Gravity Smoke Vents in Storage Occupancies

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Debate on smoke vents – raging for some time

NISTIR 6196-1

Sprinkler, Smoke & Heat Vent, Draft Curtain Interaction -- Large Scale Experiments and Model Development

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Interaction of Sprinklers with Smoke and Heat Vents

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Influence of the Fire Location and the Size of a Compartment on the Heat and Smoke Flow Out of the Compartment

Wojciech Węgrzyński, Marek Krajewski

THE IMPACT OF AUTOMATIC SMOKE AND HEAT VENTS ON SPRINKLER SYSTEM PERFORMANCE

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ABSTRACT

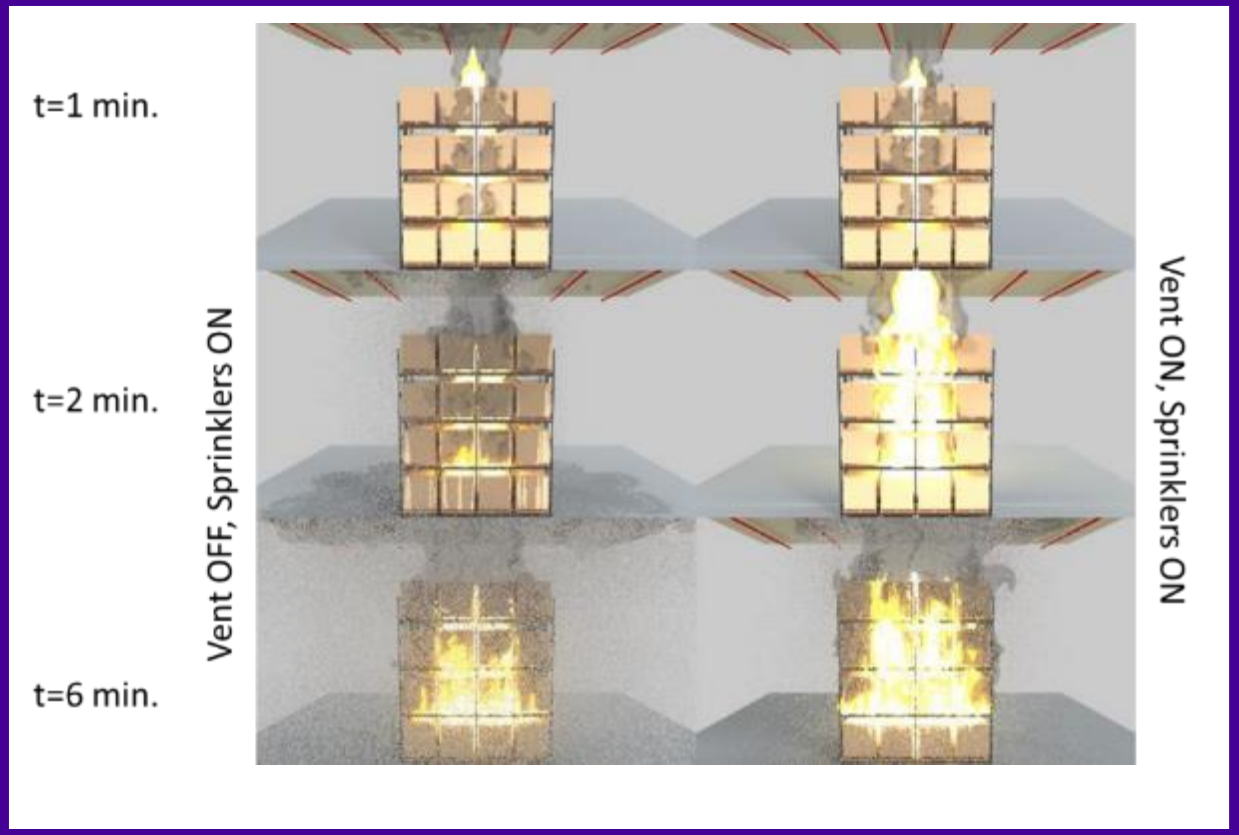
The numerical modelling tool FireFOAM is applied to study the interaction of automatically operated smoke vent and sprinkler systems. Two configurations are considered: 1) a design fire scenario with an imposed heat release rate (HRR) that increases rapidly to 10 MW within 80 s (extracted from a high hazard commodity fire test), in which the sprinkler system activation is modelled but no coupling exists between the sprinklers and the fire (no water injection), and 2) a commodity fire scenario (palletized cardboard boxes) with fully coupled water suppression, pyrolysis, and combustion physics. The design fire results demonstrate that the sprinkler activation times may be significantly delayed due to early operation of the smoke vent when the vent is positioned directly above the fire, even where the smoke vent is designed to operate at a higher temperature and with a slower thermal response than the sprinkler thermal link. The delay leads to an approximate doubling in the fire size at the time of 1st sprinkler activation, compared to the baseline case without a smoke vent. This result is relatively insensitive to the vent thermal link settings, but highly sensitive to the offset distance between the fire and the smoke vent. The commodity fire simulations compared the fire growth and suppression for cases with/without both smoke vents and sprinklers, and for a case where a sprinkler is placed directly beneath the smoke vent. The preliminary simulation results are limited to the first 2.5 minutes after ignition and do not reveal the ultimate outcome of the fire. As expected, the results showed that the smoke vent itself does not limit the fire growth. All cases with sprinklers significantly reduced the fire size and are likely to lead to a controlled fire outcome. The case that combines both sprinklers and smoke vents resulted in delayed sprinkler activations compared to the case with sprinklers only, resulting in a larger peak fire size. Where the sprinkler was placed directly beneath the smoke vent, the sprinkler activated early and prior to the smoke vent resulting in the smallest fire size and least amount of heat release.

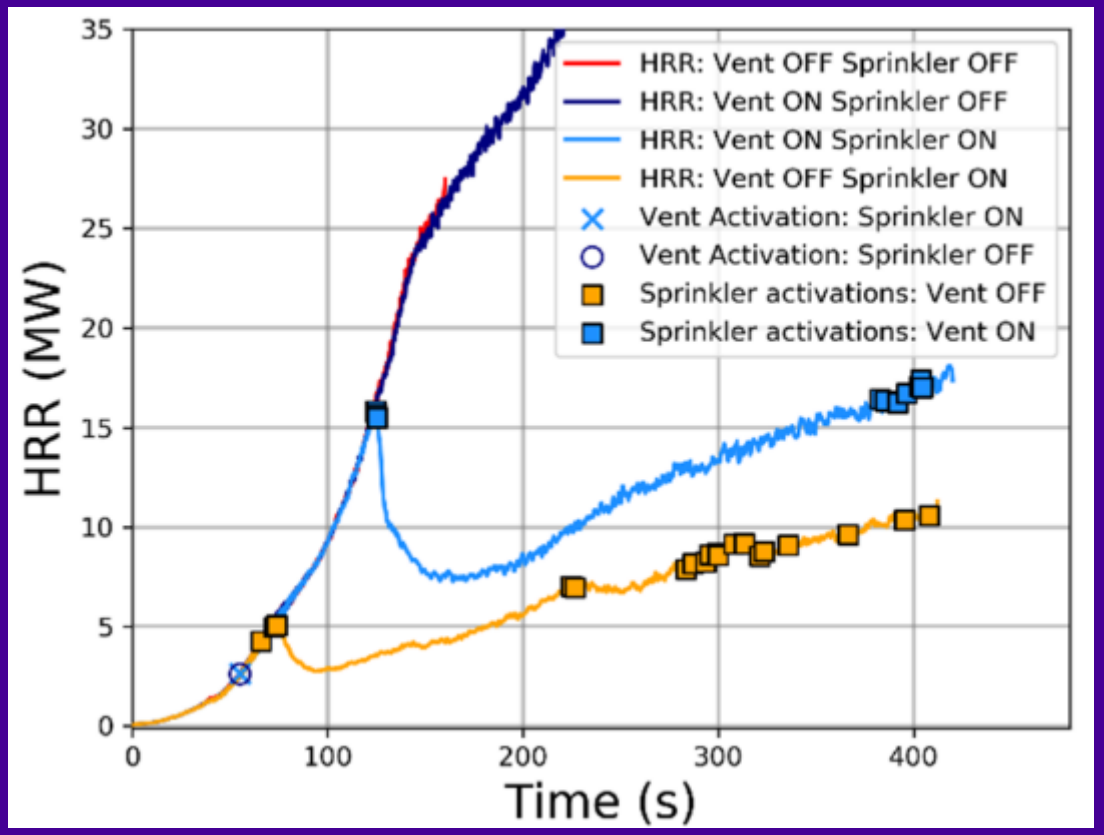
INTRODUCTION

Smoke and heat vents are designed to improve tenability in building fires by removing the products of combustion. They can be activated manually, or automatically via the detection of smoke and/or heat. In some instances, the use of such vents in sprinklered buildings can affect the sprinkler system performance, and vice-versa, unless appropriate considerations are made. Here, high-fidelity numerical modelling is used to evaluate the interactions of vents and sprinkler systems for a range of fire scenarios in warehouse buildings.

The typical size of smoke vents range from 1.2x1.2 m to 1.2x3.6 m, although a wide range of dimensions are manufactured. Smoke vents are arrayed to meet design requirement preventing the descent of the smoke layer for a predicted worst-case fire scenario, resulting in a wide range of floor to vent area ratios, with typical values are in the range of 20x100'. The particular vent system design is determined by an engineering assessment, which accounts for expected fire scenarios and the building dimensions. Venting may be driven by natural buoyancy and/or mechanical pumping. In this study, we consider only buoyancy driven ventilation with individually, automatically operated smoke vents. Smoke vents may also be grouped and operated together either manually or automatically. This is referred to as

Krisman et al



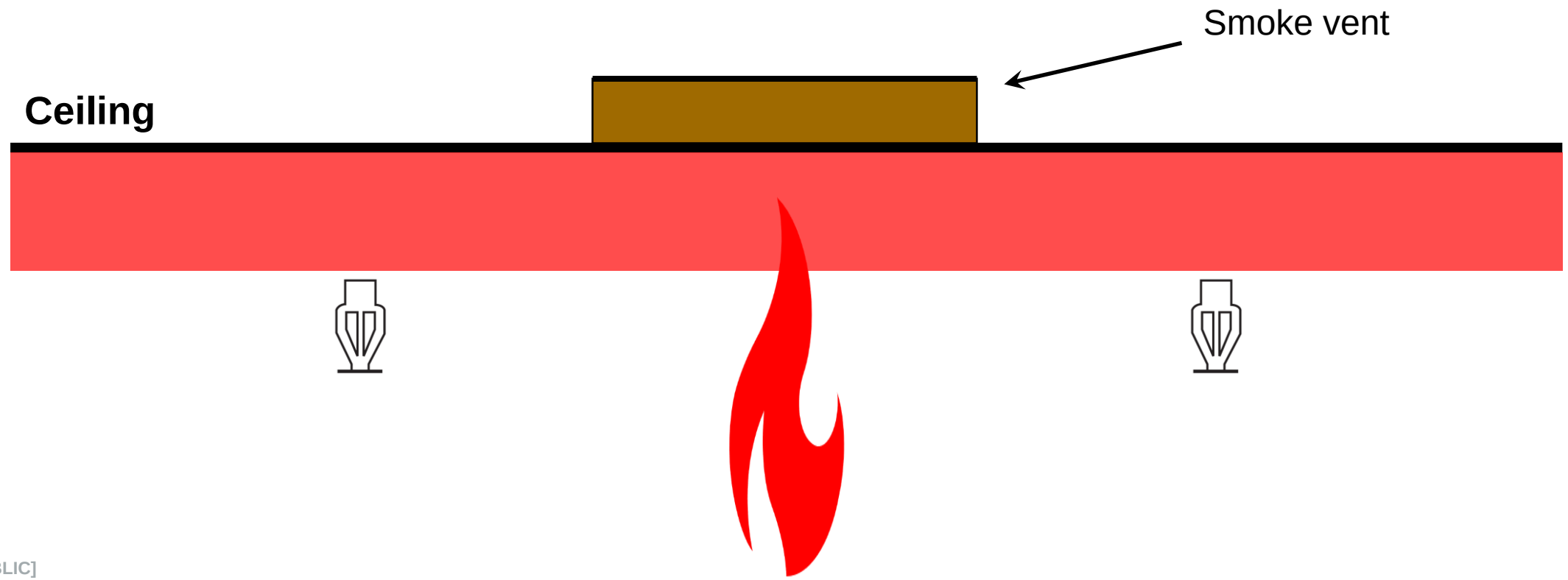


Scope of Work

- Gravity smoke vents < 3 m^2
- Storage occupancies
- Sprinklered & unsprinklered
- Numerical simulations and large-scale tests

Smoke Vents – Effect on Sprinkler Performance

Concerns with Smoke Vents?



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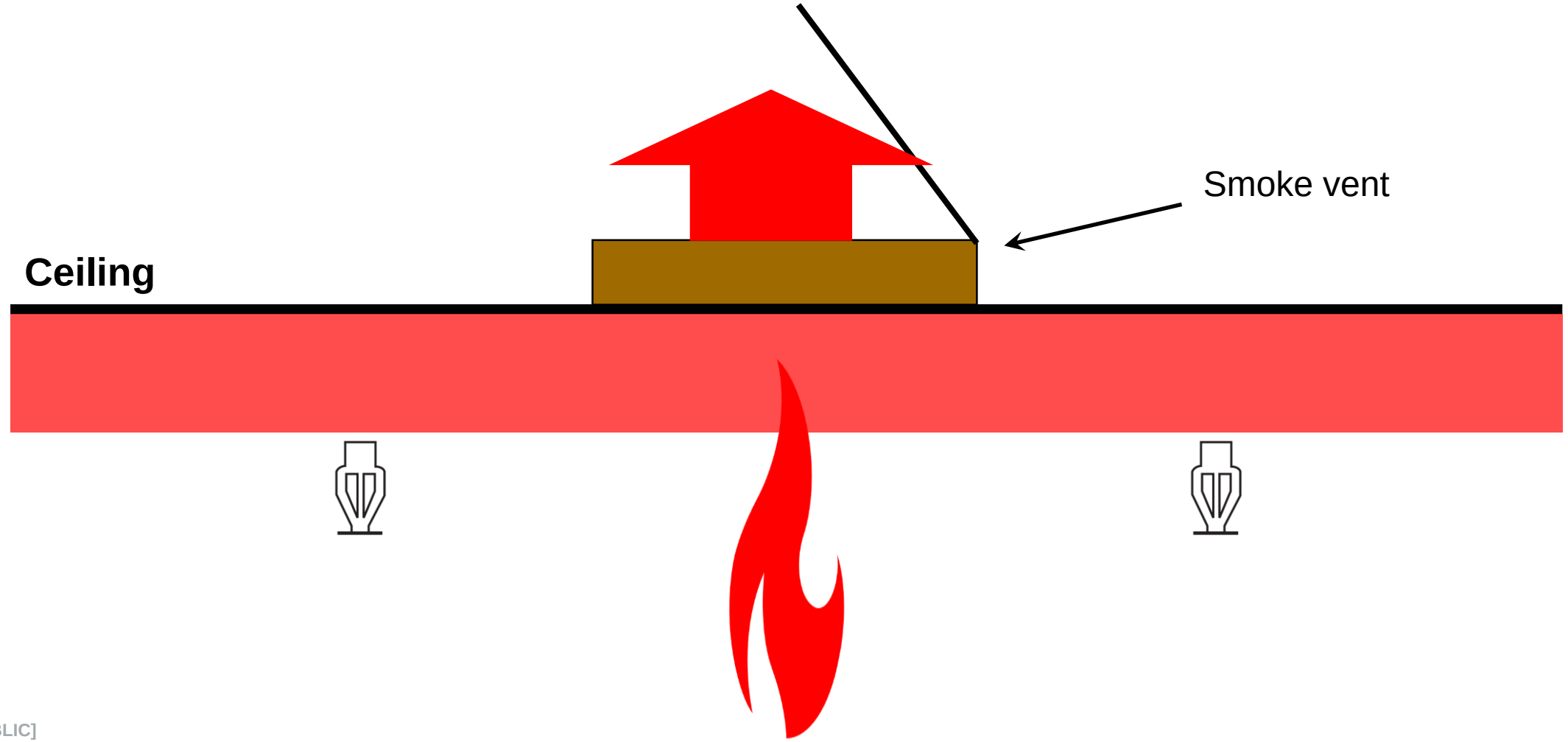

Smoke Vents – Effect on Sprinkler Performance

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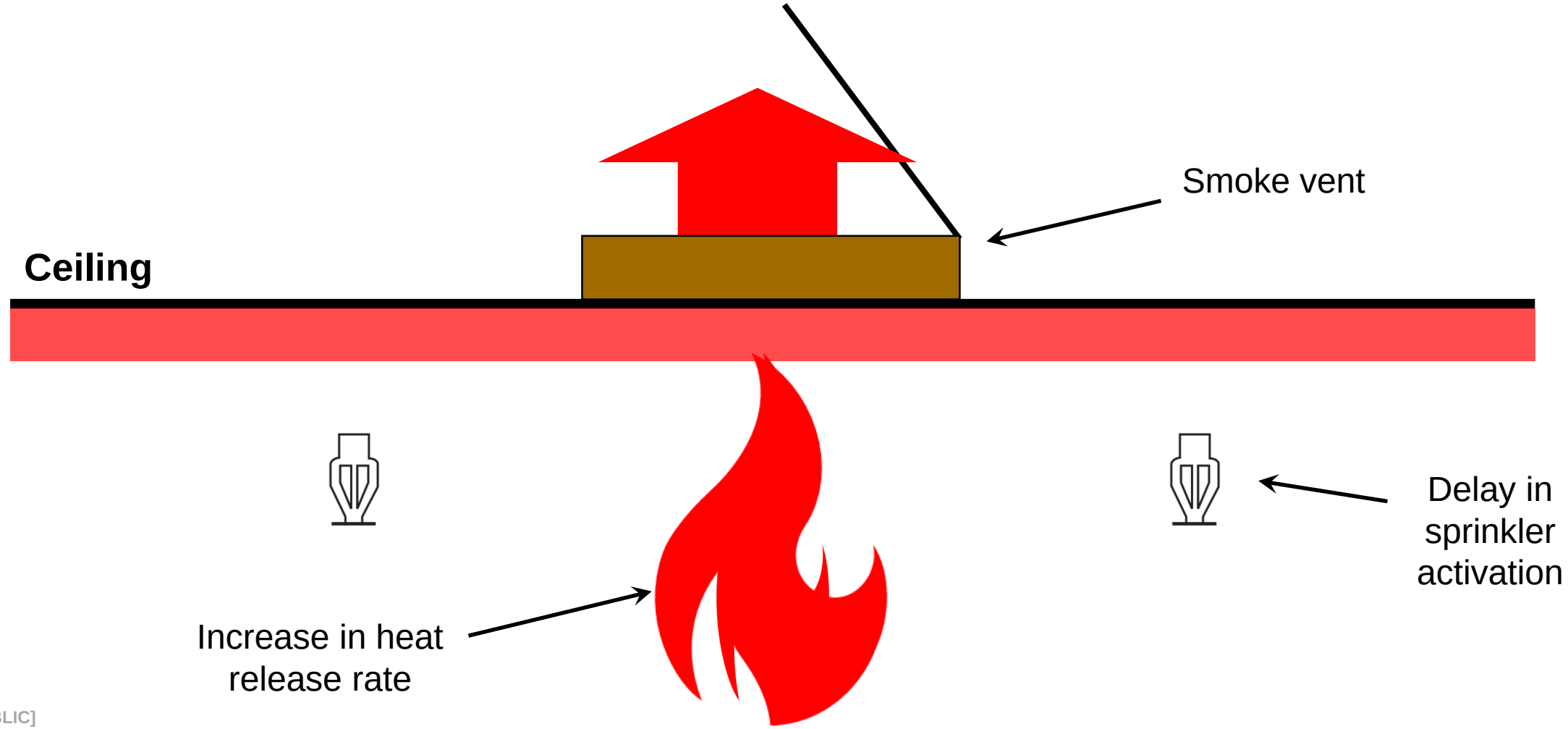


Smoke Vents – Effect on Sprinkler Performance

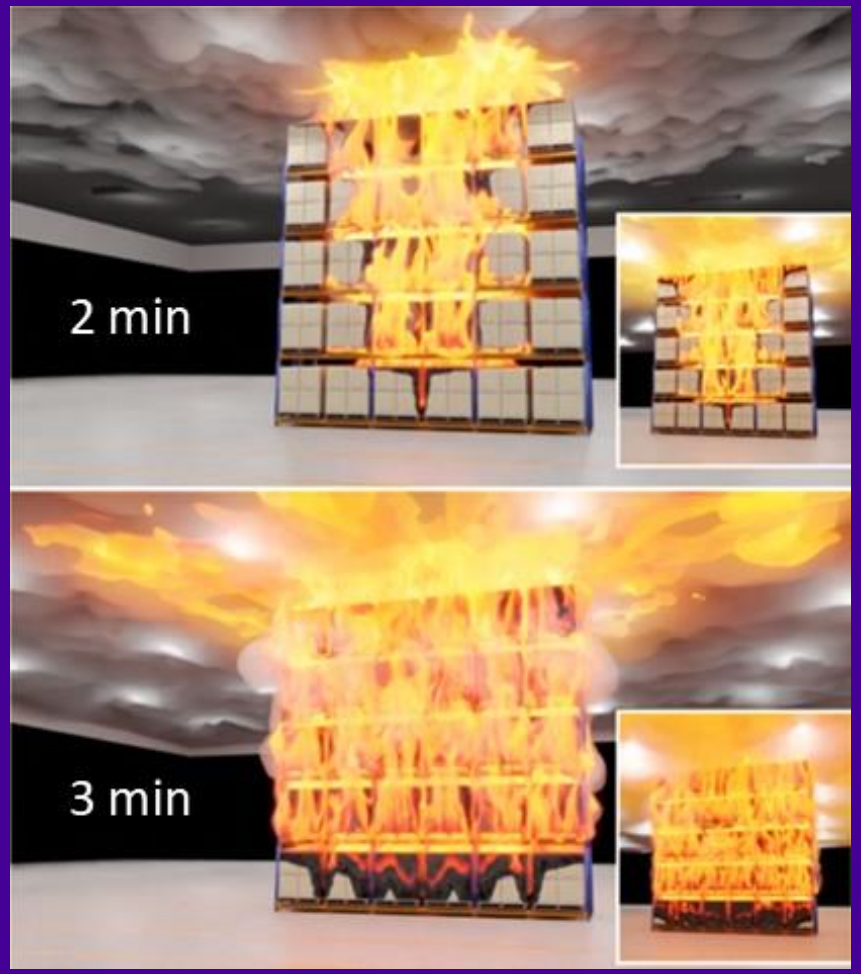
During a fire, will a heat / smoke vent operate prior to a ceiling sprinkler?

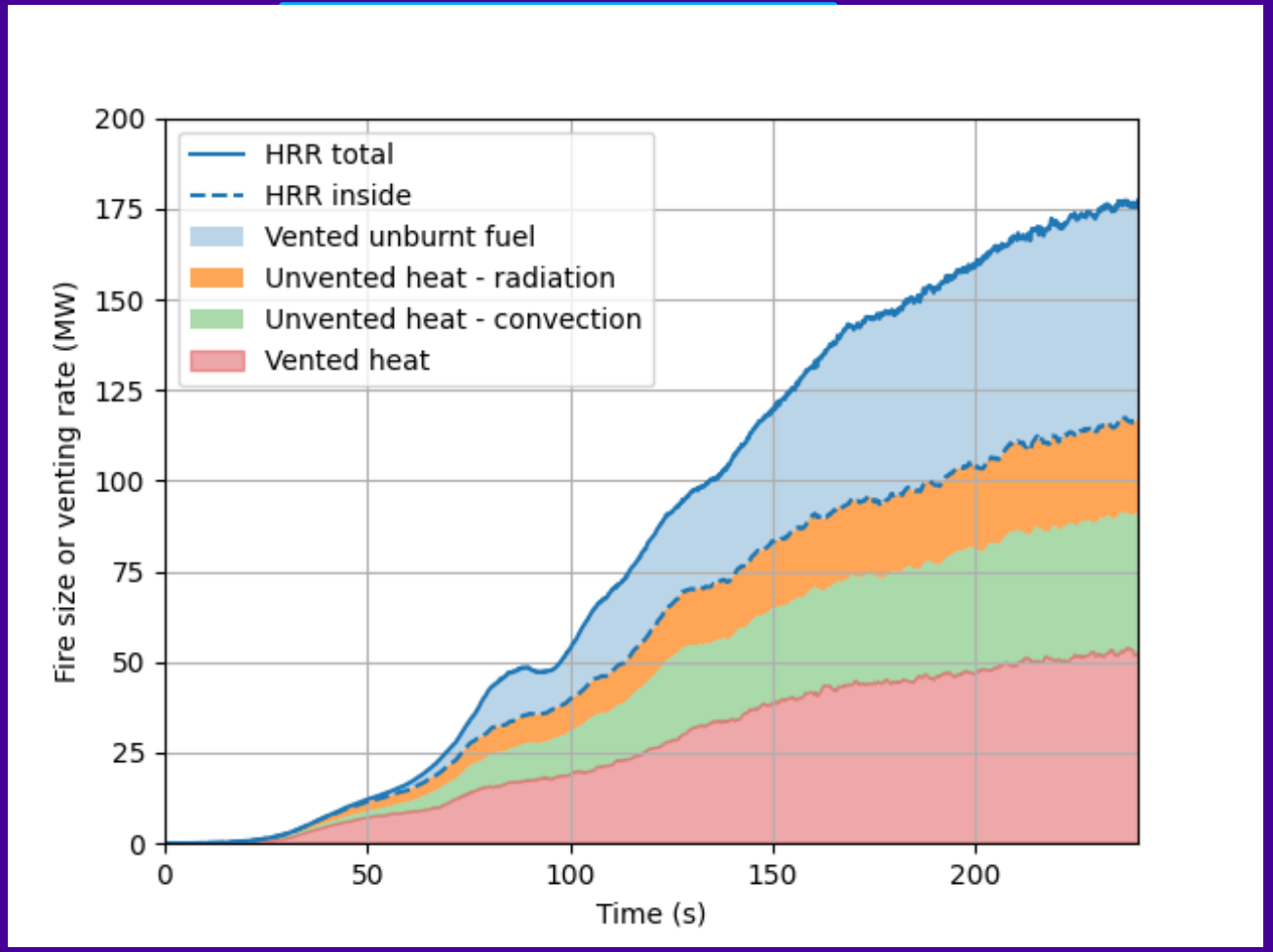
If so, can its operation compromise the ceiling sprinkler system's ability to protect the warehouse?

Risk Analysis – Overview

- Large-scale testing and numerical modeling
- Unsprinklered and sprinklered storage occupancies considered
- Wide range of conditions considered
  - Storage/ceiling height
  - Commodity type
  - Ignition scenario
  - Quality of sprinkler protection
  - Gravity smoke vents < 3 m^2

Unsprinklered Storage Occupancies





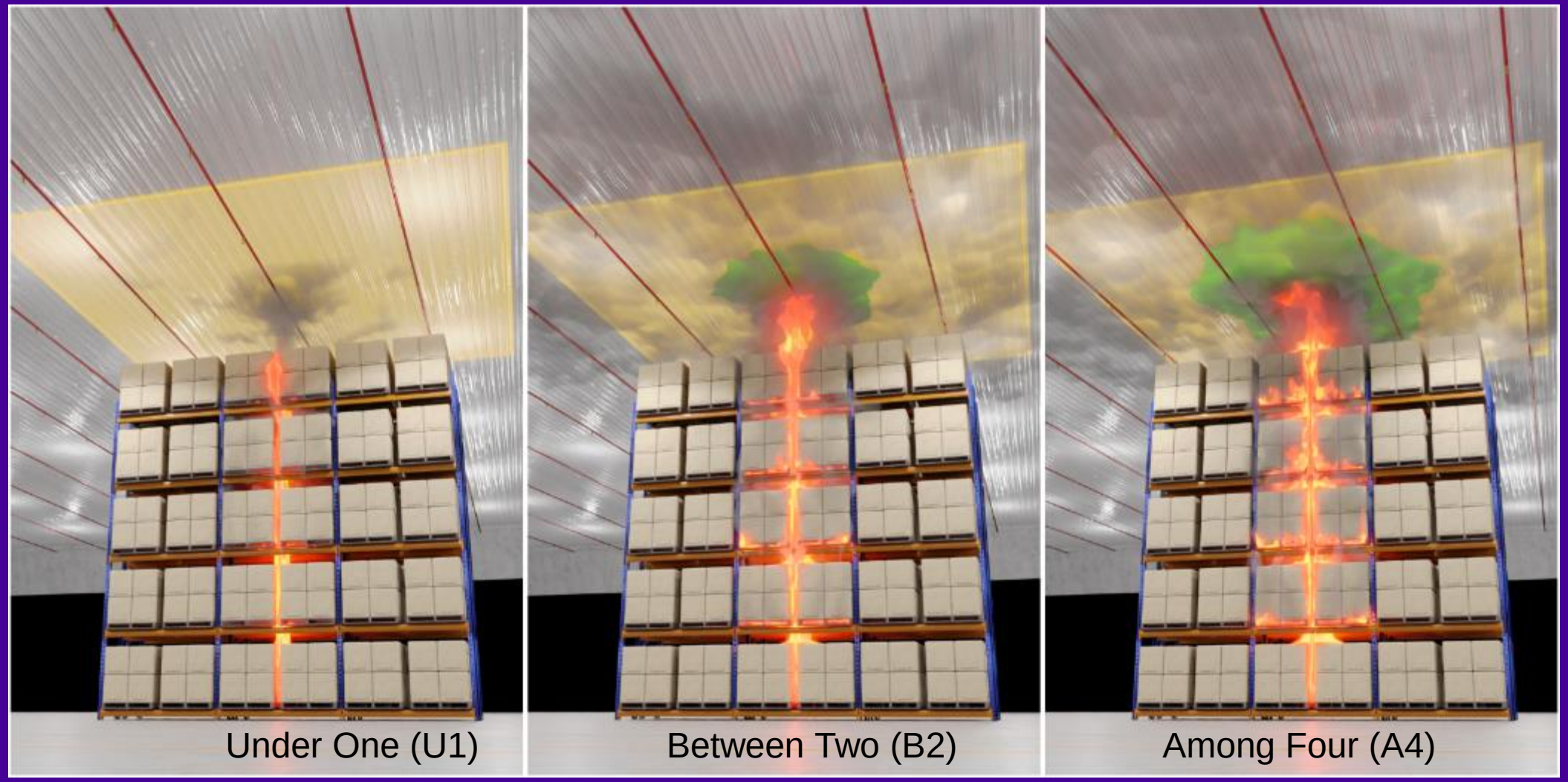
Sprinklered Storage Occupancies

- Unsprinklered results showed that smoke vents alone do not provide property protection benefit
- For sprinklered occupancies:
  - Will smoke vents open before sprinklers?
  - If they do, will they affect sprinkler performance?
  - How effective are smoke vents once sprinklers operate?

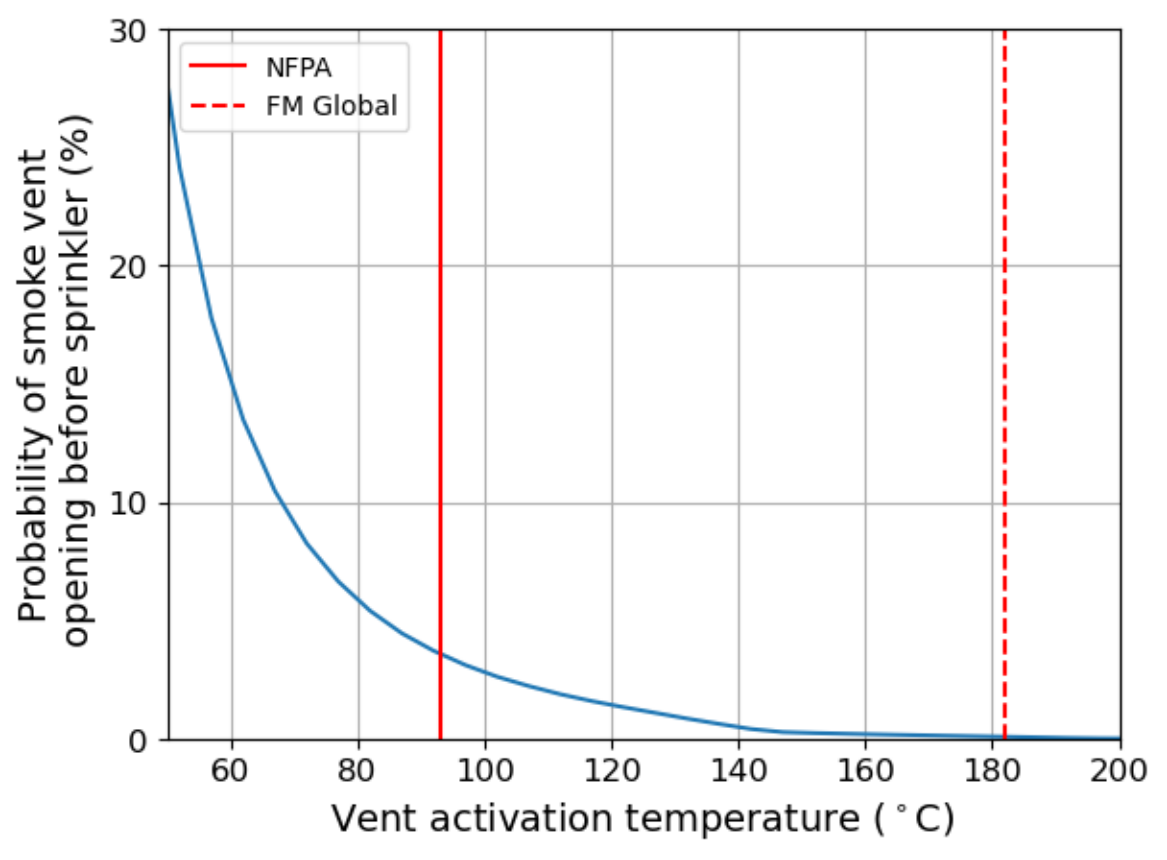
Probability of Smoke Vents Opening Before Sprinklers

- Smoke vents can be operated in several ways:
  - Manually, automatically
  - Ganged, individually
  - Left open for ventilation
- Smoke vents will have the greatest impact on sprinklers when they are open first
- What is the likelihood of automatic smoke vents opening before sprinklers?
  - Calculated using numerical modeling for wide range of conditions

Probability Calculation

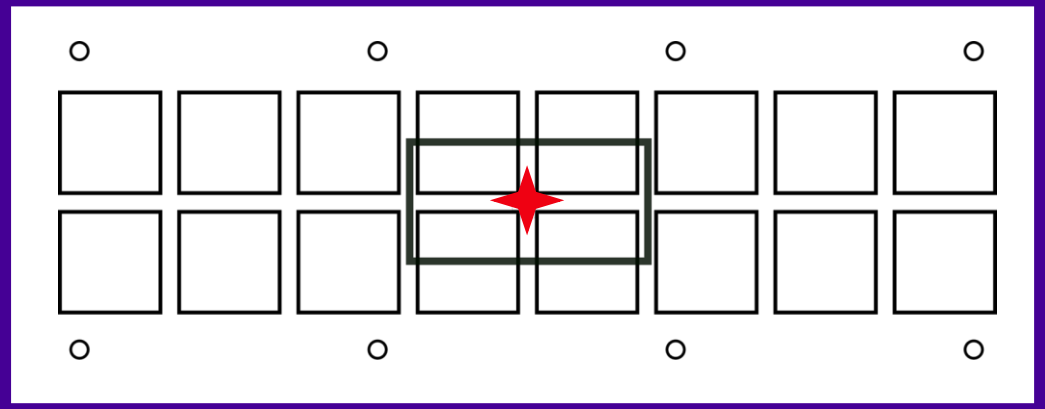


Results



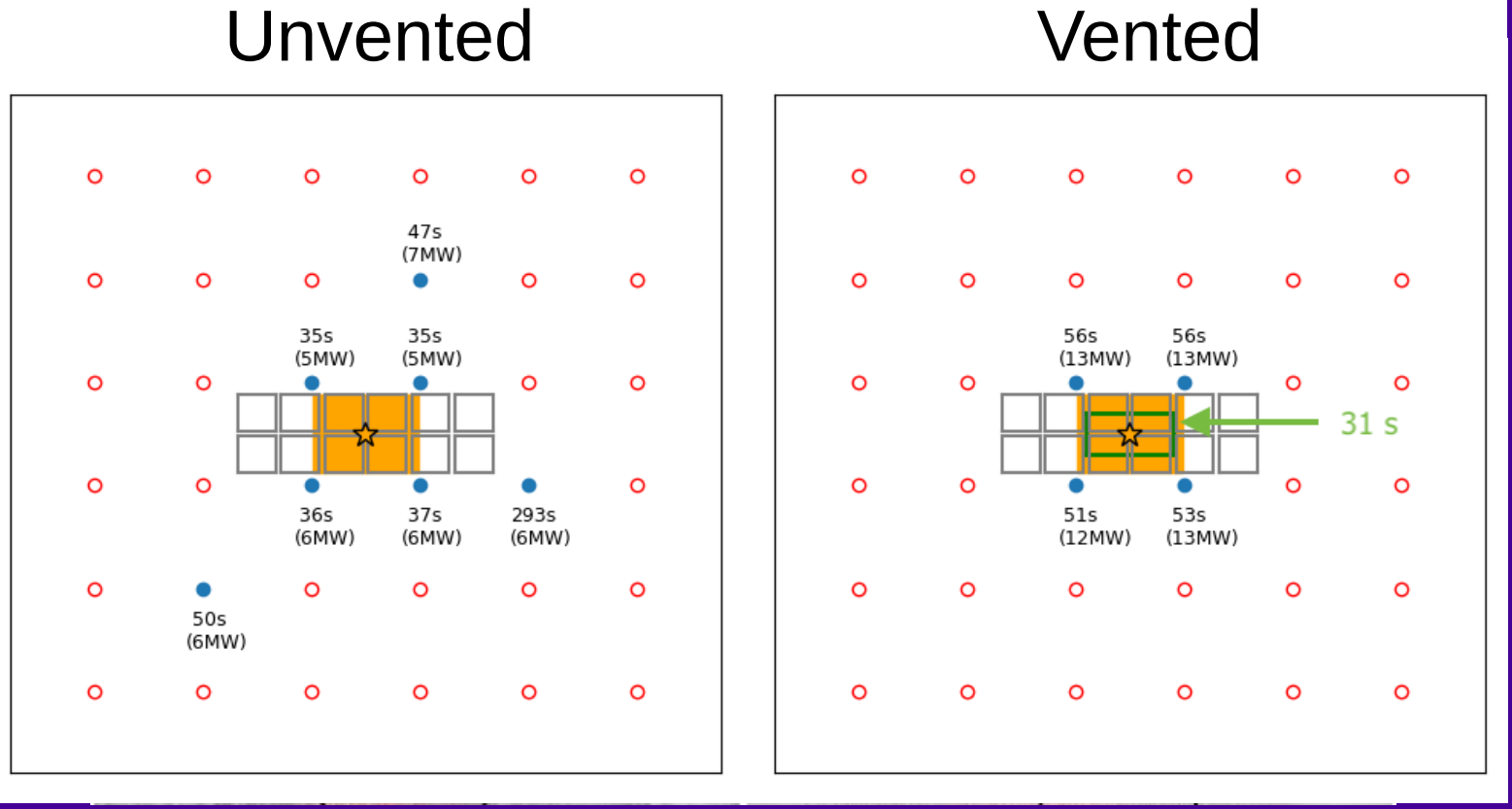
- Likelihood inherently low (fewer vents than sprinklers at ceiling)
- Likelihood decreases with increasing vent activation temperature

Test Case 1



- Cartoned Unexpanded Plastic (CUP)
- 7.6 m (25 ft) storage under 9.1 m (30 ft) ceiling
- Worst-case ignition scenario
- K240 (K16.8) QR pendent @ 2.4 bar (35 psi)
- Protection in FM Global DS 8-9

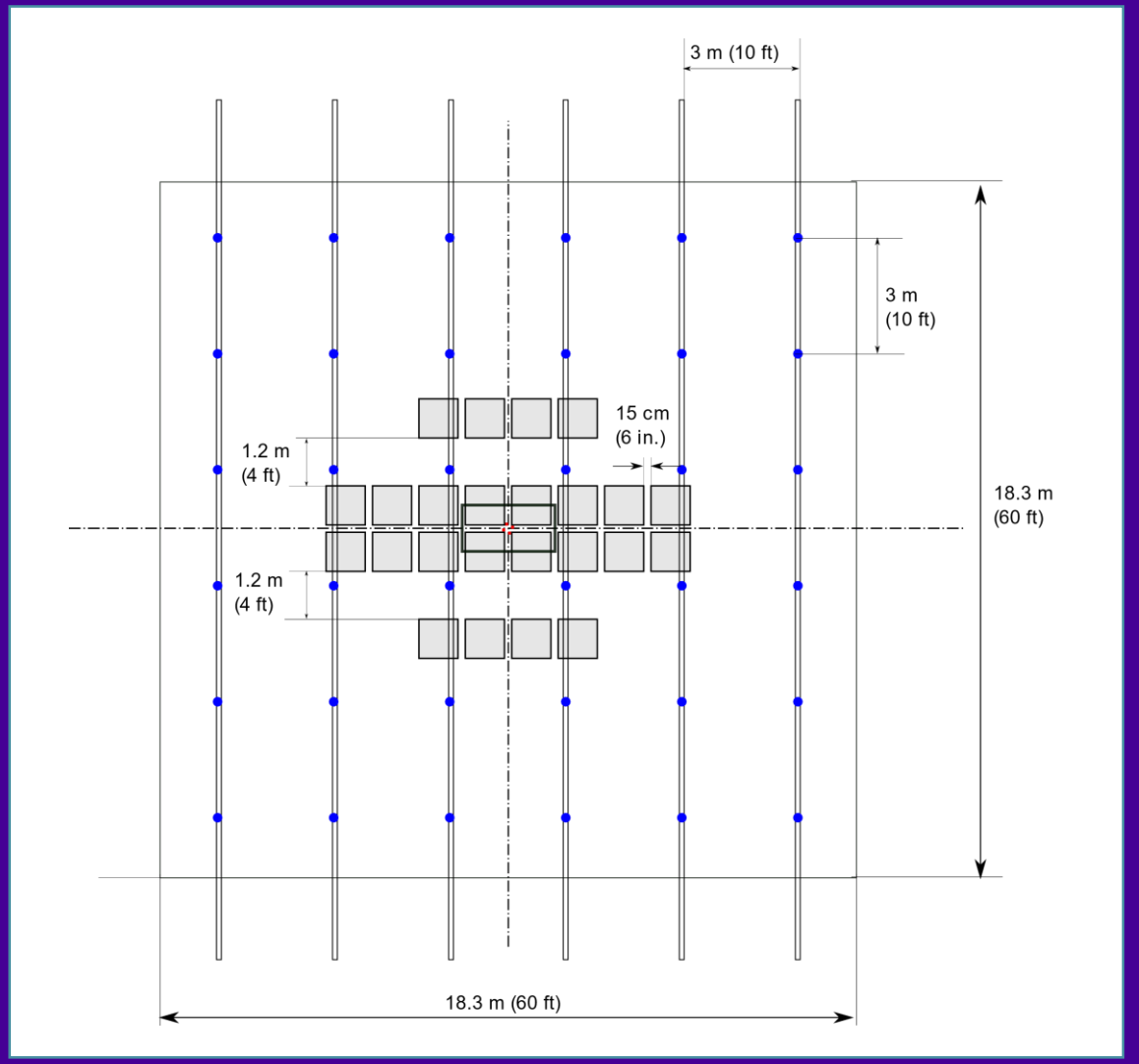
Model Results



Smoke vents delayed sprinkler operations

However, no negative effect of smoke vents on sprinkler performance

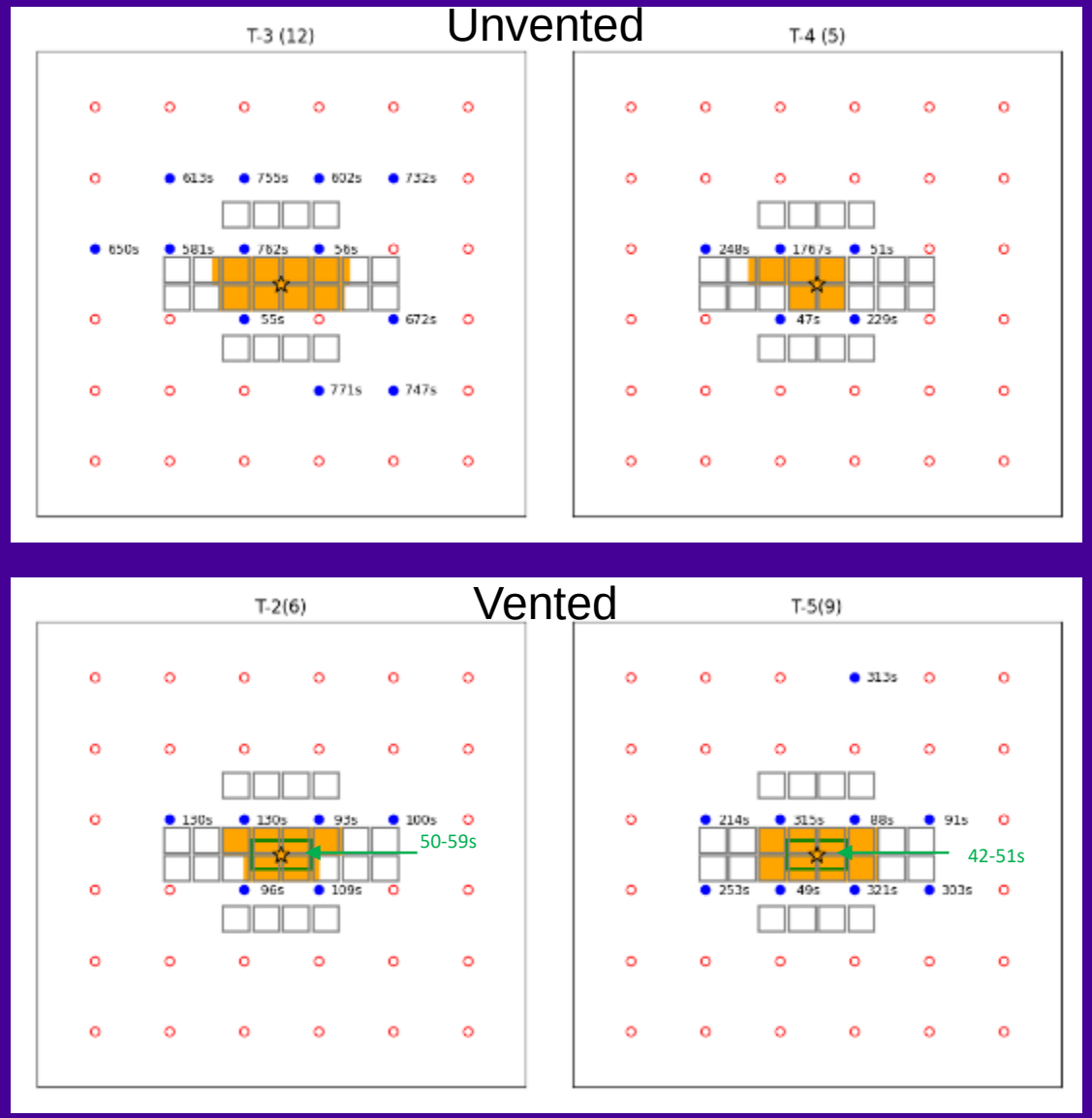
Large-scale Fire Tests - Configuration




00:30
Unvented
Vented

Results at Recommended Protection Level

	Unvented		Vented	
# of sprinklers	12	5	6	9
Fire Spread	Acceptable			
Ceiling Temperature	Acceptable			

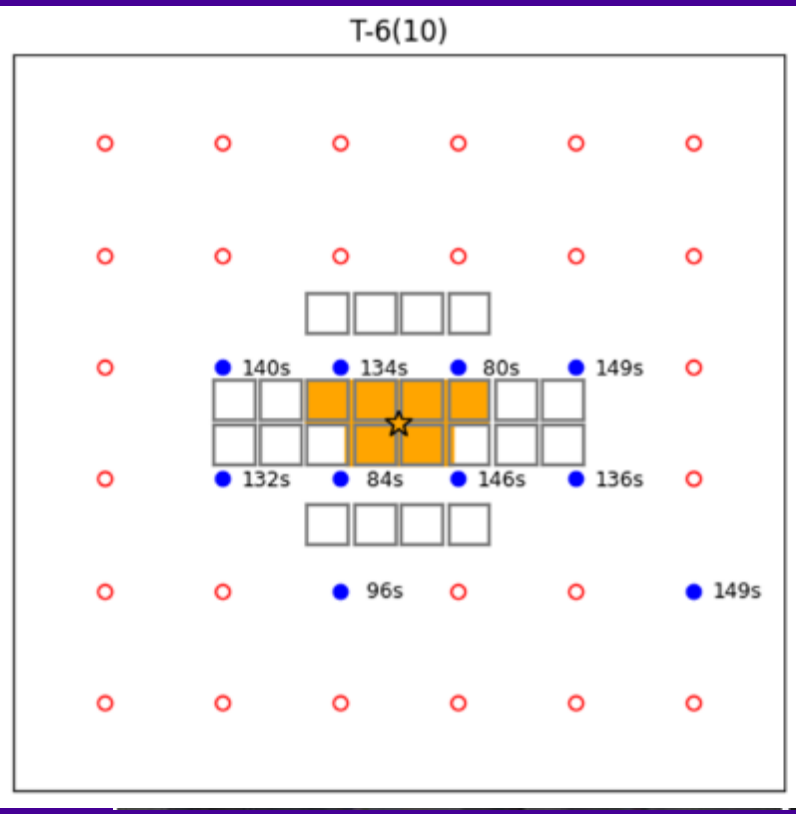


Test Case 2 – Marginal Protection

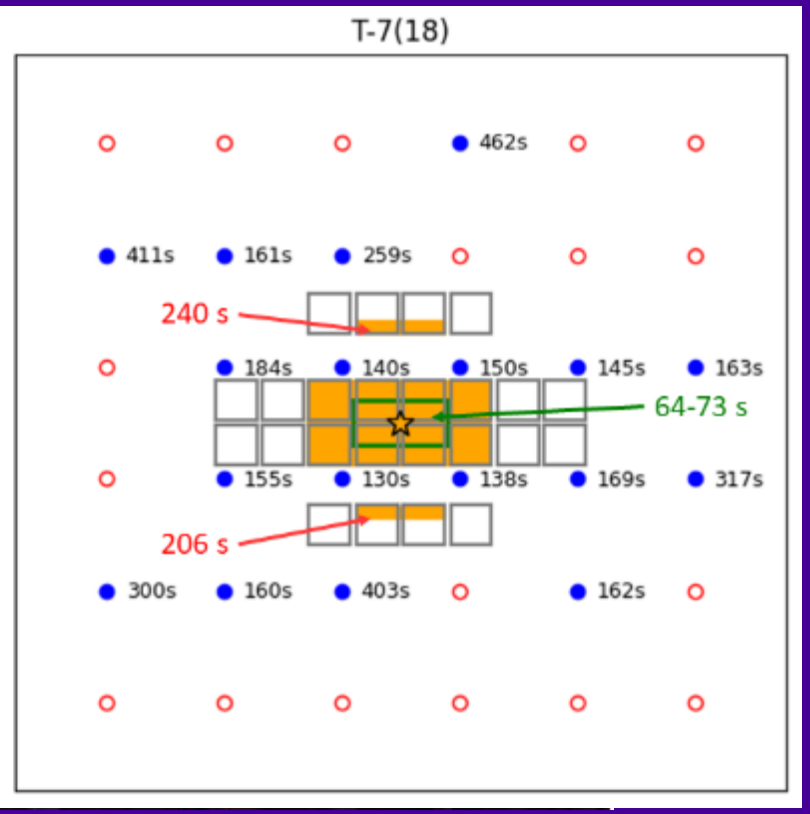
- Class 2 commodity
- 7.6 m (25 ft) storage under 9.1 m (30 ft) ceiling
- K160 (K11.2) QR upright @ 1.7 bar (25 psi)
- Protection not in FM Global DS 8-9 but in NFPA 13

Test Results at Marginal Protection Level

Unvented



Vented

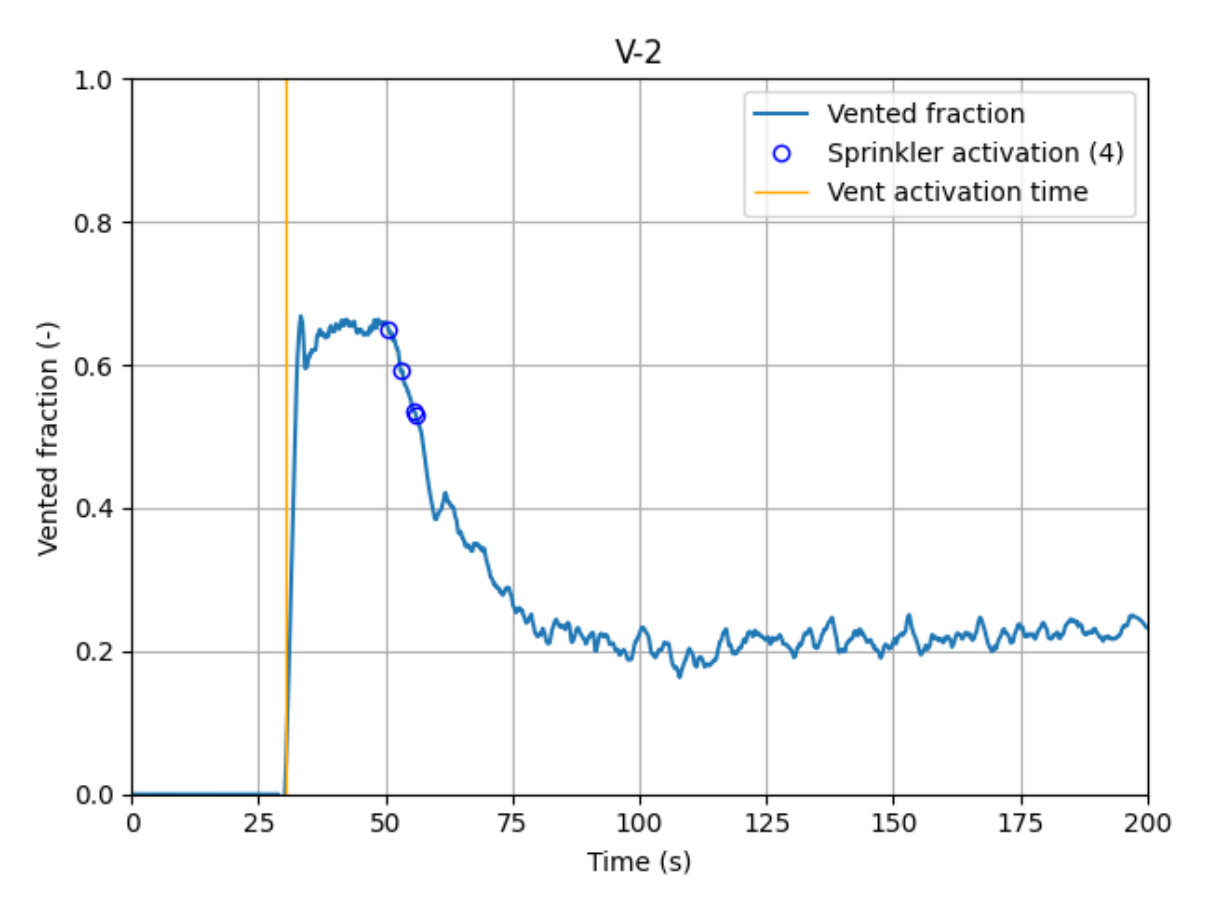


Smoke vents delayed sprinkler operations

Adverse impact

- **# of sprinklers**
- **Fire damage**

Efficacy of Smoke Vents after Sprinklers Operate



$$Vented\ Fraction = \frac{HRR\ through\ Smoke\ Vents}{Total\ HRR}$$

Smoke Vent efficacy reduced after sprinklers operate

- **Downward momentum transfer from spray to smoke**
- **Cooling of ceiling layer**

Summary

Unsprinklered – No property loss prevention benefit

Probability of automatic smoke vents opening before sprinklers is low

In worst-case scenarios

Adequate protection →	No adverse effect
Marginal protection →	Some adverse effect

Generalizable results

- ✓ Storage/ceiling height
- ✓ Commodity type
- ✓ Ignition scenario
- ✓ Gravity vents ≤ 3.7 m^2

Research Technical Report

RESEARCH TECHNICAL REPORT

Gravity Smoke Vents in Storage Occupancies

[PUBLIC]

Thank You

Thank you – any questions?

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