Structure Separation Experiments: Shed Burns without Wind

NIST WUI Fire Days 2022

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National Institute of Standards and Technology
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Insurance Institute for Business & Home Safety

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CALIFORNIA BUILDING INDUSTRY ASSOCIATION

U.S. Fire Administration

INTERNATIONAL CODE COUNCIL

FEMA

07/13/2022

Structure Separation Experiments

Goal: Provide guidance for the placement of auxiliary structures with floor area < 120 ft²

Primary objective: to quantify the effects of shed

- sizes,
- construction types,
- fuel loading, and
- separation distance

on the ignition of primary structures.

Heat Release Rate
Mass Loss Rate
Heat Flux

Structure Separation Experiments

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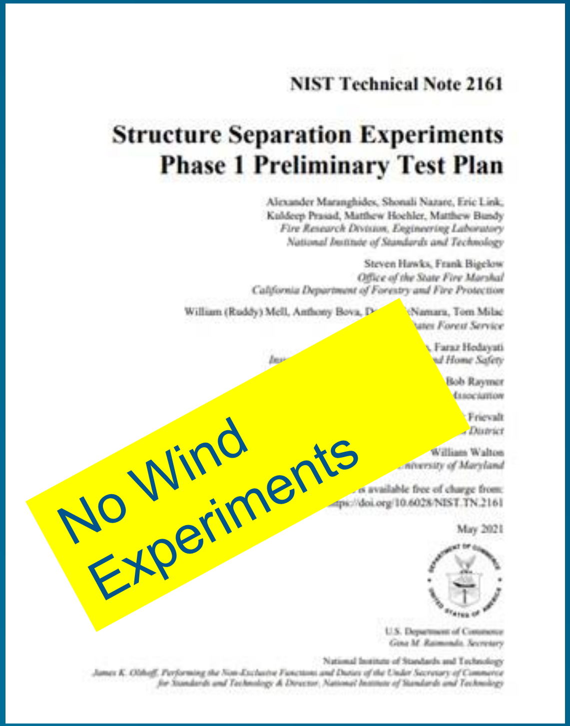
- Test Plan
- Evaluation of Hazard and Safety
- Modeling
- Experiments



NIST Technical Note 2161

Structure Separation Experiments Phase 1 Preliminary Test Plan

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May 2021

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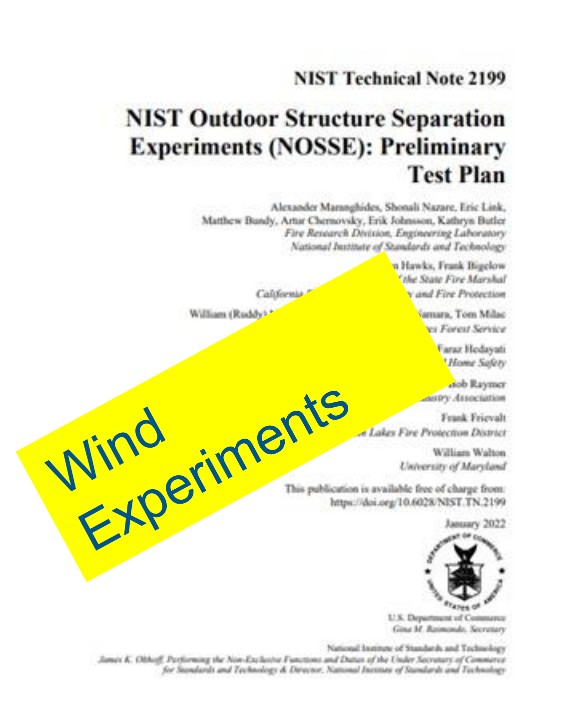
James K. Olthoff, Performing the Non-Exclusive Functions and Duties of the Under Secretary of Commerce for Standards and Technology & Director, National Institute of Standards and Technology



NIST Technical Note 2199

NIST Outdoor Structure Separation Experiments (NOSSE): Preliminary Test Plan

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January 2022

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Structure Separation Experiments

- Preliminary Structure Separation Experiments
- Measurement Verification Experiments
- Indoor Shed Burn Experiments
- Indoor Shed + Target Experiments
- Outdoor Shed Burn Experiments at IBHS


NIST Technical Note XXXX

Structure Separation Experiments:
Shed Burns without Wind

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In Review

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Preliminary Structure Separation Experiments

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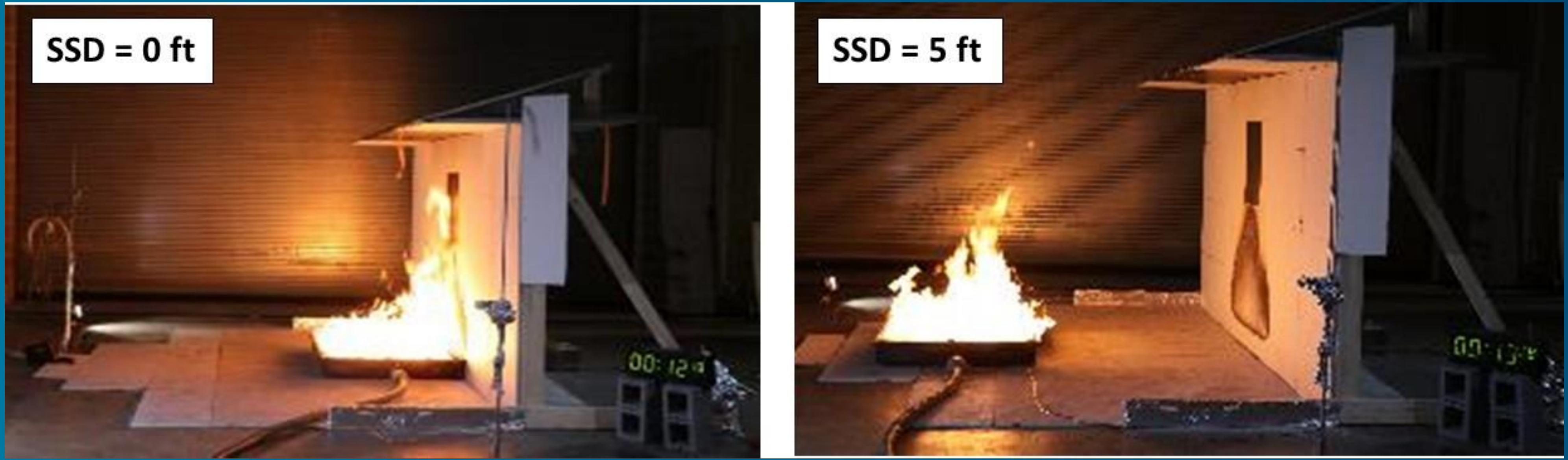
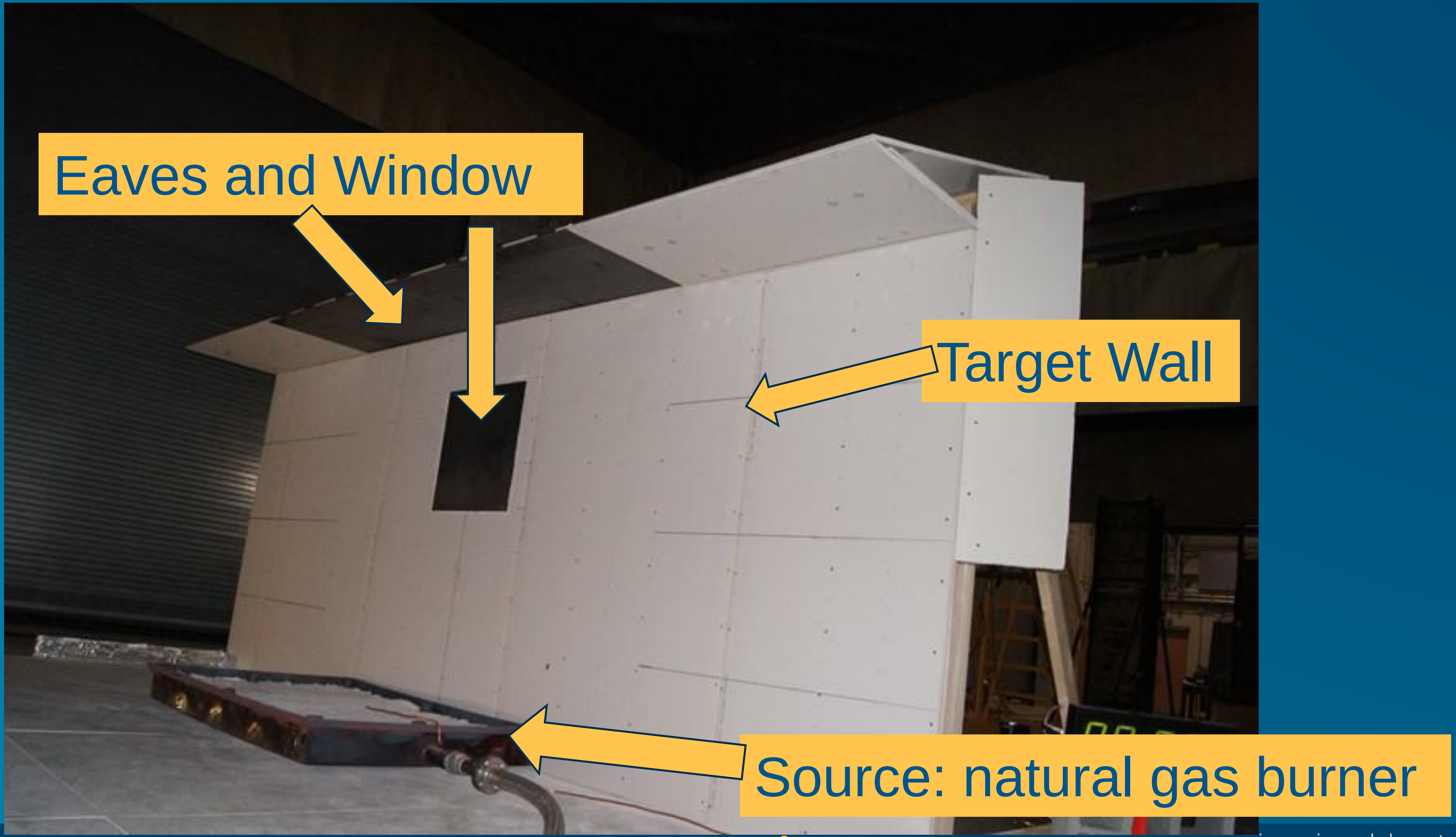


Objective: To optimize instrumentation and experimental design for shed burn experiments

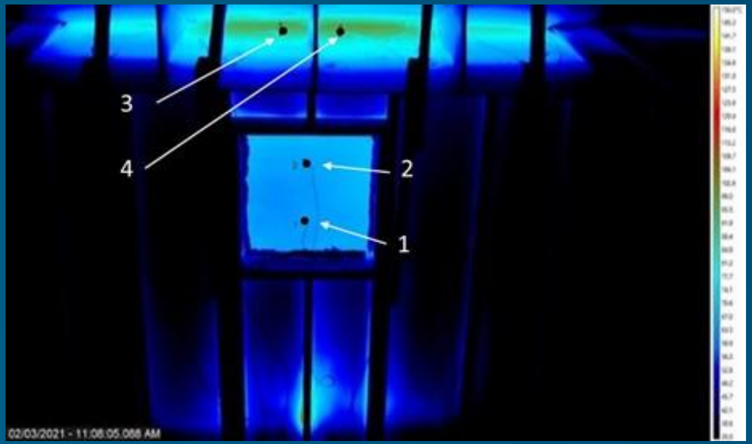
Measurements

- ✓ Heat release rate
- ✓ Temperature
- ✓ Heat Flux
- ✓ Airflow

Preliminary Structure Separation Experiments



Preliminary Structure Separation Experiments



Technical Outcomes:

- Extensive database for modeling verification
- Aided in troubleshooting and optimizing instrumentation and data acquisition
- Thermal propagation in both horizontal (along the eaves) and vertical (on the window) configurations
- Provided insights into effects of airflow bias within NFRL

Measurement Verification Experiments

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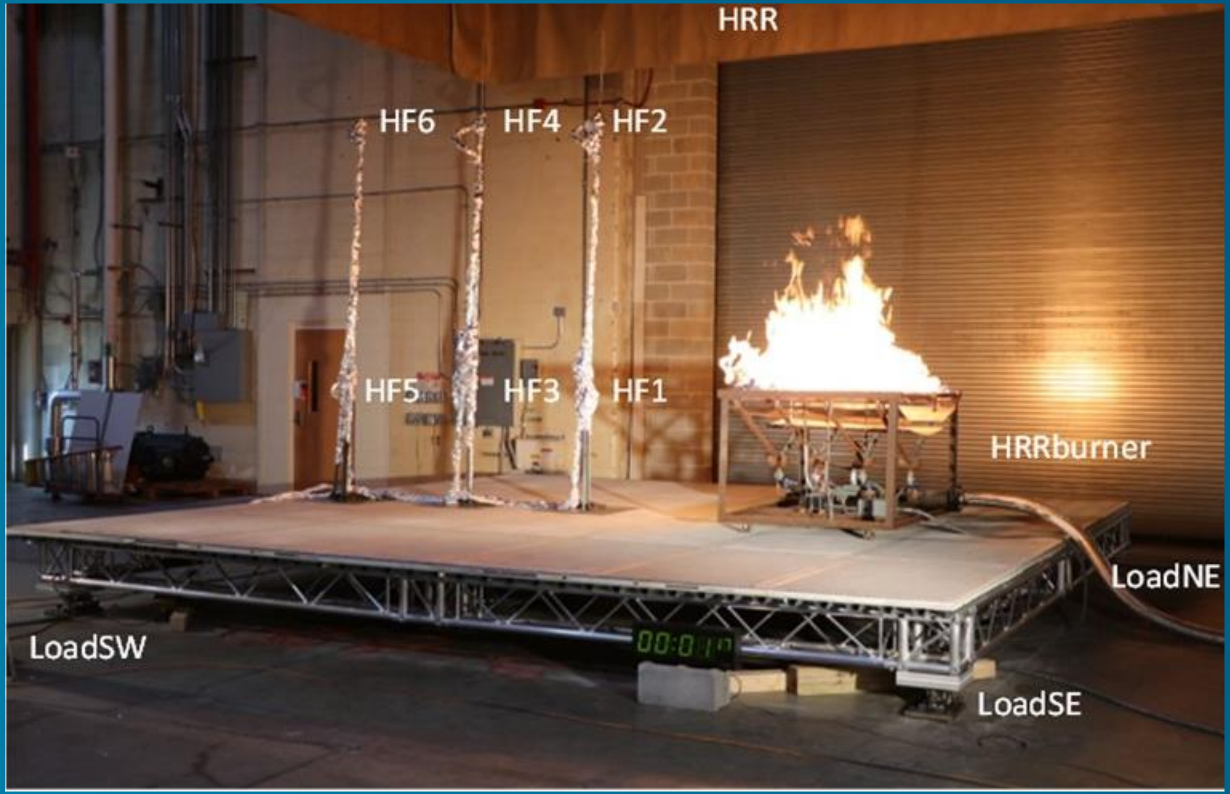
Objective: To confirm the system operations including the calorimetry, mass loss, and heat flux measurements



Measurements

- ✓ HRR
- ✓ Mass Loss
- ✓ Heat Flux
- ✓ Temperature

Measurement Verification Experiments

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Technical Findings:

- Heat release measurements using fuel consumption and oxygen consumption calorimetry showed good agreement
- Data analysis confirmed proper delay times applied for heat release computation by oxygen consumption calorimetry
- Comparison of heat release and heat flux data showed similar time dependencies
- Verification experiments confirmed the need for thermal insulation of the load cells

Uninsulated Load Cell

Insulated Load Cell

Indoor Shed Burn Experiments at NIST

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Objectives:

1. To quantify thermal exposures in terms of HRR and heat flux measurements
2. To assess the feasibility of the mass loss method for estimating HRR from a burning shed.

Measurements
- ✓ HRR
- ✓ Mass Loss Rate
- ✓ Heat Flux
  - ✓ Above the shed
  - ✓ Across the shed

Technical Coupling of Laboratory and Outdoor Experiments

Indoor Shed Burn Experiments at NIST

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Combustible

Closets

Very Small Sheds

Noncombustible

< 75 ft^3 (15 ft^2)

< 150 ft^3 (30 ft^2)

Indoor Shed Burn Experiments at NIST

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Combustible

High Fuel Loading

Low Fuel Loading

Noncombustible

Indoor Shed Burn Experiments at NIST

Test #	Test ID	Material	Shed Type	Fuel Load*	Mass, kg			Fuel Density, MJ/ft^2
					Shed	Cribs	Total combustible	
1	1B-WCh0	Wood	Closet	High (4)	49	78	127	152
2	1B-WCh0-R1	Wood	Closet	High (4)	48	78	126	152
3	1B-WCh0-R2	Wood	Closet	High (4)	48	78	126	152
4	1B-PVSh0	Plastic	Very Small	High (6)	61	115	176	161
5	1B-WVSh0	Wood	Very Small	High (6)	75	117	192	142
6	1B-SVSh0	Steel	Very Small	High (6)	42	116	116	111
7	1B-WCl0	Wood	Closet	Low (2)	49	38	87	79
8	1B-PCl0	Plastic	Closet	Low (2)	38	39	67	104
9	1B-SCl0	Steel	Closet	Low (2)	24	38	38	49

(number of 1-A cribs)

Indoor Shed Burn Experiments at NIST

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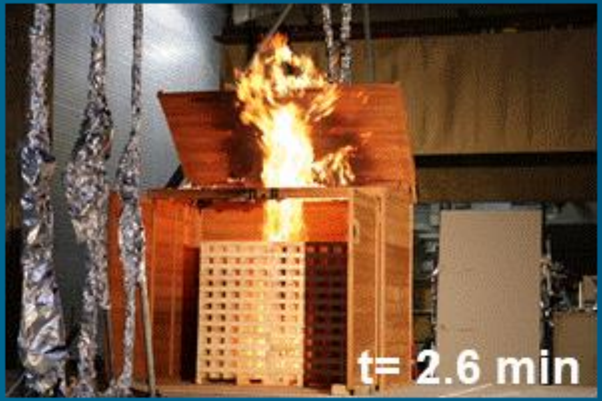
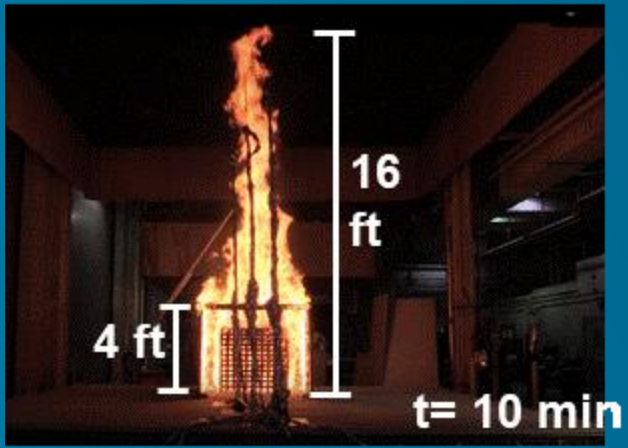


1B-WCh0



Combustible Wood Closet

Test Procedure:

- ✓ Record mass of shed and mass of cribs
- ✓ Measure moisture content of wood cribs
- ✓ Safety briefing
- ✓ Start data acquisition
- ✓ Ignition using heptane pool fire

Indoor Shed Burn Experiments at NIST

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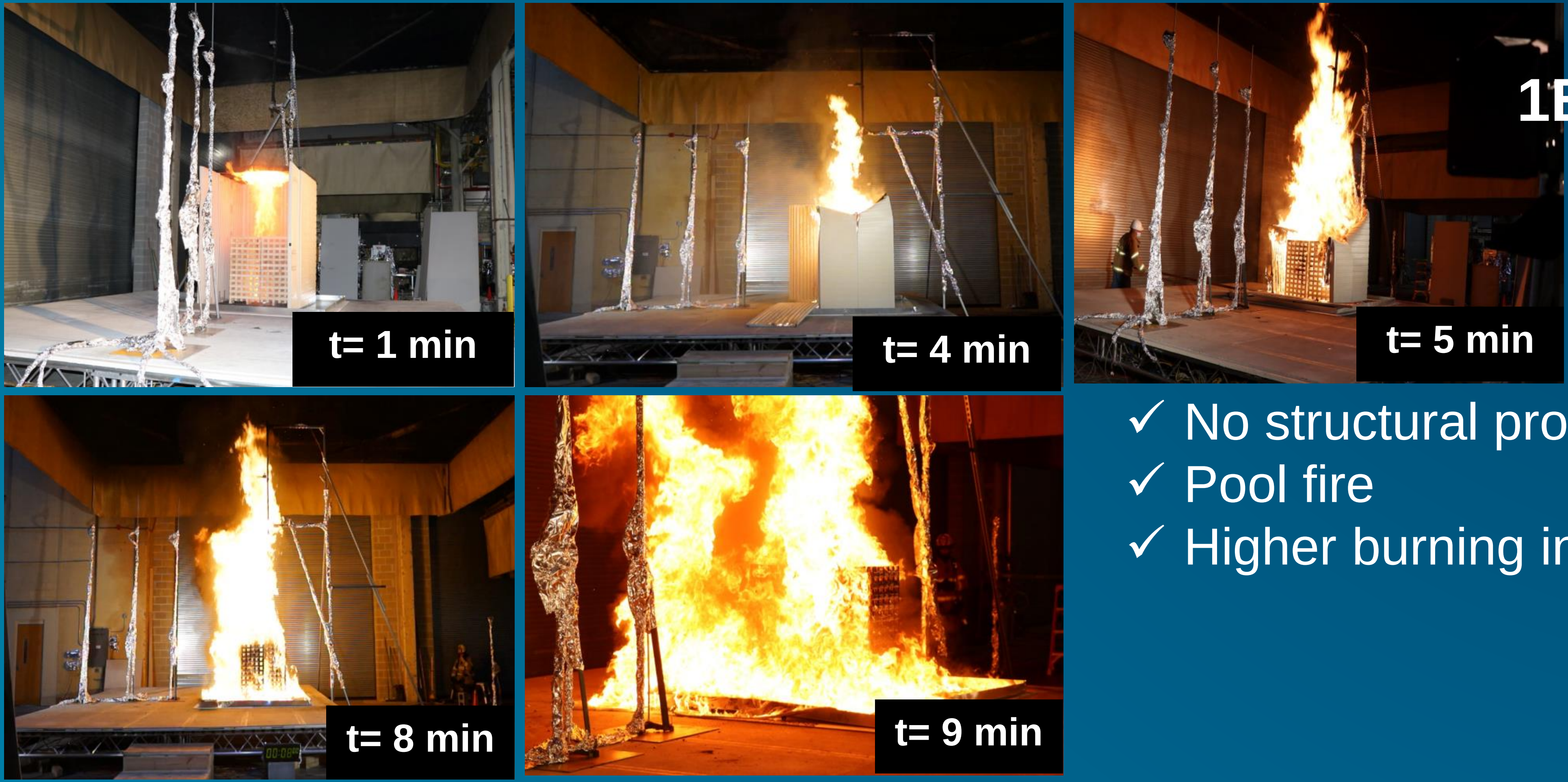

1B-PVSh0

- ✓ No structural protection
- ✓ Pool fire
- ✓ Higher burning intensity

Combustible Plastic Very Small Shed

Indoor Shed Burn Experiments at NIST

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Noncombustible Steel Very Small Shed

1B-SVSh0

- ✓ Good structural integrity
- ✓ Longer duration burn
- ✓ Flame jetting

Indoor Shed Burn Experiments at NIST

Technical Findings

- **Good Repeatability**
  - Comparisons of the HRR curves for repeated tests had similar shapes, magnitudes, and burning periods
  - Data show reproducibility of the measured quantities with PHRR variation of 5 % and THR variation of 2 %
- **Good Agreement between Oxygen Calorimetry and Mass Loss Method**
  - HRR estimated from the mass loss rate was very similar to the HRR measured by oxygen consumption calorimetry

Indoor Shed Burn Experiments at NIST

Technical Findings Contd.

- **Fire Hazard varied with Construction Material, Shed Size and Fuel Loading**
  - Construction material for wood and plastic sheds contributed approximately 60 % increase in fuel load compared to the steel shed
  - THR from source structure corresponded with their respective total combustible mass
  - Lower fuel loading density allows for higher oxygen availability and hence faster flame spread over the combustible fuel

Indoor Shed Burn Experiments at NIST

Technical Findings Contd.

- **Thermal Exposures varied Spatially and Temporarily**
  - Measured peak heat flux show an inverse square relationship with radial distance.
  - Generally, lower HFGs recorded higher heat fluxes compared to the upper HFGs due to their relative proximity to the source fire compared to the upper flux gauges.
  - Flame “jetting” resulted in very high local exposures.
  - Flame jetting depends on size of door opening.

Introduction

Preliminary Structure Separation Experiments

Measurement Verification Experiments

Indoor Shed Burn Experiments

Indoor Shed + Target Experiments

Summary/Implementation

Indoor Shed + Target Experiments at NIST

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Objective:

To assess target structure performance for exposures from different sheds (construction, size, fuel loading) placed at different SSDs with no added wind field.

Target Structure Performance
- ✓ Window
- ✓ Vent
- ✓ Eaves
- ✓ Exterior layer of wall

Measurements
- ✓ HRR
- ~~✓ Mass Loss Rate~~
- ✓ Heat Flux
- ✓ Temperature

Realistic no-wind scenario

Indoor Shed + Target Experiments at NIST

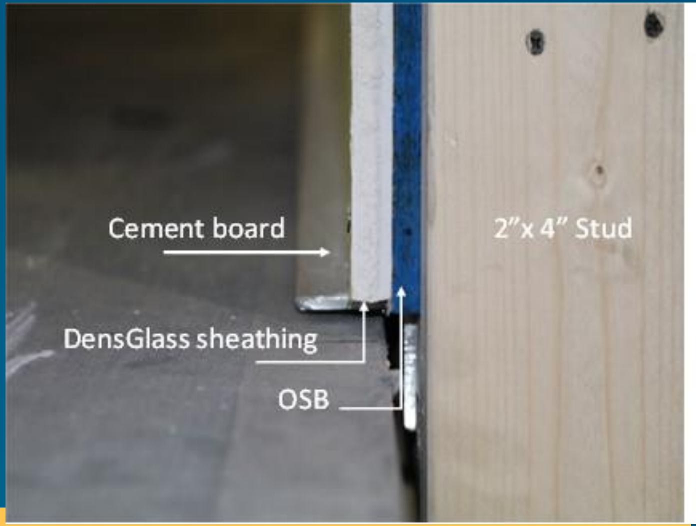
Eave Vent Front

Eave Vent Back

Shutter Open

Shutter Closed

Annealed Glass Window



X Section of Wall

Indoor Shed + Target Experiments at NIST

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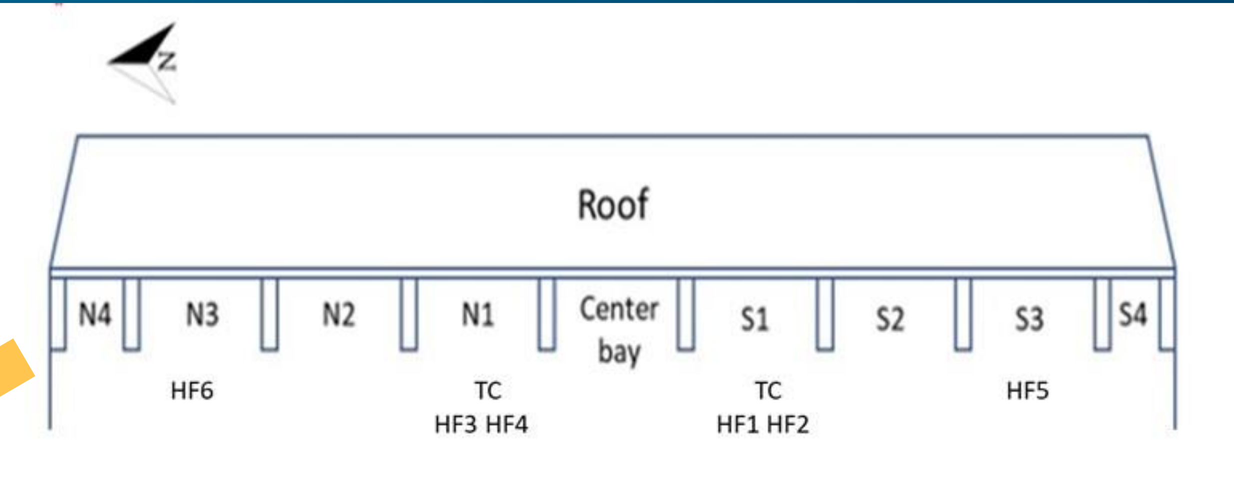
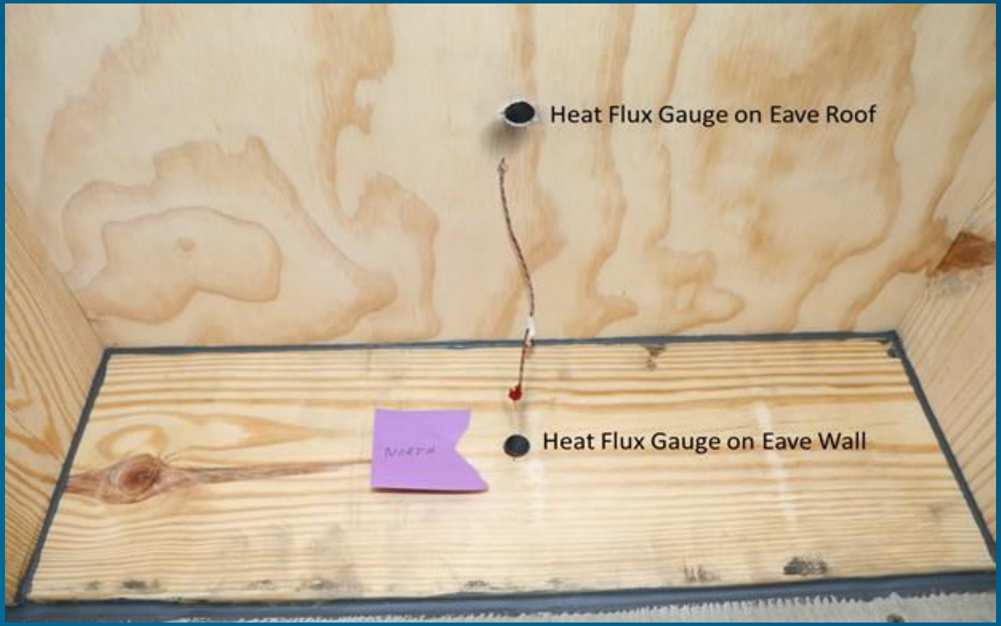


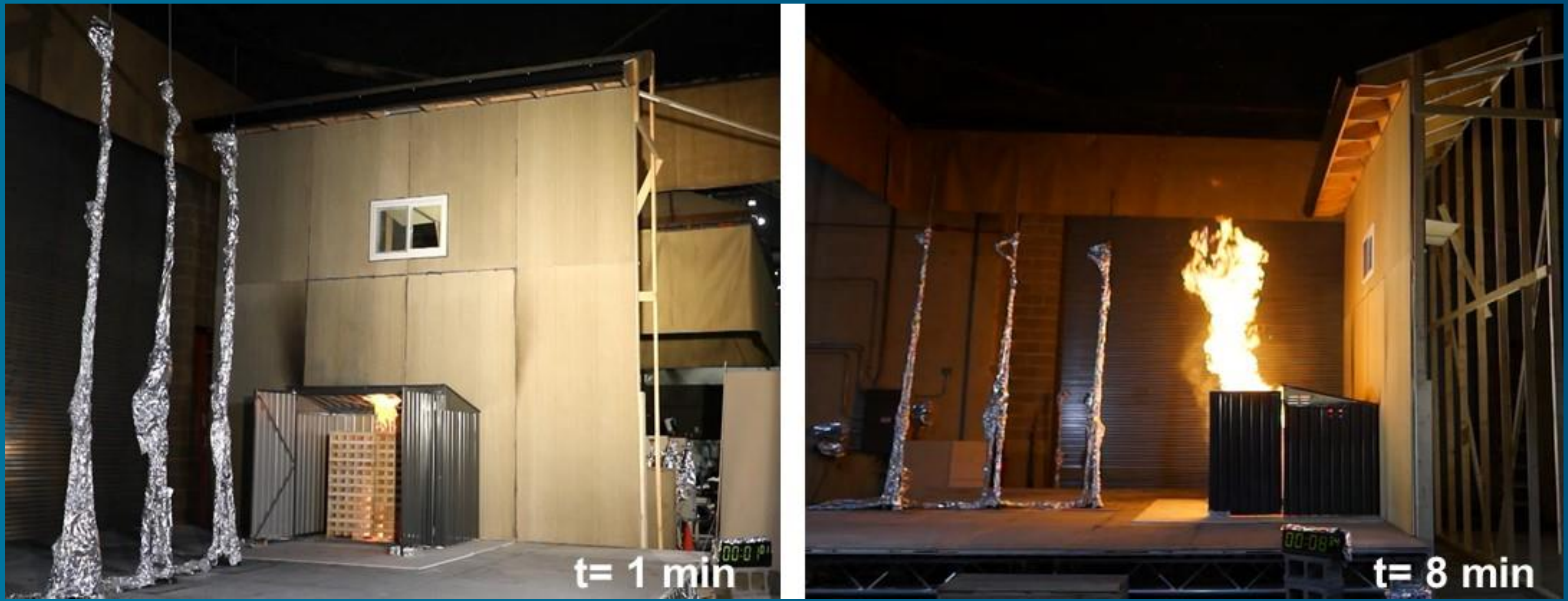


Indoor Shed + Target Experiments at NIST

1B-WCh0-0

- **Wood Closet**
- **Low fuel loading**
- **SSD = 0**
- **No wind**

Indoor Shed + Target Experiments at NIST



- Steel Closet
- High fuel loading
- SSD = 0
- No wind

1B-SCh0-0

Indoor Shed + Target Experiments at NIST

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1B-SVSh0-5

- **Steel Very Small Shed**
- **High fuel loading**
- **SSD = 5 ft**
- **No wind**

Shed Orientation
Door Opening

Indoor Shed + Target Experiments at NIST

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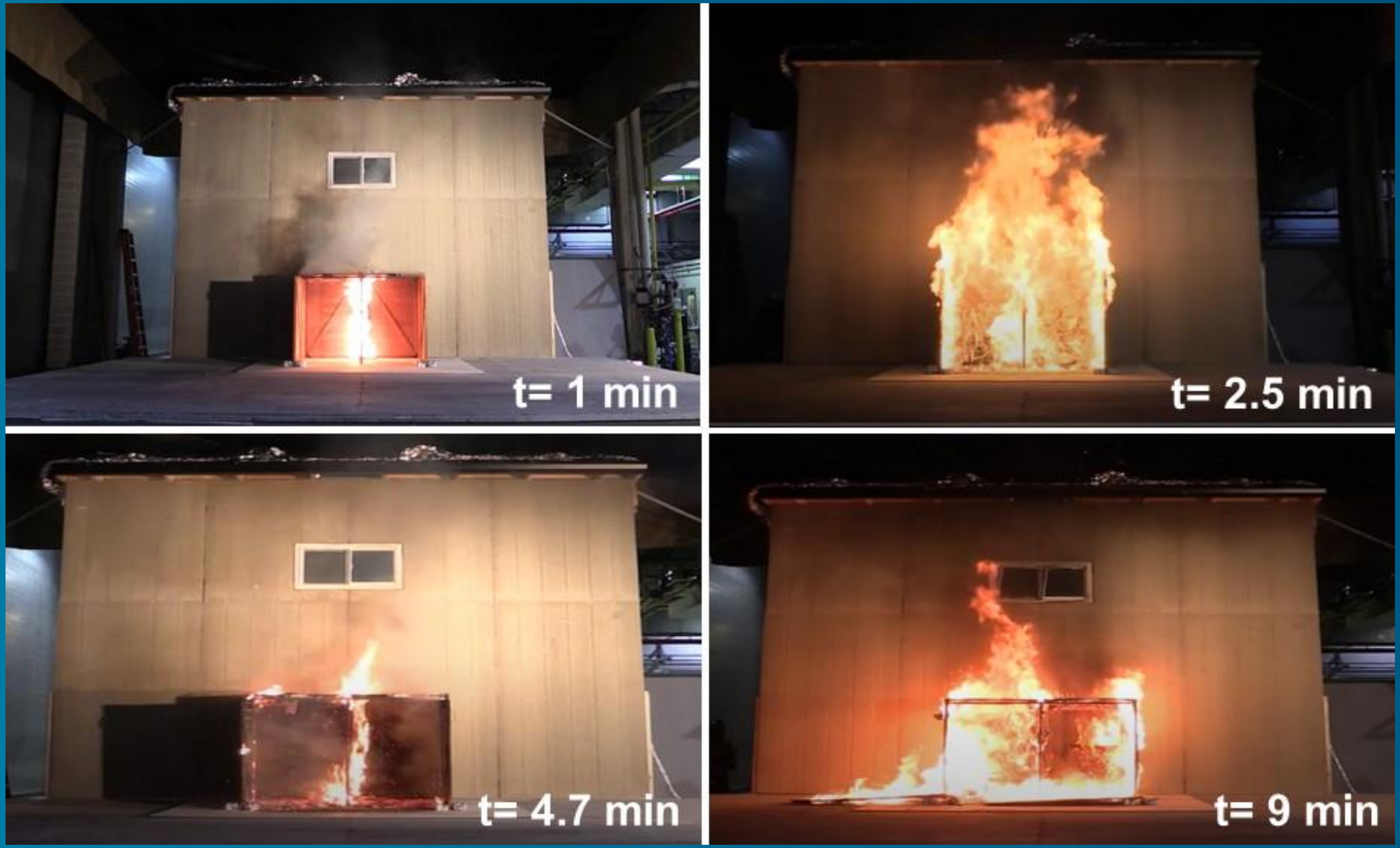

1B-WC00-0

- Wood Closet
- No fuel loading
- SSD = 0
- No wind

Exterior Wall Performance

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With extra protective layer

Significant spalling of cement board

Cracking of cement board

No thermal damage to sheathing

Without extra protective layer Closet

Code Compliant

Significant thermal damage to OSB

Window Performance

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Flame Contact | No Flame Contact

Introduction

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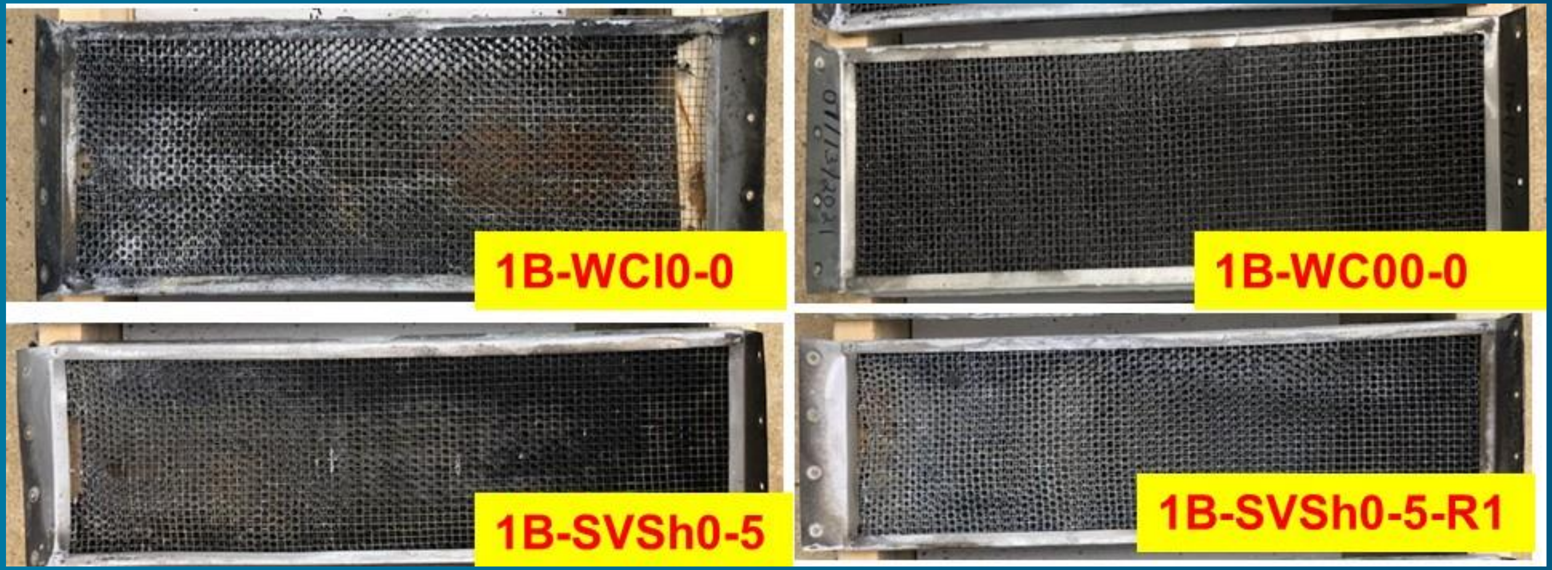
Indoor Shed + Target Experiments

Summary/Implementation

Vent Performance



- ✓ Flame contact
- ✓ Intumescent coating activated

- X No flame contact
- X Intumescent coating not activated

Vent Performance

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- **ASTM E 2886 exposure:** 300 kW ± 10 kW for 10 min
- **Failure Criterion:** T_{vent} > 360 ºC on the unexposed side of the vent

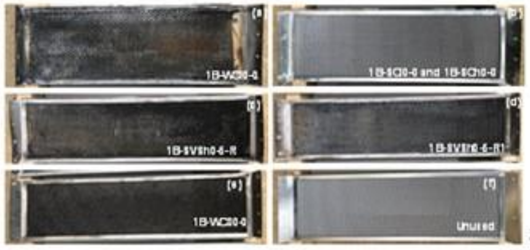

Figure 118. Photographs of vents showing effects of exposure compared to the unused vent in (f).

The radiant and convective heat exposure were significantly lower with noncombustible Closets (test 1B-SC10-0 and test 1B-SCh0-0), with the door-opening facing away from the target wall, keeping the temperatures in the vent area well below the activation temperature of the intumescent coating. However, for the Very Small steel shed with door-opening facing towards the target wall and with an SSD = 5 ft (test 1B-SVSh0-5 and test 1B- SVSh0-5-R1), the vents were exposed to significant radiant and convective heat. While the intumescence mechanism activated during such high heat exposures, the protective barrier thus formed was not effective for a longer duration of exposures. The performance of these vents cannot be interpreted as failures with respect to the standard test method (ASTM E 2886) as the thermal exposures to the vents were significantly different than those specified in the standard. The standard test method (ASTM E 2886) specifies exposure of vents to flaming fire with HRR of 300 kW ± 10 kW for 10 min.

Table 15. Maximum measured temperatures at the vent during thermal exposures from burning sheds.

Test ID	Material	PHRR, MW	Maximum measured temperature at the vent, °C					
			TCventFront		TCventBack		TCshBack	
			Peak 1	Peak 2	Peak 1	Peak 2	Peak 1	Peak 2
1B-WC10-0	Wood	3.38	952	—	[illegible]	[illegible]	265	310
1B-SC10-0	Steel	0.89	58	—	55	—	46	—
1B-SCh0-0	Steel	1.40	116	—	101	—	72	—
1B-SVSh0-5	Steel	2.71	400	434	153	[illegible]	275	278
1B-SVSh0-5-R1	Steel	3.11	403	855	[illegible]	[illegible]	371	709
1B-WC00-0	Wood	2.77	386	—	[illegible]		372	—

141

Peak exposures tested > 10-20x ASTM exposure

Caulking Performance

Flame Penetration

Use of FR caulking prevented flame penetration in subsequent tests

Summary

Target Hardening, Shed Usage, and Further Research

Summary (1 of 5)

Target Hardening

- ✓ Replace annealed glass windows with tempered glass where fire exposures are expected on the structure. This should be done in conjunction with window screens and other necessary structure hardening for embers and fire (HMM).
- ✓ Use flame-retardant caulking around windows and eave vents.
- ✓ Additional gypsum panel sheathing may be used to prevent ignition of combustible layers of the exterior wall assembly.

Summary (2 of 5)

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Shed Usage

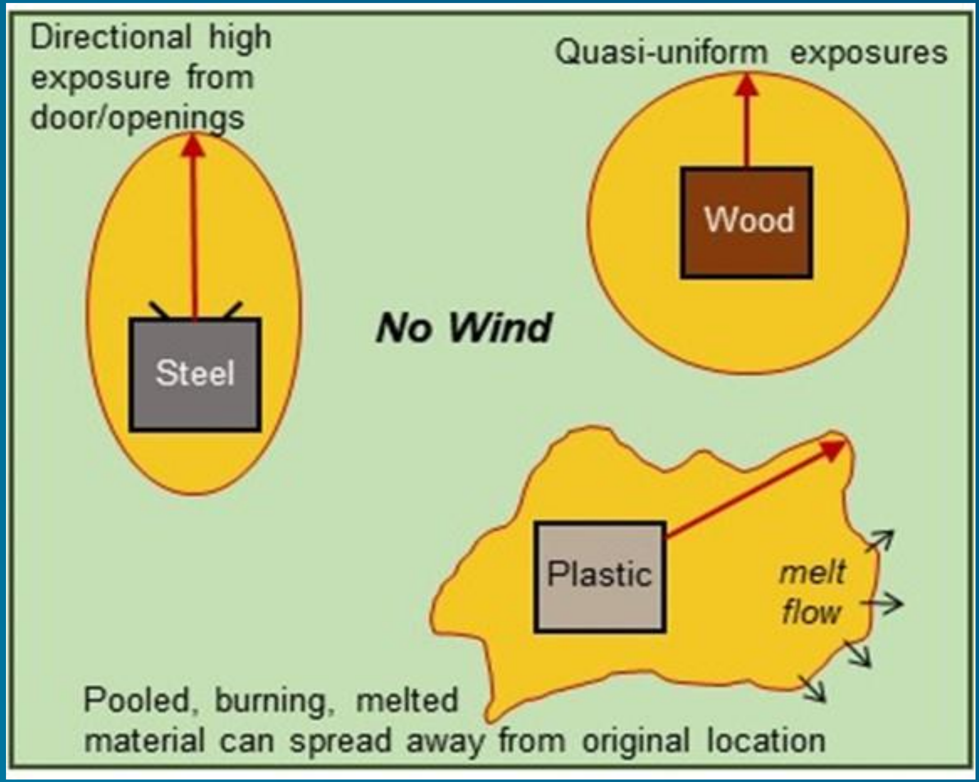
Consider Remove, Relocate, Reduce (RRR) as specified in HMM to reduce fire exposures.

- Minimum SSD = 10 ft for Closet and Very Small sheds (< 26 ft^2).

Summary (3 of 5)

Shed Usage

Choose construction materials to reduce exposures; however, this alone cannot substitute for RRR and SSD



Summary (4 of 5)

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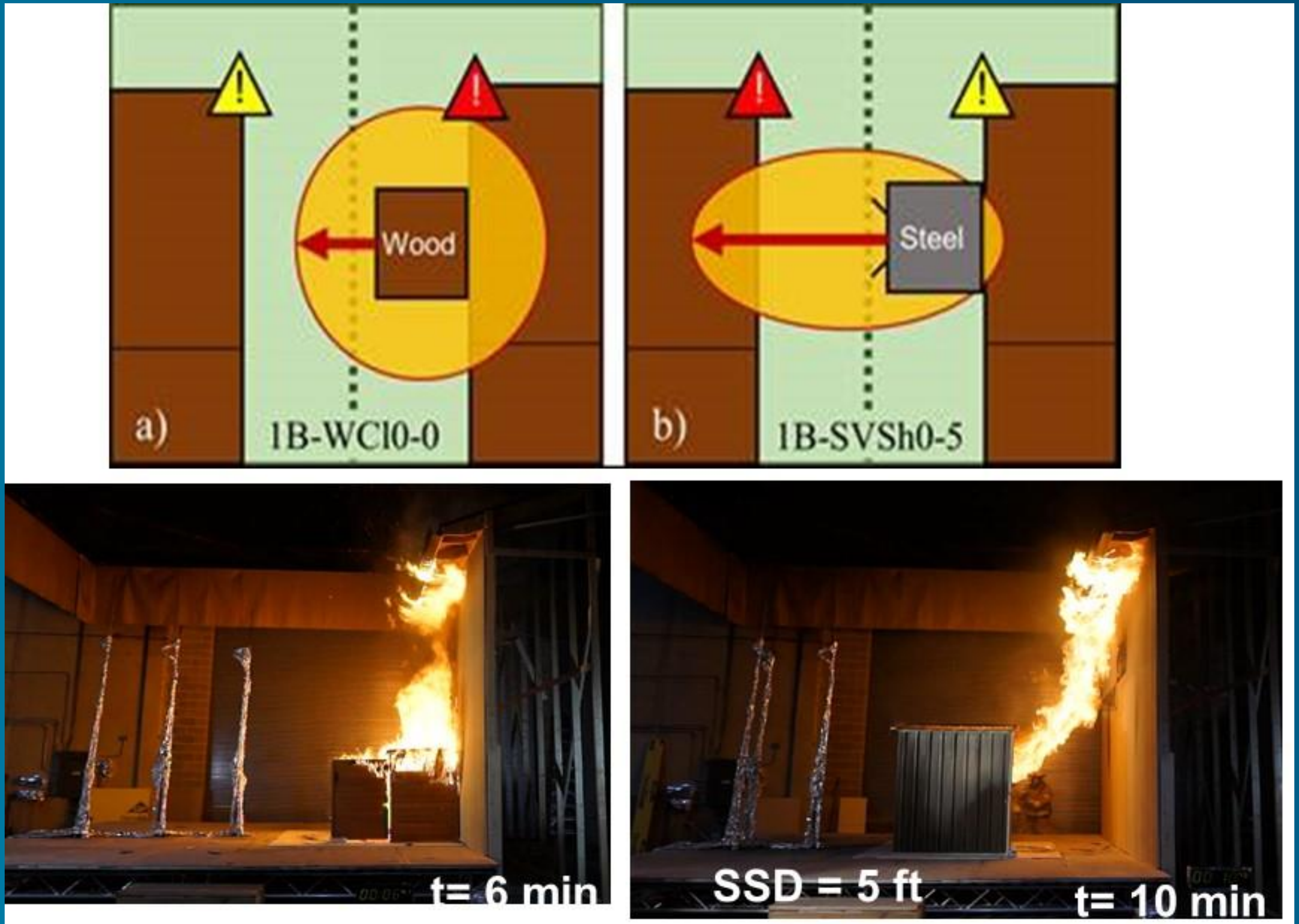
Consider relative position of neighboring residence for door orientation of noncombustible steel shed.



Summary (5 of 5)

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Further Research

- ✓ The standard test method for assessing performance of eave vents needs to be further assessed for realistic thermal exposures. **N**IST **E**ave **V**ent **E**xperiments (NEVE) have been planned to assess vent performance exposed to flaming fires.
- ✓ Assess the performance of fire caulking for extended exterior use. Work is planned at NIST to assess the fire performance of flame retarded caulking that has been exposed to accelerated weathering.

Introduction

Preliminary Structure Separation Experiments

Measurement Verification Experiments

Indoor Shed Burn Experiments

Indoor Shed + Target Experiments

Summary/Implementation

NIST Outdoor Structure Separation Experiments with Wind (NOSSE)

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- ✓ 13 experiments
- ✓ High Fuel Loadings
- ✓ Wood Sheds
- ✓ Steel Sheds
- ✓ Shed Sizes
  - ✓ Closet (< 15 ft²)
  - ✓ Very Small (< 30 ft²)
  - ✓ Small(< 64 ft²)

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