

# **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

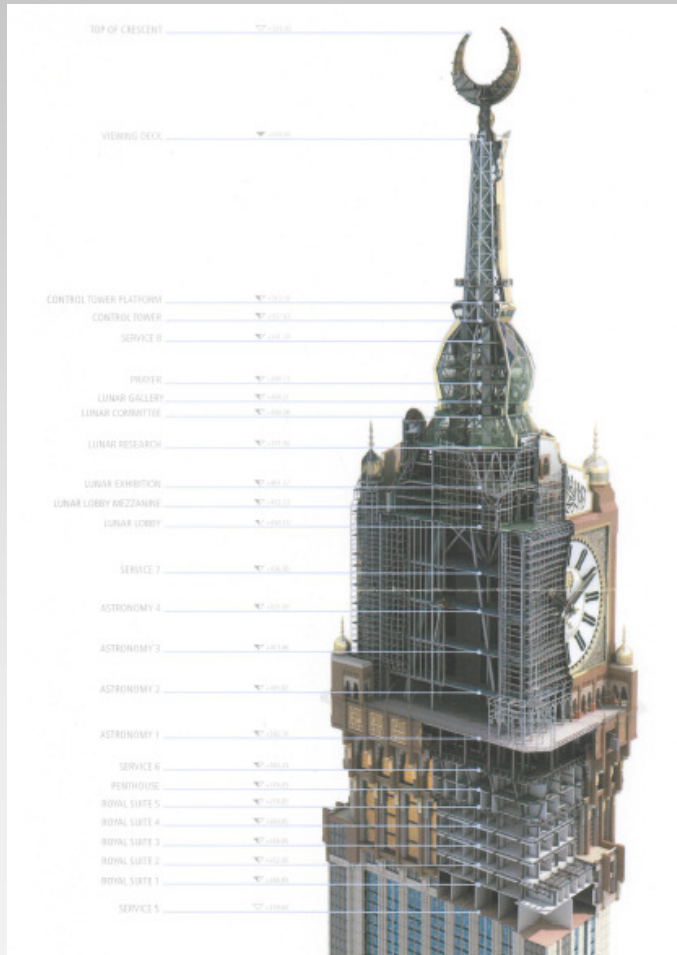
## Case Study Clock Tower in Mecca



### Some Facts

- Overall building floor area is 1,4 million m<sup>2</sup> 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

## Case Study Clock Tower in Mecca



### Protection of the Clock Tower

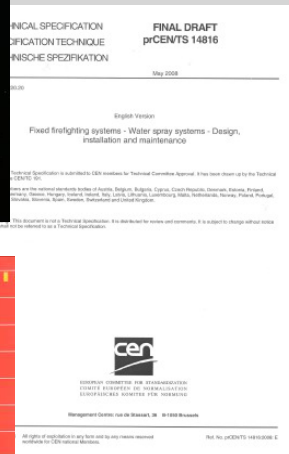
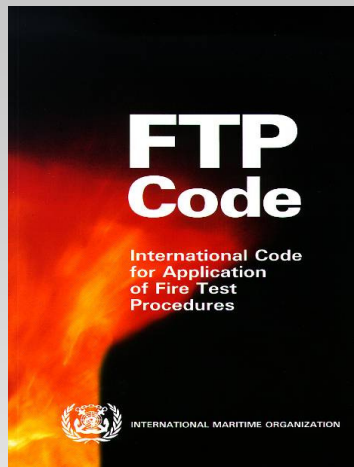
- The upper 210 m of the clock tower is made of a light weight steel construction with compound cladding
- A conventional sprinkler system could not be used due to weight restrictions (water storage / pipework)

➔ 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 m<sup>2</sup> 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



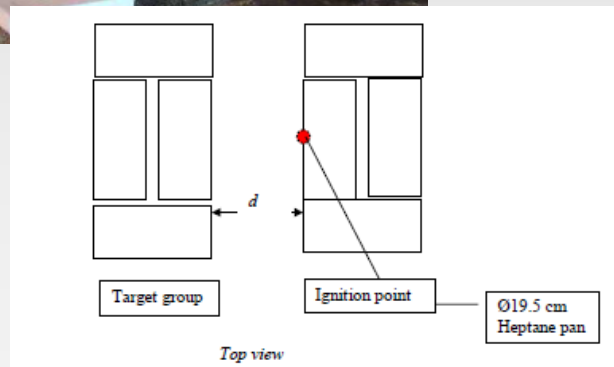
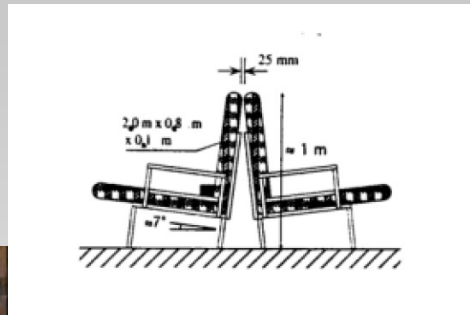
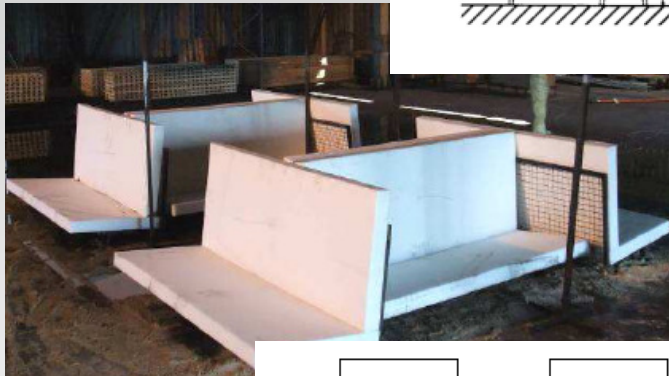
## **Fire Tests for Large Ceiling Height**



### **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

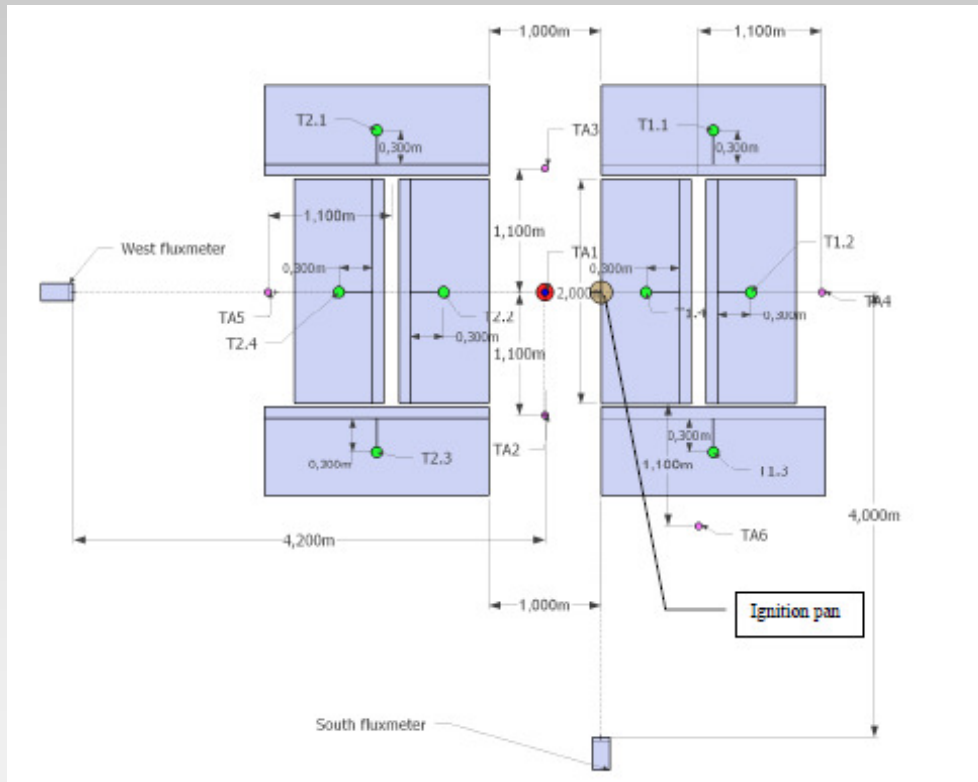


# **Fire Tests for Large Ceiling Height**

## **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**

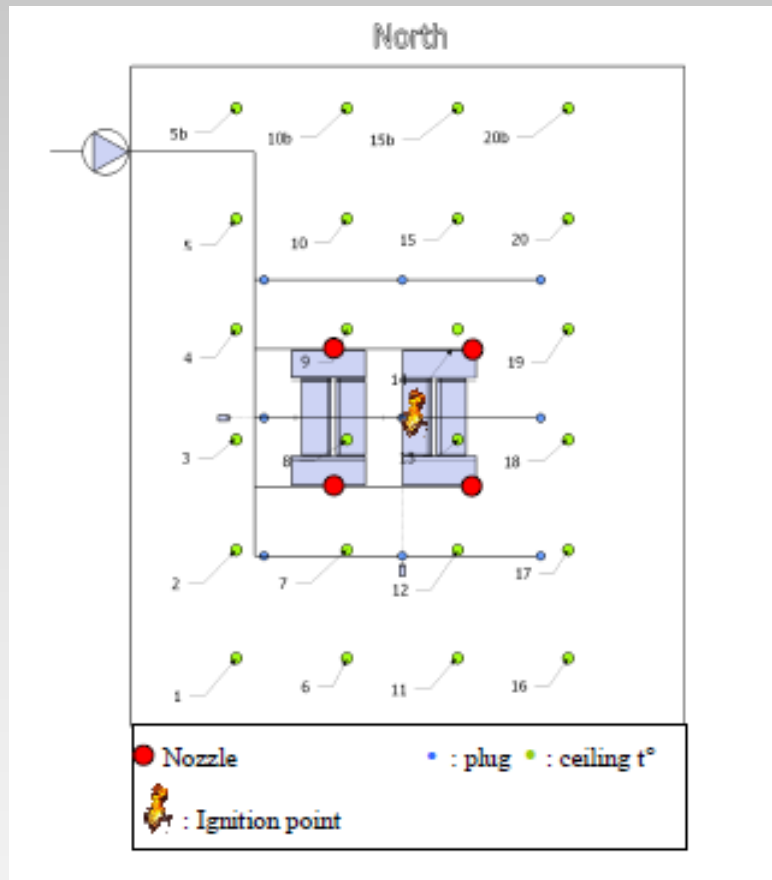
## Fire Tests for Large Ceiling Height



### 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



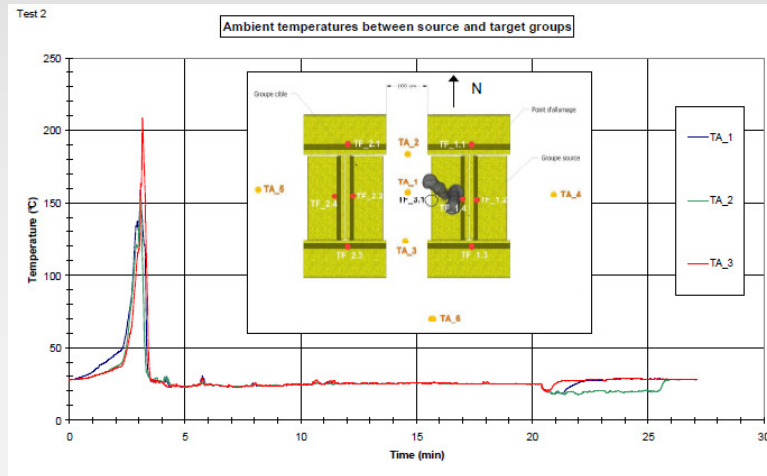
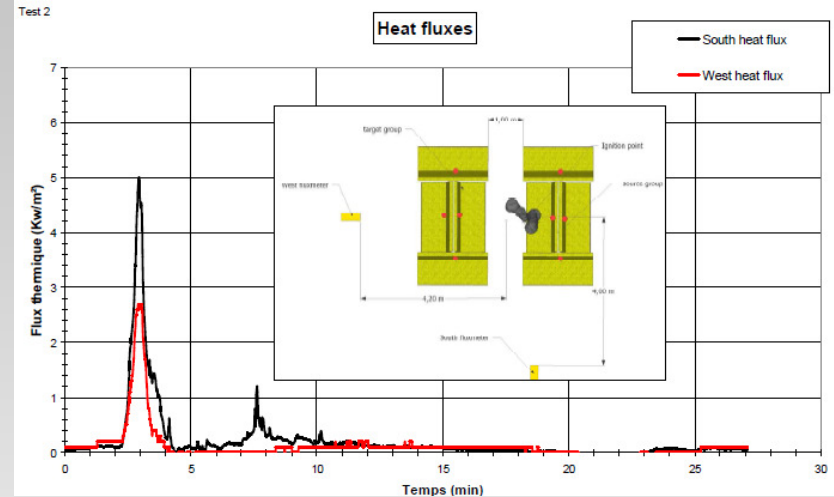
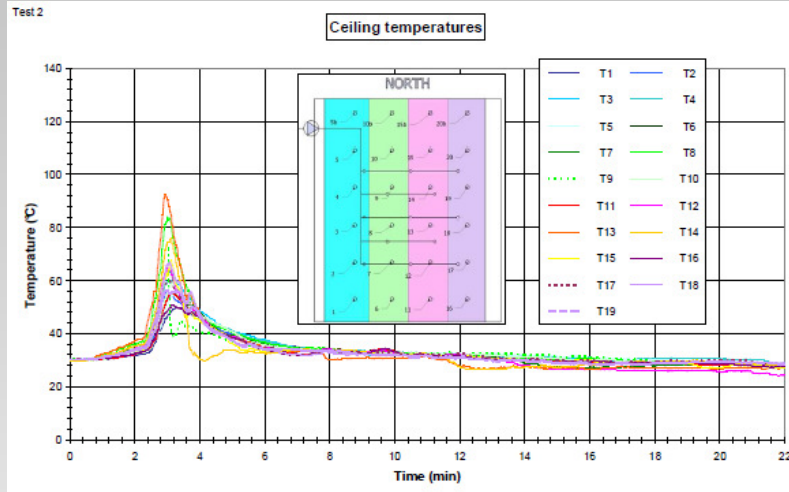
### Fire Test Results under 4 Nozzles

- Activation of 4 nozzles within 2 min 50 sec
- Rapid temperature and heat radiation reduction
- Fire is controlled / No propagation to target sofas

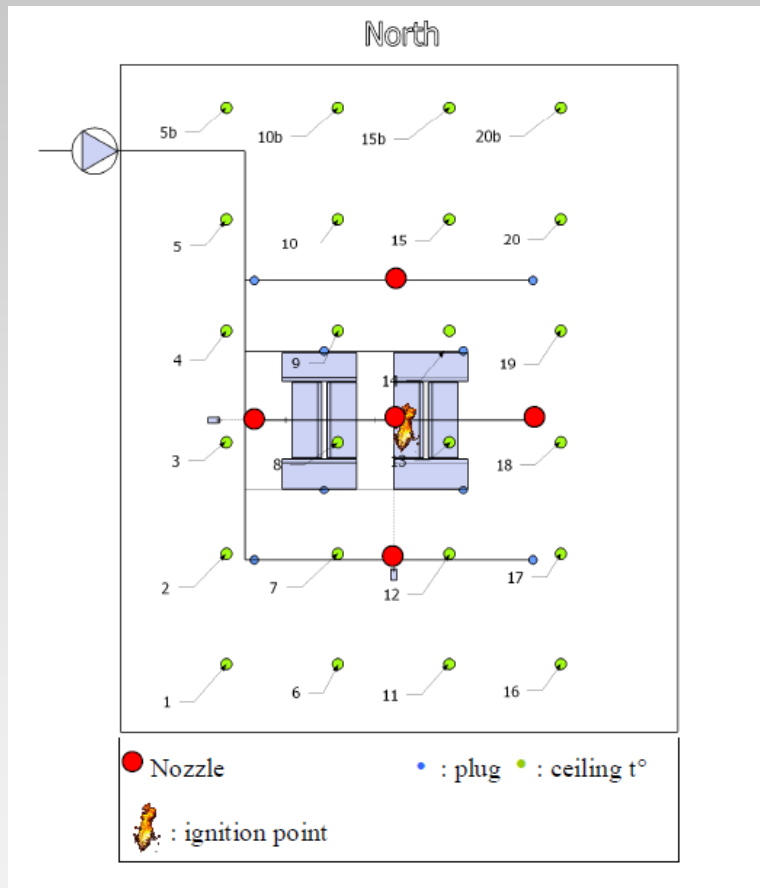
## Fire Tests for Large Ceiling Height

 <p>t=0s Start of fire test</p>	 <p>t=1min</p>	 <p>t=3min53s Remaining flames at floor level</p>	 <p>t=4min</p>
T0 : ignition of the heptane pan	T0+1 min: propagation on mattress surface	T0+3 min 53 s	T0+4 min: mattresses continue to burn slowly
 <p>t=2min</p>	 <p>t=2min15s Flames height : 2m</p>	 <p>t=6min</p>	 <p>t=10min</p>
T0+2 min: fire is spreading on the top of ignition mattress.	T0+2 min 15 s: HRR is increasing rapidly	T0+6 min	T0+10 min
 <p>t=2min44s 1st nozzle operates</p>	 <p>t=3min07s</p>	 <p>t=16min Remaining small flames</p>	 <p>t=18min20s no more flames</p>
T0+2 min 44 s: operation of first nozzle. Right hand mattress starts to pyrolyse. T0+ 2 min 45 s: 2 <sup>nd</sup> nozzle operates T0+2 min 48 s: 3 <sup>rd</sup> nozzle operates	T0+2 min 51 s: 4 <sup>th</sup> nozzle operates. Water mist reaches floor level T0+3 min 07 s: fire control with slight suppression.	T0+16 min	T0+18 min 20 s: no more flames. End of test

## Fire Tests for Large Ceiling Height



## Fire Tests for Large Ceiling Height












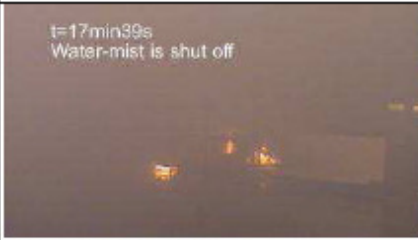


### Fire Test Results under 1 Nozzle

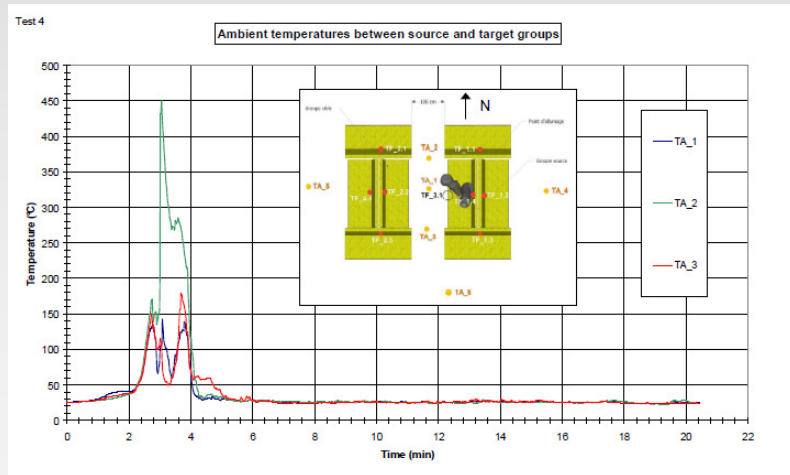
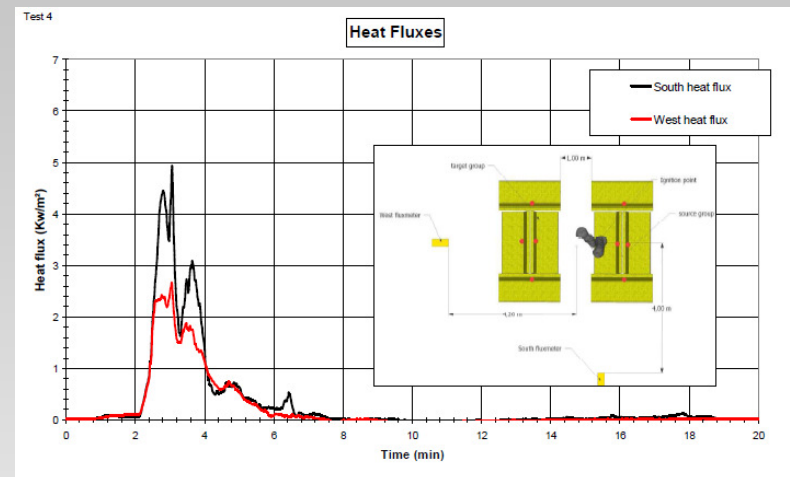
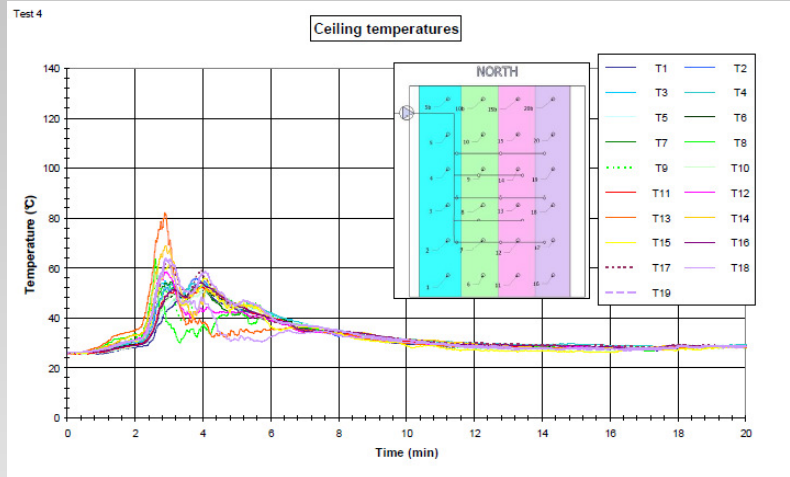
- Activation of 3 nozzles within 2 min 50 sec
- Rapid temperature and heat radiation reduction
- Fire is controlled / No propagation to target sofas



## Fire Tests for Large Ceiling Height

<p>t=0s Start of fire test</p>  <p>T0 : ignition of the heptane pan</p>	<p>t=1min</p>  <p>T0+1 min: start of propagation on mattress surface</p>	<p>t=4min17s</p>  <p>T0+4 min 17 s: start of fire control. Water-mist reaches floor level.</p>	<p>t=5min</p>  <p>T0+ 5 min</p>
<p>t=2min08s Flames height: 2m</p>  <p>T0+2 min 08 s: fire is spreading on the top of ignition mattress. Flames are about 2m height.</p>	<p>t=2min30s Start of pyrolyse</p>  <p>T0+2 min 30 s: HRR is increasing rapidly. Right hand mattress starts to pyrolyse (red arrow)</p>	<p>t=6min31s Remaining flames at floor level</p>  <p>T0+6 min 31 s: remaining flames at floor level</p>	<p>t=7min</p>  <p>T0+7 min</p>
<p>t=2min35s 1st nozzle</p>  <p>T0+2 min 35 s: operation of the first nozzle.</p>	<p>t=3min</p>  <p>T0+3 min</p>	<p>t=10min</p>  <p>T0+10 min</p>	<p>t=17min39s Water-mist is shut off</p>  <p>T0+17 min 39 s: end of test</p>
<p>T0+2 min 39 s: 2<sup>nd</sup> nozzle operates T0+2 min 51 s: 3<sup>rd</sup> nozzle operates</p>			

## Fire Tests for Large Ceiling Height



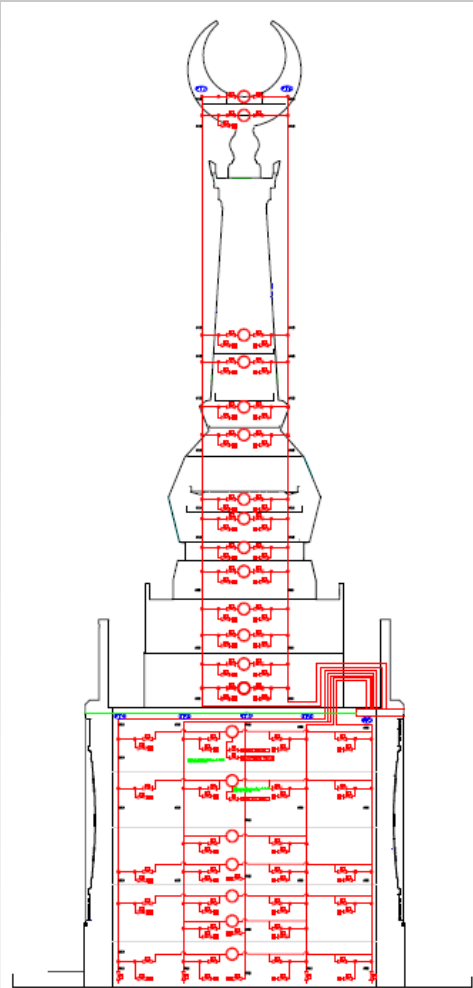
## Fire Tests for Large Ceiling Height



**Reference free-burn test without water mist**



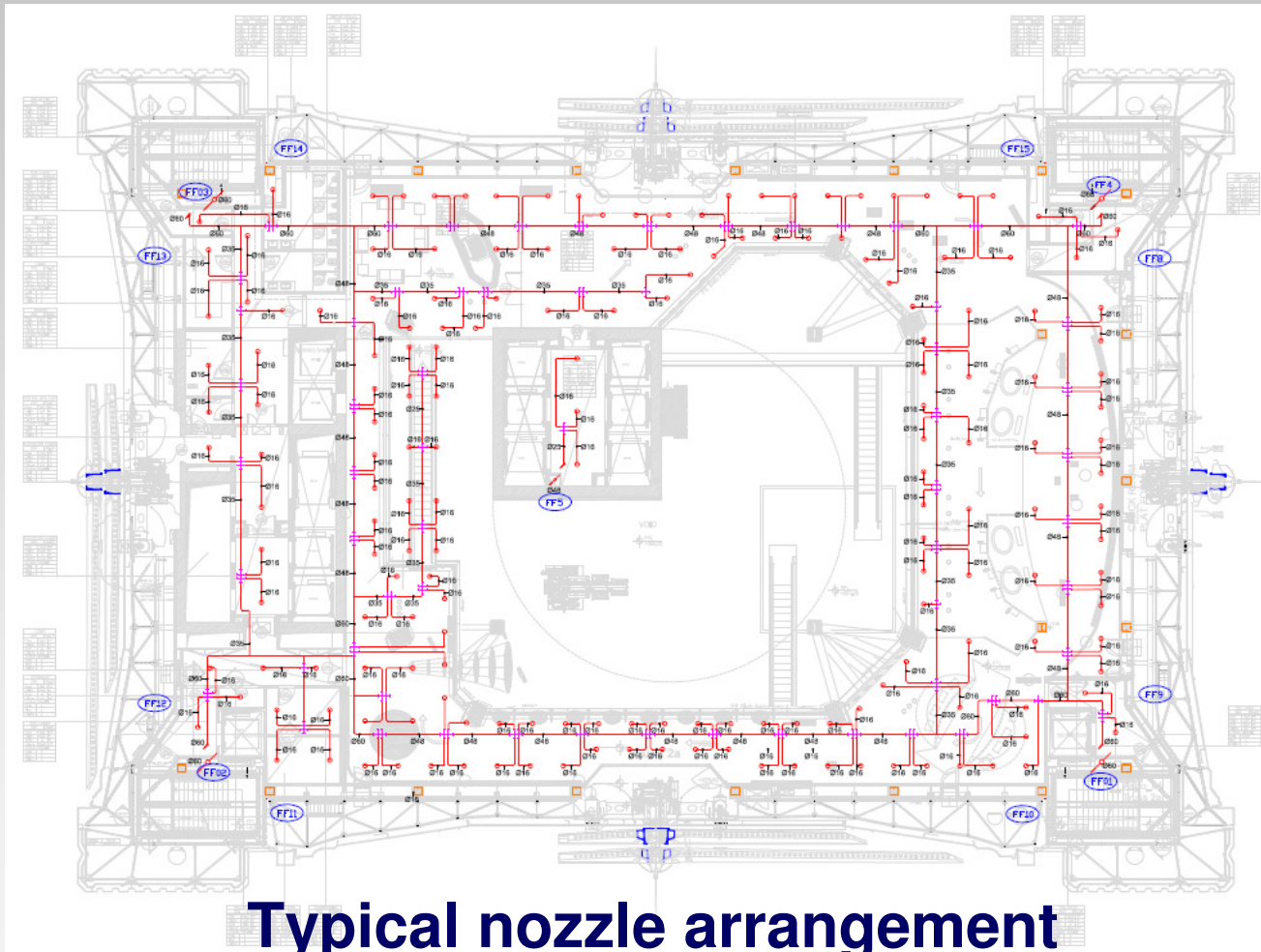
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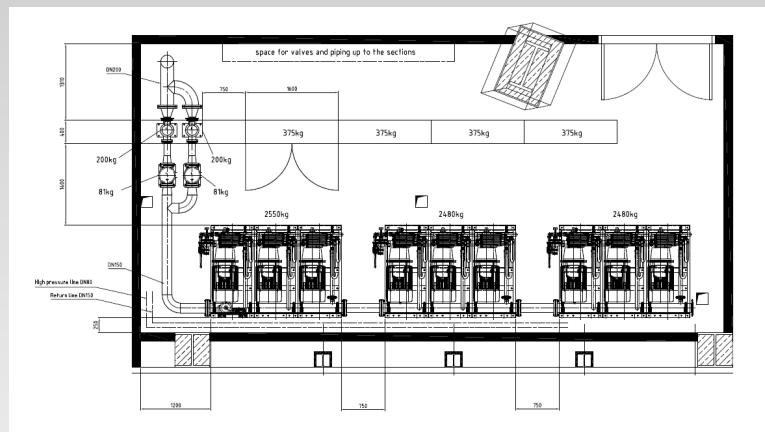
### Protection Concept

- 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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### 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**