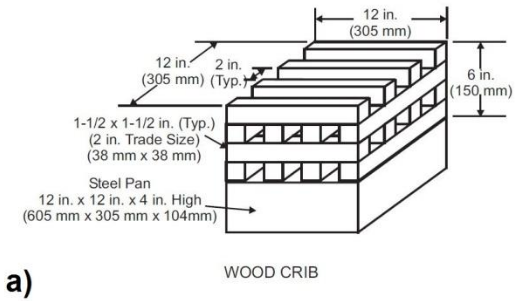
b)

Plan view of the test chamber: a) ignition source at the corner behind benches (configuration C1); b) ignition source at the center of the wall behind the benches (configuration C2). WMN: water-mist nozzle location; Riv: heat-detector (by *Kidde-Fenwal Inc.*) location

Test-chamber height	L1	L2	d	d_riv	D
2.4	5.9	2.3	3.6	1.0	L2/2 in all tests but the last one; d/2 in the last test

SCOPE:
Resembling an electric-heater fire

DESIGN CHOICE:
Wood-crib (2.9 kg) fire, accelerated by a manually-activated heptane (0.24 l) pool fire



Sketch (a) and photo (b) of wood crib and accelerant container

Evaluation of **peak Heat Release Rate** (HRR) from the wood-crib fire as an estimate of fire size in the compartment:

$$HRR = MLR \cdot \Delta h_c = C \cdot \left(\frac{S}{H}\right)\left(\frac{m_i}{t}\right) \cdot \Delta h_c \approx 230\ \mathrm{kW}$$

MLR: mass-loss rate, Δh_C: wood heat of combustion (= 12 MJ kg^{-1}), *C*: empirical constant (= 7.44 × 10^{-4}), *S*: clear spacing between sticks in the same layer (= 50 mm), *H*: crib height, m_i: initial mass, *t*: stick thickness

Xu Q., Griffin G.J., Jiang Y., Bicknell A.D., Bradbury G.P., White N., *J Therm Anal Calorim* 91 (2008) 355-8

Temperature and Mass-Loss Evaluation

Set of 7 **thermocouples** (type K, 0.5 mm wire diameter, 1 Hz acquisition frequency):

- T_gas (3 probes): gas temperature **76 mm below the ceiling**, at the symmetry axis of the ignition source, at the heat-detector location and symmetric to *Riv*
- T_crib: gas temperature at the **center of the ignition-source** top surface
- T_sts: surface temperature of the **timber bench** bottom surface, at the symmetry axis of the ignition source
- T_clg: surface temperature at the **ceiling** and at the ignition-source symmetry axis
- T_rad: associated with **hot-plate thermometer** and located at 500 mm height from the floor, close to the container exit

Load cell to measure damage ratio $(m_i - m_f)/m_i$ of wood crib and timber benches

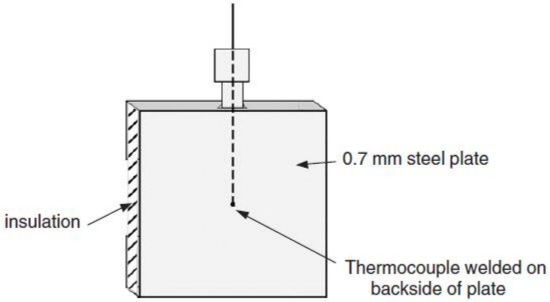
The **bench damage ratio** was selected as the quantitative representation of the chosen **pass/fail** criterion.

As for **moisture content** of timber benches, it was monitored before each to have it **lower than 5%**; mass loss was measured after benches were let dry out.

HINT FOR THE FUTURE:
Measuring the moisture content **right after discharge** to evaluate quantitatively the consequences on timber benches, even those due to false alarms.

Hot-plate thermometry was employed to evaluate incident radiant heat flux as representative of HRR and overall fire evolution (Ingason H, Wickström U., *Fire Saf J* 42 (2007) 161-6).

Notably, the plate was placed in front of the presumed fire location, between the wood crib and the involved bench. So, it was set at **0.6 m** height from the floor and at the corner next to the crib in both configurations.



$$q = \frac{\varepsilon_{PT}\sigma T_{PT}^4 + (h_{PT} + K_{cond})(T_{PT} - T_\infty) + \rho_{st} c_{st} s(\Delta T_{PT}/\Delta t)}{\varepsilon_{PT}}$$

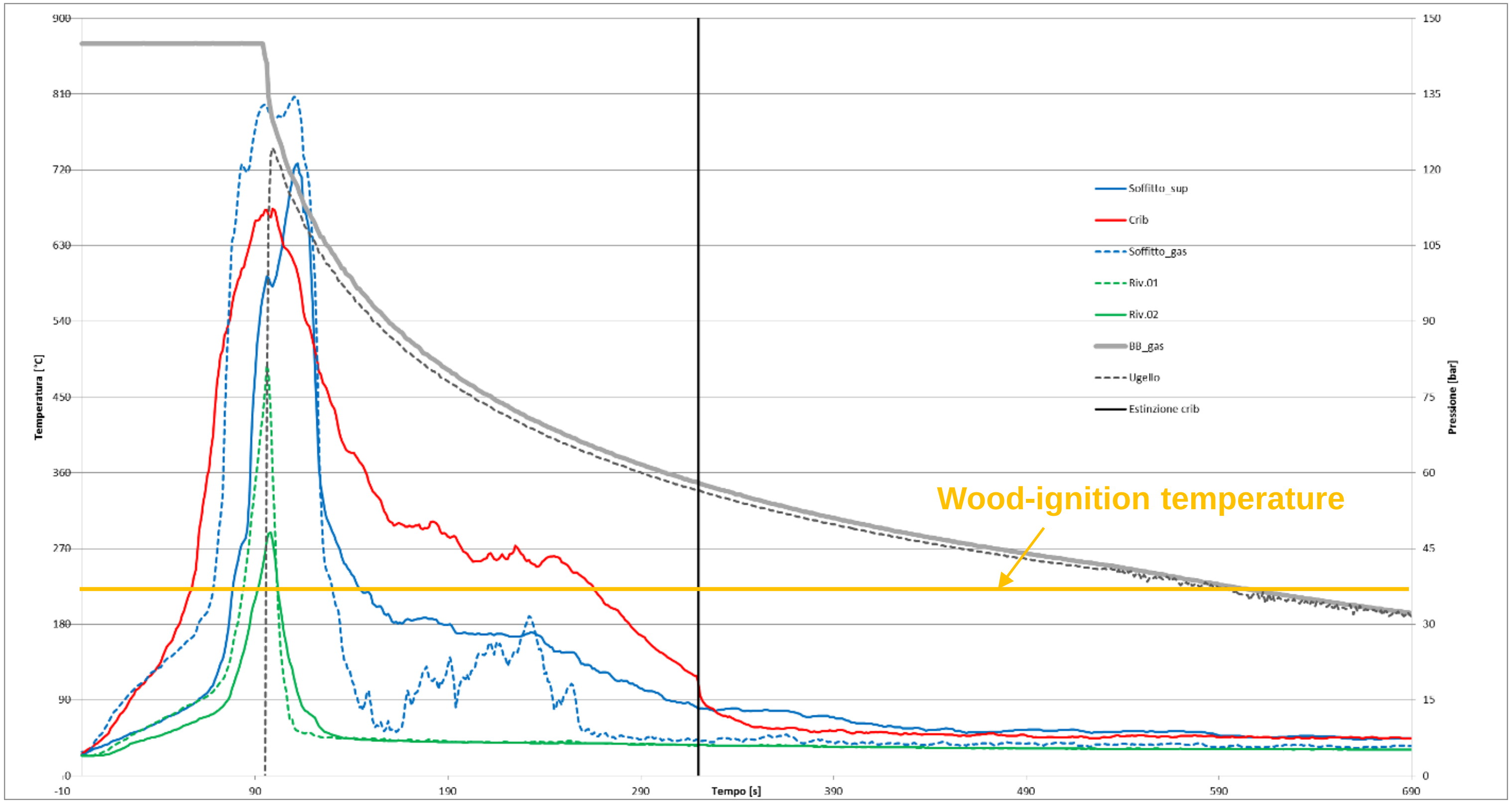
ε_{PT}: plate-thermometer emissivity, σ: Stefan-Boltzmann constant, T_{PT}: plate-thermometer temperature, h_{PT}: convective heat-transfer coefficient, K_{cond}: conduction correction factor, T_∞: room temperature, ρ_{st}: steel density, c_{st}: steel specific heat capacity, s: steel plate thickness, t: time

Test Matrix and Initial Conditions

The following parameters were identified and varied through the test series:

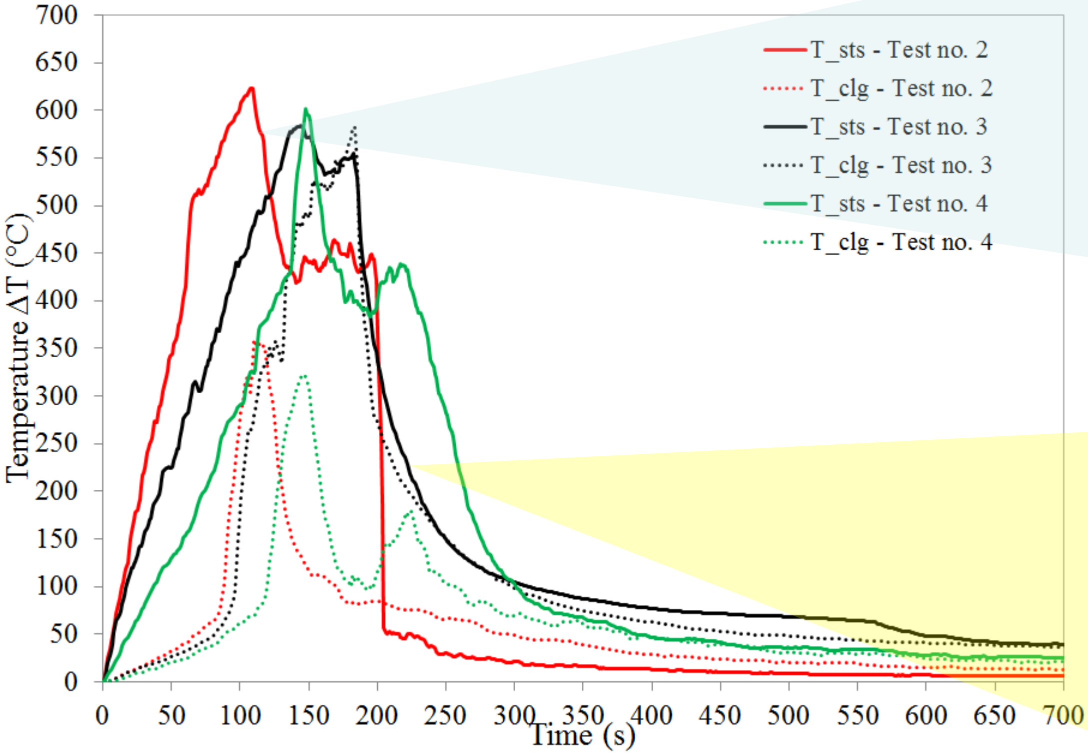
- Location of the ignition source
- Initial room temperature (T_i)
- Discharge activation time (τ_{act}, heat-detector threshold @ 165 °C)
- Ventilation (0.7 × 1.9 m door)
- Distance between the nozzles and the wall behind benches (D)
- Presence of drywall boards attached to the back of the benches
- Distance between benches and the wall behind (δ)

Test no.	Ignition source	T_i [°C]	τ_{act} [s]	Ventilation	D [m]	Drywall boards	δ [mm]
1	corner (C1)	20 - 30	alarm + 5	NO	1.15	NO	0
2	center (C2)	20 - 30	alarm + 5	NO	1.15	NO	0
3	center (C2)	20 - 30	180	NO	1.15	NO	0
4	center (C2)	20 - 30	alarm + 5	NO	1.15	NO	0
5	center (C2)	20 - 30	alarm + 5	NO	1.15	YES	250
6	center (C2)	> 80	alarm + 5	NO	1.15	NO	0
7	center (C2)	> 80	alarm + 5	YES	1.80	NO	0



Example of the whole temperature/pressure dataset, with a reference to **wood-ingnition temperature** (Babrauskas V., *Interflam 2001*, pp. 71-88)

Temperature and Pressure Trends (Test no. 2 – 4)



DELAYED ACTIVATION

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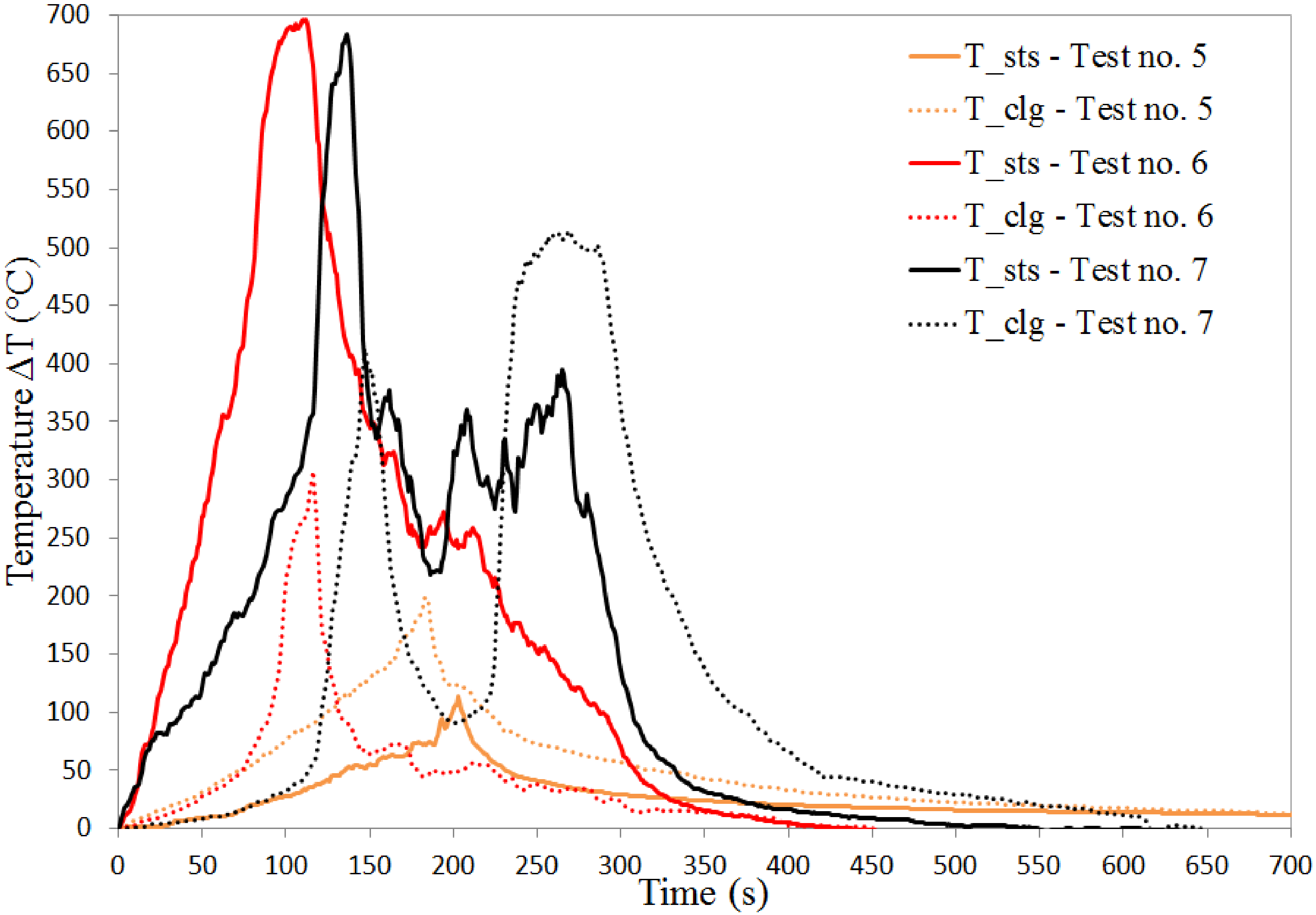
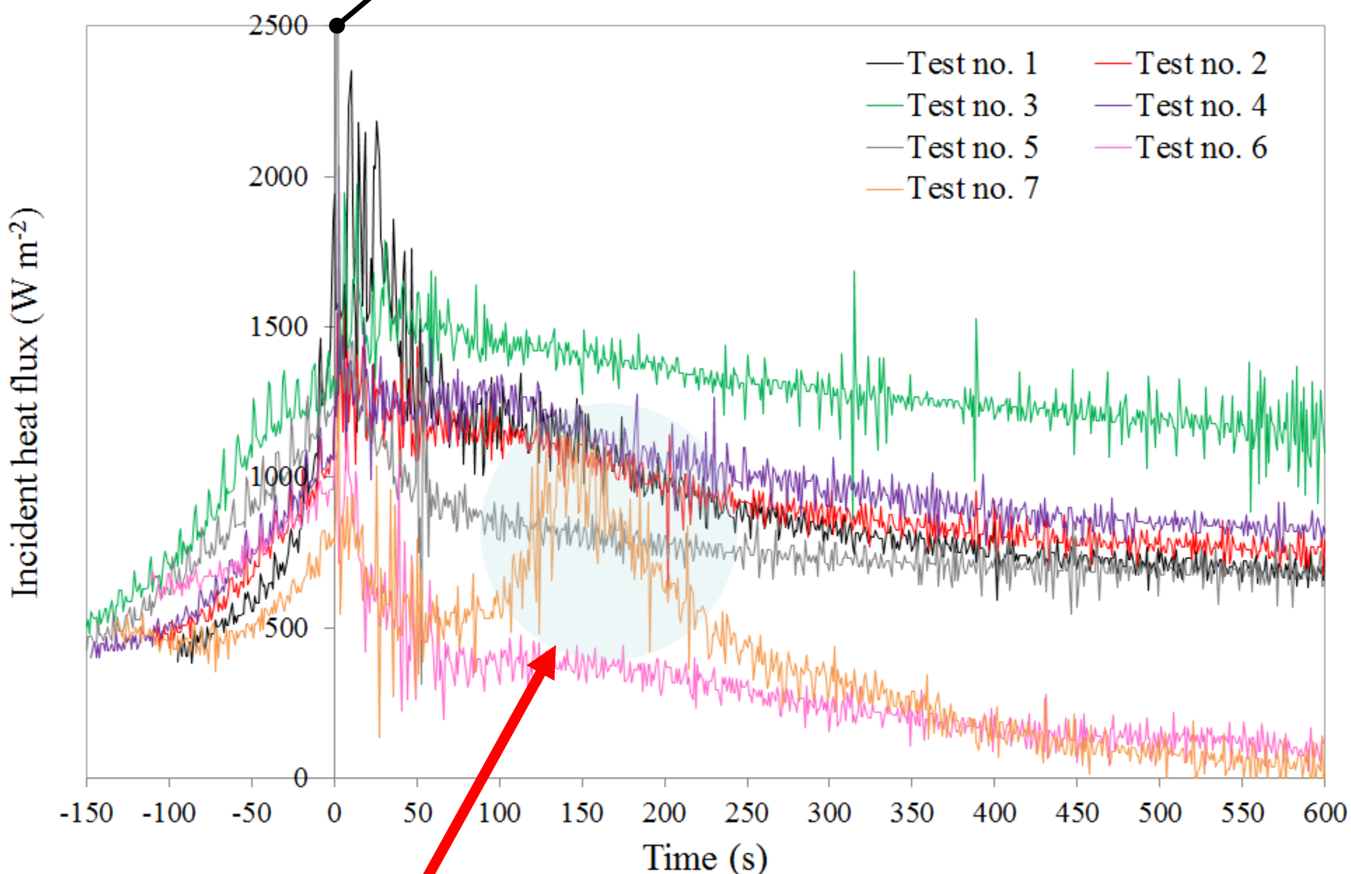
Temperature and Pressure Trends (Test no. 5 – 7)



Discharge activation



RE-GROWTH in worst-case scenario

Photo Shooting

PRE-TEST

Test no. 1

Test no. 7

Test no. 5

Summary of Experimental Outcomes

Ignition source in the corner

Ignition source at the center

Delayed τ_{act}

Unexpected smoldering

Drywall boards

$T_i \uparrow$

$T_i \uparrow$ + $D \uparrow$ + ventilation

	Test no. 1	Test no. 2	Test no. 3	Test no. 4	Test no. 5	Test no. 6	Test no. 7
Heat-detector activation time [s]	91	100	107	143	179	107	129
Discharge activation time [s]	96	105	182	148	184	112	134
Smoldering materials at the end	NO	NO	NO	YES	NO	NO	YES
Overall suppression	YES	YES	YES	YES	YES	YES	YES
Wood-crib fire extinction time [s]	267	284	226	273	256	311	327
Initial wood-crib mass [g]	2813.2	2745.5	2750.5	2849.5	2907.5	3230.0	3175.5
Wood-crib damage ratio	12%	14%	11%	7%	12%	5%	12%
Initial bench mass [kg]	NM	NM	43.5	43.5	43.0	43.0	41.5
Bench damage ratio	NM	NM	3%	1%	0%	1%	1%

NM: Not Measured

Conclusions and Recommendations

- A water-mist system was **designed** and **tested** as inspired by recognized standards for application in **sauna scenarios**
- The proposed system was capable of controling and suppressing the fire in all tests (**timber-bench damage ratio ≤ 3%**)
- The **ignition-source location**, the **presence of drywall boards** behind timber benches and the presence of a **gap between benches and the wall** behind did **not** prove **critical** in determining system performance
- A **heat-detector-governed discharge** was **effective** in containing damage ratio, with respect to a fixed, longer activation time
- **Initial room temperature** does **not** appear to be **crucial** in determining system performance
- The **worst-case scenario** showed that **natural ventilation** and a **larger nozzle-to-bench** distance may imply **re-ignition** and **smoldering** materials at the end, yet damage ratio did not vary with respect to the other tested conditions
- The developed water-mist system may be considered suitable for enclosures endowed with **self-closing doors**

Acknowledgments and Q&A

Under the auspices of: Virgin active, STARPOOL wellness concept

Big thanks to:

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- Bettati Antincendio S.r.l. staff for their support throughout the experiments

Thanks for your kind attention.
Questions?

Dr. Paolo E. Santangelo

Dipartimento di Ingegneria "Enzo Ferrari"
Università degli Studi di Modena e Reggio Emilia

Via P. Vivarelli 10
41125 Modena, Italy

Tel.: + 39 059 205 6101
Fax: +39 059 205 6129
E-mail: paoloemilio.santangelo@unimore.it

Dr. Luca Tarozzi

Bettati Antincendio S.r.l.

Via B. Disraeli 8
42124 Reggio Emilia, Italy

Tel.: + 39 0522 369728
Fax: +39 0522 791052
E-mail: tarozzi@bettatiantincendio.it