Characterizing the Flammability of Nomex Fabric for the Preparation of FM²

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Introduction

Space flight safety

- Increased oxygen level
- Reduced cabin pressure
- Change in gravity (buoyancy)

⇒ Materials that are not flammable on Earth can become flammable when these conditions change.

FM² (Flammability of Materials on the Moon)

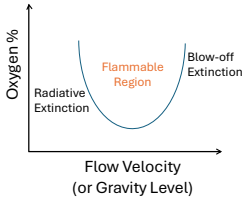
- Planned fire experiments on the moon.
- Currently scheduled in the next few years.
- Will determine limiting oxygen concentration (LOC) for a flight-relevant material (Synergy Pro).

Research Objectives

To complement the FM² data and understand how fire behaves for spaceflight relevant materials in different environmental conditions.

Specific Aims

- Investigate flammability of **Nomex HT90-40®** in different environments.
- Understand the effects of oxygen and concurrent flow rate (pressure is constant at **8.2 psi**).
- Determine **LOC.**



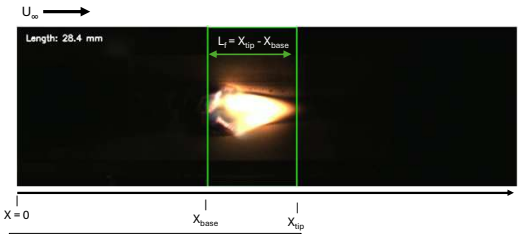
Tracking Method

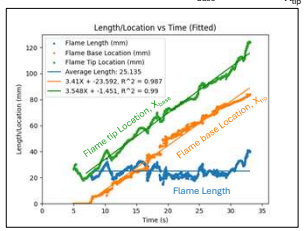
Software: Python

- Used OpenCV for video processing
  - BGR (Blue, Green, Red) → HSV (Hue, Saturation, Value)

Approach:

- Tracks flame base (X_{base}) and tip (X_{tip}) positions.
- Deduce flame length ($L_f = X_{tip} - X_{base}$)
- Plot positions and apply fit line to deduce flame spread rates (V_{base}, V_{tip}).





Example:
Oxygen: 23%
Flow rate: 10 cm/s
Ignition time: 5 seconds

→ V_{base} = 3.41 mm/s
→ V_{tip} = 3.55 mm/s
→ L_f = 23.14 mm

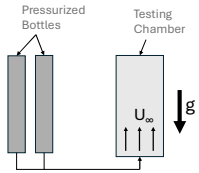
Testing Method

Flow Tunnel:

- Drop tower:
  - Oxygen: **24%** to **38%** oxygen
  - Flow speed: **15 cm/s** and **30 cm/s**
- Ground testing:
  - Oxygen: **22%** to **38%**
  - Flow speed: **5 cm/s** to **30 cm/s** (increments of 5 cm/s)



Flow Tunnel



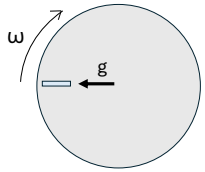


Centrifuge:

- Spins to generate centrifugal force
  - Simulates **Lunar gravity** (~1.62 m/s²)
- Drop tower:
  - Oxygen: **28%**
- Ground testing:
  - Oxygen: **25%**, **28%**, and **38%**



Centrifuge



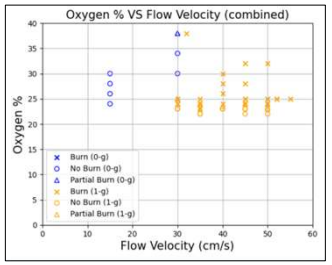
Zero Gravity Research Facility

- A 5.2 s drop tower.
- In the drop tower, the unit is in free fall, simulating **microgravity**



5.2 Second Drop Tower

Results



* Assuming a buoyant velocity of 25 cm/s

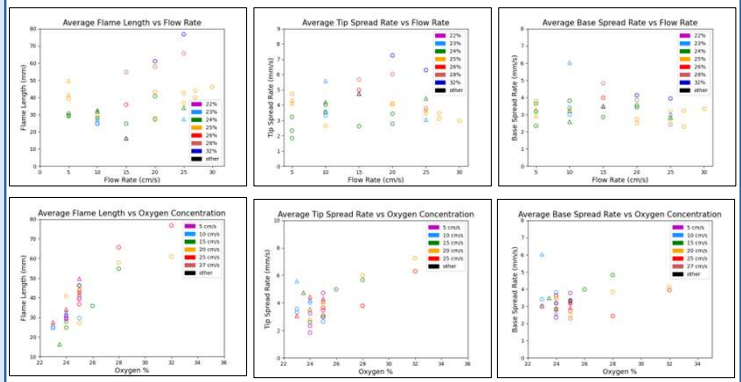


0G
38% O2
30 cm/s

1G
38% O2
~7 cm/s

- Limiting oxygen concentrations (LOC):
  - 1G → **~23%** Oxygen
  - Lunar-G → **~29%** Oxygen
  - 0G → **~38%** Oxygen

1G Flow Tunnel Flame Tracking:



- Data from tracking is collected and plotted to compare the effects of different conditions for 1G flow tunnel tests.
  - Independent variables → **Flow Rate** and **Oxygen %**
  - Dependent variables → **flame length**, **base spread rate**, and **tip spread rate.**

Conclusion

- Gravity has significant effects on the material's flammability.
  - Nomex HT90-40® behaves differently than other materials when burned.
- Oxygen concentration is observed to increase flame length and tip spread rate.
  - Inconclusive for base spread rate (need more testing).
- Flow rate has negligible effect on flame length and flame spread over the tested range.
  - Likely due to the buoyant force outweighing the imposed flow

Acknowledgements

- Support from Zero-G Facility Staff.
- NASA's Office of STEM Engagement.
- Ohio Space Grant Consortium.
- CWRU School of Engineering.
- NASA Glenn Research Center (Grant #80NSSC22M0011).