FDS SIMULATION OF THE COMBINED USE OF SPRINKLERS AND WATER MIST FIRE EXTINGUISHING SYSTEMS

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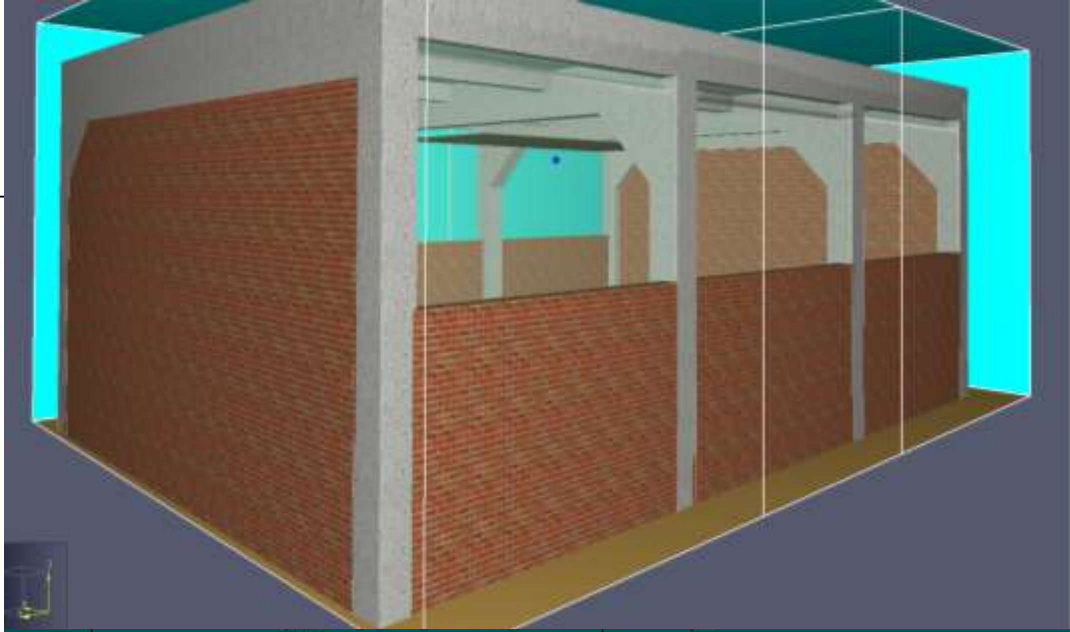
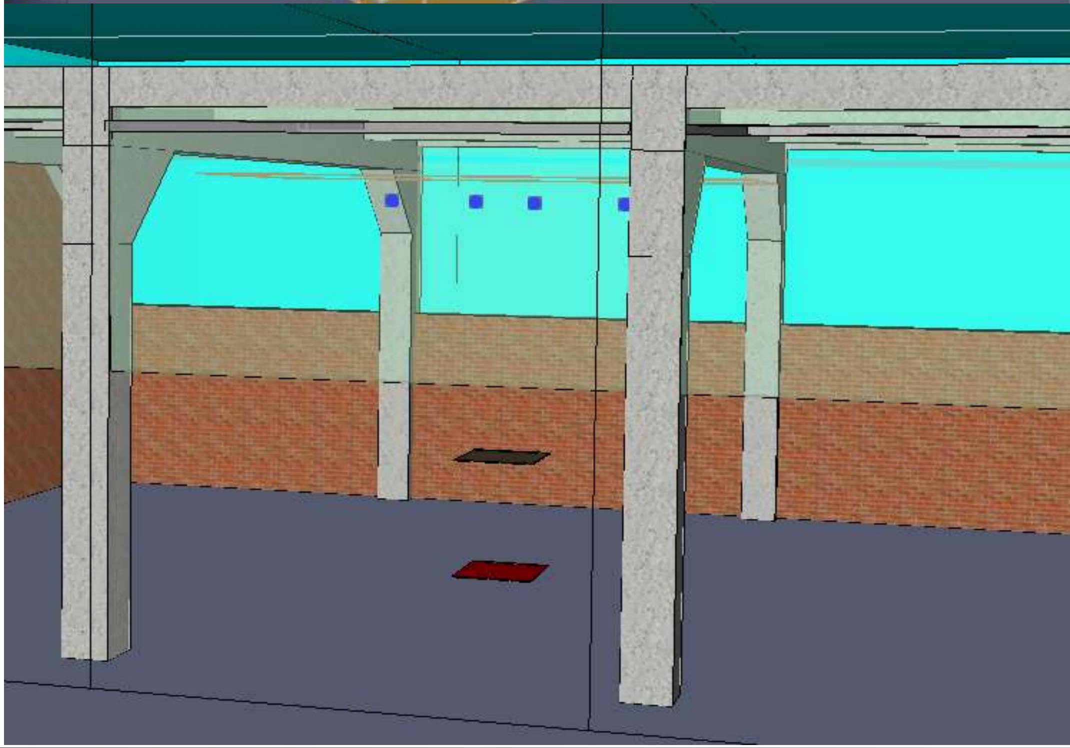
GOALS OF THE RESEARCH



- The purpose of this study is to investigate the effect of sprinkler water droplets with relatively large diameter on the movement of several orders of magnitude smaller water mist particles.

- The aim of the simulation is to analyze the flow field under a 1m x 1m shelf element with installation height of 1.5 m in the middle of the room, with and without n-heptane tray fire, using a combination of sprinklers and water mist extinguishing systems.

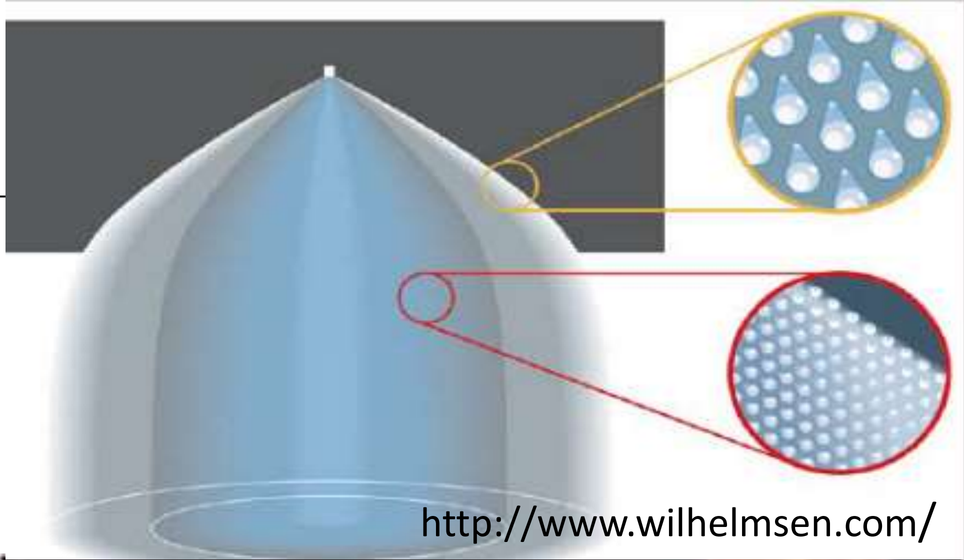


INTRODUCTION

- In fixed fire extinguishing systems, water is generally used in sprinklers and water mist in fire suppression equipment.
- Between the two methods, the most important differencies are:
  - the rate of flow,
  - the size of water droplets,
  - and the droplet size distribution.
- Standard sprinkler-sprays contain diameter droplets larger than 1 mm in high proportion.
- The water mist consists of fine droplets, where 99% of the droplets are less than 1mm. Due to the very fine dispersion, the water mist can exhibit gaseous-like behavior and superior mixing characteristics

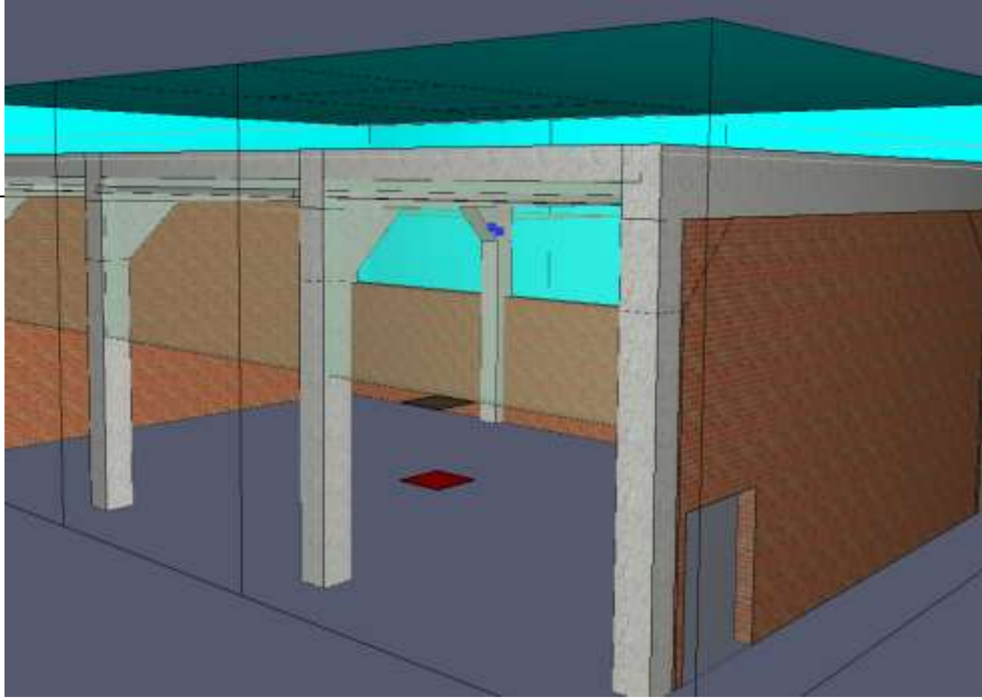
INTRODUCTION

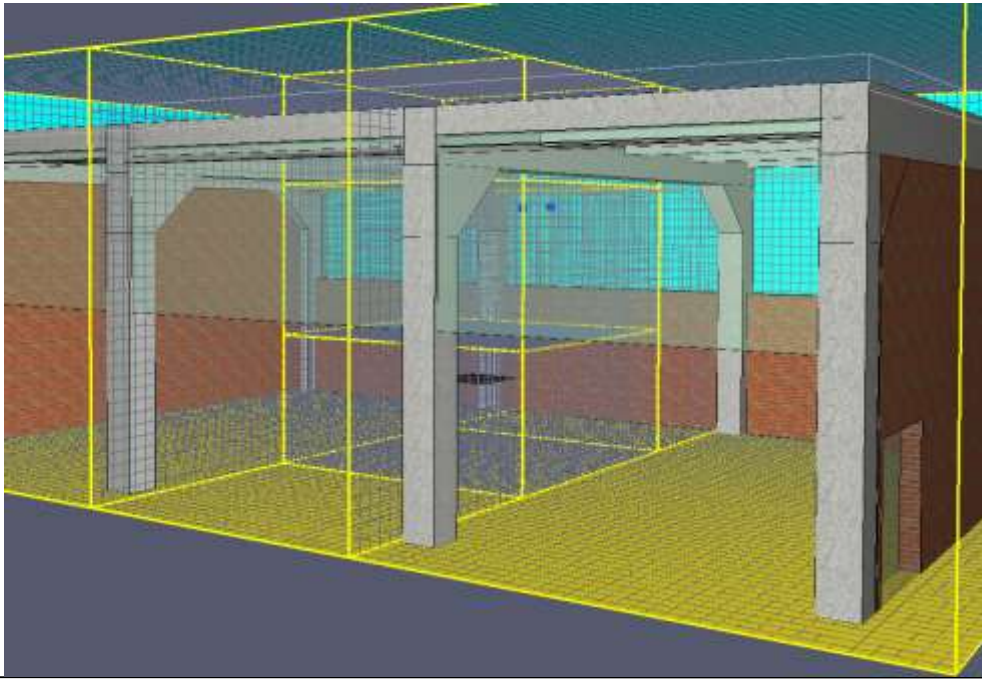
- In regard to the quantitative characterization of sprays, four factors are needed to properly characterize a water spray for fire suppression purposes.
  - drop size distribution (diameter and range),
  - spray flux density,
  - spray angle,
  - spray momentum.
- Water mist systems mainly work by flame extinguishing where the droplets evaporate, lowering the flame temperature.
- Very small droplets are rapidly decelerated, and may have difficulties in penetrating into the flame zone.



METHODS AND DISCUSSION

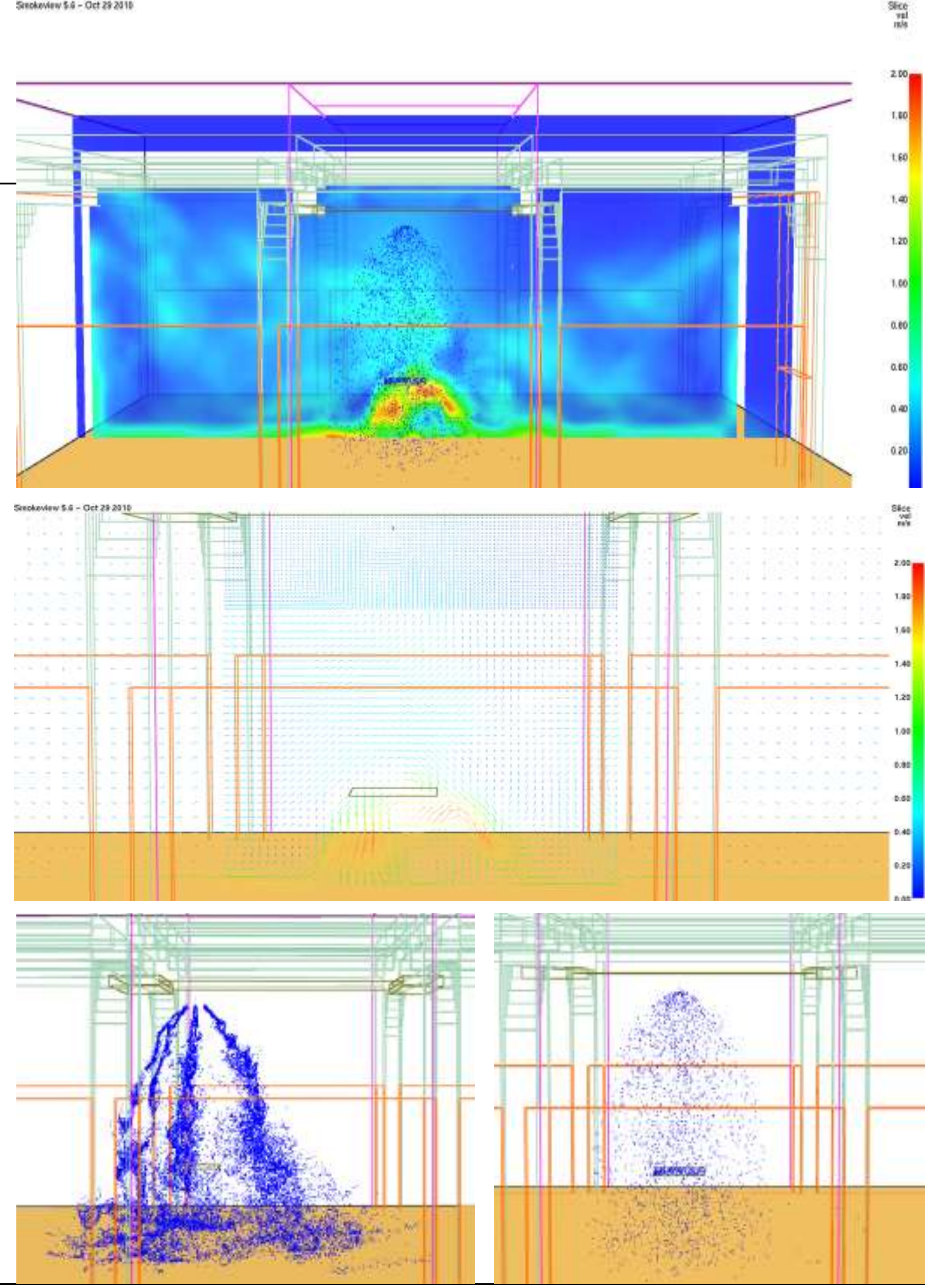
- We placed the computational domain in a 16.9m long, 10.1m wide and 5.1m high room.
- In simulation, a complex mesh was introduced. In the close neighborhood of the test domain, finer mesh, while farther, coarser mesh was applied. The space is divided into 7 grids.
- Each grid has a different density. Typically, cells of 20cm were applied in the field while, near the test domain, 10cmx 5cm cells were used. Close to the sprinklers, cells are column-shaped with a base of 10cmx10cm and height of 5cm.
- Total number of cells in the entire field is about 400 000.





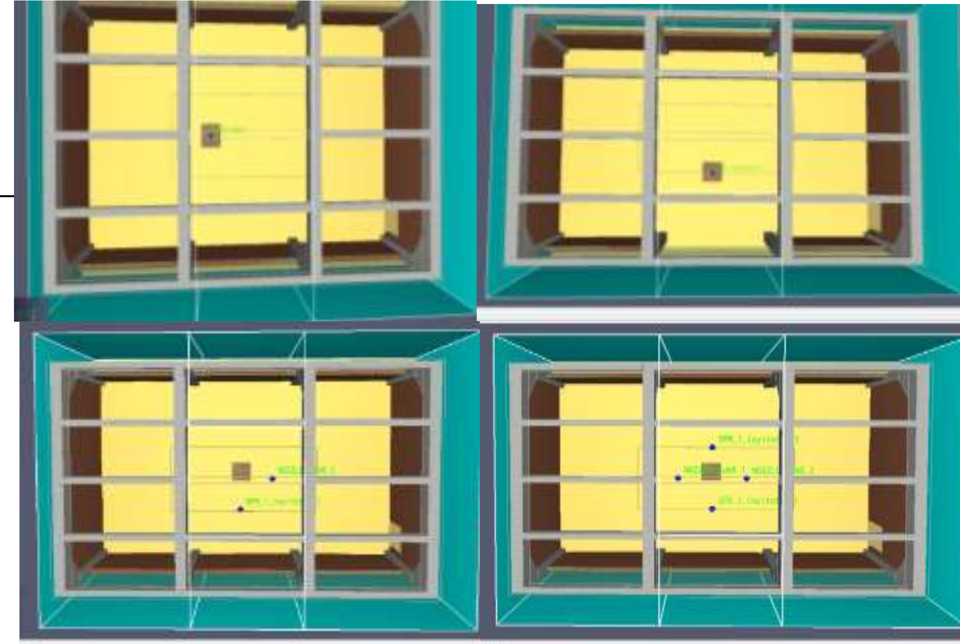
SIMULATIONS AND RESULTS

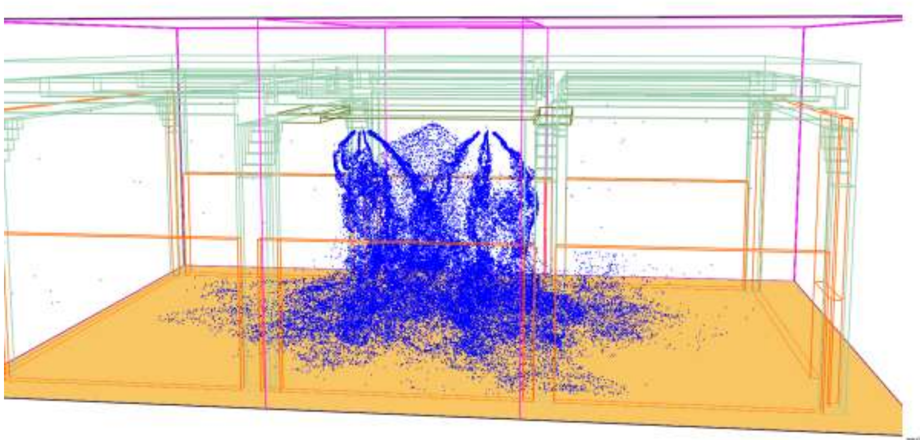
- A series of FDS runs was performed without fire, for the standard sprinkler system and high pressure water mist system. The runs were aimed at observing the effect of the combined use of sprinkler and water mist on the flow patterns.
- A series of FDS runs was performed for the standard sprinkler system and high pressure water mist system against a 2.4 MW Heptane tray fire scenario.
- A series of FDS runs was performed for the standard sprinkler system and high pressure water mist system with parallel operation against a 2.4 MW Heptane tray fire scenario.

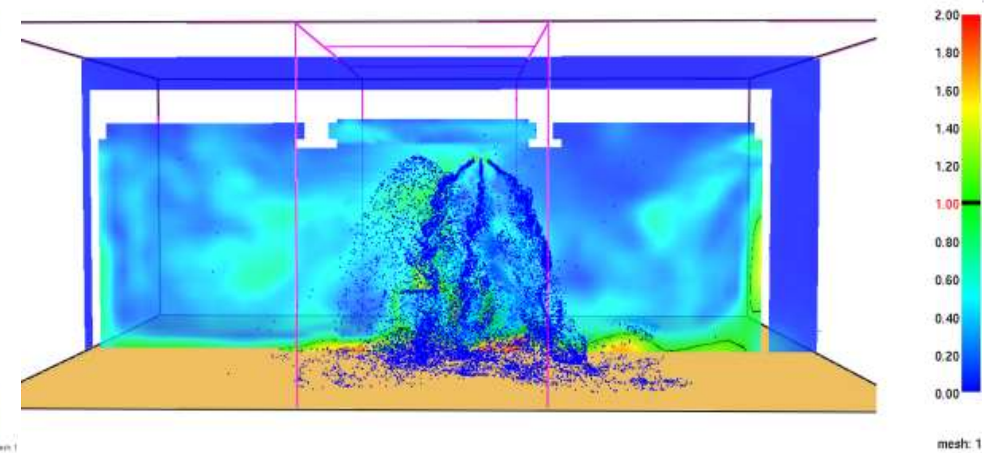


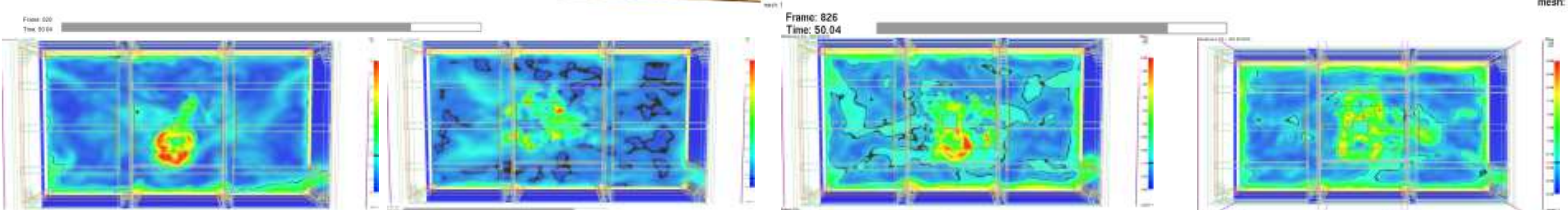
BEHAVIOR WITHOUT FIRE

- In this arrangement, a sprinkler and a water mist head was placed over the shelf element.
- Inserting more number of heads in the model results a quicker growing velocity field and more balanced velocity under the tray.



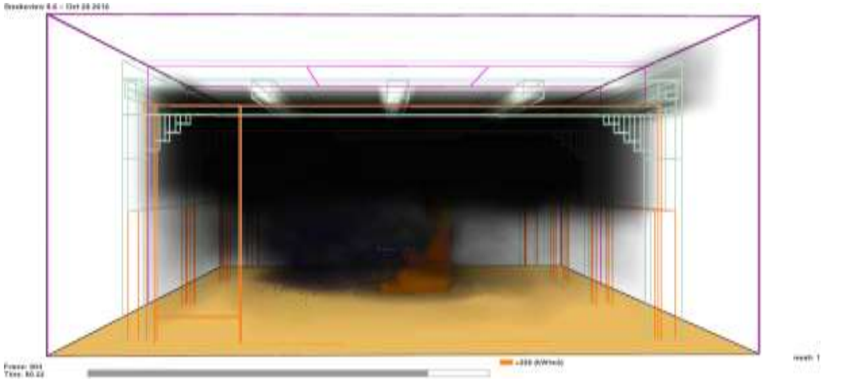




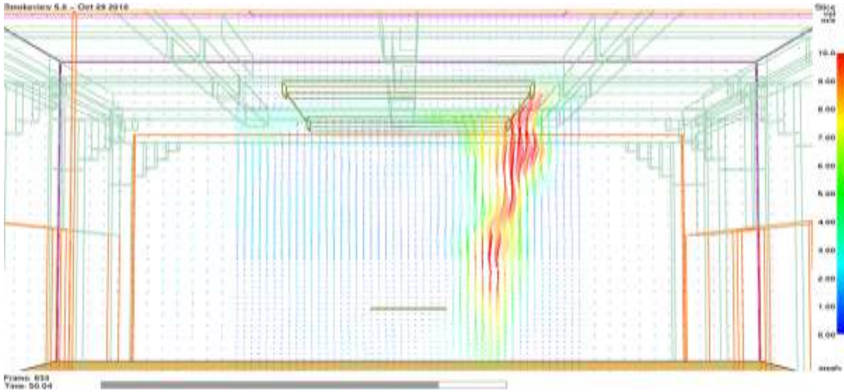


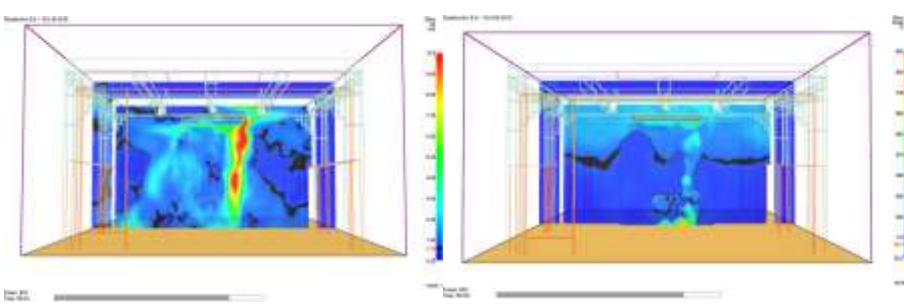
TRAY FIRE BEHAVIOR WITH FULL VOLUME FLOW RATES CASE 1: B.VK0.SP1.T1

- Test plane is in the common axis of the fire and the sprinkler. Analyzing the scalar field and vector space, we can state that plume emerging from fire under the tray generates an up-current of 10m/s while droplets escaping from sprinkler head move with a velocity of 0.5-0.6m/s near the fire center. Sprinkler droplets change the shape of the plume. It can be seen that the plume escapes from beneath the tray on the side being farther from the sprinkler. The plume and impulse forces generated by sprinkler droplets form a turbulent area under the tray.
- Due to the intensive water spread, the ambient temperature is 80°C in the area under the tray.

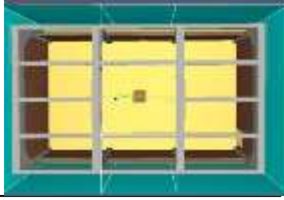


water mist flow pattern, smoke propagation

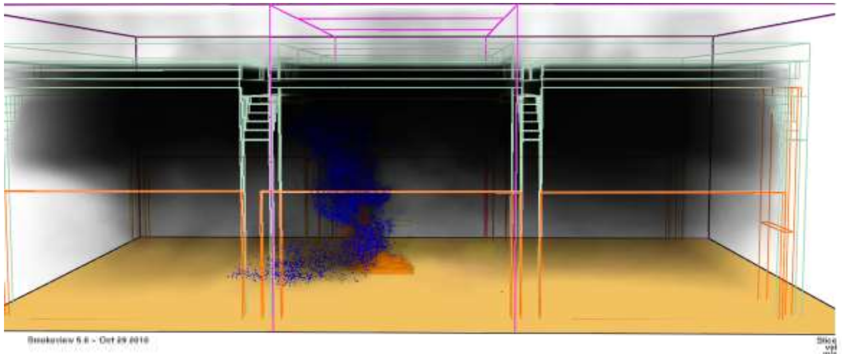




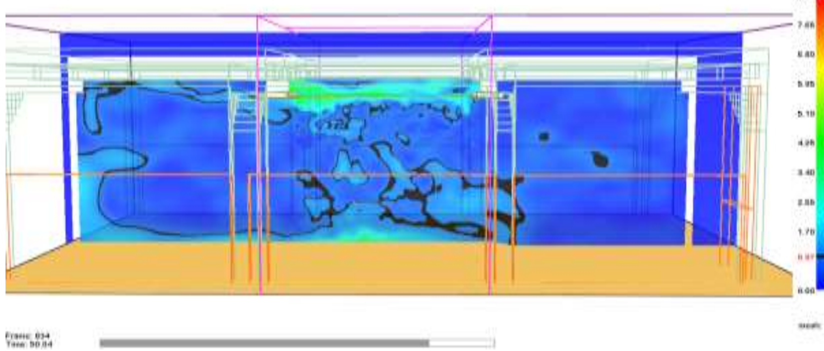
TRAY FIRE BEHAVIOR WITH FULL VOLUME FLOW RATES CASE 2: B.VK1.SP0.T1



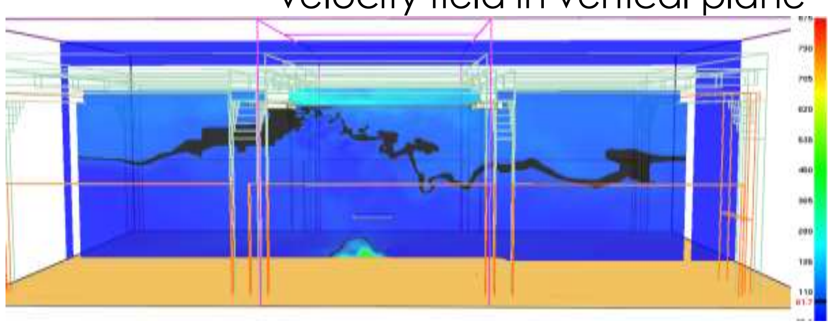
- In this arrangement, one water mist head is placed at 1.5 m from the axis of the shelf element, and the head was started 5 s after lighting the fire
- Test plane is in the common axis of the fire and the water mist head. Analyzing the scalar field and vector space, we can state that plume emerging from the fire under the tray generates an buoyancy of 8.5 m/s but the classic buoyancy plume is not generated. The plume and impulse forces generated by water mist build up a turbulent area under the tray.
- The temperature is about 350 °C locally near the fire. Due to the water mist, the ambient temperature is below 80 °C in the area under the tray.



water mist flow pattern, smoke propagation

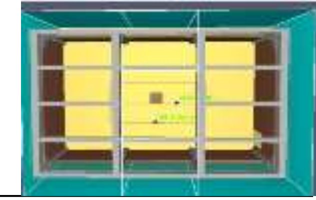


velocity field in vertical plane

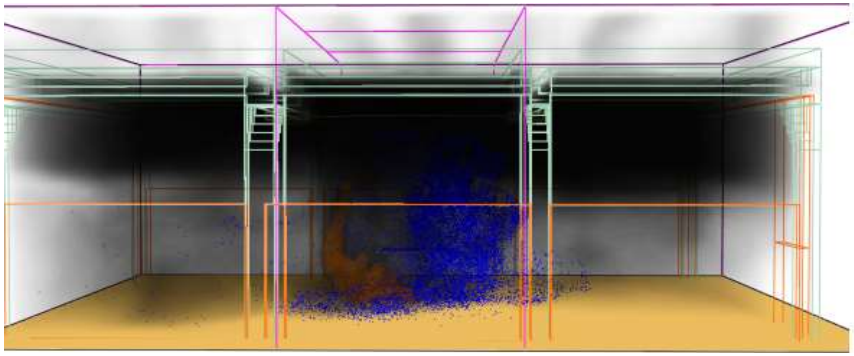


temperature field in vertical plane

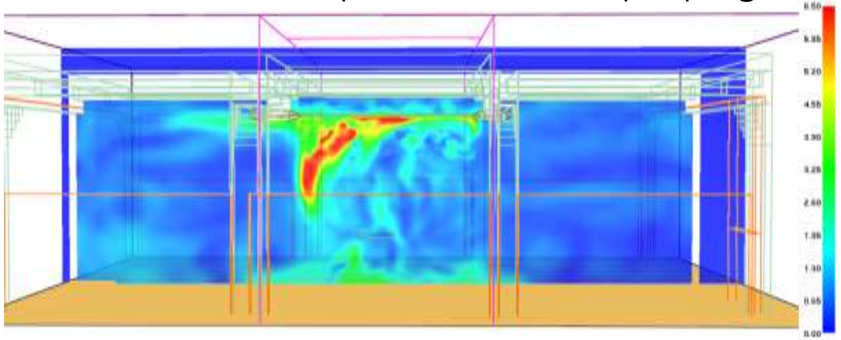
TRAY FIRE BEHAVIOR WITH FULL VOLUME FLOW RATES CASE 3: B.VK1.SP1.T1



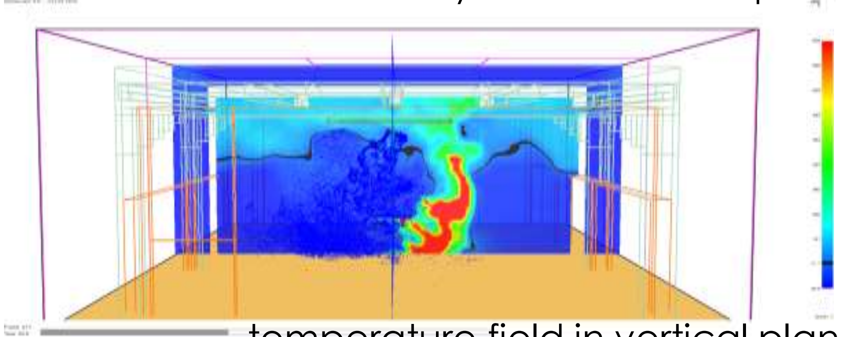
- In this arrangement, one water mist head is placed at 1.5 m from the axis of the shelf element, and the head was started 5s after lighting the fire
- Test plane is in the common axis of the fire and the water mist head. Analyzing the scalar field and vector space, we can state that plume emerging from fire under the tray generates an up-current of 8.5m/s but the classic buoyancy plume is not generated. The plume and impulse forces generated by water mist build up a turbulent area under the tray.
- The temperature is about 350°C locally near the fire. Due to the water mist, the ambient temperature is below 80°C in the area under the tray.



water mist flow pattern, smoke propagation

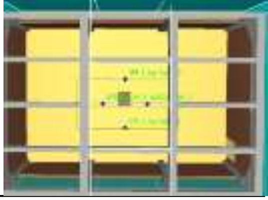


velocity field in vertical plane

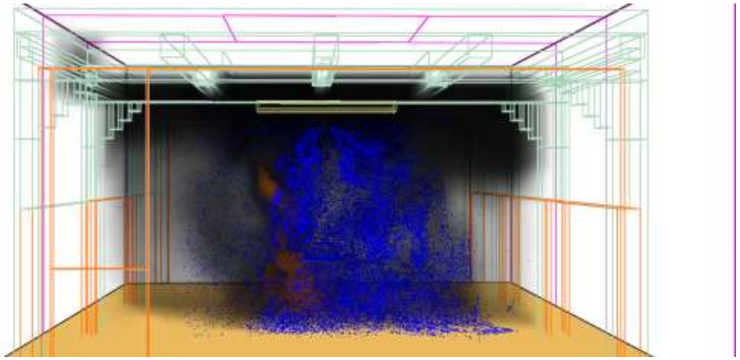


temperature field in vertical plane

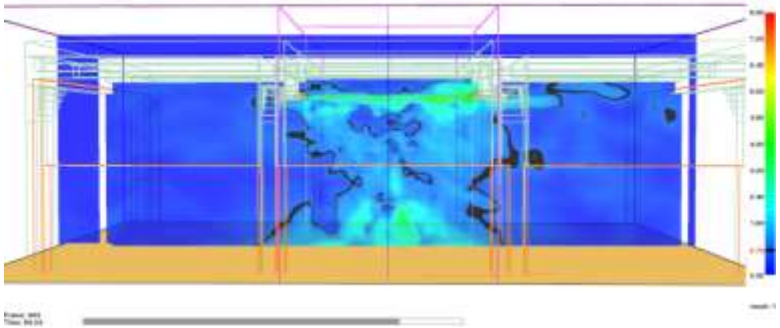
TRAY FIRE BEHAVIOR WITH FULL VOLUME FLOW RATES B.VK2.SP2.T1



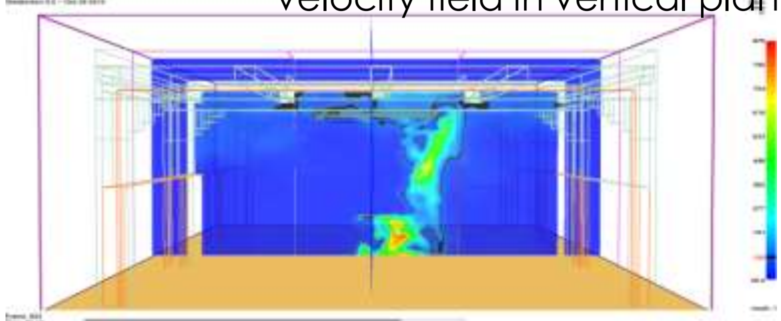
- In this arrangement, two sprinklers and two water mist heads are placed, each at 1.5m from the axis of the shelf element, and the heads were started 5s after initiating the fire.
- Test plane is in the common axis of the fire and the water mist head.
- Plume emerging from fire under the tray generates a buoyancy of 8.0 m/s. The plume and impulse forces generated by water mist build up a turbulent area under the tray.
- The temperature is about 350 °C locally near the fire. Due to the water mist, the ambient temperature is below 80 °C in the area under the tray (farther from the plume).



water mist flow pattern, smoke propagation



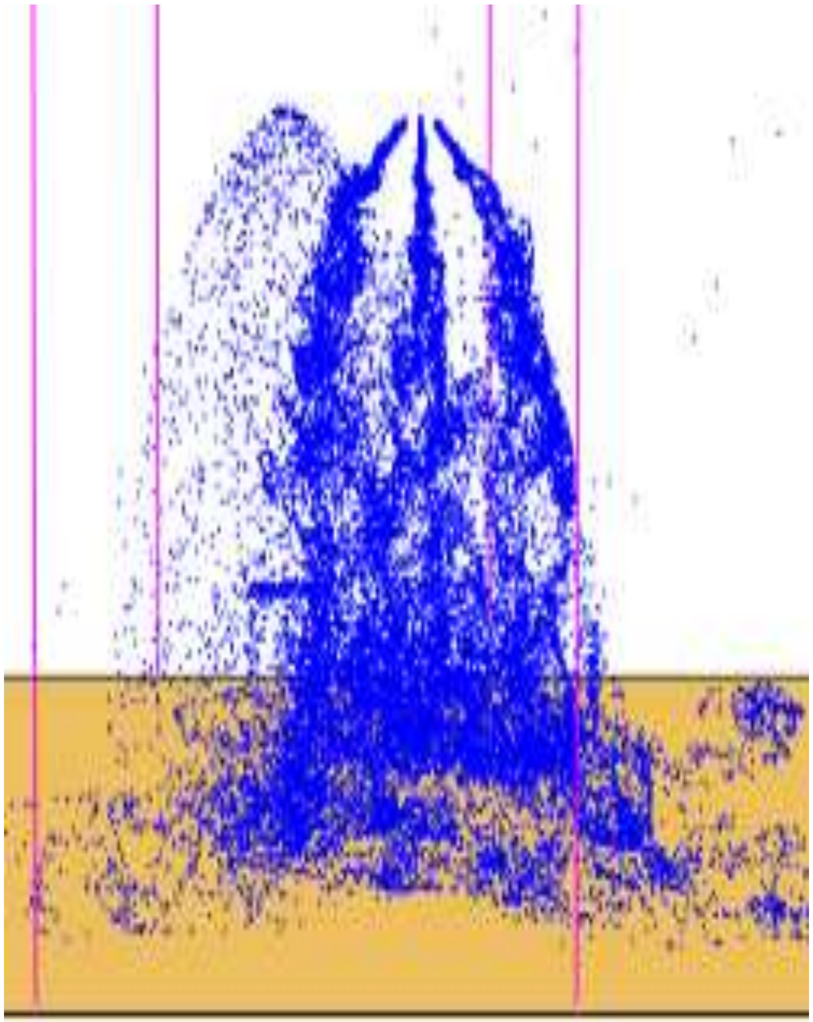
velocity field in vertical plane



temperature field in vertical plane

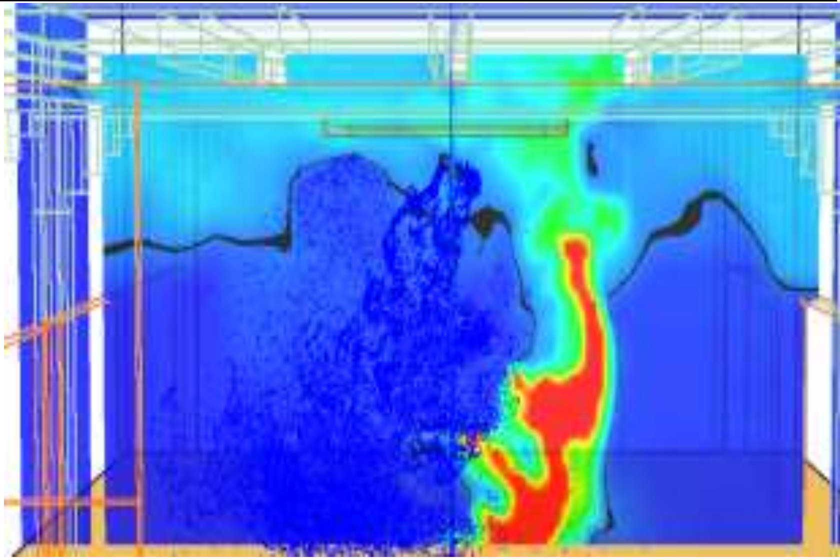
CONCLUSIONS

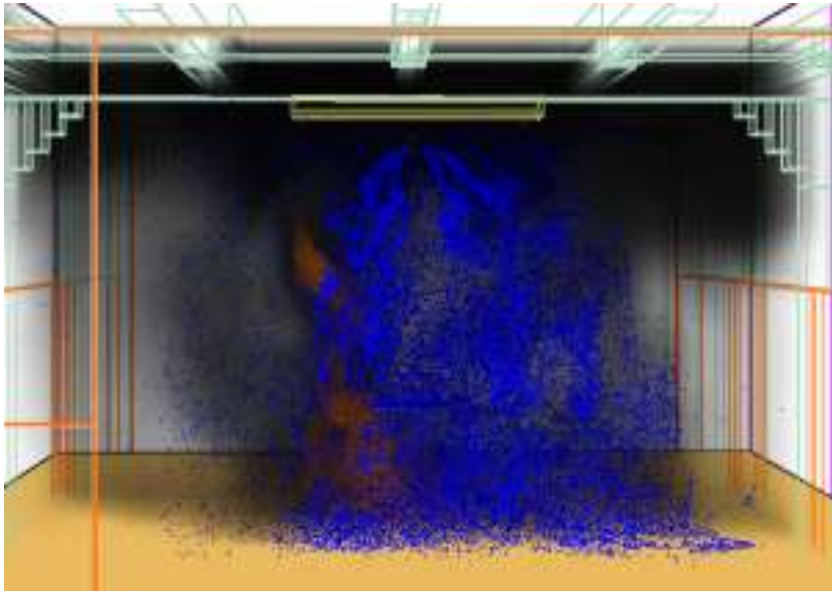
- The plume generated by the fire significantly modifies the water mist field. Droplets up to 30μm, existing in form of precipitation, are deflected from their trajectories by the up-current generated by the plume moving with 5-6 m/s. Plumes of fires of 2-3 MW deflect small droplets from the core of flame, thus, they cannot reach the center of the fire. In the case of sprinklers with average droplet sizes of 500 μm, this effect can be observed less.
- In the asymmetric test models both with sprinkler and water mist, plume trajectory was deflected to the opposite direction. Advisably, in measurement configuration, heads shall symmetrically circle the core of flame both in the model with sprinkler alone and water mist alone.



CONCLUSIONS

- While increasing number of sprinklers and water mist heads (meaning more quantity of fire-fighting water), decreasing ambient temperature can be observed near the flame core, plume and tray being investigated. Near the sprinklers and water mist heads, significant temperature drop can be seen.
- Impulse force of sprinklers deflects smoke accumulated on the ceiling to the occupational zone more effectively. When sprinklers and water mist heads work together, this smoke deflecting effect is somewhat smaller. This simulation result shall be investigated with introduction of additional test planes. Examination shall be extended to analysis of the extinction coefficient.





CONCLUSIONS

- When water mist and sprinkler worked together, impulse force generated by the mass of sprinkler droplets forced also water mist droplets to move closer to center of fire.
- The previous simulation result opens up a new examination arrangement: when placing sprinkler and water mist heads next to each other, the effect described above might be enhanced.
- As the Lagrangian model does not model agglutination of droplets, this test result shall be examined by real measurements.