# Oxygen Saturated Materials Diffusion and Permeation Flammability Testing

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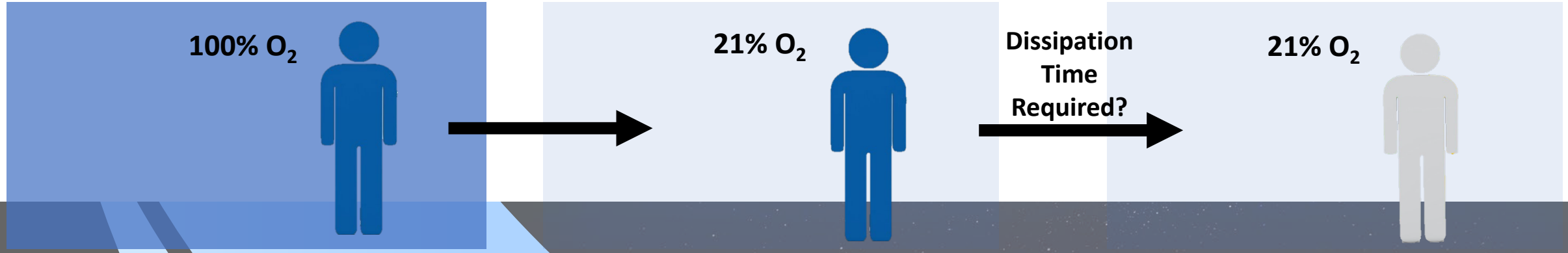
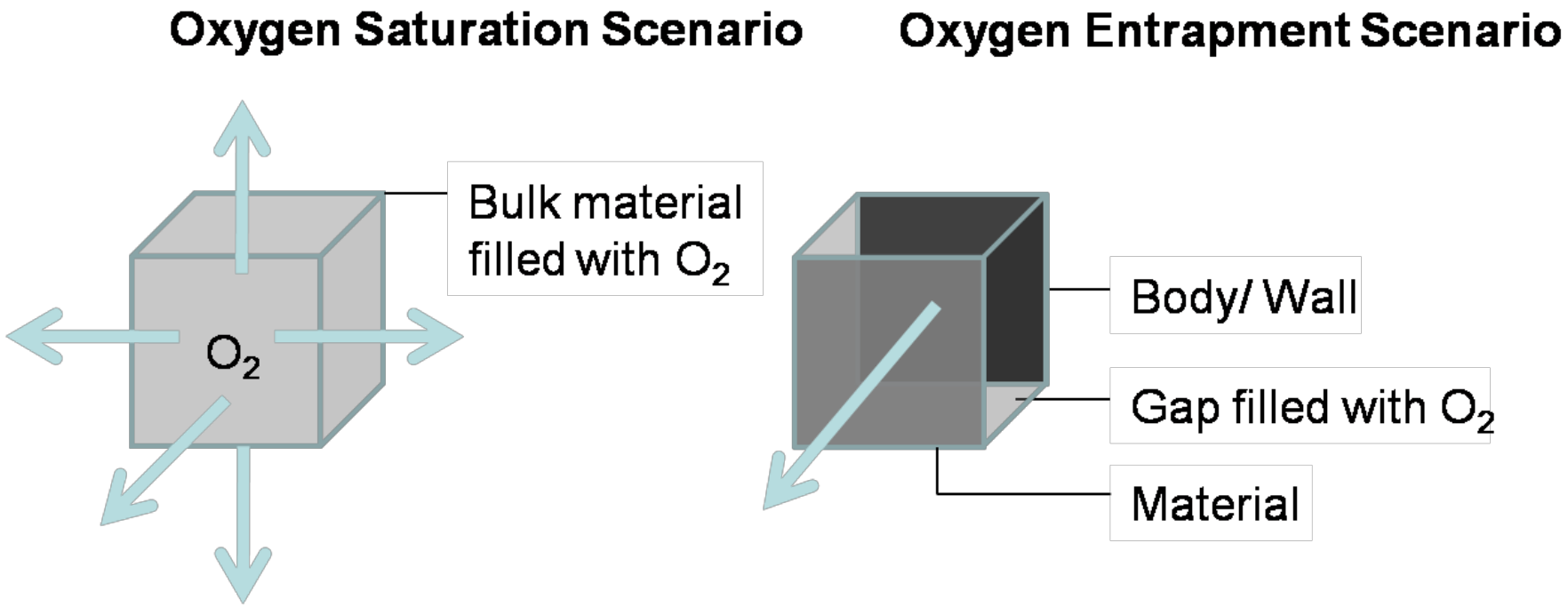
# Background

- Increased material flammability in high oxygen concentrations presents safety/operational concerns.
- When exiting a higher oxygen concentration environment and moving to a lower one, localized high oxygen concentrations can remain.
- Understanding time needed to dissipate oxygen and equilibrate with new environment can:
  - Reduce the likelihood of fires or
  - Improve procedures/efficiency as NASA moves to longer missions with increased extravehicular activities in both spacecraft and off-Earth habitats.
- **This paper examines the time required for common spacecraft materials exposed to 100% oxygen to return to reduced ambient flammability.**



# Scenarios of Concern

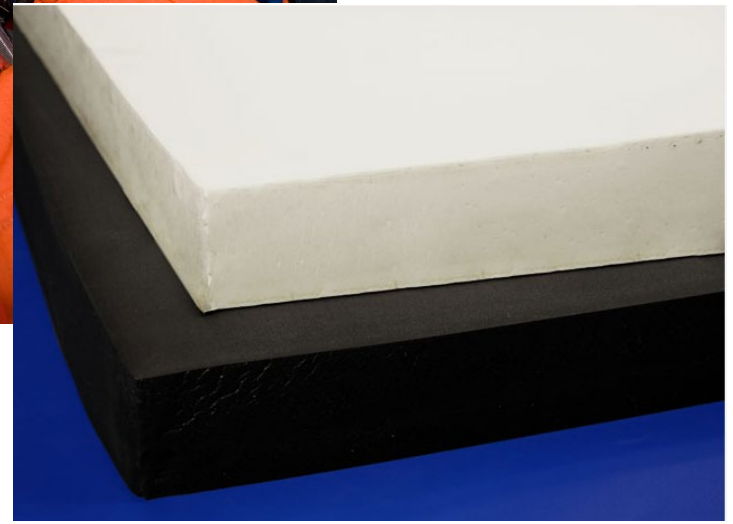
- Once a material is saturated with oxygen
  - How much time needed to equilibrate with new environmental oxygen percentage?
  - How is material flammability impacted with time?



# Test Materials

- This test series focused on space suit & space cabin environment materials.
  - Potential oxygen entrapment layups (ACES suit)
  - Foams due to high risk for oxygen saturation

| *$O_2$ Entrapment Scenarios* | *$O_2$ Saturation Scenarios* |
|---|---|
| *Advanced Crew Escape Suit (ACES)* | *Cabin Environment Materials* |
| ACES External Suit layup (Nomex, Gortex) | L-200 Minicel® Polyethylene foam |
| | Pyrell Polyurethane foam |
| | Viton (Mosite) Foam |

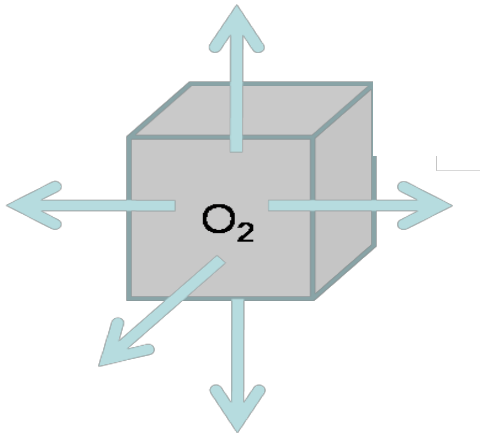


# Test Methodology

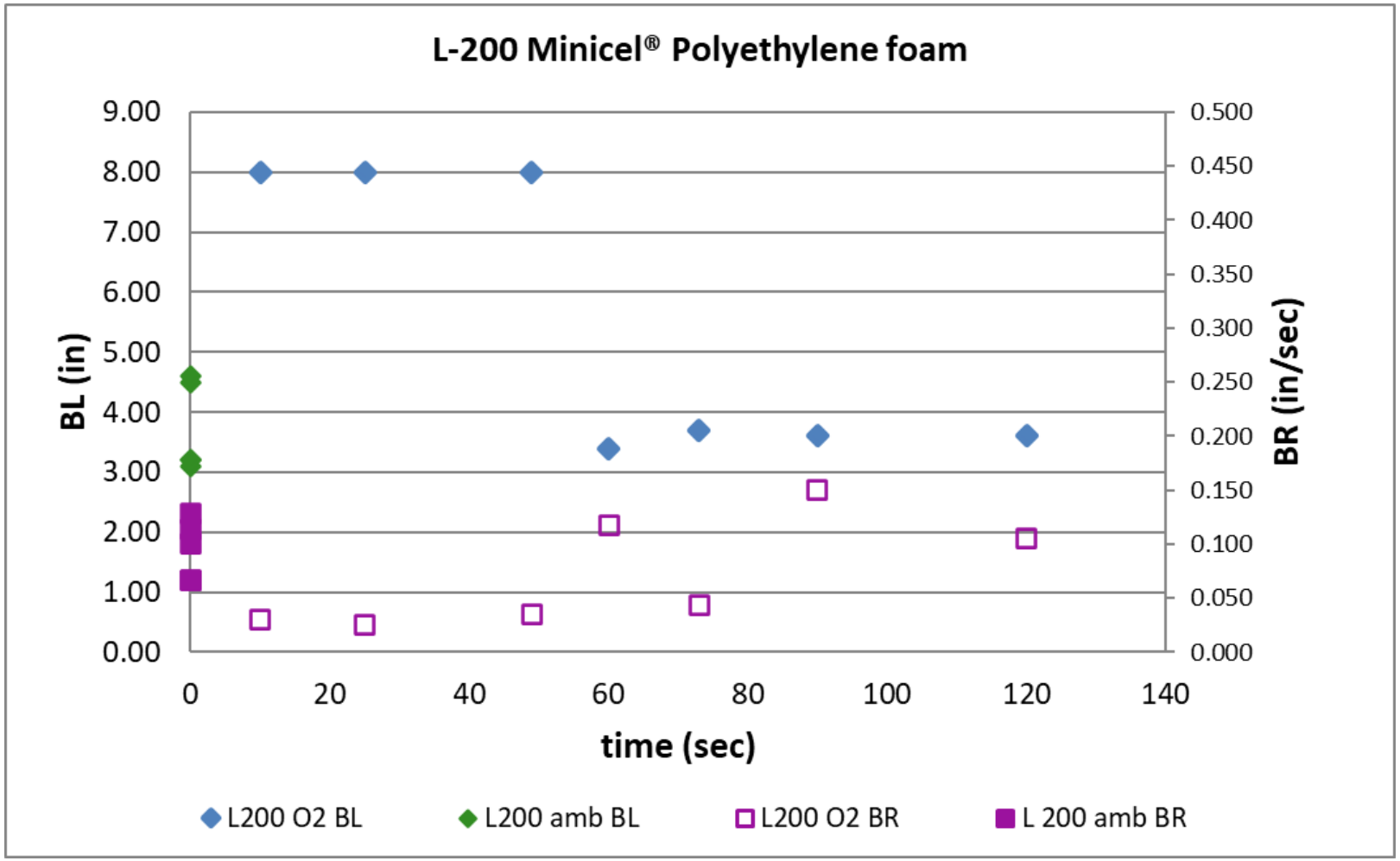
- Materials were placed inside of an enclosure (rabbit trap) with a removable door.
  - Enclosure provided by WHA International.
- Materials allowed to soak in 100% $O_2$ for 20-30 min.
- Materials door opened and material ignited at defined dissipation time.
- Material Flammability Performance Recorded
  - Burn Length
  - Burn Rate

# L200 Minicel

**Oxygen Saturation Scenario**

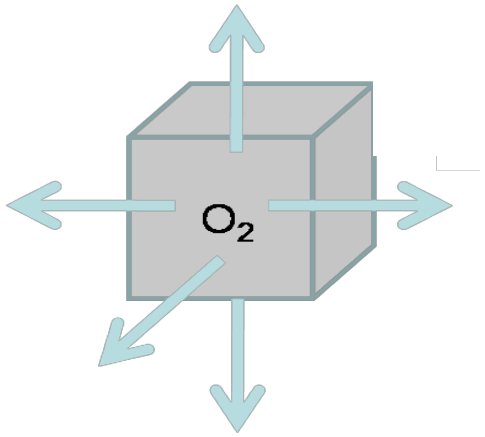



- After ~60 seconds of allowed dissipation time, materials achieved ambient level burn lengths.
- Burn rates were not notably impacted by oxygen concentration.

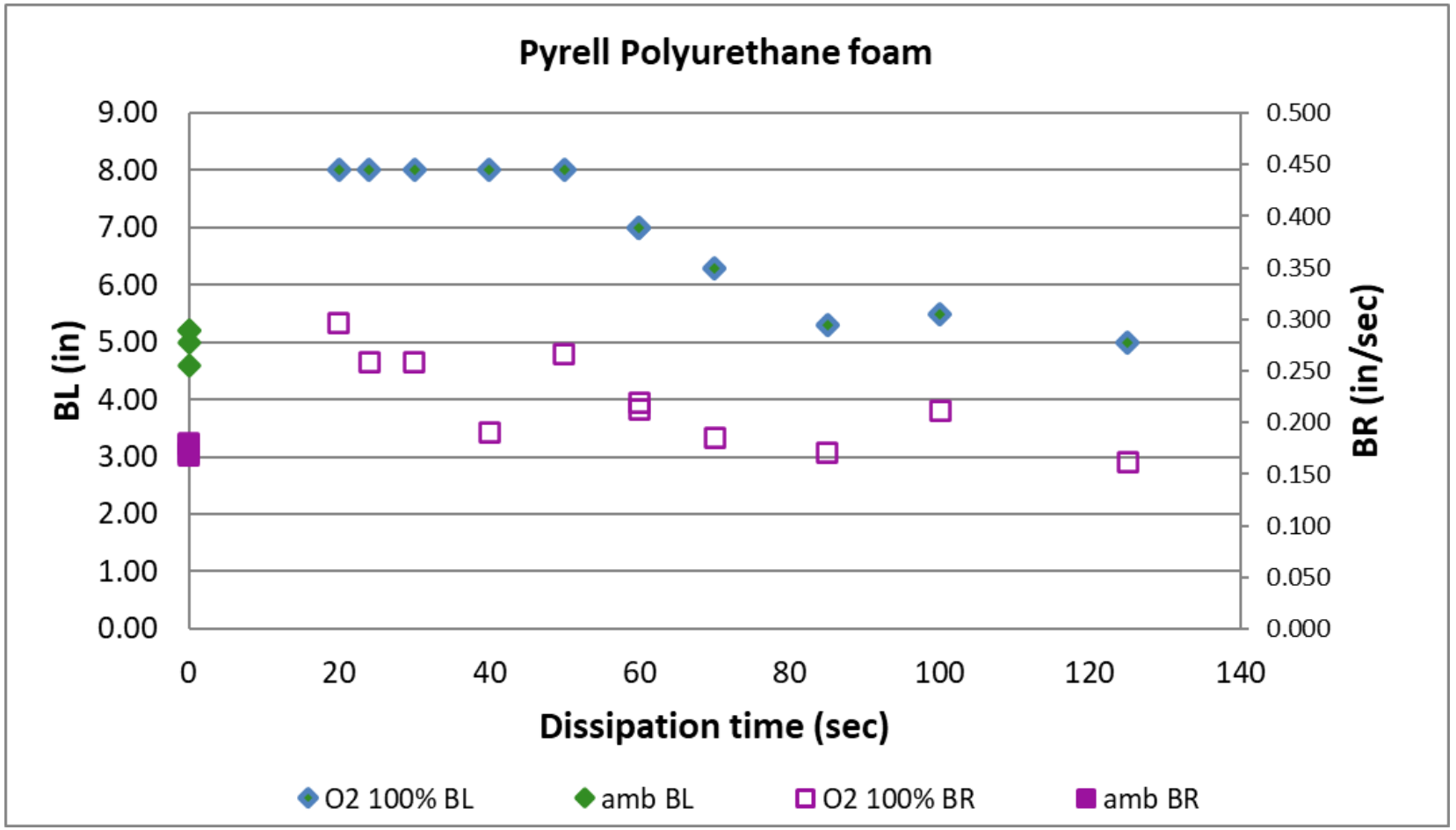


# Pyrell Polyrethane Foam

**Oxygen Saturation Scenario**

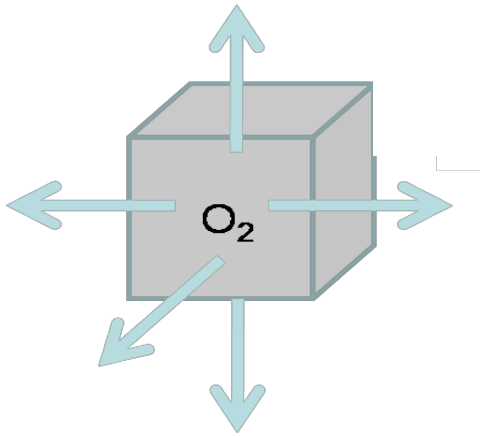



- After 85 seconds of allowed dissipation time, materials achieved ambient level burn lengths.
- After 85 seconds of allowed dissipation time, materials achieved ambient level burn rates.

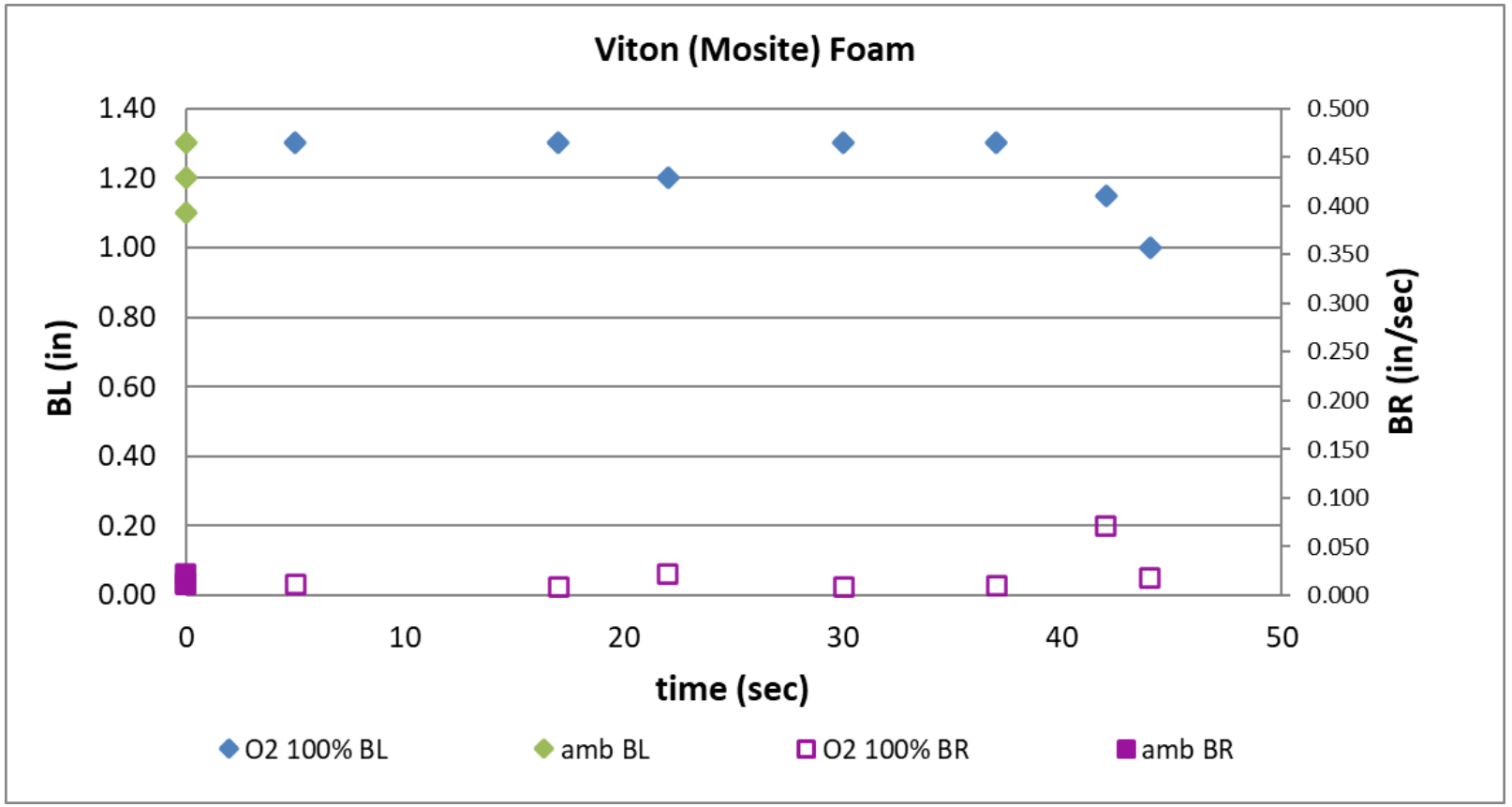


# Viton (Mosite) Foam

**Oxygen Saturation Scenario**



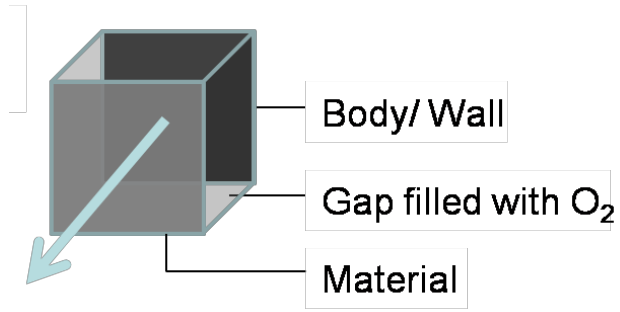

- Mosite foam does not appear to absorb oxygen. Material demonstrated ambient level burn lengths without any dissipation time.
- Burn rates were not notably impacted by oxygen concentration.



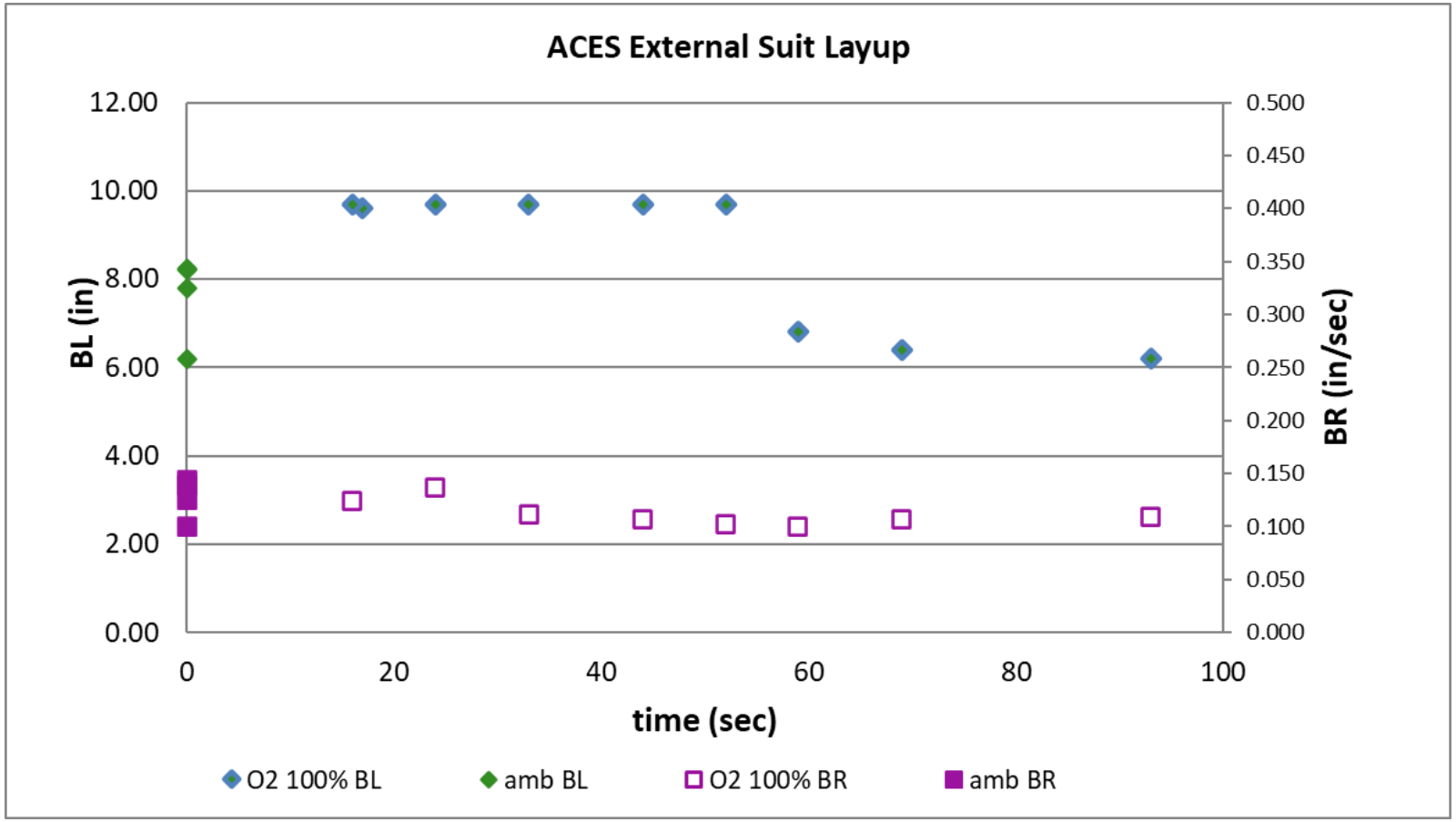
# ACES External Suit Layup (Nomex, Gortex)



**Oxygen Entrapment Scenario**




- After 60 seconds of allowed dissipation time, materials achieved ambient level burn lengths.
- Burn rates were not notably impacted by oxygen concentration.



# Summary Results



- For materials & layups examined in this test series, a worst case of 85 seconds was required for materials to reach ambient level flammability behavior.
- Additional smoke imaging was also performed to further evaluation demonstrating ~45-50 seconds needed for smoke to visibly dissipate from the enclosure area.

| Required Dissipation Times for Materials Saturated in a 100% $O_2$ to Reach Ambient Level Flammability Behavior | | | | |
|---|---|---|---|---|
| **Test Material** | **Thickness (in)** | **Soak Time @100% $O_2$ (min)** | **Dissipation time to reach Ambient Burn Lengths (sec)** | **Dissipation Time to Reach Ambient Burn Rates (Sec)** |
| L-200 Minicel® Polyethylene foam | 2.01 | 20-30 | 60 | 0 |
| Pyrell Polyurethane Foam | 2.00 | 20-31 | 85 | 85 |
| Viton (Mosite) Foam | 0.31 | 20-32 | 0 | 0 |
| ACES External Suit (Nomex/Gortex) Lay-up | 0.03 | 20-33 | 60 | 0 |
| **Worst Case Dissipation Times Required to Reach Ambient Flammability Conditions** | | | **85** | **85** |

# Validation Testing Conclusions

- Foams and materials that function as oxygen barrier materials were evaluated as highest risk materials due to their ability to limit oxygen diffusion or bulk material oxygen saturation.
- For materials evaluated in this test series, a worst case of 85 seconds was required to reduce flammability equal to ambient conditions.
- Data implies that minimal operational impacts are needed for space suits, cabin materials, and personnel when moving between oxygen environments.