# Effectiveness of Water Mist System for the Protection of Mass Timber Buildings: Test Results

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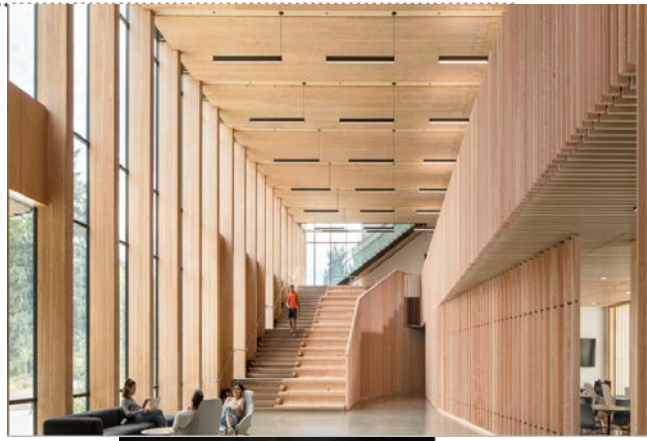
# Water Mist Systems for Mass Timber Buildings

- **The International Building Codes (IBC) has recently accepted the proposed changes for IBC 2021**
  - which allow the maximum of 9 storeys of exposed mass timber construction for residential and business occupancies with sprinkler protection. The proposed changes also allow exposed mass timber for all occupancies with varying height limitations as long as sprinkler protection is provided.
- **Increasing building height limitations and allowing exposed mass timber wall/ceiling → resorting to fire suppression systems.**
- **There are concerns that sprinkler systems could create post-fire water damage and mold problems in mass timber structures.**
  - Water Mist System is considered for **Minimal amount of water usage**, **less post-fire water damage** and **easy clean-ups**.



Figures :
https://structurecraft.com/materials/mass-timber/cross-laminated-timber
the fire suppression test conducted for the glulam structure using high pressure water mist system (Stanwick, 2003)

# Current Requirements for Water Mist systems

- **System Objectives: Life safety ?**
  **Or Life safety + Property protection?**
  - ✓ In protection of mass timber buildings both life and property protection
  - ✓ suppression system should provide not only fire control but also fire suppression and extinguishment
  - ✓ Timber buildings with exposed timber elements should be considered as special cases since a greater fire load is expected
- **Objectives of Conventional sprinkler systems: Life safety for residential buildings [NFPA 13, NFPA 13R, NFPA 13D ]**
- **Objectives of water mist system: specific to hazard scenarios**
  - ✓ Only fire control and suppression rather than extinguishment are required in FM 0402 and BS 8458 (for residential and domestic ) with the focus primarily on providing life safety
  - ✓ “in special circumstances with great fire loads or hazards, enhanced performance, reliability and resilience arrangement should be provided” [BS 8458]

# Current Requirements for Water Mist systems

- **Design Methods and Testing Protocols**
  - ✓ Fundamentally different approaches employed for water mist systems
- **Conventional sprinkler systems: Hazzard classification, Area/density curve**
  - ✓ The hazard classification system for the conventional sprinkler system provides design bases of the area/water density curve, which provides a required water spray rate for each of the five hazard levels [NFPA 13].
- **Water mist system: verifications through full-scale fire tests**
  - ✓ Water mist standards also adopt part of the hazard classifications
  - ✓ Generally, water mist systems are required to be designed based on verifications through full-scale fire tests as part of listing process.
  - ✓ There are many technical factors other than water spray densities affecting the efficiency of water mist systems.
- **No standard/test protocols considered the use of water mist systems in mass timber buildings. Therefore, without verifications through full-scale fire tests, these existing standards and test protocols should not be incorporated.**



Figure: NRC Report-Water mist systems for protection of mass timber structures - phase 2 residential fire suppression tests (available at http://publications.gc.ca/collections/collection_2020/cnrc-nrc/NR24-50-2020-eng.pdf)

# Experimental study objectives

- **The main objective of the testing program was to experimentally investigate the performance of water mist suppression systems in fire scenarios involving mass timber structures, with a focus on residential occupancies.**
- **A series of fire suppression tests was conducted using water mist and sprinkler systems.**
- **The performance of the fire suppression systems was investigated in relation to:**
  - ✓ Controlling and suppressing the residential fire scenario
  - ✓ Limiting fire severity in the room and maintaining tenable conditions
  - ✓ Protecting mass timber structures by limiting fire spread to CLT panels
  - ✓ Minimizing water and fire damage on the test assemblies

# Test Descriptions

# Test Method

- ✓ Fire scenarios that represent the most severe fire cases in residential occupancies
- ✓ Repeatability of the test method
- ✓ Fire scenarios that enable investigation of the involvement of exposed mass timber structures in the fire
- ✓ Systematic test methods that allow investigation of the performance of water mist system in comparison to sprinkler systems

**→ the current standard test methods of the water mist systems (e.g. UL 2167 and BS 8458 ) and sprinkler systems (UL 1626) for residential applications.**

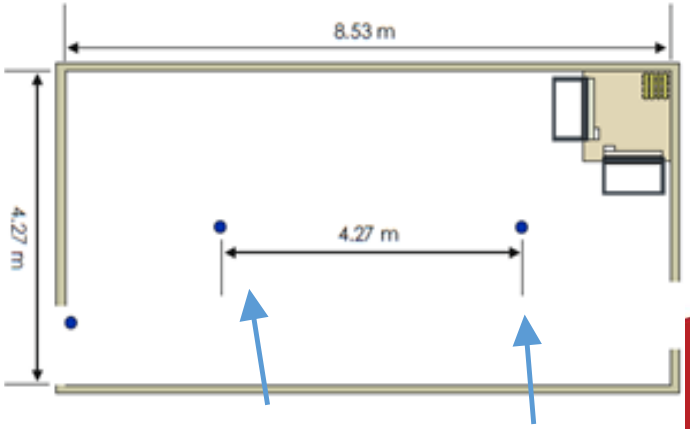




Fig. 1. Test room.

# Test Set-up

- Test room: 8.53 m (L) × 4.27 m (W) × 2.4 m (H)
- The walls and ceiling of the room were constructed from light-weight wood frames and sheathed with non-combustible materials (Densglas gold boards). The floor of the room was non-combustible concrete.
- Ventilation was provided by 2 doors of 2.2 m height each
- Fuel package at a corner : wood crib and simulated furniture
- CLT corner
- Two nozzles and one dummy nozzle

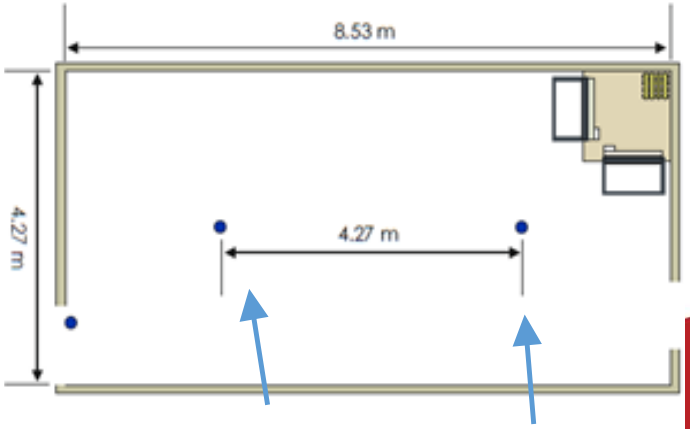
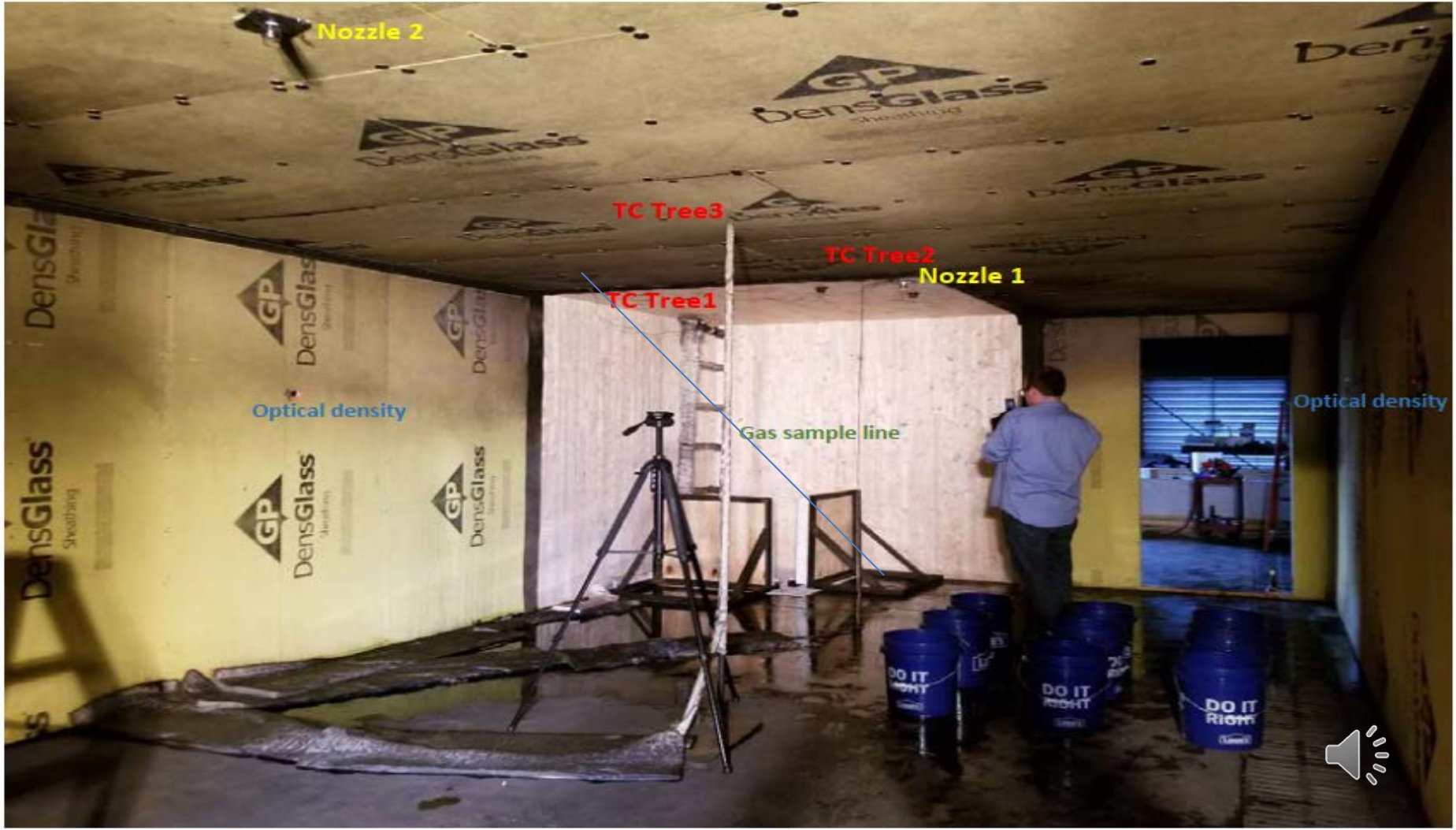




Fig. 1. Test room.


Nozzle 2
TC Tree3
TC Tree2
Nozzle 1
TC Tree1
Optical density
Gas sample line
Optical density

# Test Set-up suppression system


HPWM Type A  Type B  LPWM Type C  Sprinkler Type D

| Type | Description | K factor [lpm/bar$^{1/2}$] | Max. Spacing [m] | Temperature rating [°C] | operating pressure [bar] |
|---|---|---|---|---|---|
| A | HPWM Marioff Hi-Fog (C40 Residential) | 2.4 | 4.27 | 79* | 50 or70 |
| B | HPWM Marioff Hi-Fog (C10 Light hazards) | 4.1 | 5 | 79* | 80 |
| C | LPWM VID (OH-VOS Light hazards) | 16.5 | 4.5 | 79 | 8 |
| D | Sprinkler Tyco (TY123 Residential) | 43.2 | 5.5 | 79 | 0.92 bar for spacing 4.3 m |

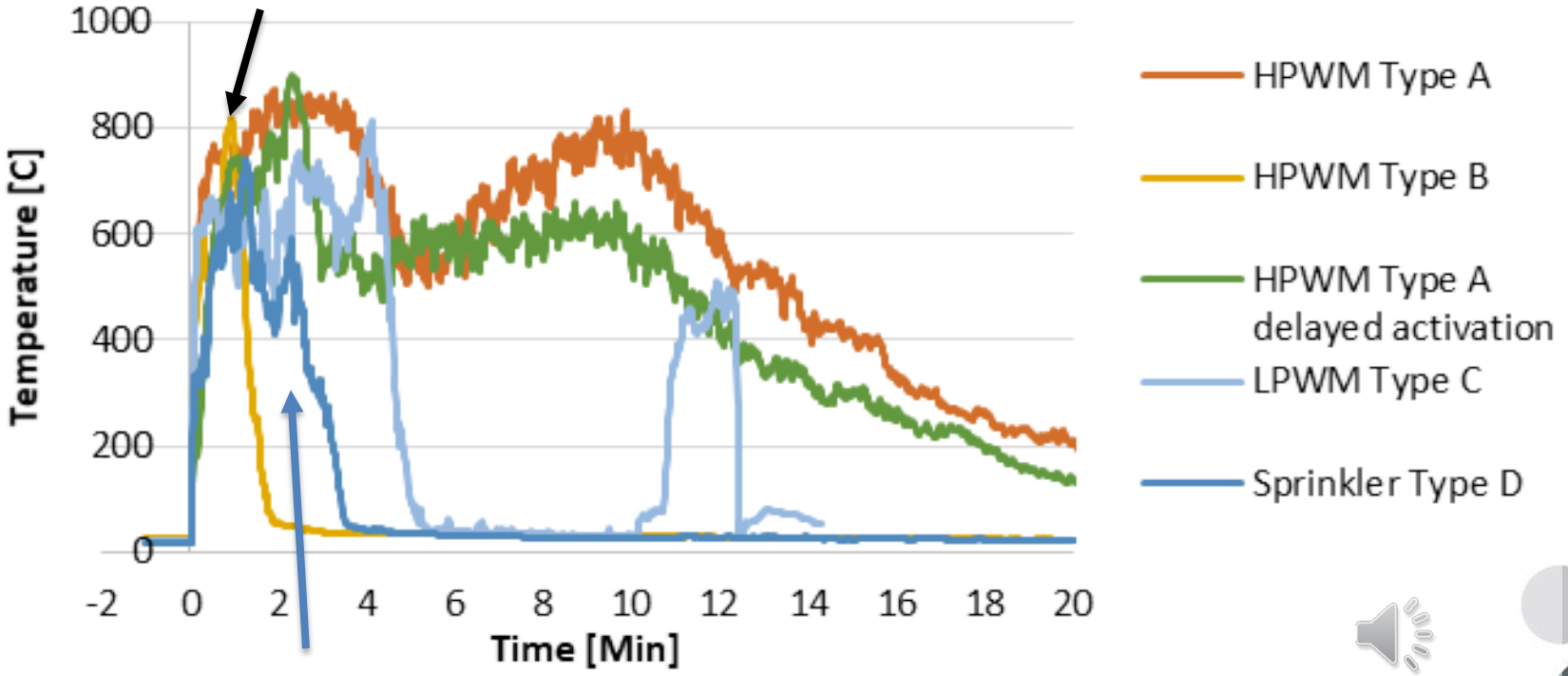
* It should be noted that in real installations, Type B and C nozzles would apply the temperature rating of 57°C or 68°C as per its UL Listing, For traditional sprinklers (Type D) the most common temperature rating is 68°C. The temperature rating of 79°C applied in this study represents an activation with a built in safety factor in the tests.

# Test Matrix

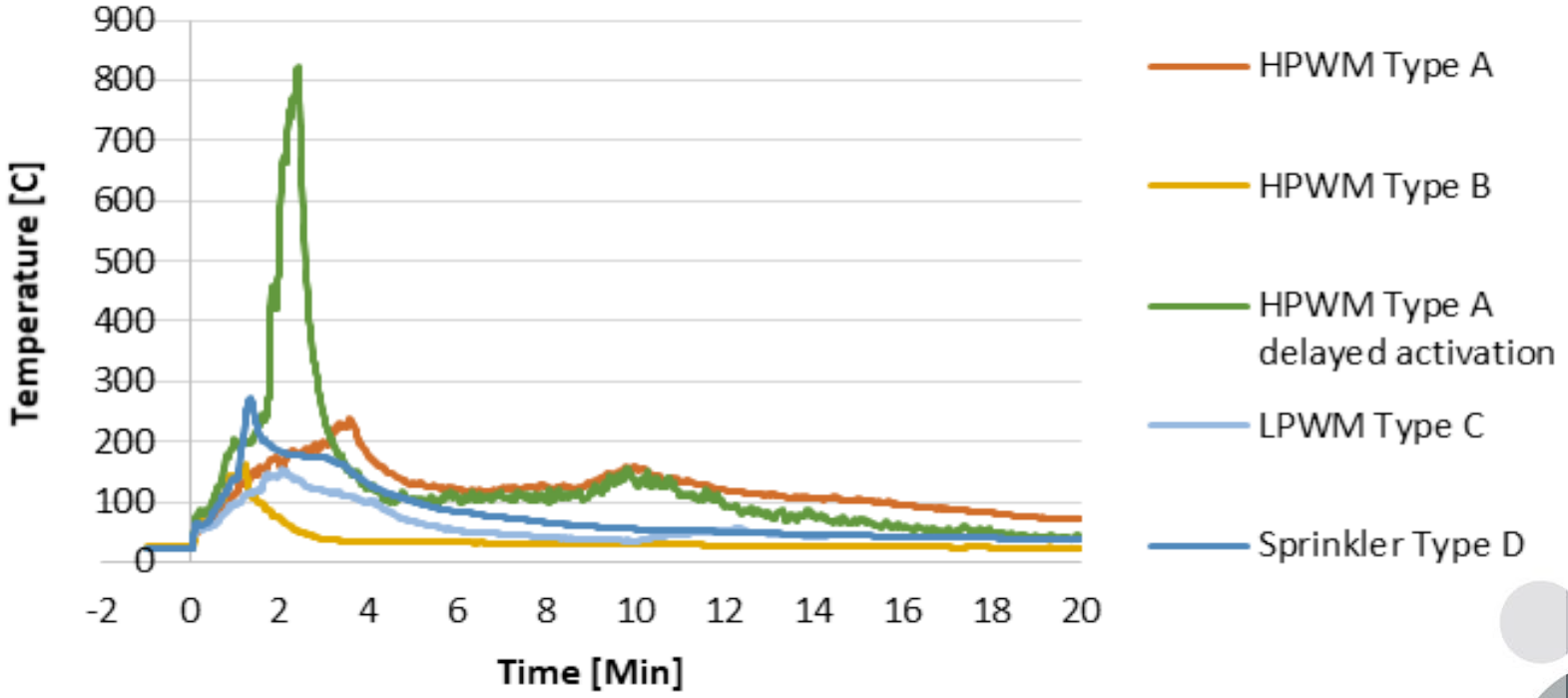
| Test ID | Suppression System | Nozzle type | Operating pressure (bar) | Temperature Rating (°C) | Water spray density (l/min·m$^2$) | Note |
|---|---|---|---|---|---|---|
| 1 | HPWM | A | 51.7 | 79 | 0.9 | minimum protection designed for life safety |
| 2 | HPWM | A | 72 | 79 | 1.1 | maximum protection designed for life safety |
| 3 | HPWM | B | 80.3 | 79 | 2.0 | designed for property protection |
| 4 | HPWM | B | 80 | N/A | 2.0 | designed for property protection delayed manual activation approx.1 minute |
| 5 | HPWM | A | 52 | N/A | 0.9 | designed for life safety delayed manual activation approx.1 minute |
| 6 | LPWM | C | 8.6 | 79 | 2.7 | designed for property protection |
| 7 | LPWM | C | 8.6 | N/A | 2.7 | designed for property protection delayed manual activation approx.1 minute |
| 8 | Sprinkler | D | 0.94 | 79 | 2.3 | After 2$^{nd}$ sprinkler head activated, Water supply system failed |
| 9 | Sprinkler | D | 0.94 | 79 | 2.3 | After 2$^{nd}$ sprinkler head activated, Water supply system failed |
| 10 | Sprinkler | D | 0.94 | Simulated 79 | 2.3 | Sprinkler activations simulated |

# Test Results

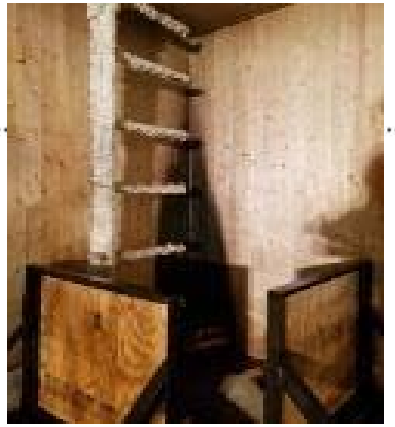
# Test Results
# fire control_flame temperature



# Test Results
# property protection_CLT ceiling temperature



# Test Results fire damages



HPWM Type A

HPWM Type B

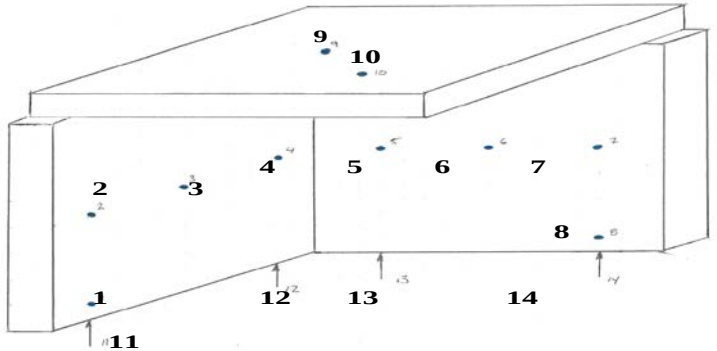
LPWM Type C

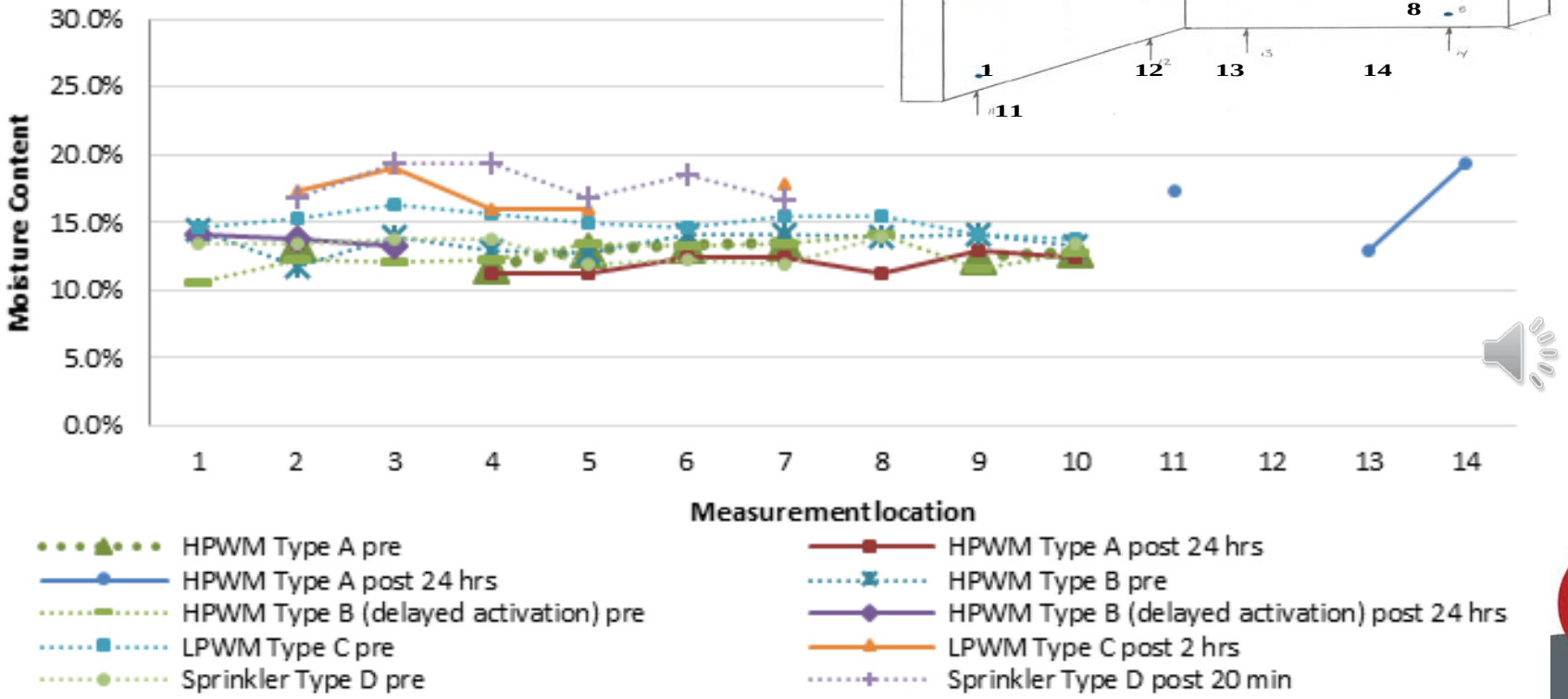
Sprinkler Type D

HPWM Type B delayed

HPWM Type A delayed

# Test Results
# moisture content



# Conclusions

- The test results showed that the water spray rate of HPWM was four times lower than that of the sprinkler system
- Both systems effectively control the residential fire scenario involving mass timber structure.
- Most systems (HPWM, LPWM and sprinklers) tested in this study did not prevent the fire damage on the exposed mass timber walls, but HPWM system with a wide spray angle demonstrated rapid fire suppression and effective protection of the exposed mass timber walls.
- The moisture contents measured after the tests indicated that water could be absorbed effectively through the joints along the bottom edge of the mass timber walls. A further study is necessary to understand the long term effects of the water damage on the mass timber.

# Next Step
# Developing a Guide for Water Mist System for MTB

## Design Consideration for Water Mist systems

- Compartment Volume and Ventilation Conditions
  - ✓ affects the effectiveness of water mist systems in gas phase cooling /oxygen depletion
- Type of Fuel and Droplet/spray Characteristics
  - ✓ To protect exposed mass timber ceiling/walls, for fuel wetting, spray characteristics –spray angles should be carefully examined
- System Actuation
  - ✓ To limit the fire spread and development, a wet pipe system and automatic nozzles with a quick-response thermal element for residential and domestic occupancies
  - ✓ Potential delay for dry-pipe system, but no specific requirement available for water mist
- Nozzle spacing and Layout
  - ✓ To protect exposed walls and ceilings of mass timber structural elements, listing info should be re-assessed
- Water spray rates and Discharge duration
- Water usages/damages
  - ✓ preventing activation of nozzles far from the fire origin
- Fire Damages

Looking for Reviewers ! Please Contact
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# Thanks