Water Mist Simulations in the Marine Sector

Bjarne P. Husted
Associate professor
Lund University

Outline of talk

1. What is water mist.
2. Use of water mist as a replacement for Halon
3. Testing of water mist systems.
4. Applications for the use of water mist in the marine sector
5. Simulations of water mist system on ships

Why use water mist

- Ban of Halon (Montreal Protocol in 1987)

- Protection of passenger ferries ("Scandinavian Star" incident in 1990)

- Environmental friendly

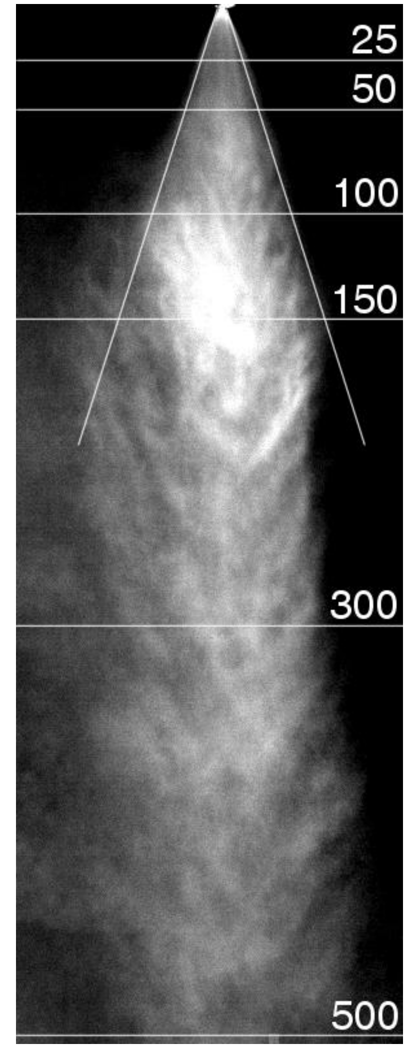
Water mist is one of several alternatives to Halon, other alternatives are

- CO_2
- N_2 mixtures (trade names are Inergen & Argonite)
- Chemical reaction producing powder (used on Mir)
- Other chemicals (Novec 1230 ($C_6F_{12}O$), FM 200)

What is water mist

- Fine water droplets
- NFPA 750 (US)
  - The first standard on water mist
  - 99% of the droplets should be below 1 mm
  - Typically droplets are 200 – 500 µm

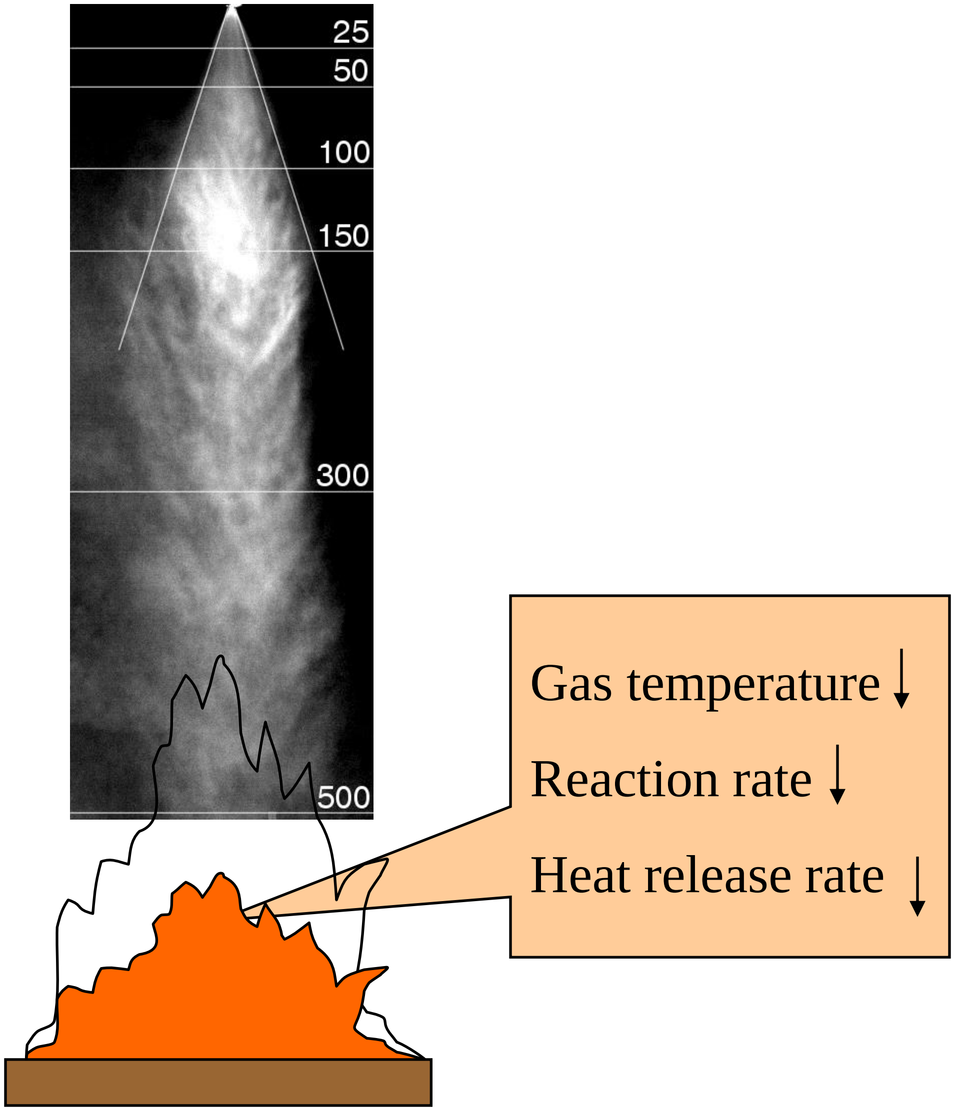
- European standard
  - CEN/TS 14972:2011



How does water mist work

Primary mechanism

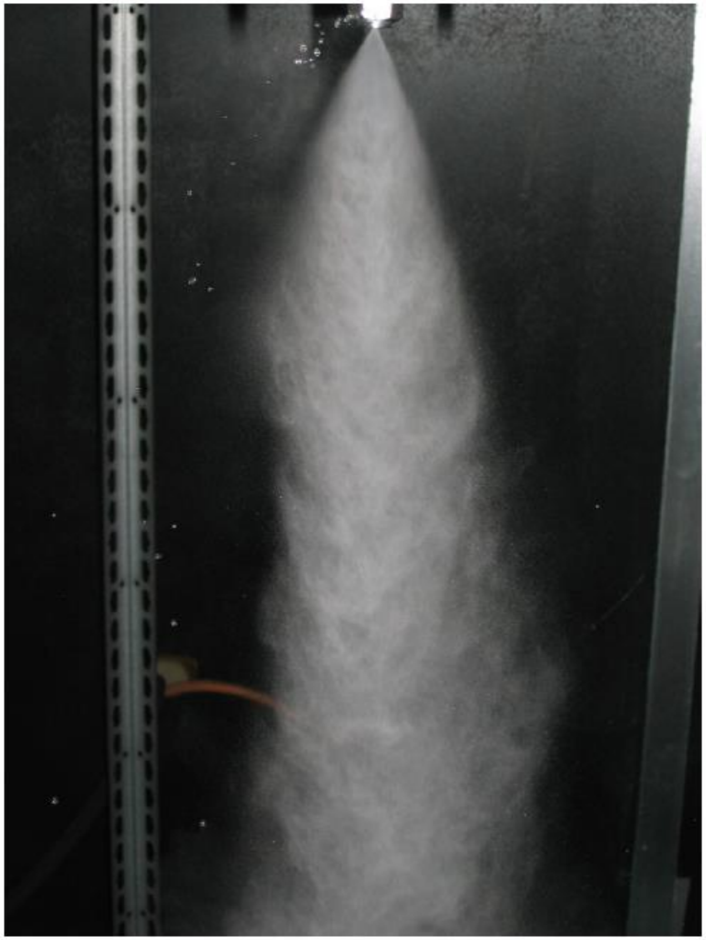
- Cooling of gasses
  - Droplets evaporate
  - Flame temperature lowers
  - Reactions are slowed down



Water mist also has it limitations

- The water are small droplets and not a gas
  - Difficult for droplets to go pass an obstacle
- Limits visibility when released
- Ventilation conditions can effect the performance

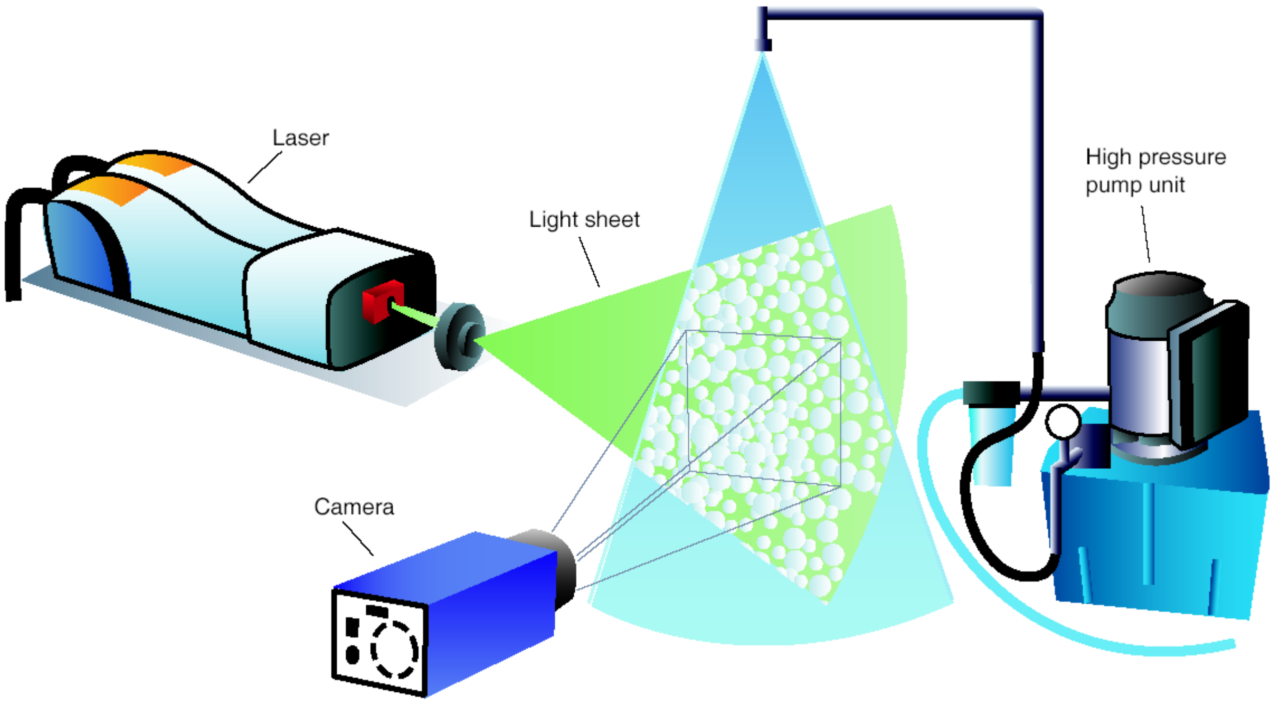
Two different high pressure nozzles at 100 bar

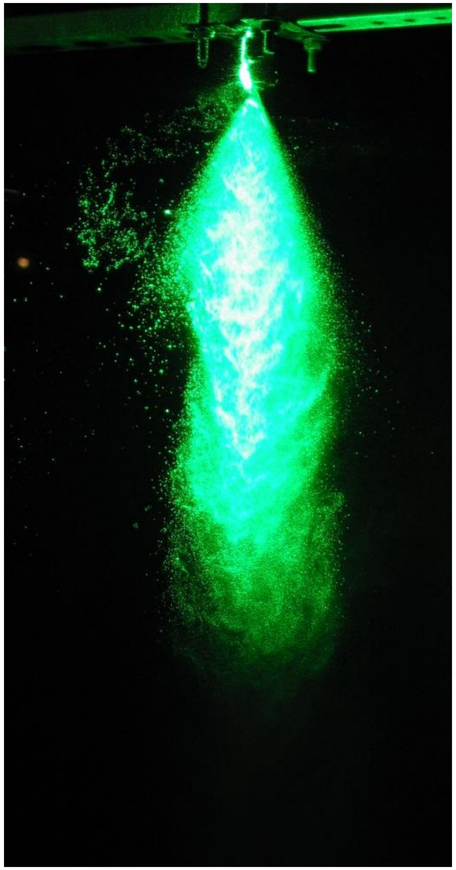


Hollow cone, 0.38 l/min
Danfoss 1910

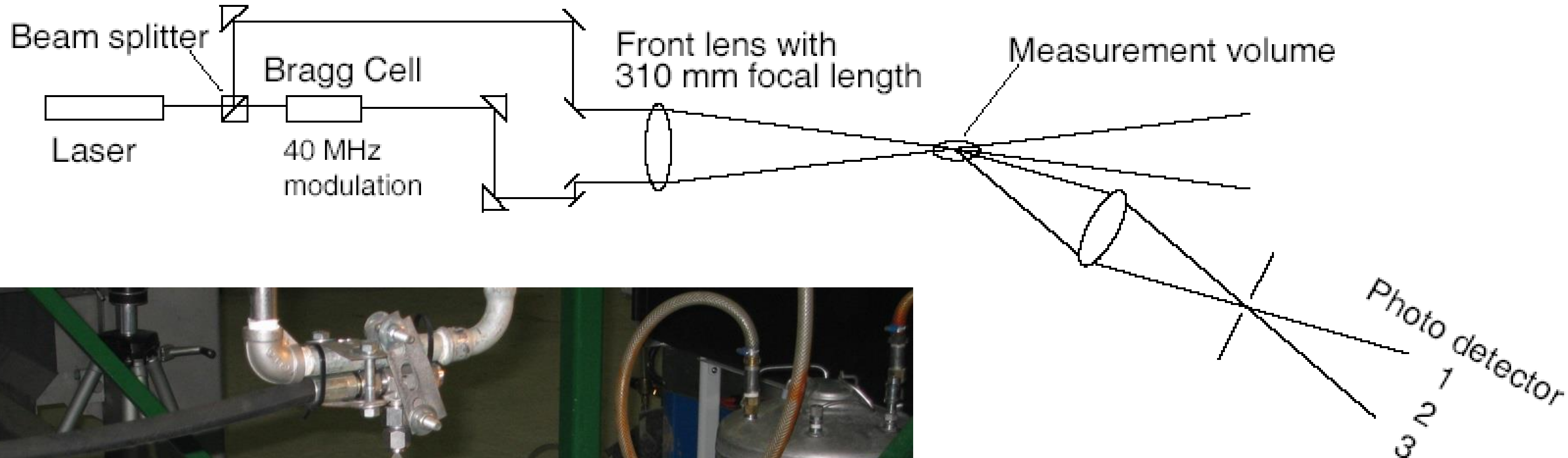
Full cone, 0.13 l/min
Lehler 212.085

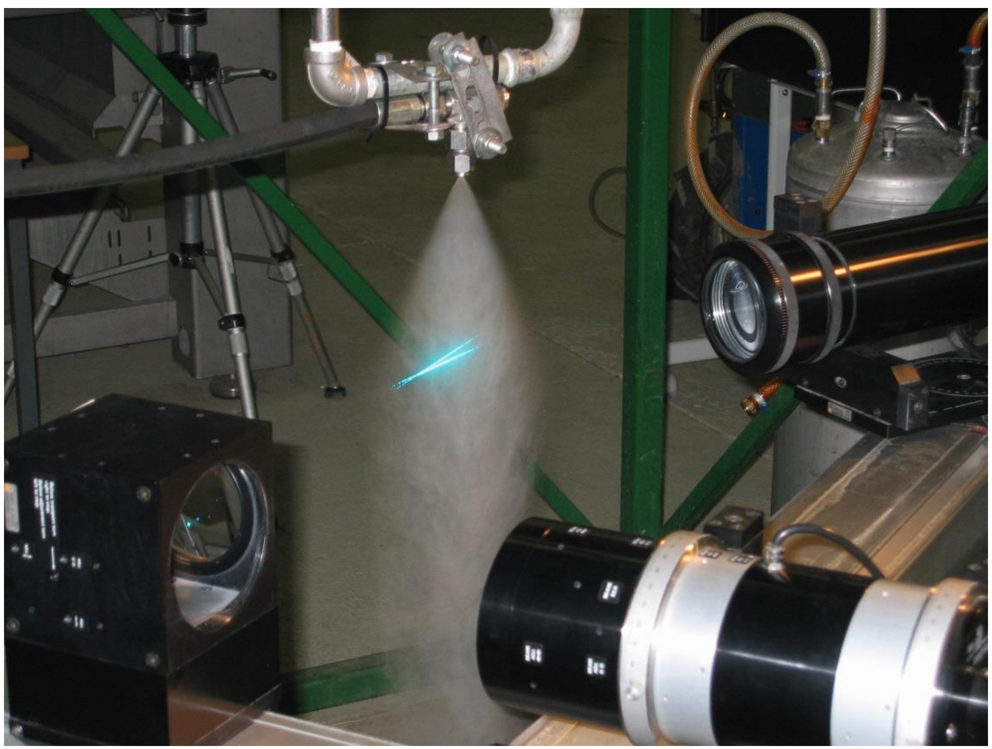
Measurement method I
Particle Image Velocimetry (Velocity)





Measurement method II
Phase Doppler Anemometry (Vel. & Droplet size)



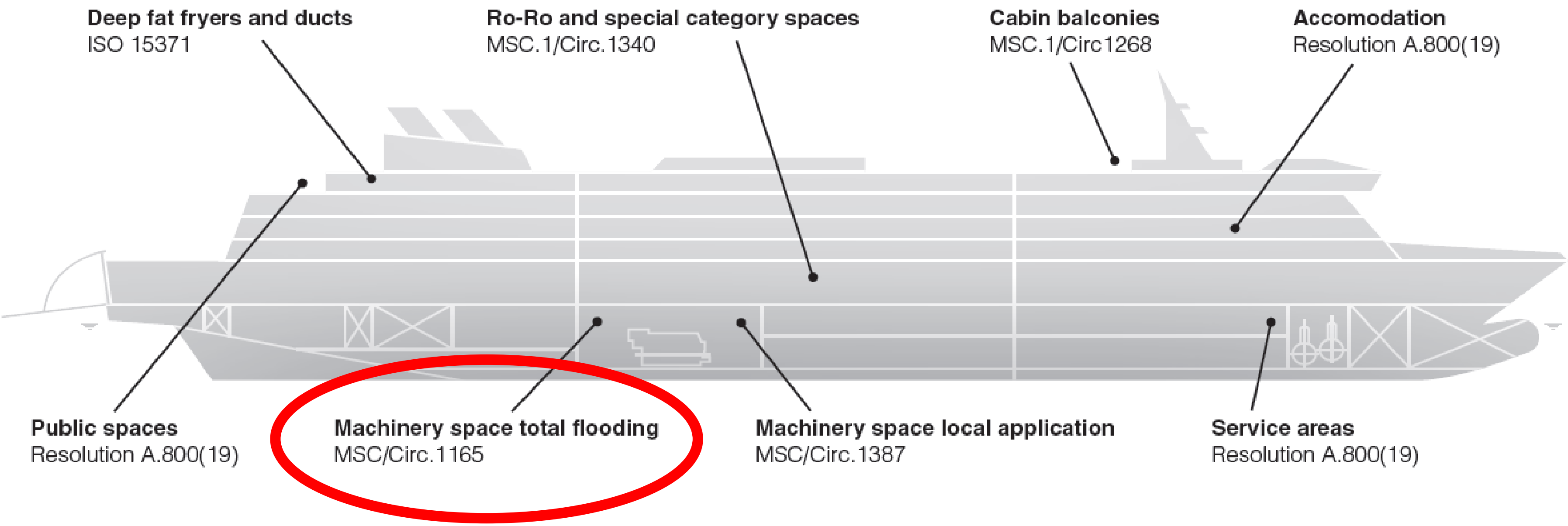


Obstacle for a more wide spread use of water mist

- Lack of engineering methods for designing water mist systems

- Full scale tests are very expensive
  - but currently this is the only option for approving water mist systems

Standards for water mist systems on ships



Source: www.marioff.com/media/brochures/en_GB/brochures/

Water mist in machinery space, total flooding
IMO MSC/Circ. 1165

Combinations of pool fires and spray fires, 8 tests

Test No.	Fire Scenario	Test Fuel
1	Low pressure horizontal spray on top of simulated engine between agent nozzles.	Commercial fuel oil or light diesel oil
2	Low pressure spray in top of simulated engine centred with nozzle angled upward at a 45° angle to strike a 12-15 mm diameter rod 1 m away.	Commercial fuel oil or light diesel oil
3	High pressure horizontal spray on top of the simulated engine.	Commercial fuel oil or light diesel oil
4	Low pressure concealed horizontal spray fire on the side of simulated engine with oil spray nozzle positioned 0.1 m in from the end of the engine and 0.1 m^2 tray positioned on tope of the bilge plate 1.4 m in from the engine end at the edge of the bilge plate closest to the engine.	Commercial fuel oil or light diesel oil
5	Concealed 0.7 m × 3.0 m fire tray on top of bilge plate centred under exhaust plate.	Heptane
6	Flowing fire 0.25 kg/s from top of mock-up (see figure 3).	Heptane
7	Class A fires wood crib (see Note) in 2 m^2 pool fire with 30 s preburn. The test tray should be positioned 0.75 m above the floor as shown in figure 1.	Heptane
8	A steel plate (30 cm × 60 cm × 5 cm) offset 20° to the spray is heated to 350°C by the top low pressure spray nozzle positioned horizontally 0.5 m from the front edge of the plate. When the plate reaches 350°C, the system is activated. Following system shutoff, no reignition of spray is permitted.	Heptane

Test are preformed by fire laboratories

- As an example of test
  - SINTEF NBL in Norway
  - The largest IMO approved machinery space on board ship is now
    - 3348 m^3 with 10,1 m headroom

- Other laboratories testing water mist systems
  - DBI in Denmark
  - SP in Sweden

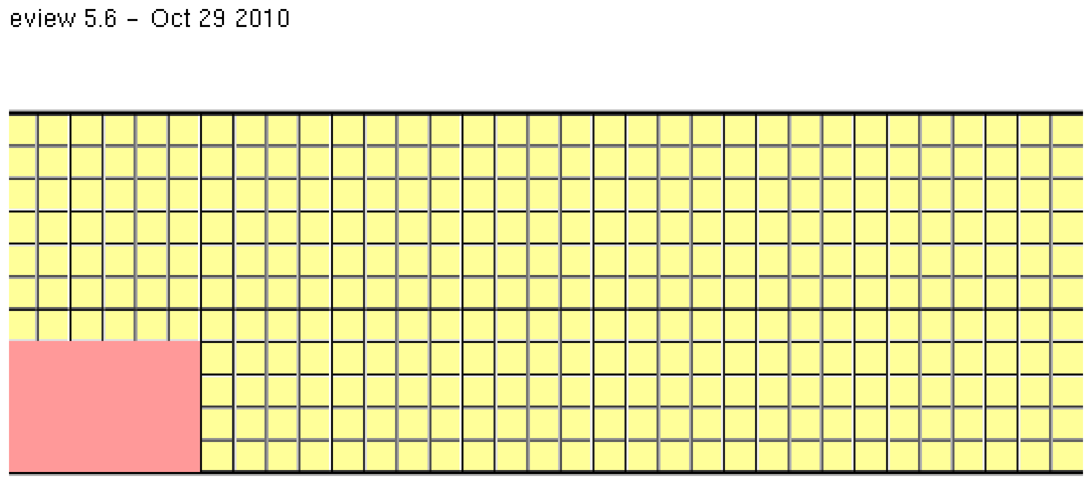
Simulating fires on ships

- Simulating smoke spread
  - Geometry can be imported from CAD program
  - Important to define leakage of compartments
  - Can be used to check detection systems
  - Can be combined with evacuation modelling

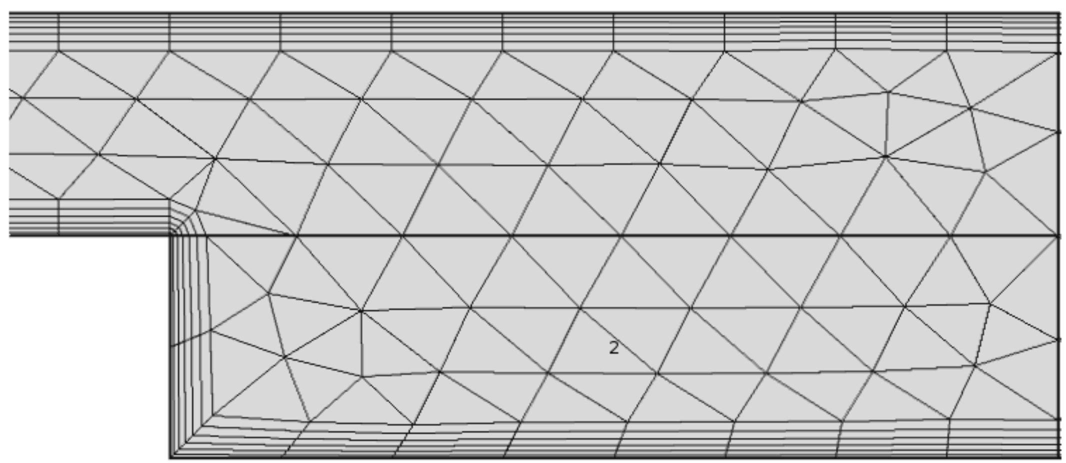
- Advanced topics
  - Simulate fire spread
  - Simulate extinguishment
    - An example will be shown

The geometry is split into small control volumes

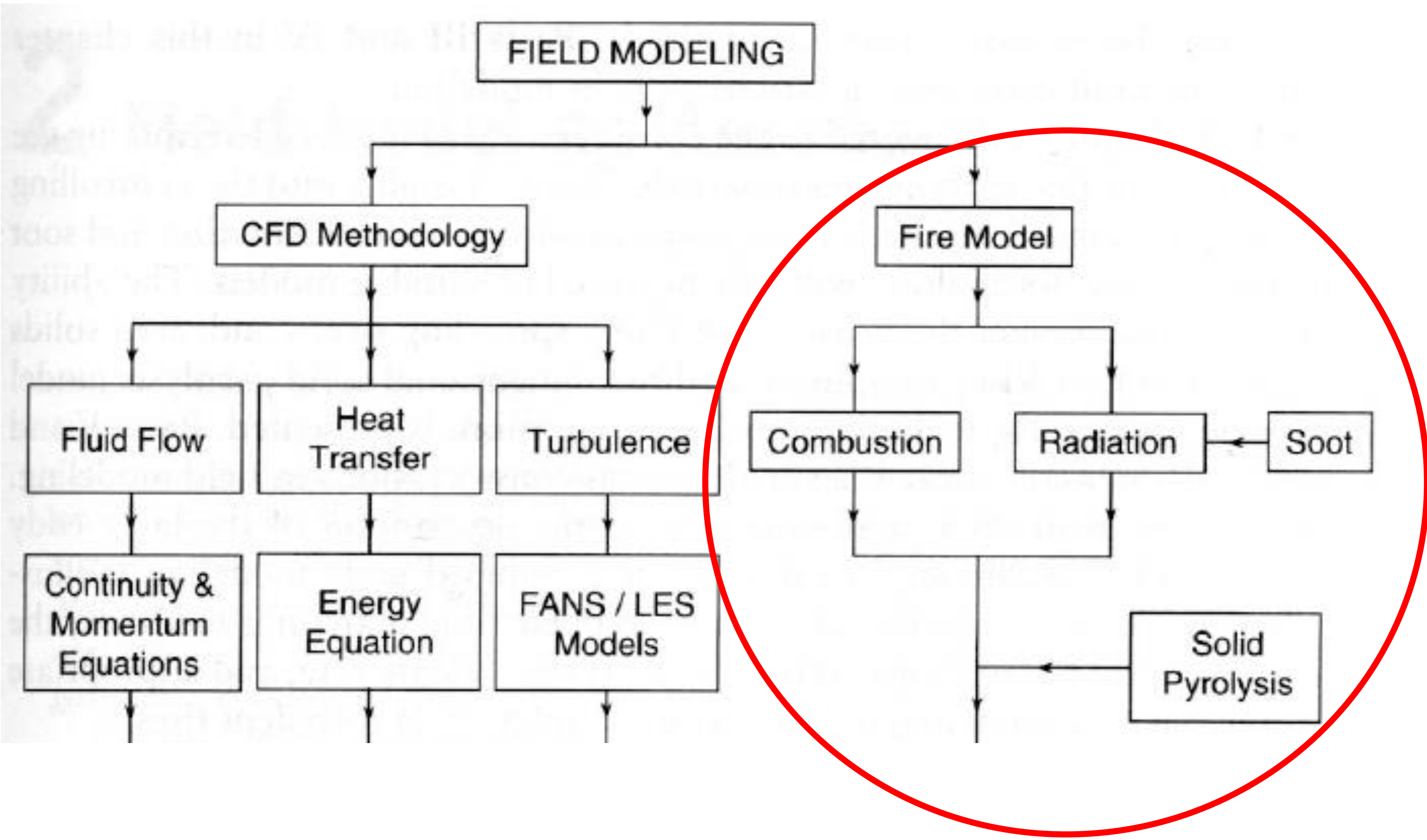
- Structured grid (FDS)



- Unstructured grid (Comsol, FireFOAM)



Additional models in order to model fire



Example with engine room and water mist Experiments and Simulation

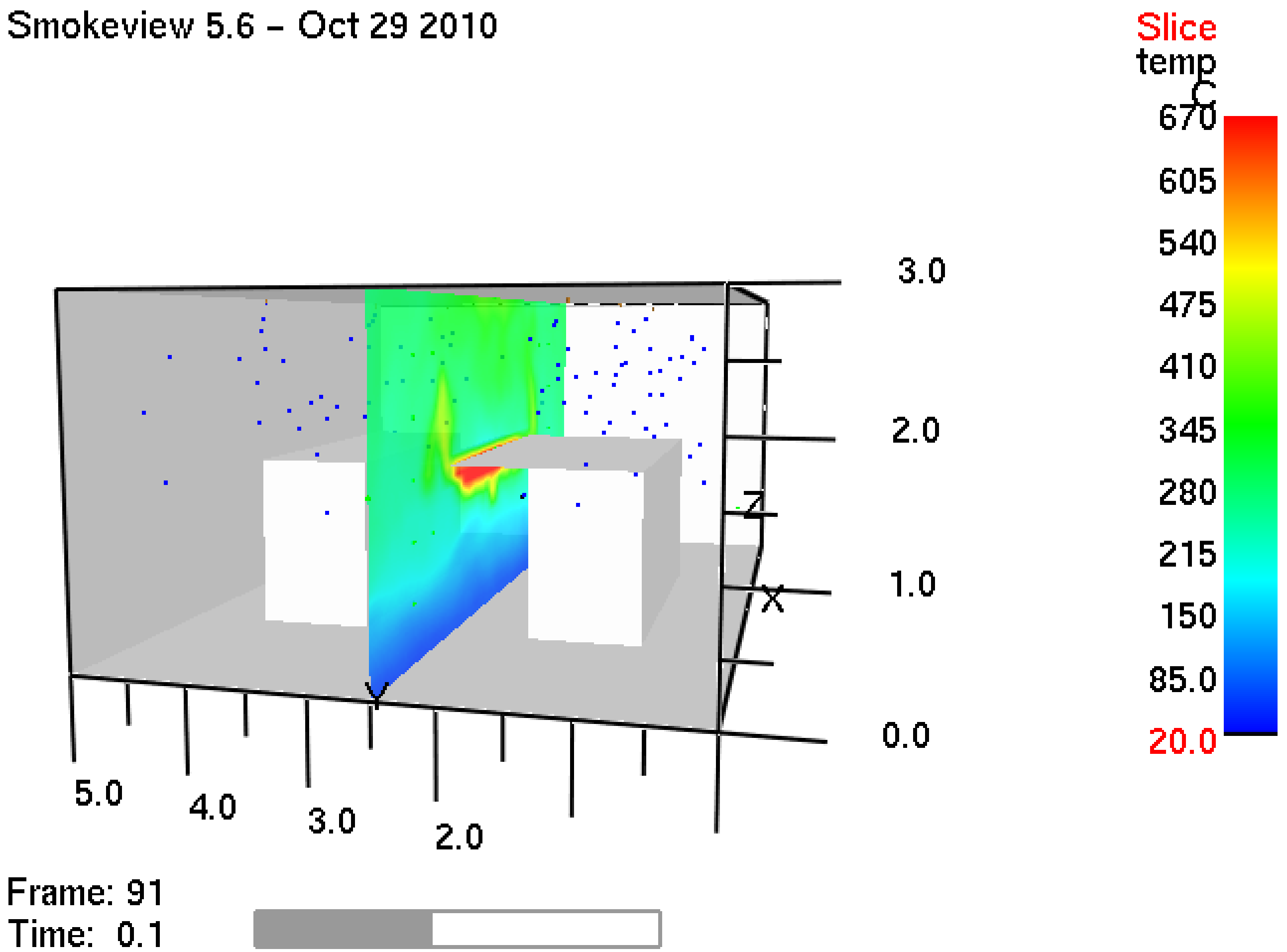
- Experiment carried out by the US navy (from FDS Validation Guide)

- Simulation (input file from FDS validation guide)
  - Large Eddy Simulation, Fire Dynamic Simulator version 6
  - Lagrangian particle tracking
  - For the simulations, the extinguishment time is taken to be when the Heat Release Rate drops to half of its specified value

Recorded extinguishment times for the USCG/HAI water mist suppression tests in a small shipboard machinery space

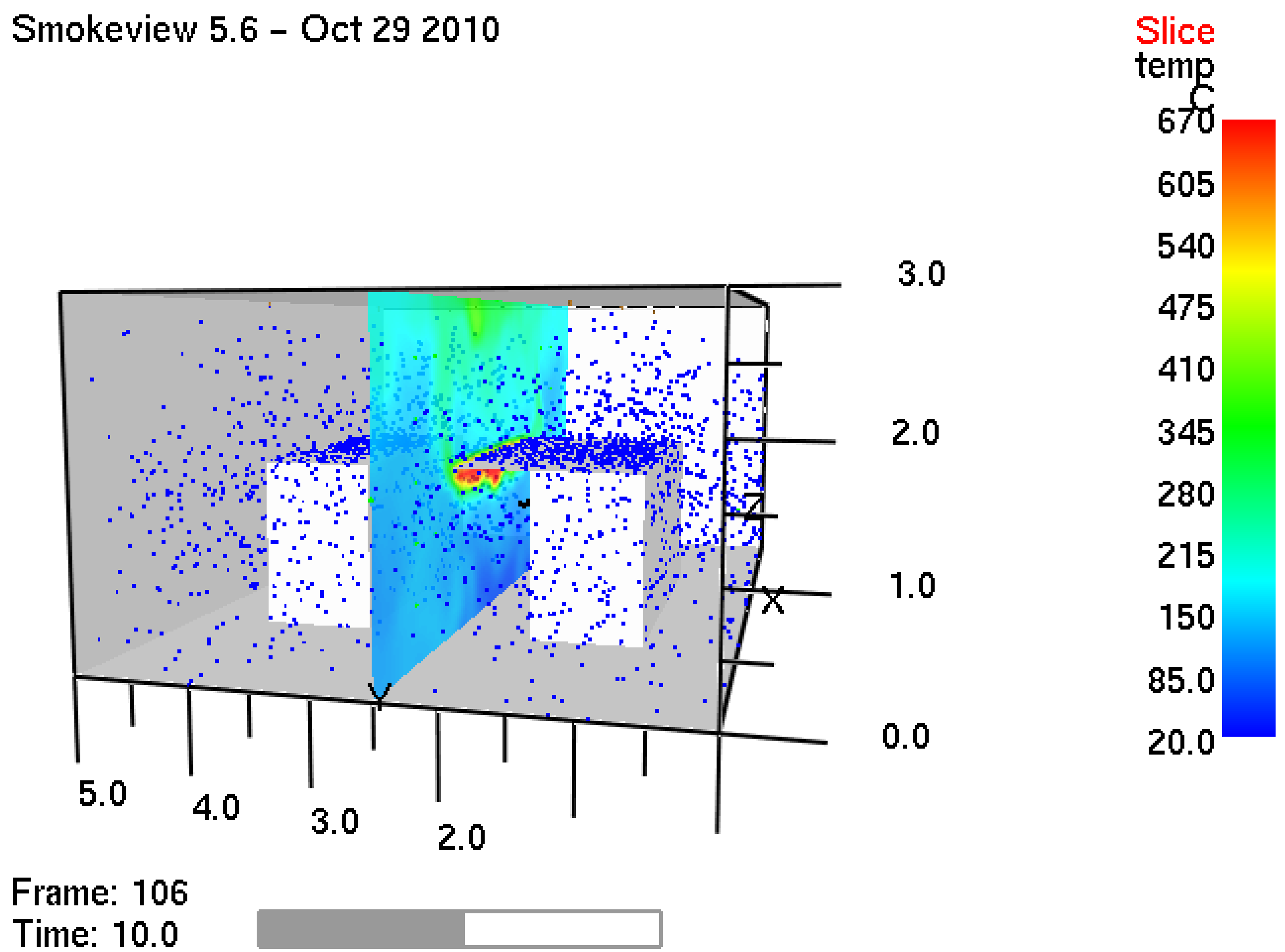
System		Navy	Grinnell	Fogtec	Chemetron	Fike
Number of Nozzles		6	6	6	15	6
Operating Pressure (bar)		70	13	100	12	21
Flow Rate (L/min)		68	75	22	70	48
Assumed Median Drop Size (μm)		175	225	100		200
Assumed Initial Velocity (m/s)		75	32	90		41
Assumed Spray Angle (deg.)		120	90	120		90
Fire Scenario	Ventilation	Extinguishment Time (s)				
1.0 MW Spray	Closed	15	26	21	27	21
1.0 MW Spray	Natural	15	40	32	43	35
1.0 MW Spray	Forced	17	55	76	357	133
0.5 MW Spray	Closed	34	70	39	53	56
0.5 MW Spray	Natural	41	117	67	158	140
0.5 MW Spray	Forced	124	No	No	No	No
0.25 MW Spray	Closed	157	360	169	314	277
0.25 MW Spray	Natural	206	No	290	525	566
0.25 MW Spray	Forced	No	No	No	No	No

Time = 0 s



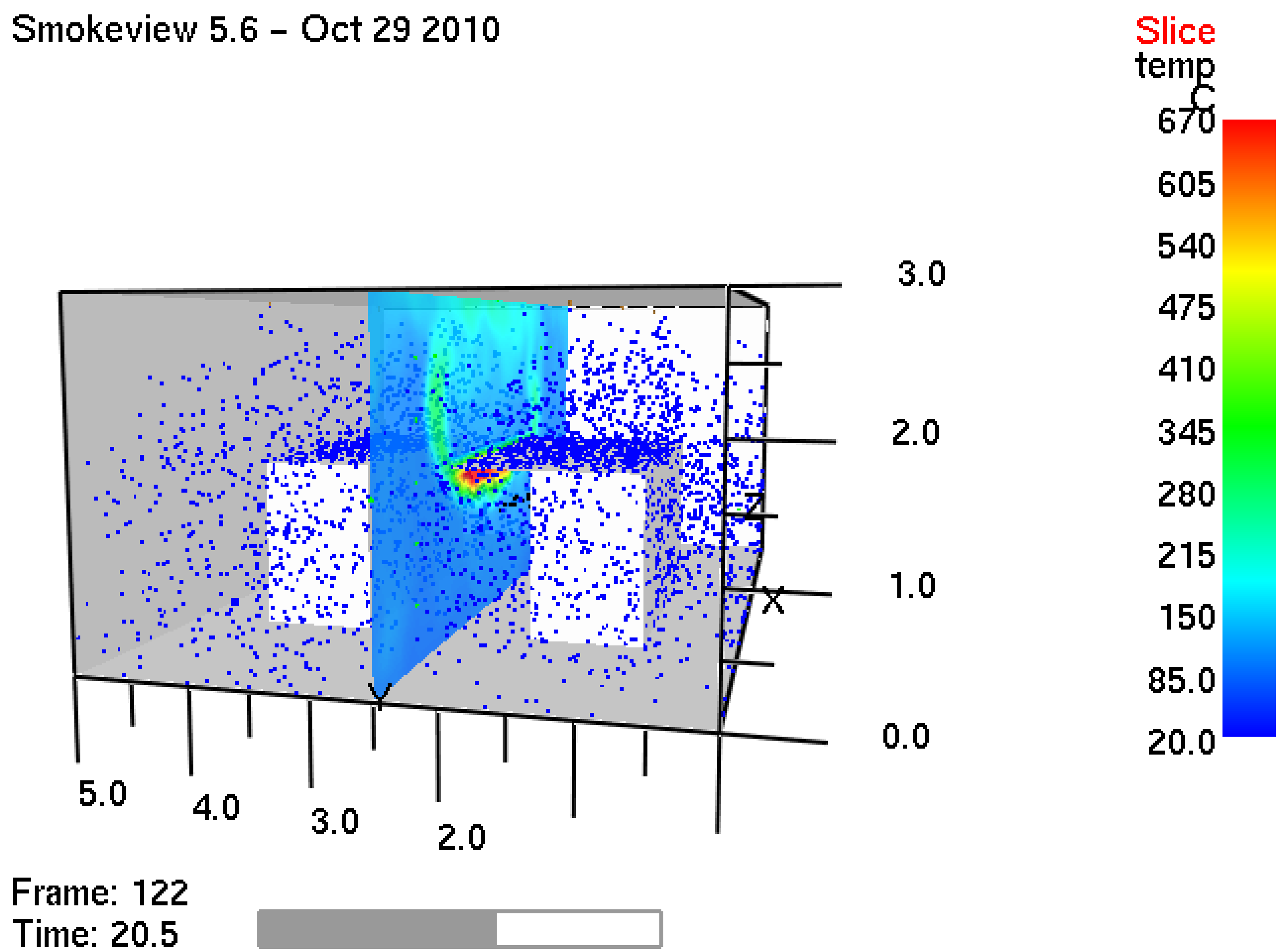
Smokeview 5.6 - Oct 29 2010
3.0
2.0
1.0
0.0
Z
X
Y
5.0
4.0
3.0
2.0
Frame: 91
Time: 0.1
Slice
temp
C
670
605
540
475
410
345
280
215
150
85.0
20.0

Time = 10 s

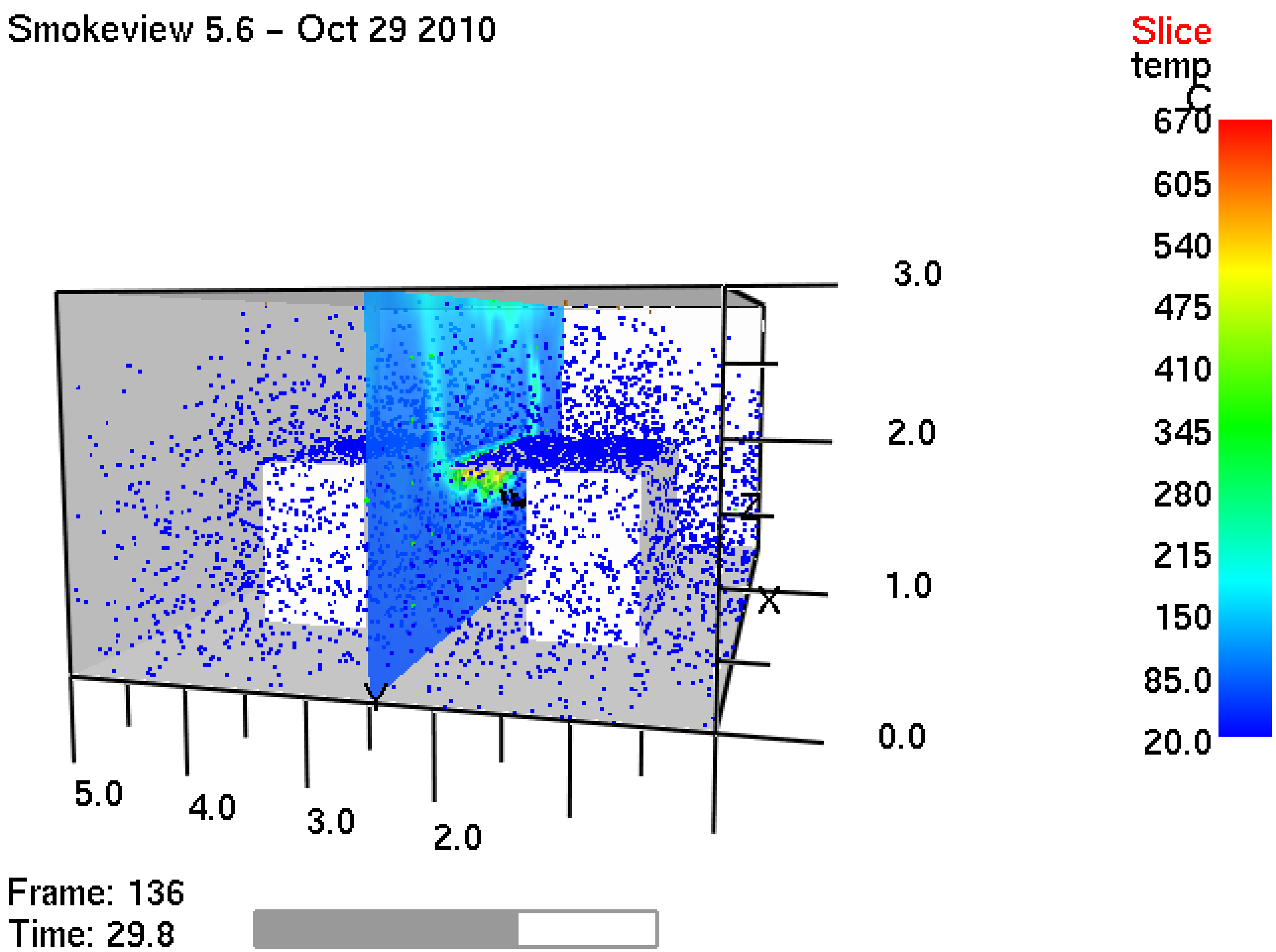


Smokeview 5.6 - Oct 29 2010
Slice
temp
C
670
605
540
475
410
345
280
215
150
85.0
20.0
3.0
2.0
1.0
0.0
Z
X
Y
5.0
4.0
3.0
2.0
Frame: 106
Time: 10.0

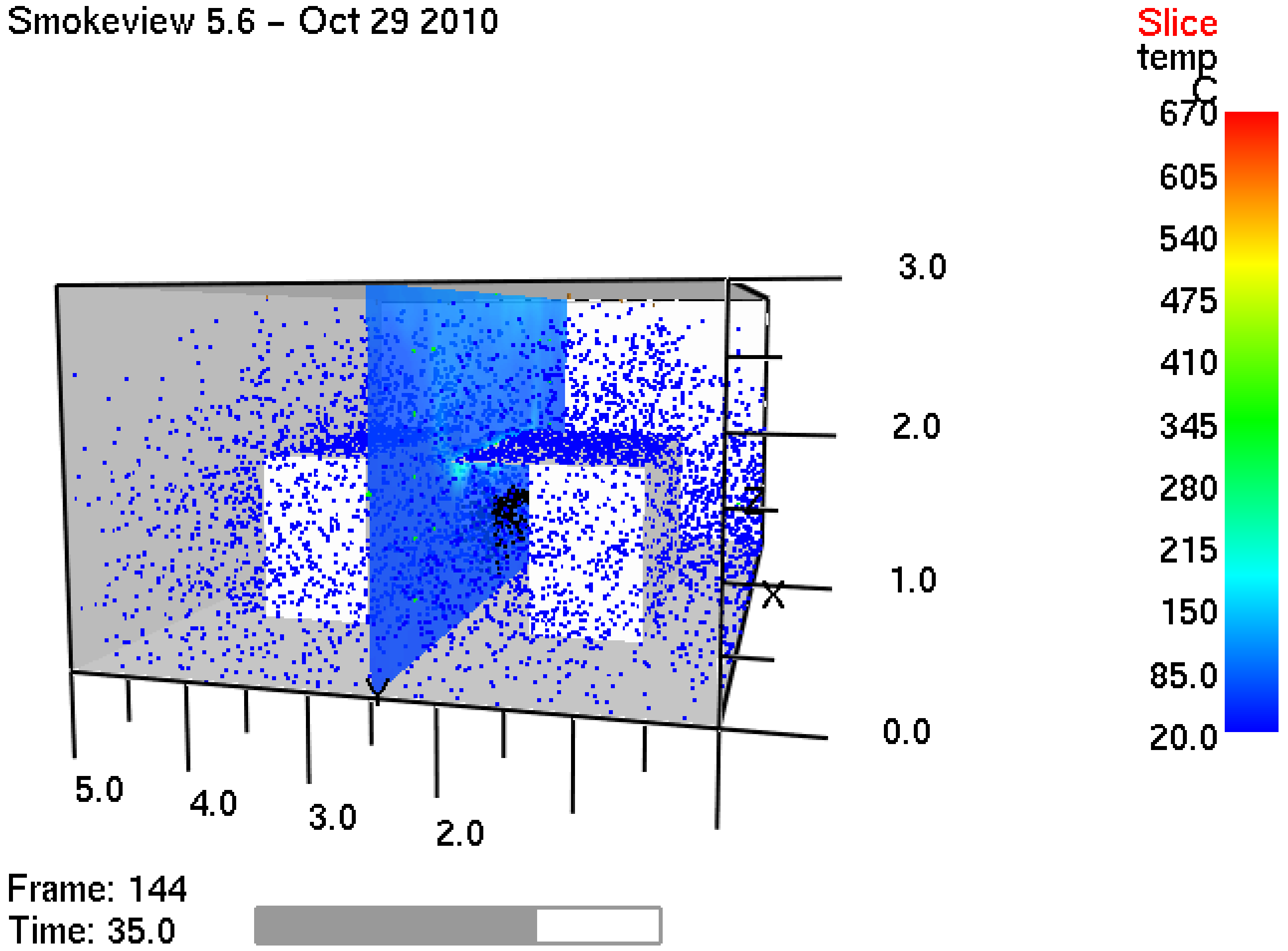
Time = 20 s


Smokeview 5.6 - Oct 29 2010
Slice
temp
C
670
605
540
475
410
345
280
215
150
85.0
20.0
3.0
2.0
1.0
0.0
5.0
4.0
3.0
2.0
Z
X
Frame: 122
Time: 20.5

Time = 30 s

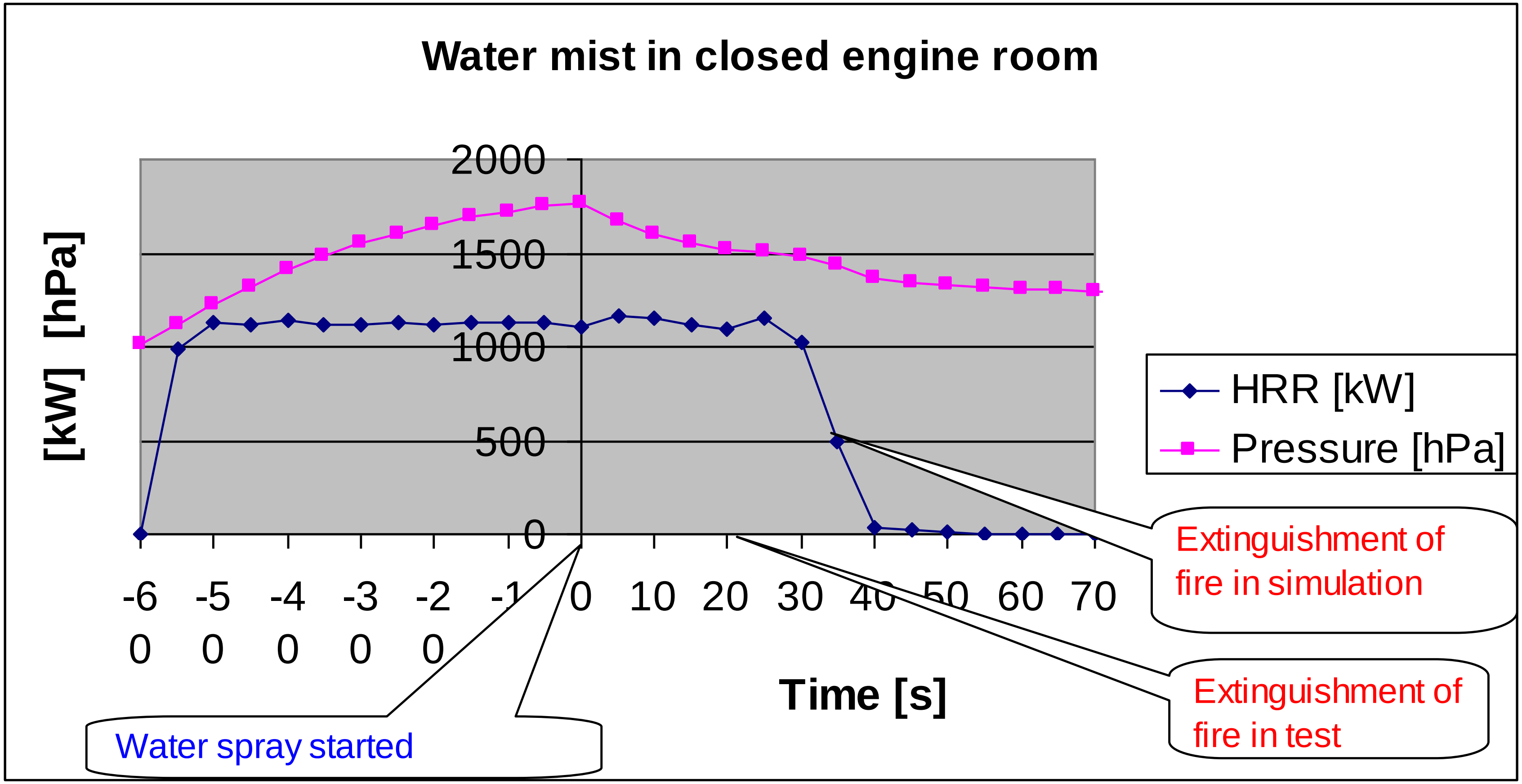

Smokeview 5.6 - Oct 29 2010
Slice
temp
C
670
605
540
475
410
345
280
215
150
85.0
20.0
3.0
2.0
1.0
0.0
5.0
4.0
3.0
2.0
Z
X
Frame: 136
Time: 29.8

Time = 35 s



Smokeview 5.6 – Oct 29 2010
Slice
temp
C
670
605
540
475
410
345
280
215
150
85.0
20.0
3.0
2.0
1.0
0.0
5.0
4.0
3.0
2.0
Frame: 144
Time: 35.0

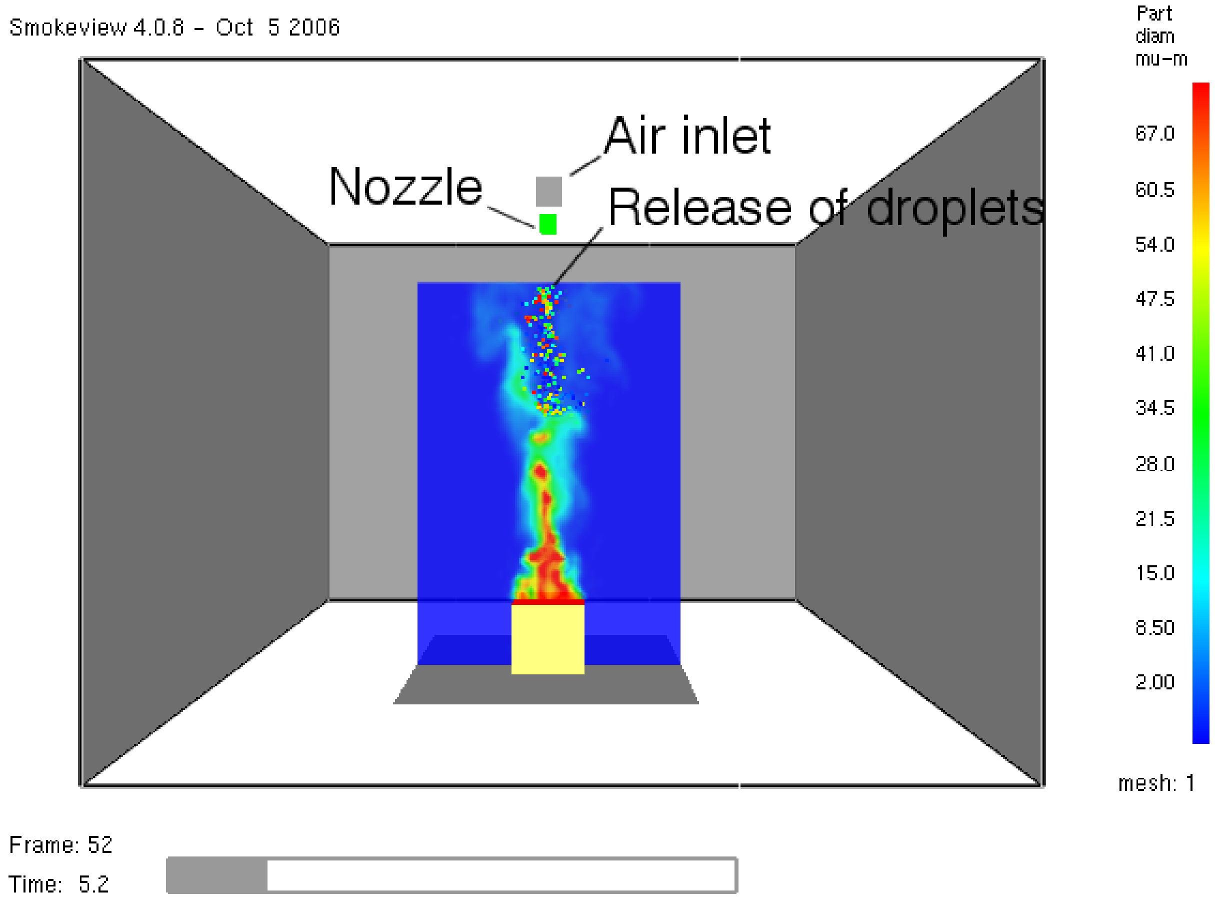
Results of simulation



Other work, references

- **E.A. Kolstad, B.P. Husted.** *"Effect of water mist and ventilation on engine room fire."* Interflam 2013, London 2013.
- **E.A. Kolstad.** Effect of Water Mist Suppression System in Engine Room: Case Study of Fire in The Cruise Liner MS Nordlys. Master thesis. University of Bergen. June 2014

Thank you



Smokeview 4.0.8 - Oct 5 2006
Air inlet
Nozzle
Release of droplets
Part
diam
mu-m
67.0
60.5
54.0
47.5
41.0
34.5
28.0
21.5
15.0
8.50
2.00
mesh: 1
Frame: 52
Time: 5.2