



Towards performance-based dimensioning of water mist systems

by

Dr. Maarit Tuomisaari

Sr.Mgr / Research, Testing, Approvals

Marioff Corporation Oy

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1. Design and dimensioning methods (**prescriptive** or **performance-based**)
2. Physical justification behind system specific dimensioning
3. Conclusions and current stage

Example cases:

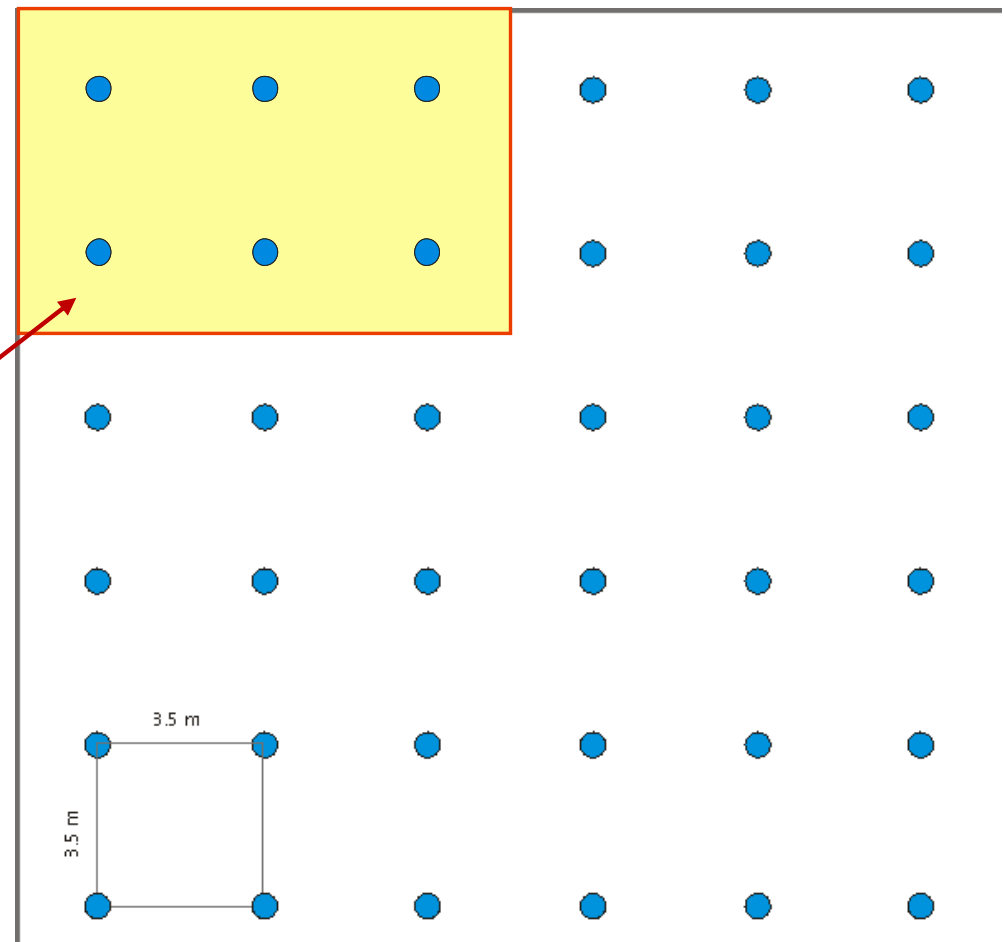
traditional sprinkler system (“trad”) and
high pressure water mist sprinkler system (“wm”)

1. DESIGN AND DIMENSIONING METHODS (PRESCRIPTIVE OR PERFORMANCE-BASED)

PRESCRIPTIVE DESIGN AND DIMENSIONING

- EN 12845 / CEA 4001 applies to all sprinkler systems
- Design and installation parameters are the same to all sprinkler systems

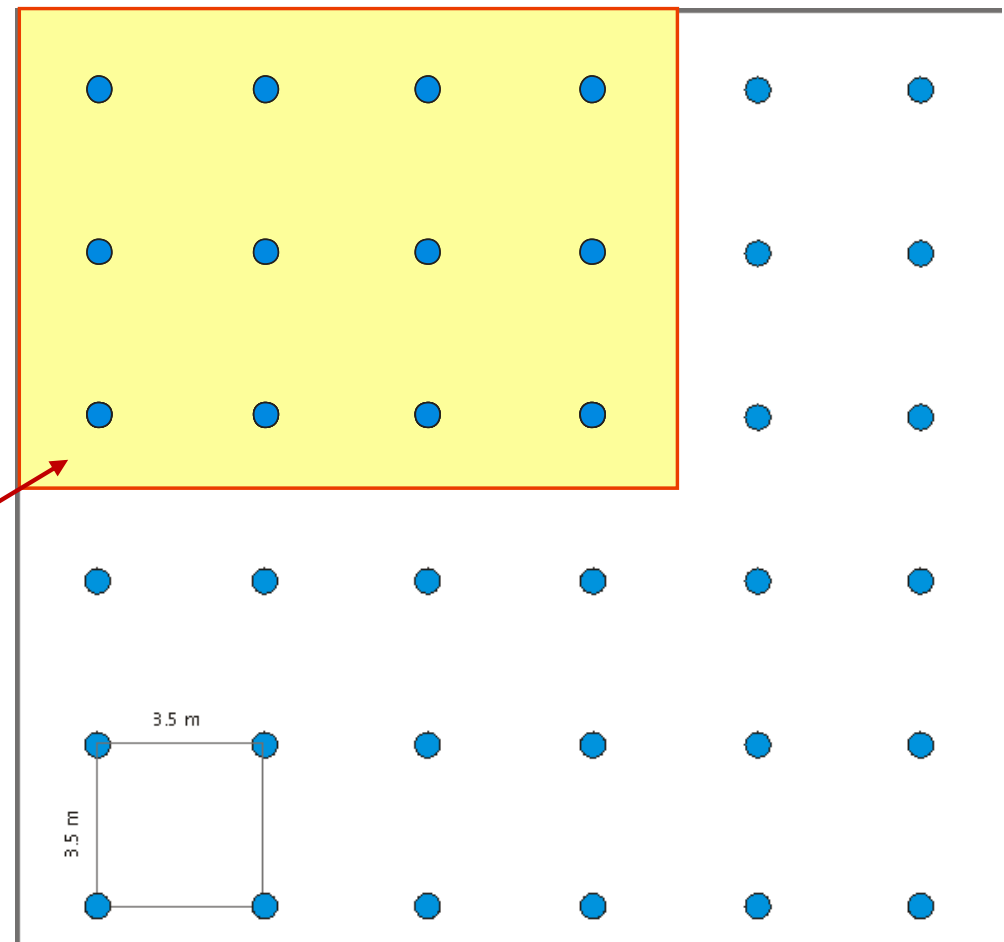
EN 12845 / CEA 4001			
Hazard class	Design area (m ²)	Design flux density (mm/min)	Nominal number of sprinklers
OH1	72	5	6
OH2	144	5	12
OH3	216	5	18



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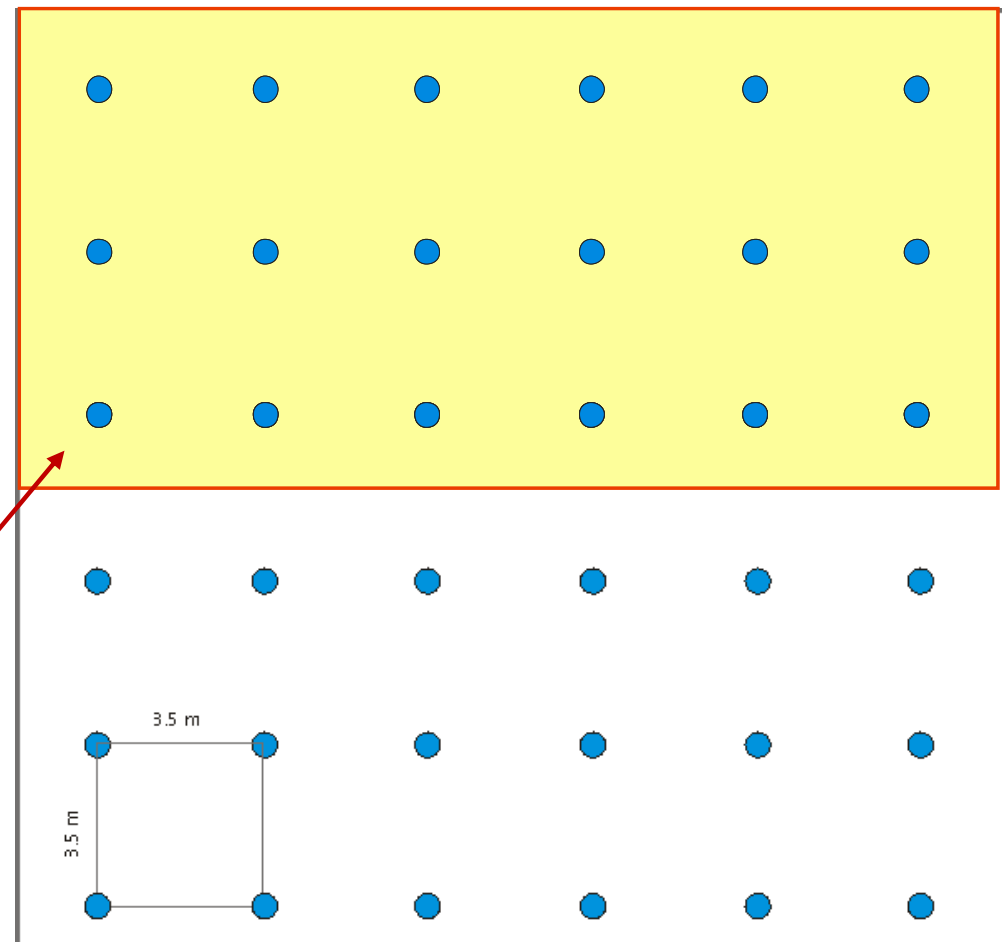
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- Traditional sprinkler systems rely primarily on two-dimensional wetting.
- History has shown that with the same prescriptive design criteria the given prescriptive design area approach together with the fixed design flux density works sufficiently well to all sprinkler systems
- Water mist sprinkler systems rely on a combination of three-dimensional gas cooling, local inerting and blocking of radiant heat with the two-dimensional wetting being only one of the many suppression mechanisms. The relative importance of the different mechanisms is system specific.
- It is not possible to give prescriptive design criteria with a single fixed design number (like flux density) to cover all the very different water mist systems and, hence, the design and installation parameters of water mist systems are defined on a performance basis.

PERFORMANCE-BASED DESIGN

- Design and installation parameters for water mist sprinkler systems are defined in full scale fire tests and they are entirely system specific



PERFORMANCE-BASED DESIGN

PRESCRIPTIVE DIMENSIONING

- Water mist sprinkler system dimensioning is required to be based on the prescriptive design area requirements



Hazard class	OH2		OH3			
Design area (m ²)	72		144		216	
Sprinkler system type	trad	wm	trad	wm	trad	wm
Sprinkler coverage area (m ²)	12	25	12	12	12	9
Nominal number of sprinklers	6	3	12	12	18	24
Max number of activations in tests		4				
Safety factor	< 1					

(* VdS approval tests for HI-FOG systems)

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Max number of activations in tests		4		7		10
Safety factor		< 1		1.7		2.4

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(* VdS approval tests for HI-FOG systems)

CEN/TS 14972: At least 4
prEN 14972: At least 6

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Nominal number of sprinklers	6	3 → 6	12	12	18	24
Max number of activations in tests		4		7		10
Safety factor		< 1		1.7		2.4

(* VdS approval tests for HI-FOG systems)

Mixing performance-based design and prescriptive dimensioning requires artificial "fixing".

PERFORMANCE-BASED DESIGN AND DIMENSIONING

- What if also the dimensioning was based on full scale fire tests?

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Max number of activations in tests (*)	4	4	9	7	≥ 18	10
Measured safety factor	1.5	< 1	1.3	1.7	≤ 1	2.4
Design safety factor						

(* VdS approval tests for HI-FOG systems)

PERFORMANCE-BASED DESIGN AND DIMENSIONING

- What if also the dimensioning was based on full scale fire tests?
- The only prescriptive number would be the Safety factor of 1.5

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(* VdS approval tests for HI-FOG systems)

PERFORMANCE-BASED DESIGN AND DIMENSIONING

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Design area (m ²)	72		144		216	
Sprinkler system type	trad	wm	trad	wm	trad	wm
Sprinkler coverage area (m ²)	12	25	12	12	12	9
Design number of sprinklers	6 → 6	3 → 6	12 → 14	12 → 11	18 → 27	24 → 15
Max number of activations in tests (*)	4	4	9	7	≥ 18	10
Measured safety factor	1.5	<1	1.3	1.7	≤1	2.4
Design safety factor	1.5					

(* VdS approval tests for HI-FOG systems)

Mixing prescriptive design and performance-based dimensioning contradicts the current experience.

CONSISTENT DESIGN AND DIMENSIONING

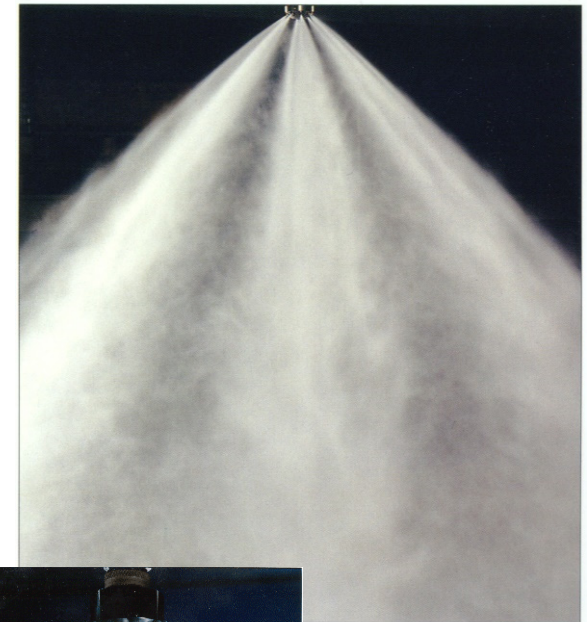
- **Prescriptive** design / **Prescriptive** dimensioning
- **Prescriptive** design / **Performance-based** dimensioning
- **Performance-based** design / **Prescriptive** dimensioning
- **Performance-based** design / **Performance-based** dimensioning

Hazard class	OH1		OH2		OH3	
Design area (m²)	72		144		216	
Sprinkler system type	trad	wm	trad	wm	trad	wm
Sprinkler coverage area (m ²)	12	25	12	12	12	9
Nominal / Design number of sprinklers	6	6	12	11	18	15
Max number of activations in tests (*)		3		7		10
Safety factor		1.5		1.5		1.5

2. PHYSICAL JUSTIFICATION BEHIND SYSTEM SPECIFIC DIMENSIONING

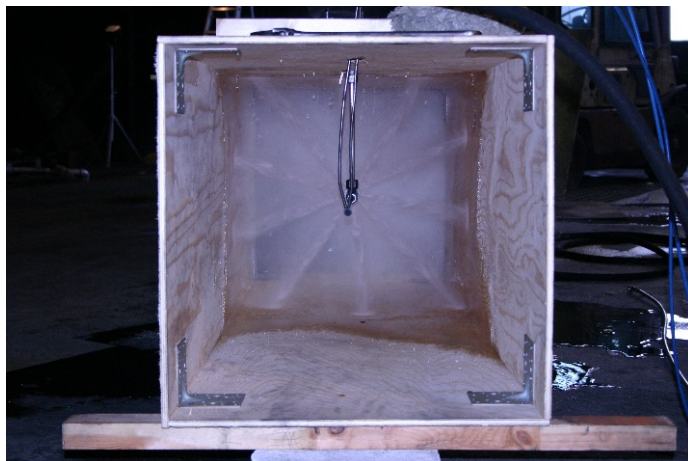
WHAT AFFECTS THE NUMBER OF ACTIVATIONS?

- There are several different issues that affect the number of activations:
 - Spray characteristics
 - Bulb characteristics (T rating, RTI)
 - Spacing between sprinklers
 - Water flow rate...
- Spray characteristics play THE major role
- All downward water sprays entrain parts of the ceiling jet into the sprays and divert that heat down, but a high pressure water mist spray and/or a narrower spray does it more effectively than a traditional sprinkler spray:
the hot smoke spread is restricted preventing activations further away from the fire.

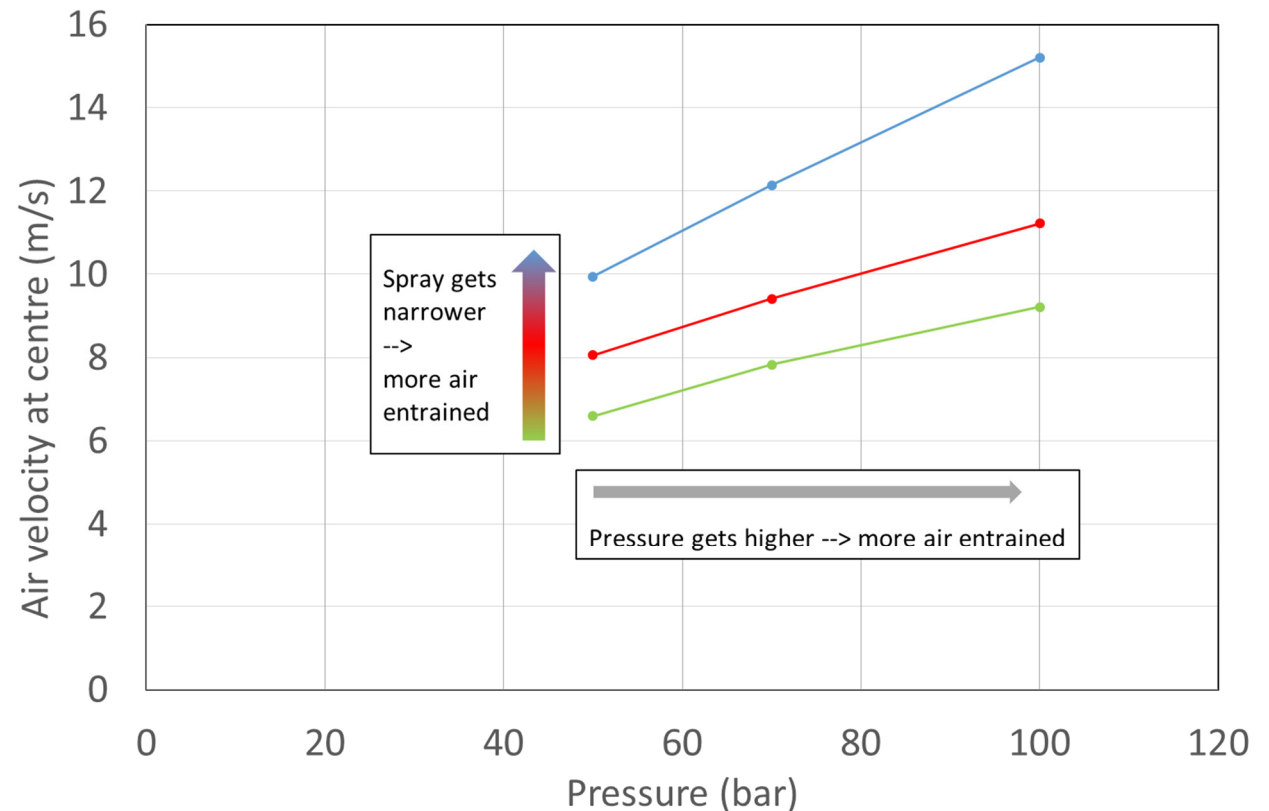


NUMBER OF ACTIVATIONS : EXPERIMENTAL 1

- The trend was verified in a systematic experimental study together with Dr. Jukka Vaari / VTT and published in **VTT Technology Report 54, 2012**

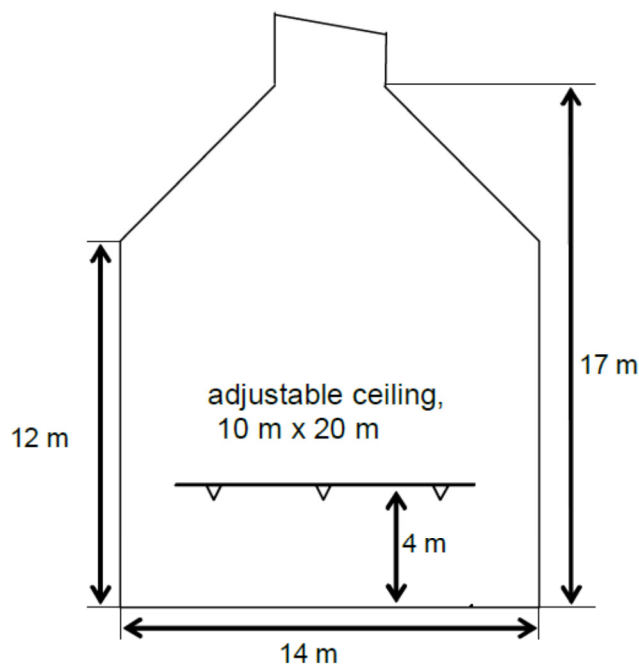


Air entrainment rate by different sprays

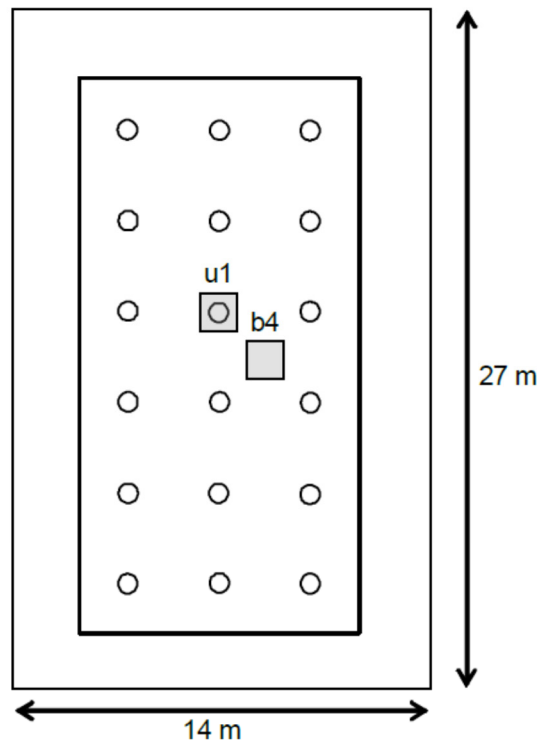


NUMBER OF ACTIVATIONS : EXPERIMENTAL 2

- Generic full scale tests in a large test hall with a 200 m² ceiling
- The tests were supplemented by validated FDS simulations run at the time of the testing and again just recently



Side view



Top view

Sprinkler types:

Traditional
High pressure water mist

Test fires:

Concealed wood crib
Open heptane pool
Constant HRR (2 MW)

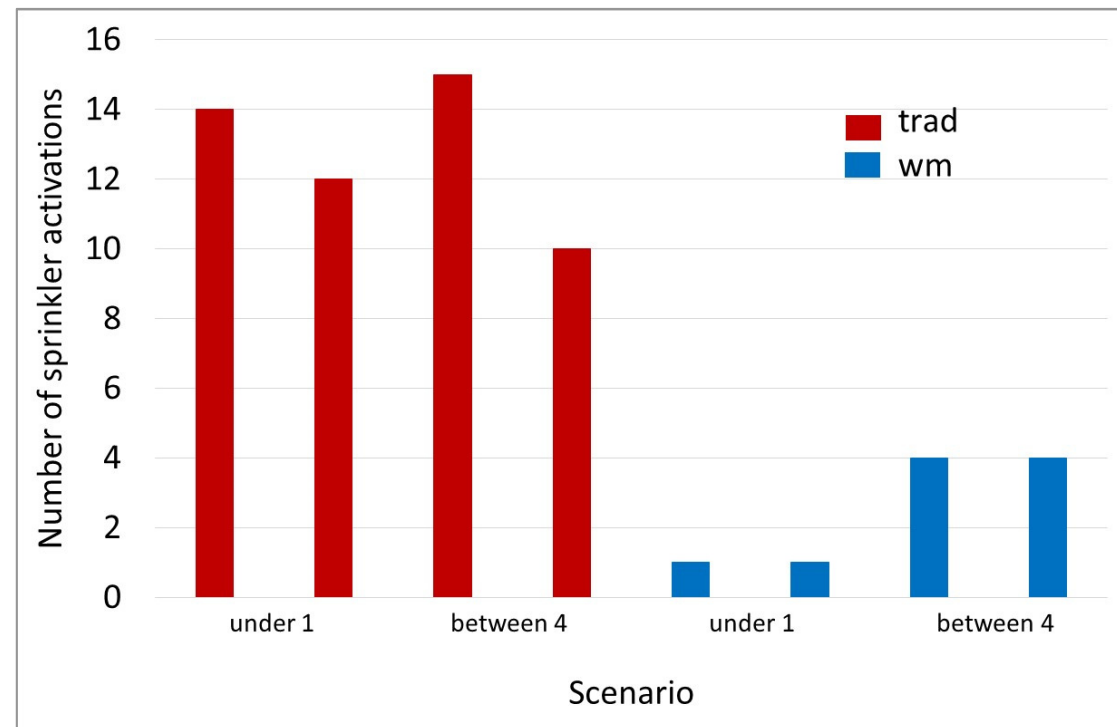
Fire locations:

Under 1 & Between 4

Ceiling heights:

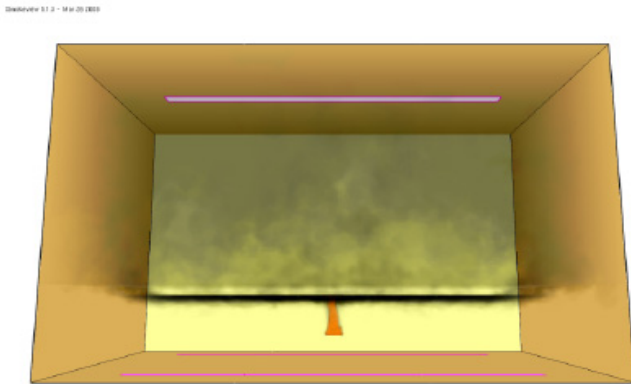
2.5 m & 4 m

NUMBER OF ACTIVATIONS : EXPERIMENTAL 2



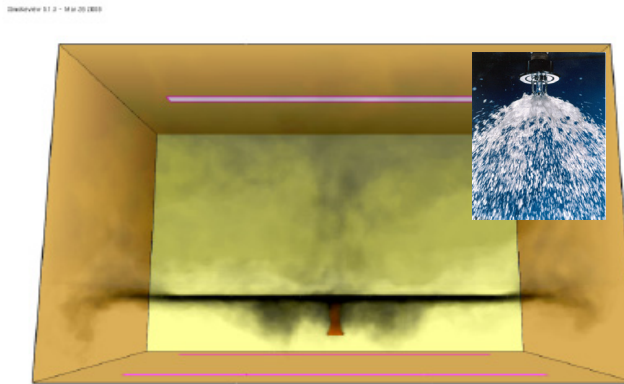
NUMBER OF ACTIVATIONS : SIMULATIONS 1

The VTT test hall with a 200 m² movable ceiling allowing free spread of smoke past the ceiling edges into the volume above the ceiling



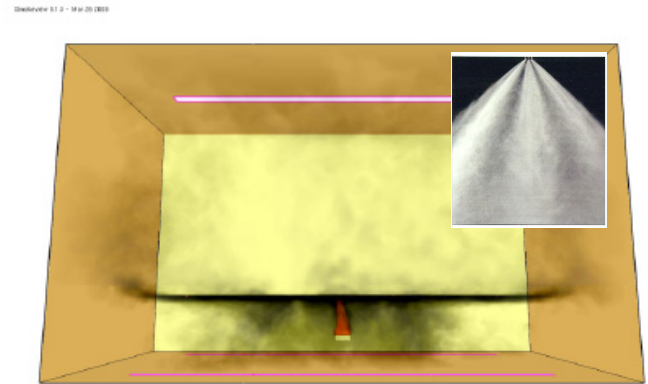
FREE BURN

Hot smoke spreads freely towards and past the edges of the ceiling into the volume above it.



TRADITIONAL SPRINKLERS

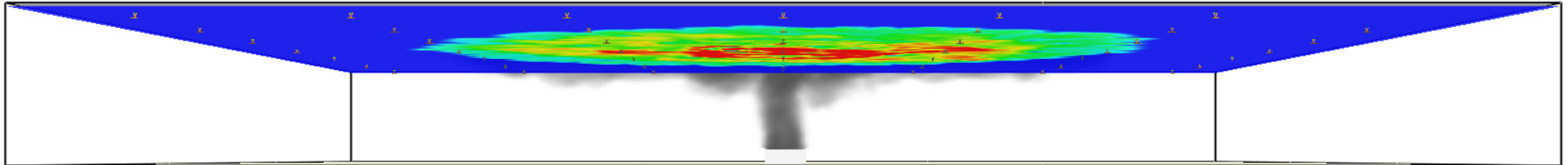
The spread of hot smoke is somewhat limited but large amounts pass the sprinklers along the ceiling and into the volume above it.



HI-FOG SPRINKLERS

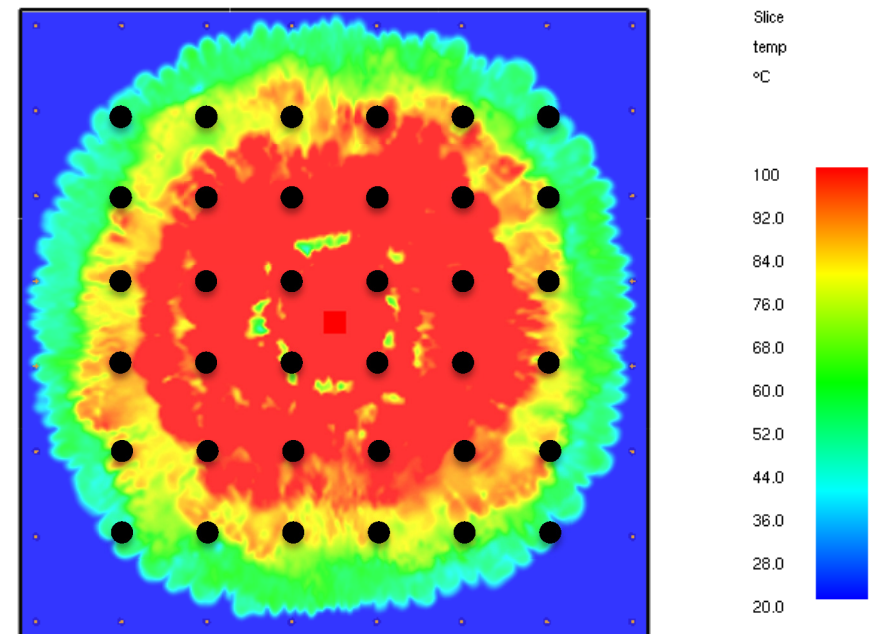
(high pressure water mist)
Most of the hot smoke gets entrained into the high momentum water mist sprays and gets cooled and pushed down. The spread of hot smoke is essentially stopped.

NUMBER OF ACTIVATIONS : SIMULATIONS 2



FDS simulations on the number of activations by Dr. Kati Laakkonen / Marioff

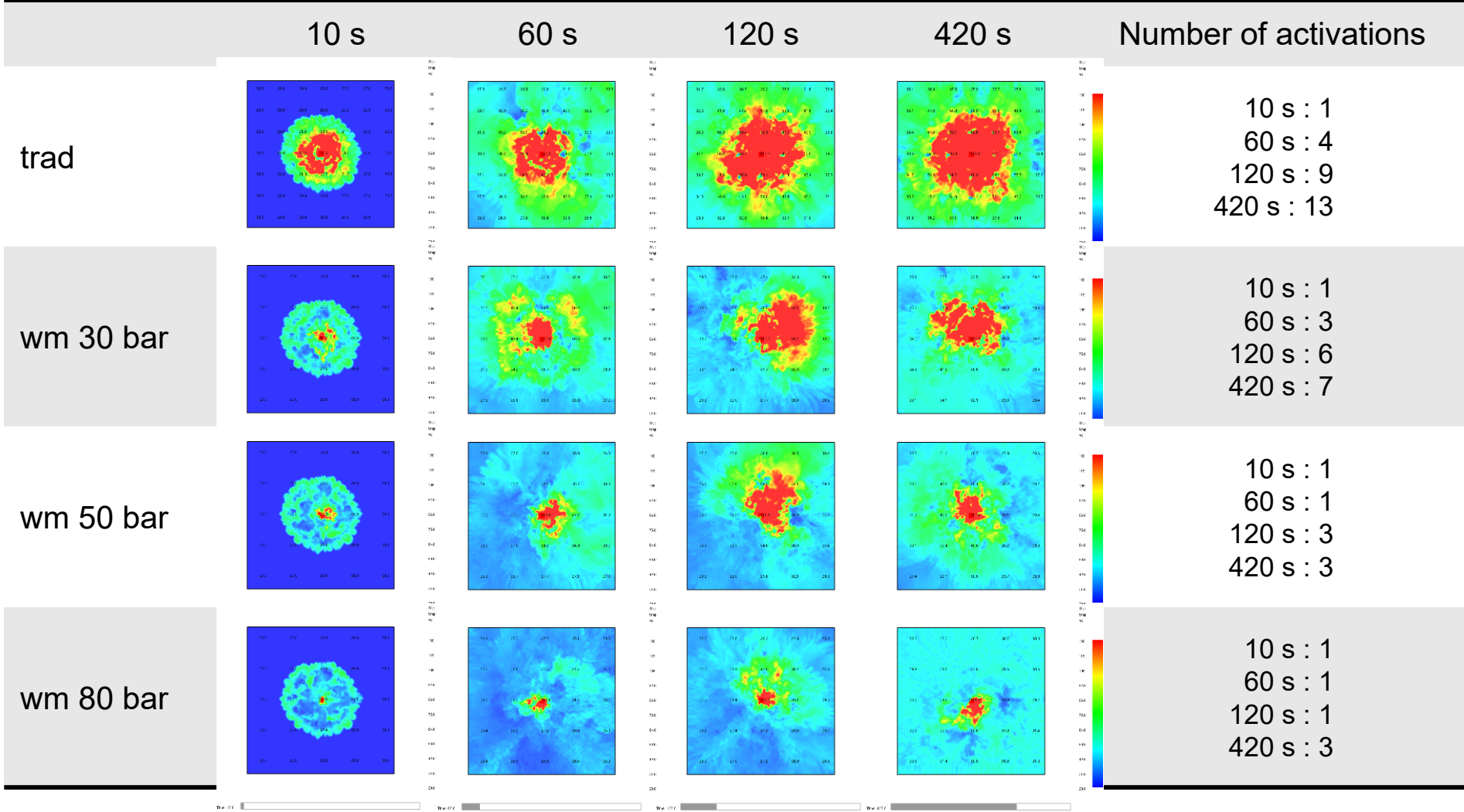
- 2.5 m ceiling height
- constant HRR
- Two scenarios:
 - (i) fire under one sprinkler
 - (ii) fire between four sprinklers



Time: 20.0

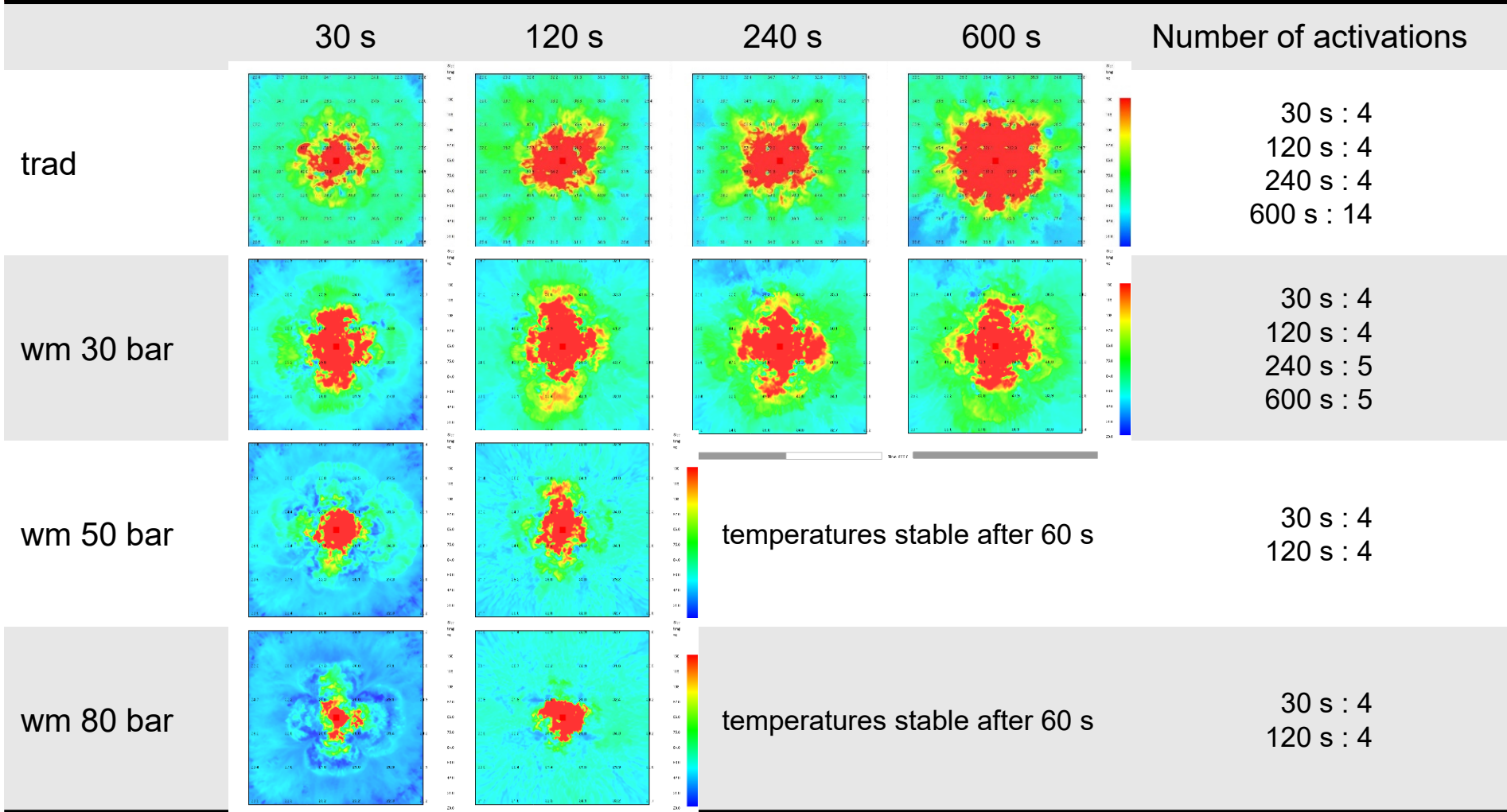
NUMBER OF ACTIVATIONS : SIMULATIONS 2

Ceiling height 2.5 m Scenario : fire under 1 sprinkler



NUMBER OF ACTIVATIONS : SIMULATIONS 2

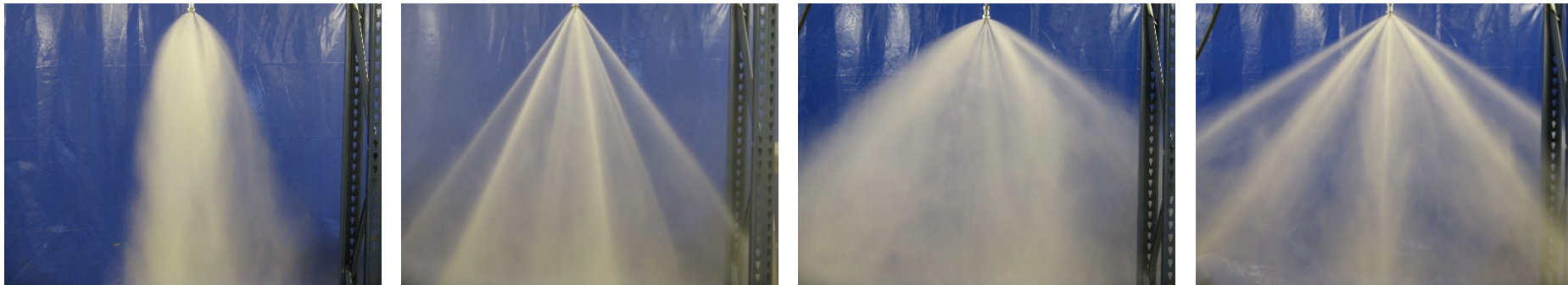
Ceiling height 2.5 m Scenario : fire between 4 sprinklers



3. CONCLUSIONS AND CURRENT STAGE

CONCLUSIONS

- Spray characteristics have a major effect on
 - i. the water mist sprinkler system performance
 - performance-based, system specific design and installation criteria
 - ii. the number of water mist sprinkler activations
 - performance-based, system specific dimensioning criteria



- Dimensioning should be based on the maximum number of sprinklers activating in the fire tests with a fixed safety factor of 1.5

CURRENT STAGE

- FM Approvals is the first authority applying performance-based approach for both the design and dimensioning

Fire Tests for Water Mist Systems for the Protection of Data Processing Equipment Rooms/Halls

Appendix M ...above Raised Floor

Appendix N ...below Raised Floor

“The design area of the water mist system shall be 6 nozzles or 1.5 times the number of operated nozzles during fire performance testing, whichever is greater.”

- Currently (August 2018) there are three different FM Approved systems for above raised floor with dimensioning for 18 nozzles and for 6 nozzles.



Thank You For Your Attention



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Web: www.marioff.com

Youtube: <https://www.youtube.com/user/MarioffHIFOG/>