Firebrand Generation from Burning Vegetation and the Ignition of Fuel Beds by Firebrands

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NIST Annual Fire Conference
Gaithersburg, MD
April 4th, 2007

NIST
National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

NIST Collaborators

- Dr. William ‘Ruddy’ Mell
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- Mr. Alexander Maranghides
- Dr. J.C. Yang
- Dr. William Pitts

Firebrand Production

- Firebrands or embers produced as trees and buildings burn
- Lofted firebrands ignite fuels far removed from the fire (spotting)
- **Understanding firebrand ignition of surrounding fuel beds – important to mitigate fire spread in communities**

- In Japan, numerous fires start after an earthquake
- Roof tiles are displaced-wood surfaces exposed to firebrands
- Spotting becomes major factor in fire spread

2003 Southern California Fire

1995 Kobe Earthquake

International Collaboration Established BFRL-NIST (USA) and BRI (Japan)

- Lack of detailed theory on ability of firebrands to ignite fuels limit CFD models predict fire spread [Babrauskas, 2003]
- Three mechanisms are important:
  - **Firebrand Generation (Not Studied in Detail)**
  - **Firebrand Transport (Studied Extensively)**
  - **Ignition of Fuels from Firebrands (Not Studied in Detail)**

Goals

Provide Scientific Basis for WUI Building Codes/Standards

Validate WFDS Model of WUI Fire Spread

Ignition of Fuel Bed by Firebrand

Manzello *et al*., *Int'l J. Wildland Fire* 15: 427-431 (2006)

Building Research Institute

- Experiments performed at the Building Research Institute, Tsukuba, Japan

Korean Pine (*Pinus Koraiensis*)

- Korean Pine used a tree species – indigenous to China, Korean, Japan

Height: Overall height: 4.0 m; Crown Height 3.5 m
MC (dry basis): varied from 80 % to 10 %
Custom drying room constructed to vary MC

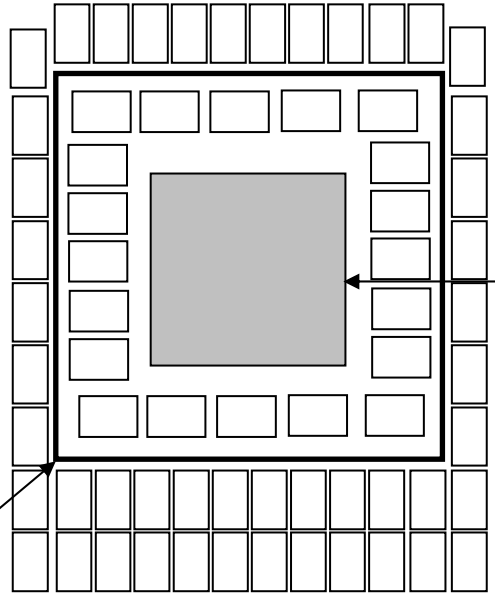
Trees mounted on 2 m (W) by 2 m (L) by 6 mm (t) Platform

Load cells placed under platform, 20 g resolution
100 ms temporal resolution

Korean Pine Tree, 50 % MC.

Firebrand Size Distribution

- Collect firebrand size distribution
  - Water filled pans (40) positioned outward from tree
  - Water quenches firebrands – oven dry determine size, mass



Tree Platform
Mounted on
Load Cells

Collected Firebrands

2 m by 2 m (6mm thick)
Steel Platform

Douglas-Fir Tree Burns at NIST

- Firebrand Collection using water pan array
  - Range of crown heights: 2.4 m – 4.5 m
  - Different moisture regimes
- Mass loss using load cells

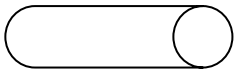
5 m (17') Doug Fir, MC = 25%

Firebrand Size Distribution

- Results compared to Douglas-Fir tree burns conducted at NIST

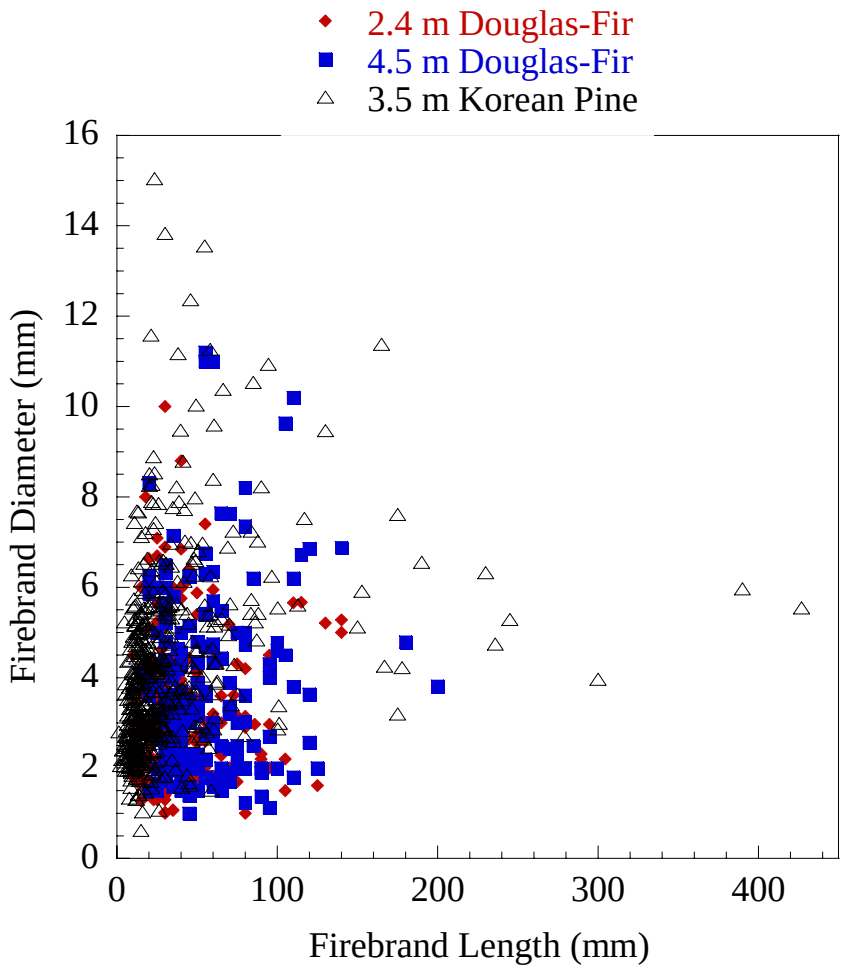
Korean Pine

3.5 m trees



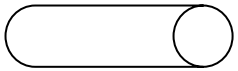
5 mm

34 mm



Douglas-Fir

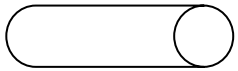
2.4 m trees



3 mm

40 mm

4.5 m trees

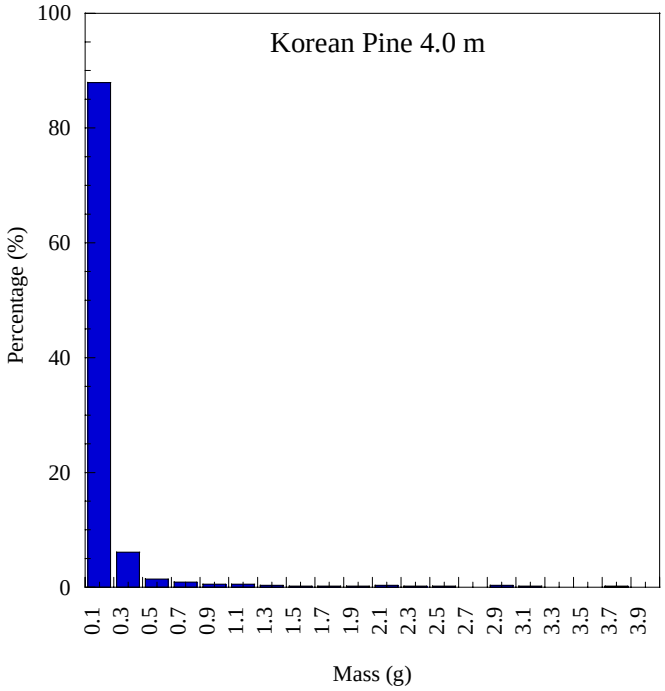


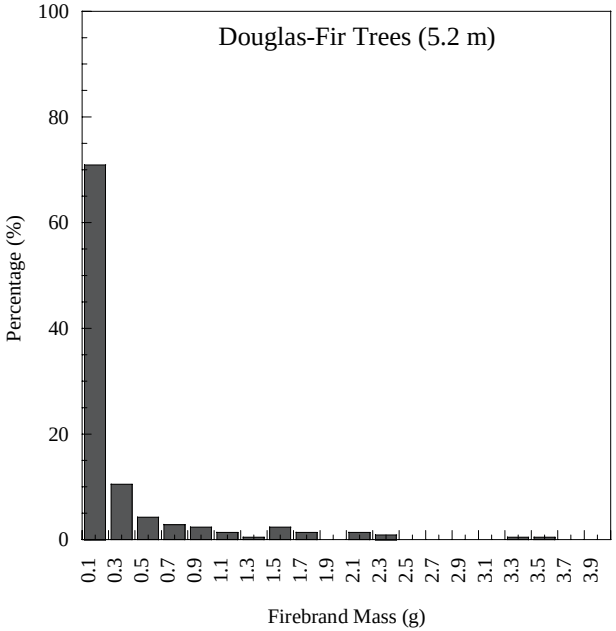
4 mm

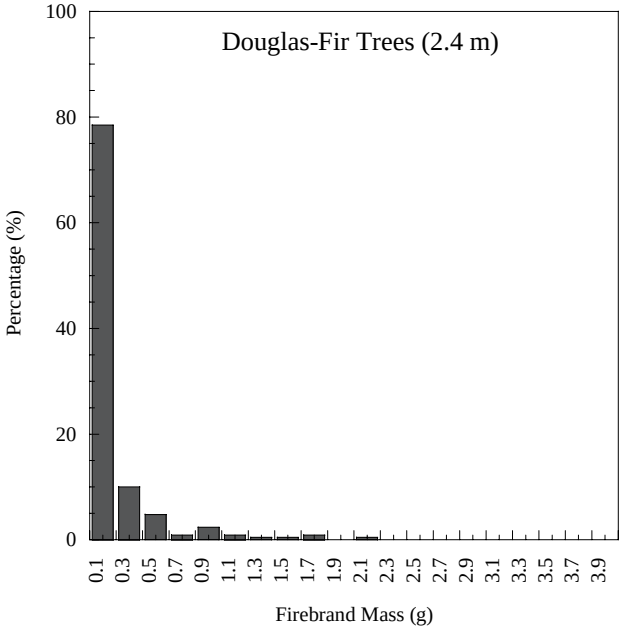
53 mm

Firebrand Mass Distribution

- Over 1500 firebrands weighed

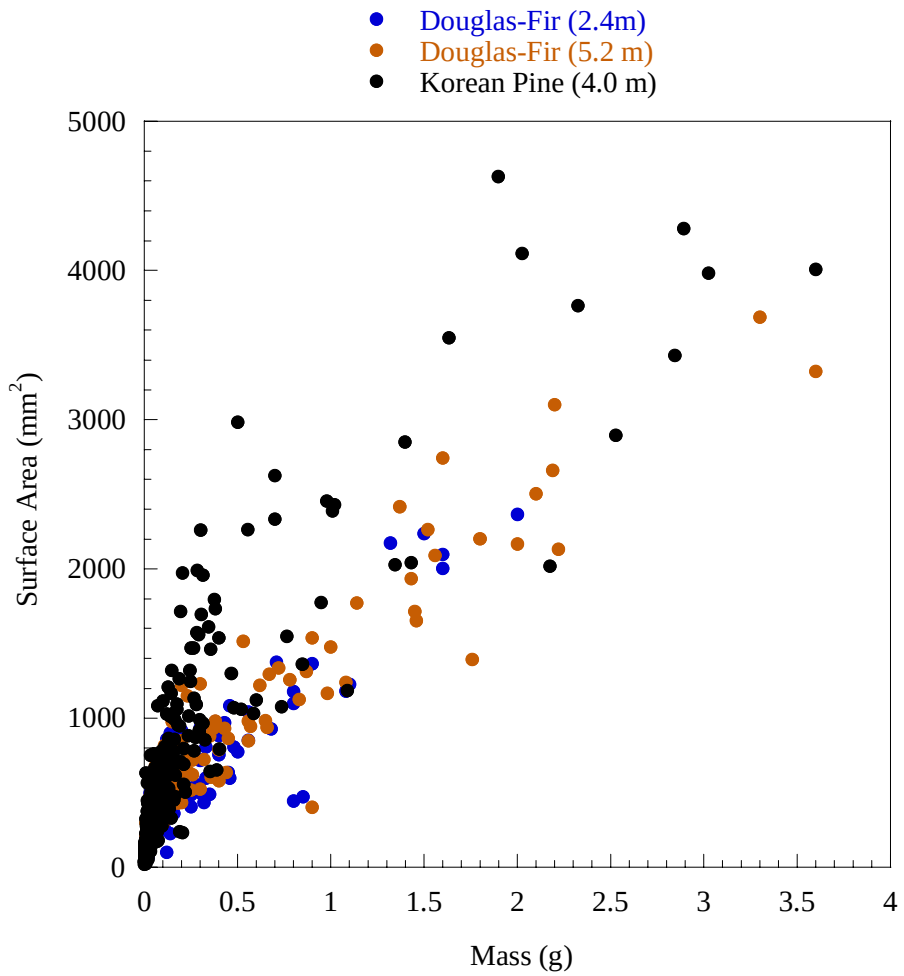






Firebrand Surface Area Distribution

- Firebrand surface area scales with mass
- Scaling dependent on species



Total Firebrand Production

- **Korean Pine Trees produced a larger mass of firebrands, per amount of fuel burned**

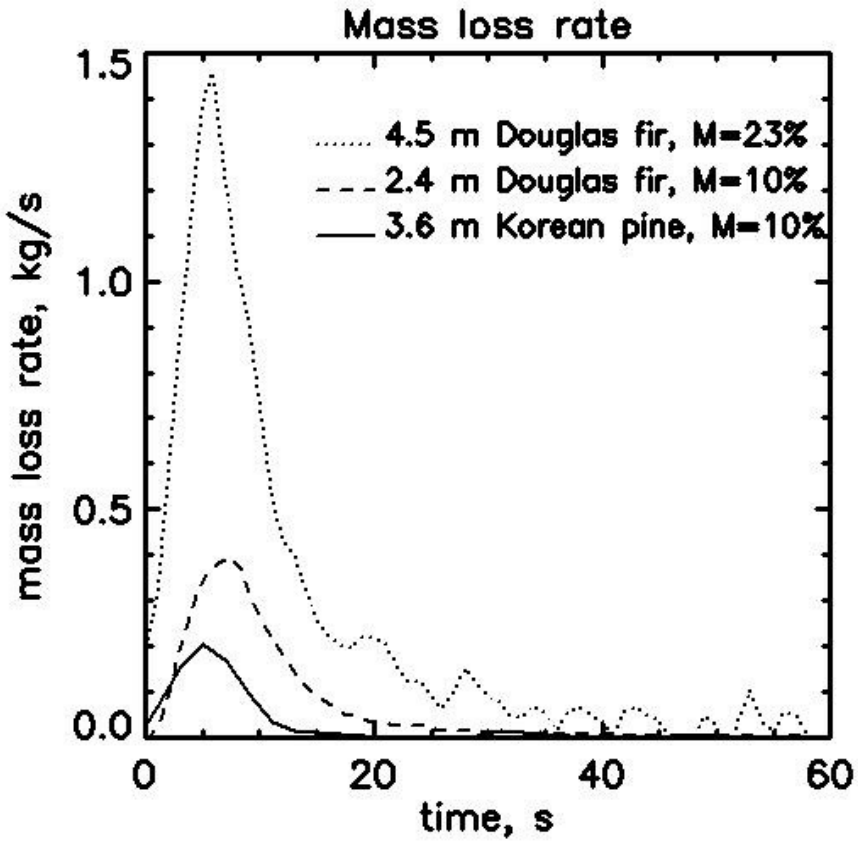
Tree Species	Mass of Firebrands, $m_{fb,}$ (g)	Mass of Firebrands/ Mass Lost During Burning (%)	Mass of Firebrands/Total Tree Mass (%)
Kor. Pine (4.0 m)	33 ± 15	2	0.28
Doug-Fir (2.4 m)	18 ± 4	0.45	0.15
Doug-Fir (5.2 m)	50 ± 5	0.2	0.08

- Douglas-Fir trees, 65 % of burnable mass needles, 17.5 % twigs 0 mm to 6 mm, and 17. 5 % twigs 6 mm to 10 mm
- Korean Pine trees, 58 % of burnable mass needles, 24 % twigs 0 mm to 6 mm, and 18 % twigs 6 mm to 10 mm

- Twigs greater than 10 mm not observed to burn over MC range in this study

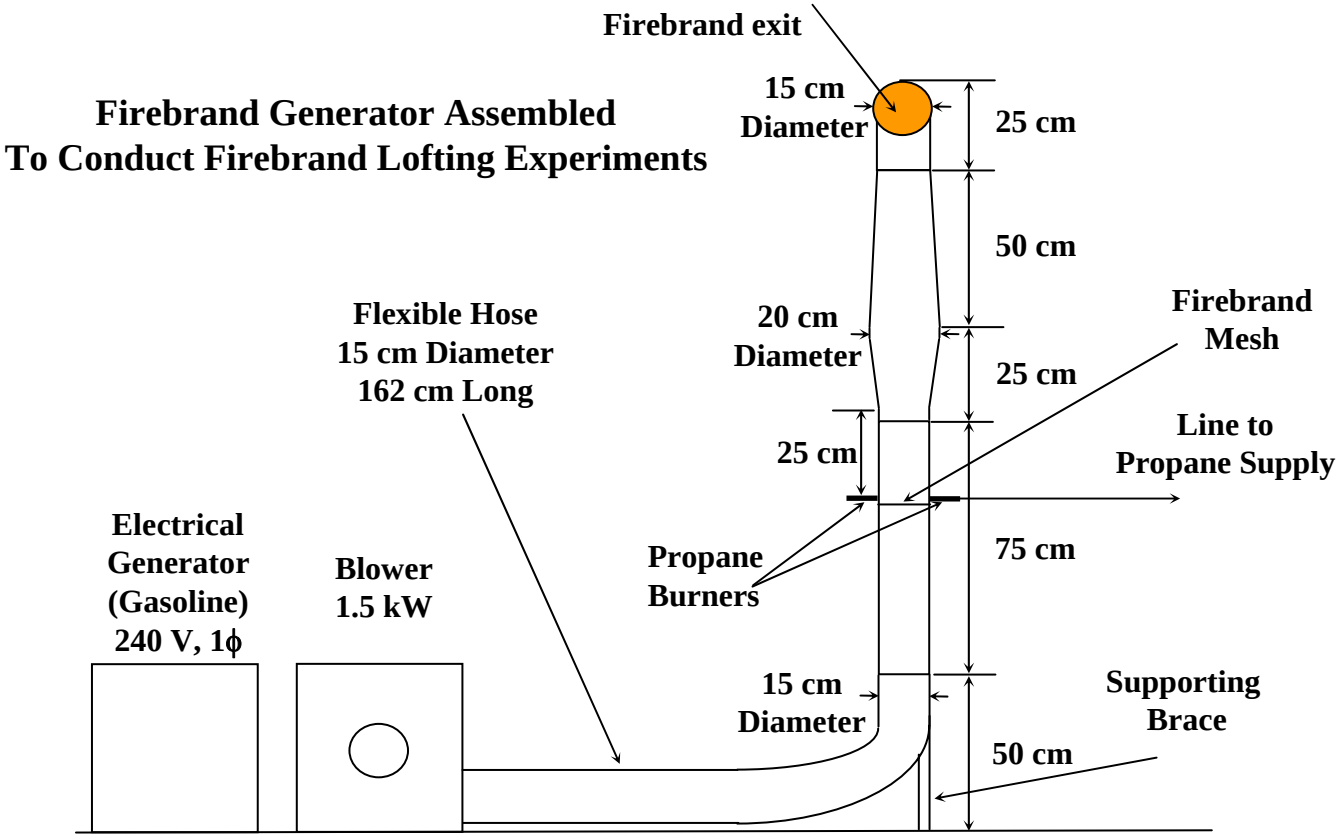
Mass Loss Rate

- Majority of firebrands collected from both species-small mass range
- Postulated that for Douglas-Fir, most firebrands consumed since generated firebrands exposed to more intense fire plume



Firebrand Generator

Capable of producing controlled and repeatable size and mass distribution of firebrands

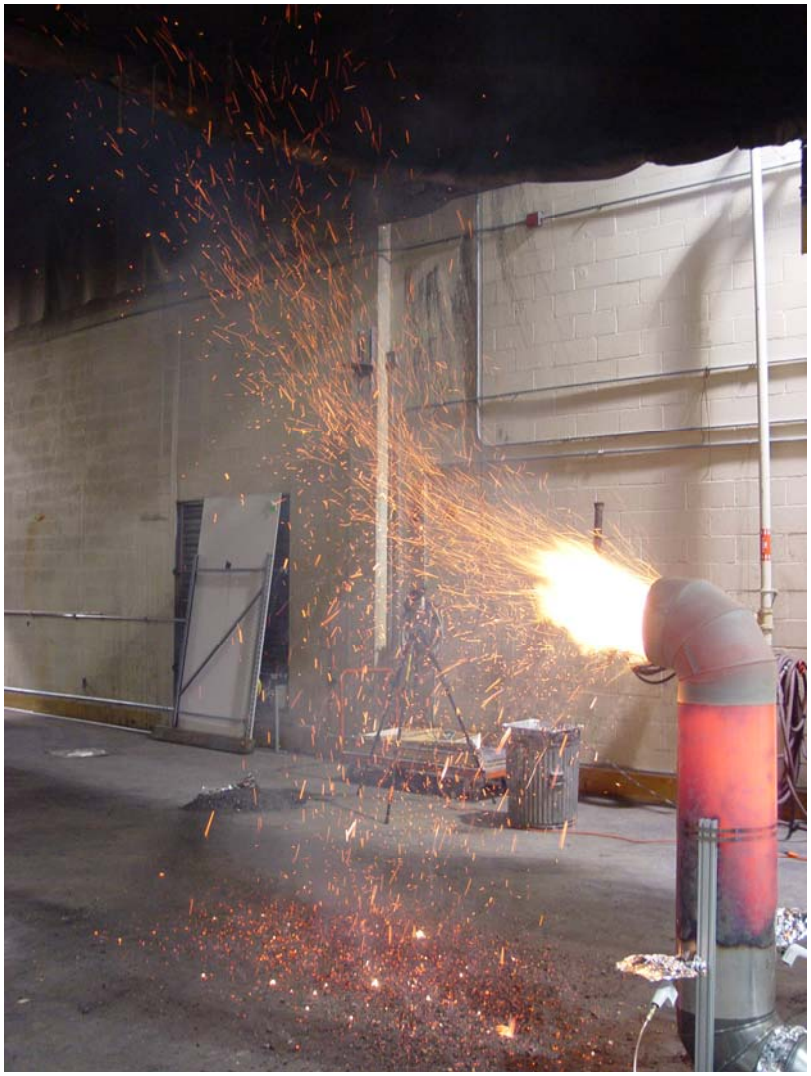


Front View

Side View

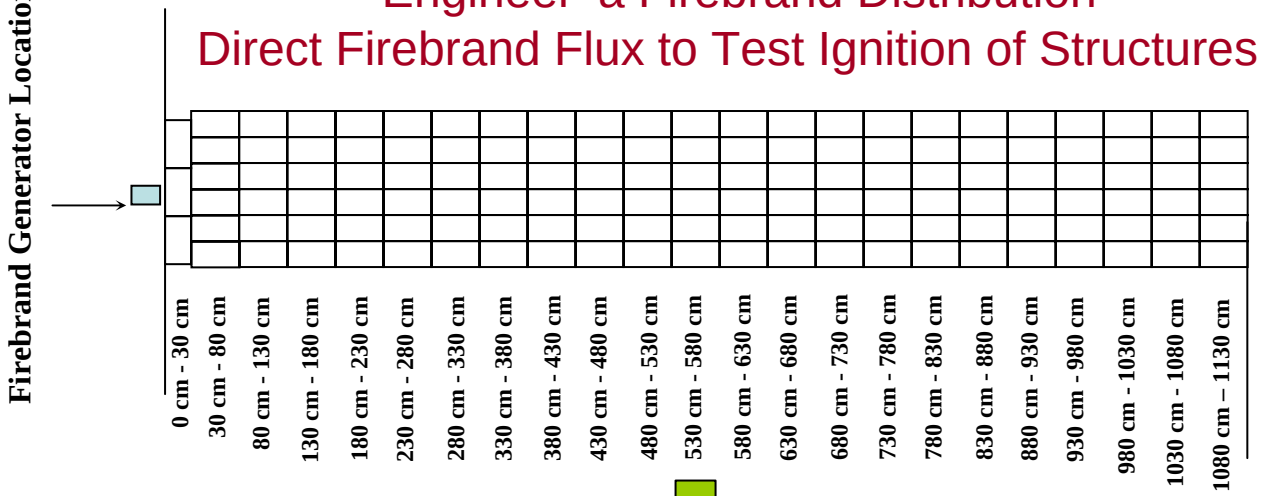
Mulched Doug Fir

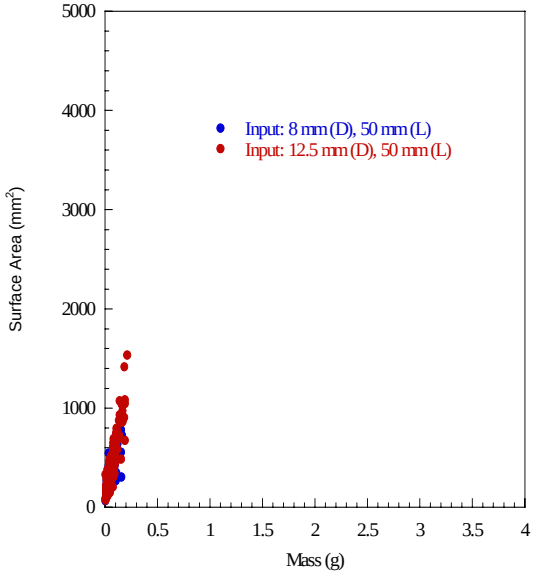
Firebrand Generator

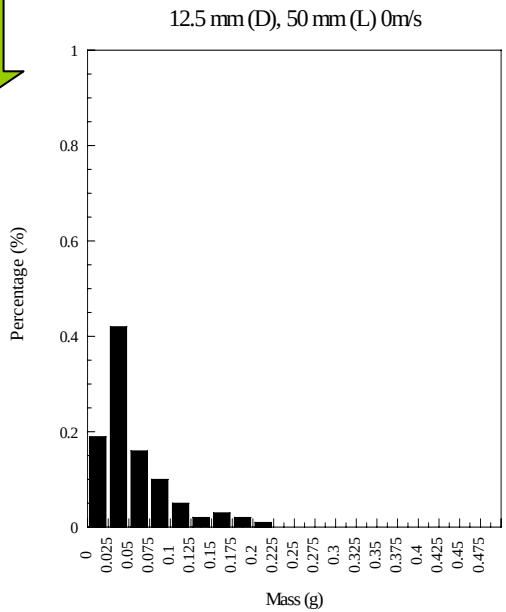


Firebrand Generator Characterization

'Engineer' a Firebrand Distribution
Direct Firebrand Flux to Test Ignition of Structures







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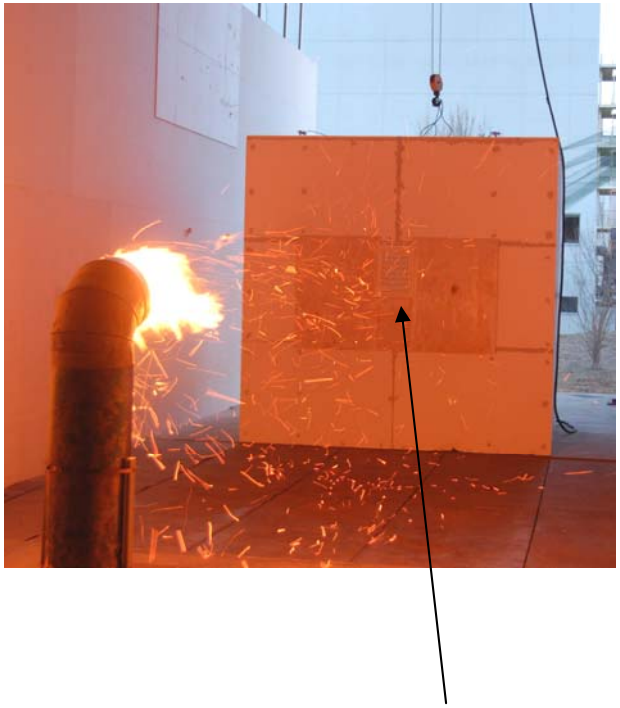
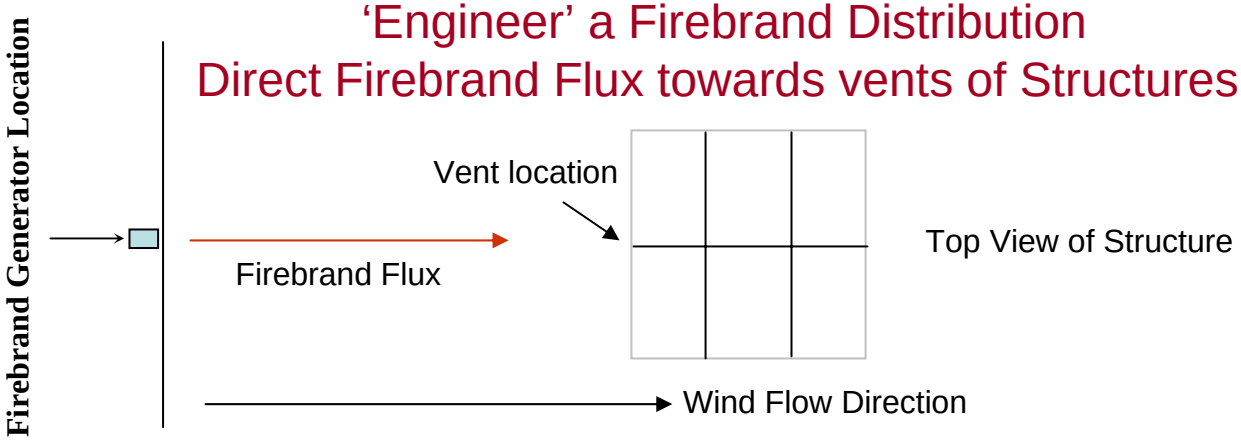
Firebrand Penetration Through Vents



Gable Vent



'Engineer' a Firebrand Distribution
Direct Firebrand Flux towards vents of Structures

Firebrand Goes Through

Screen Behind Vent
Three sizes tested 1/4 , 1/8 , and 1/16 inch

Summary

- Firebrand size distributions measured from full-scale tree burns
  - Korean Pine Trees
  - Douglas-Fir Trees

- Korean Pine trees do not produce significant numbers of firebrands if moisture content is larger than 35 % (no wind applied)

- Firebrands - cylindrical in shape

- Surface area of generated firebrands scaled with firebrand mass; scaling dependent on species

- Korean Pine trees produced a larger mass of firebrands, per amount of fuel burned

Acknowledgements

NIST

- Dr. W.L. Grosshandler
- Dr. R. Rehm

BRI

- Dr. I. Hagiwara
- Mr. S. Nanno
- Mr. K. Nakamura
- Dr. H. Masuda
- Dr. T. Naruse

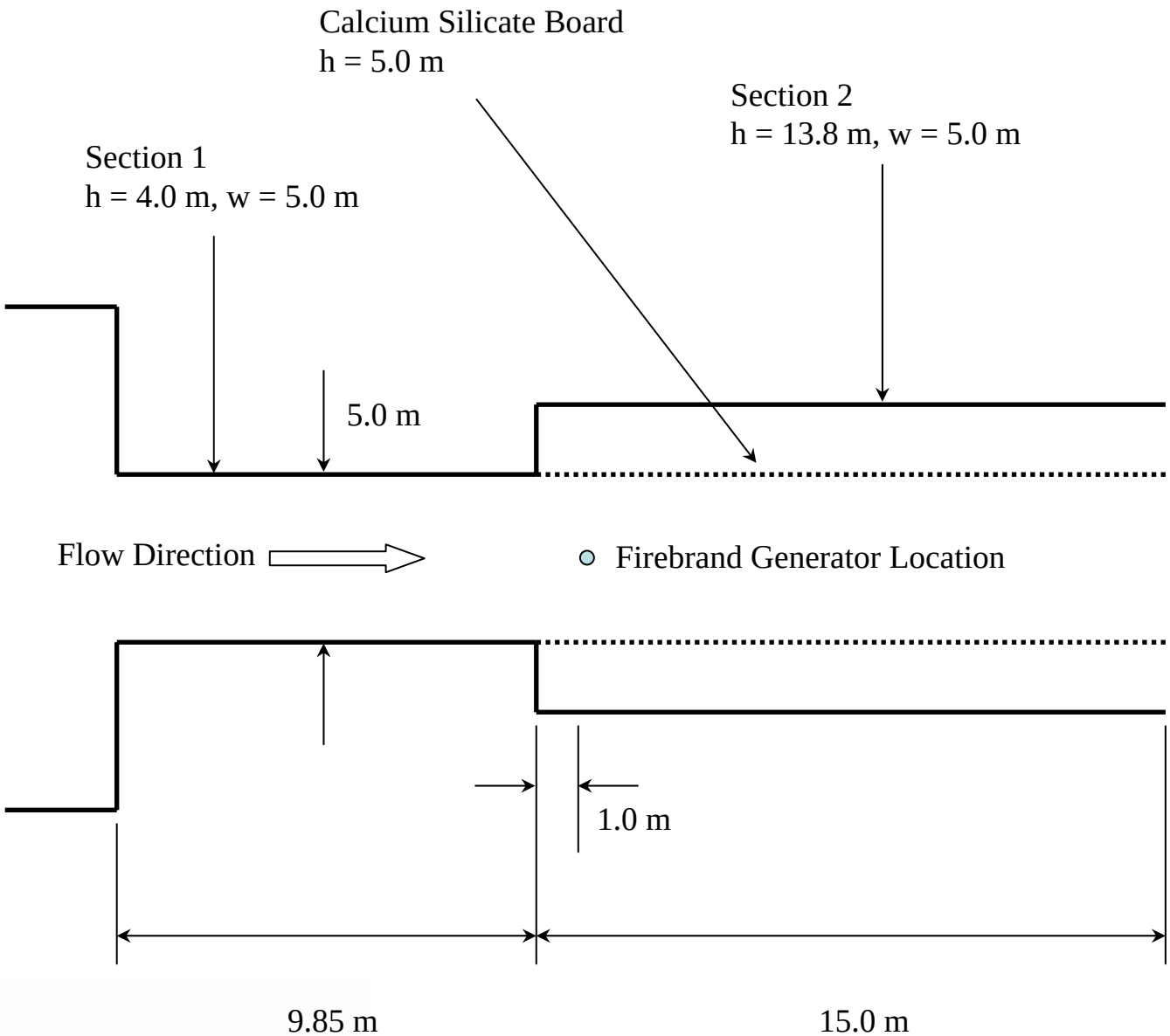
Future Work

- Investigate firebrand penetration through different vent types
- Investigate tree burns in wind field

Arigato Gozaimass

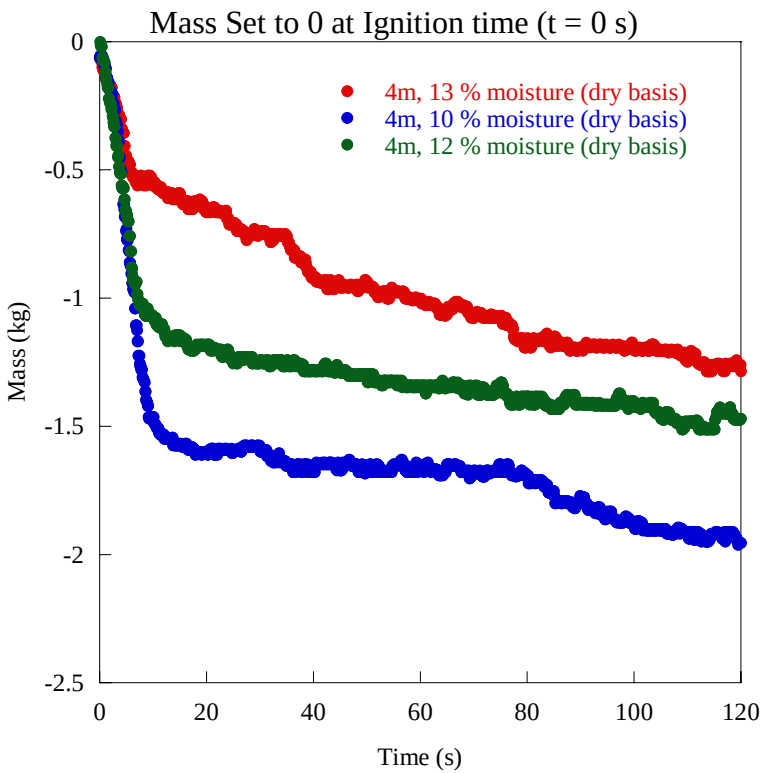
Thank You

Firebrand Generator Location

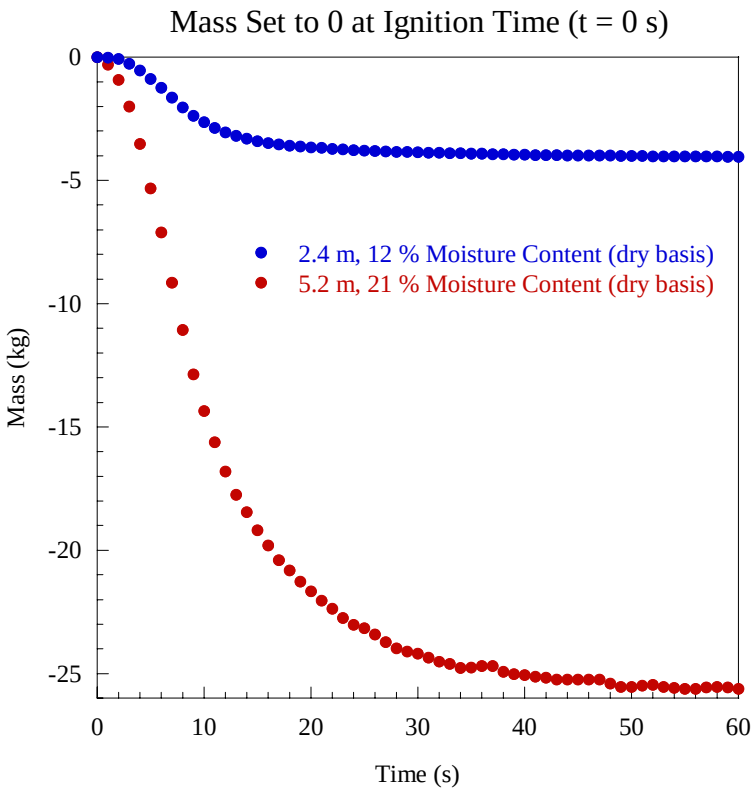


Mass Loss Measurement

- Temporally resolved mass loss obtained using during burning



Initial mass 4.0 m Korean-Pine 13 kg



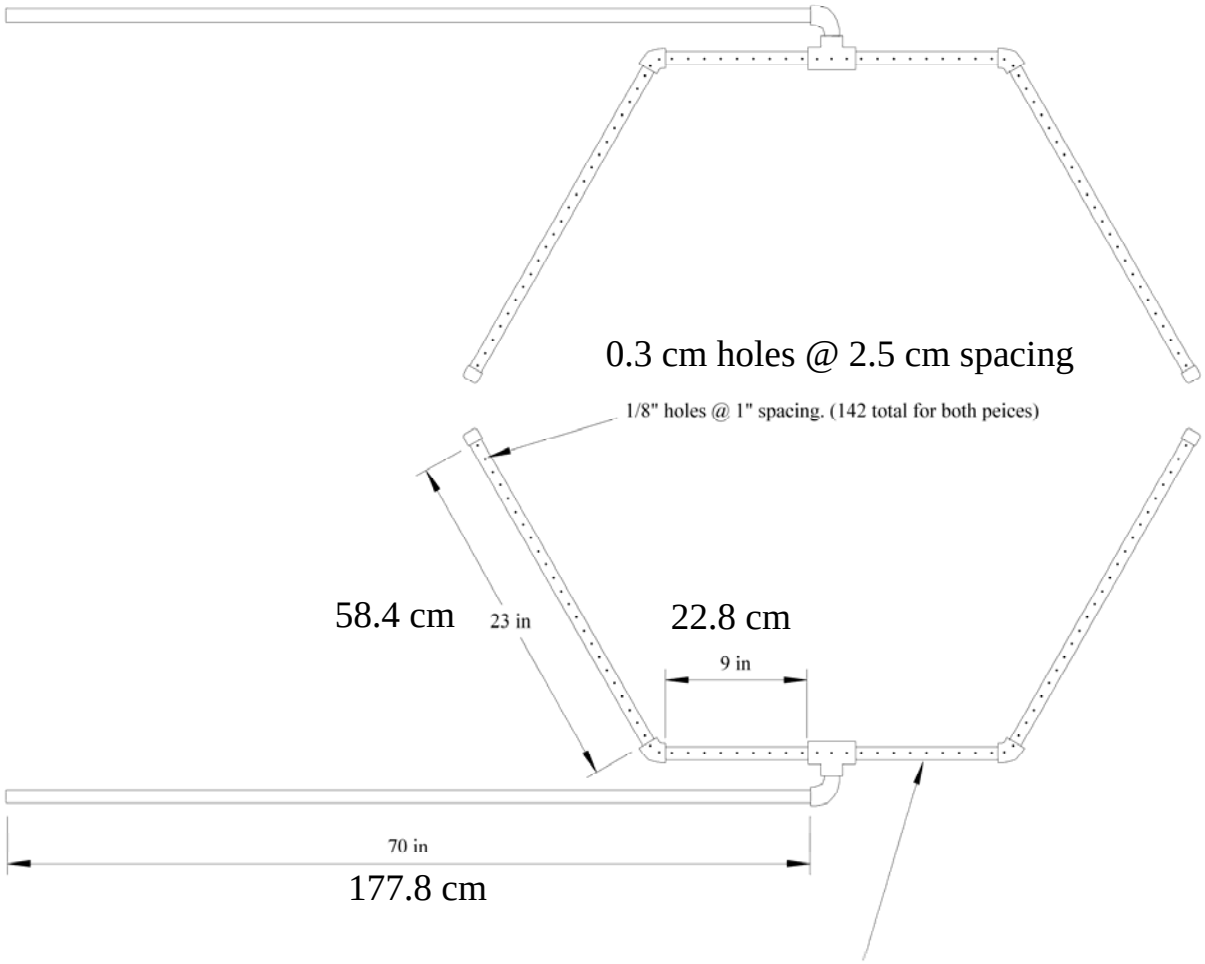
Initial mass 2.4 m Doug-Fir 10.7 kg
Initial mass 5.2 m Doug-Fir 57 kg

Moisture Content Determination

$$MC = [(M_{wet} - M_{dry}) / M_{dry}] * 100$$

Tree Ignition Methodology

- Hexagonal burner used as ignition source, ignition time 60 s.



1.9 cm (3/4 inch) schedule 40 black iron pipe
(actual dimensions: 2.67 cm outer diameter, 1.91 cm inner diameter)

Firebrand Ignition of Fuel Beds (NIST)

collected firebrands

characteristic firebrands

firebrand ignition experiments

tree burn

Tabulated ignition regime maps

Number of Firebrands Deposited	State of Firebrand at Impact	Air Flow (m/s)	Firebrand Size (mm)	Pine Needles (dry)	Pine Needles (11 %)	Shredder Paper (dry)	Shredded Paper (11 %)	Hardwd. Mulch (dry)	Hardwd. Mulch (11 %)
1	Glowing	0.5	5	NI	NI	SI	SI	NI	NI
1	Glowing	0.5	10	NI	NI	SI	SI	NI	NI
1	Glowing	1	5	NI	NI	SI	SI	NI	NI
1	Glowing	1	10	NI	NI	SI	SI	NI	NI
1	Flaming	0.5	5	FI	FI	FI	FI	FI	NI
1	Flaming	0.5	10	FI	FI	FI	FI	FI	NI
1	Flaming	1	5	FI	FI	FI	FI	FI	NI
1	Flaming	1	10	FI	FI	FI	FI	FI	NI
4	Glowing	0.5	5	NI	NI	NT	NT	NI	NI
4	Glowing	0.5	10	NI	NI	NT	NT	SI	NI
4	Glowing	1	5	NI	NI	NT	NT	SI	NI
4	Glowing	1	10	SI to FI	NI	NT	NT	SI	NI
4	Flaming	0.5	5	NT	NT	NT	NT	NT	NI
4	Flaming	0.5	10	NT	NT	NT	NT	NT	NI
4	Flaming	1	5	NT	NT	NT	NT	NT	NI
4	Flaming	1	10	NT	NT	NT	NT	NT	NI