Fire Protection for Light Structure High Rise Buildings

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Case Study Clock Tower in Mecca

- King Abdul-Aziz of Saudi Arabia aimed to build the world’s tallest and largest clock tower next to the Holy Mosque in Mecca
- Adoption of Big Ben to Arabic design
- New world landmark setting Islam’s centre of time
Case Study Clock Tower in Mecca

Some Facts
- Overall building floor area is 1,4 million m² in 95 floors with an overall height of 600 m
- Clock faces have 30 m diameter, thus 5 times Big Ben in London
- The clock tower building houses a luxury hotel, an astronomy museum, a lunar observation centre and prayer rooms
- 8 years construction time with completion in 2011
- 3 billion USD investment
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Protection of the Clock Tower

- The upper 210 m of the clock tower is made of a light weight steel construction with compound cladding

- A conventional sprinkler system could not be used due to weight restrictions (water storage / pipework)

Development of an innovative fire protection concept based on high pressure water mist technology
Fire Protection Concept

- Protection concept based on a wet high pressure water mist system for all floor areas and a deluge system behind the clock areas
- System design based on CEA 4001 OH4 with 360 m² operational area for the wet system and 60 minutes operation time
- Integration of water mist wall hydrants for manual intervention
- Challenge due to ceiling height up to 12 m in the astronomy museum areas

► Development and execution of fire tests for heights up to 12 m with a fire laboratory and fire consultants (CNPP and DAR)
System Testing and Acceptance Process

- Full scale fire test scenario was developed based on NFPA 750 and CEN TS 14972 standards

- Fire tests were defined based on public spaces test of IMO A800 concerning
  - Fire load
  - Arrangement of fire load
  - Ventilation conditions
Fire Tests for Large Ceiling Height

Fire Test Arrangement and Scenarios

- Test hall of 30 m x 20 m floor area with 24 m height
- Open ceiling at 12 m height
- Natural ventilation conditions / no enclosure effect
- Fire tests under one and between four nozzles
- Automatic glass bulb water mist nozzles
- Fire test duration 30 minutes
Fire Tests for Large Ceiling Height

Fire Load

- Fuel package adapted from IMO A800 with 2 groups of 4 sofas each made of polyether foam
- One sofa group used as ignition source, one as target
- 50 cl Heptane as igniter, being placed under the centre sofa
Fire Tests for Large Ceiling Height

Evaluation Criteria

- Temperature reduction at ceiling and in the vicinity of the fire
- Reduction of heat radiation
- Fire control and suppression to avoid fire propagation to the target sofa group
Fire Tests for Large Ceiling Height

Measurements
- Temperature at sofas (T1.1 to T1.4 and T2.1 to T2.4)
- Ambient temperature at 1,5 m Height above floor (TA1 to TA6)
- Heat flux
Fire Tests for Large Ceiling Height

Fire Test Results under 4 Nozzles
- Activation of 4 nozzles within 2 min 50 sec
- Rapid temperature and heat radiation reduction
- Fire is controlled / No propagation to target sofas
Fire Tests for Large Ceiling Height

- **T=0s**: Start of fire test
- **T=1min**: Ignition of the heptane pan
- **T=2min**: Propagation on mattress surface
- **T=2min15s**: Flames height: 2m
- **T=3min**: Fire spreading on the top of mattress
- **T=3min44s**: 1st nozzle operates
- **T=4min**: Remaining flames at floor level
- **T=5min53s**: Flames height: 3m
- **T=6min**: 2nd nozzle operates
- **T=8min**: 3rd nozzle operates
- **T=9min**: HRR is increasing rapidly
- **T=10min**: Operation of first nozzle. Right hand mattress stats to pyrolyse.
- **T=12min**: 2nd nozzle operates
- **T=14min**: Operation of second nozzle
- **T=16min**: 3rd nozzle operates
- **T=18min**: 4th nozzle operates. Water mist reaches floor level
- **T=20min**: Fire control with slight suppression
- **T=22min**: Remaining small flames
- **T=24min**: No more flames
- **T=26min**: End of test

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Fire Tests for Large Ceiling Height

Test 2

Ceiling temperatures

Heat fluxes

Ambient temperatures between source and target groups

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Fire Tests for Large Ceiling Height

Fire Test Results under 1 Nozzle
- Activation of 3 nozzles within 2 min 50 sec
- Rapid temperature and heat radiation reduction
- Fire is controlled / No propagation to target sofas
Fire Tests for Large Ceiling Height

- T0: Ignition of the heptane pan
- T0+1 min: Start of propagation on mattress surface
- T0+2 min 05 s: Flames height 2m
- T0+2 min 30 s: Start of pyrolysis
- T0+2 min 08 s: Fire is spreading on the top of ignition mattress. Flames are about 2m height.
- T0+2 min 30 s: HRR is increasing rapidly. Right hand mattress starts to pyrolyse (red arrow)
- T0+3 min: Operation of the first nozzle.
- T0+3 min: Water mist reaches floor level
- T0+4 min 17 s: Start of fire control. Remaining flames at floor level
- T0+4 min 31 s: Remaining flames at floor level
- T0+5 min: Water mist is shut off
- T0+6 min 39 s: End of test
Fire Tests for Large Ceiling Height
Conference in Prague

Fire Tests for Large Ceiling Height

Reference free-burn test without water mist
Protection Concept

- Nozzle layout based on sprinkler alternative fire test results up to 5 m ceiling height
- For ceiling heights up to 12 m specific fire tests have determined the nozzle layout
- Safety concept foresees 2 and 4 risers with ring mains at each floor
- Small bore stainless steel pipework can ideally be integrated into the open ceiling structures
- All nozzles will be supplied by one centralised pump unit
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Typical nozzle arrangement
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Protection Concept

- Wet system in all floor areas with ca. 2400 glass bulb activated nozzles

- Protection of behind clock areas with ca. 300 open nozzles, activated by separate linear heat detection system

- 83 water mist wall hydrants at all levels for manual intervention

- Pump unit with 14+1 x 98 l/min at 140 bar
Conclusion

High pressure water mist allows for hydrostatically tolerant and architecturally pleasant solutions for high rise buildings

System design must be integrated in the overall fire safety concept of the building and be evaluated by authorities having jurisdiction
Thank you for your attention