Application of Aerogel for Prosthetic Liners

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Introduction

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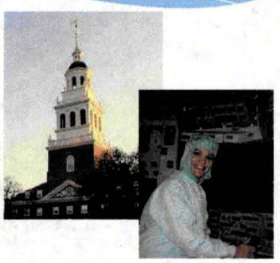
About Me

- From Miami, FL
- Junior at Harvard College
  - Major: BME
  - Minor: Economics
- 2nd KSC internship through the NASA MUST Program



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Summer Experiences

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Background

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Prosthetic Liners

- Interface between residual limb and prosthetic
- Provide comfort and control
- Many different materials
  - Cotton
  - Wool
  - Synthetics
  - Silicone or urethane gel

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Existing Liner Problems

- Tradeoff between comfort and durability
- Very hot
- Airtight – sweat pools
  - Maintenance
  - Itching
  - Odor
  - Discomfort
  - Friction (leads to injury)

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Aerogel Properties

- Hydrophobic
- Breathable
- Flexible
- Environmentally friendly
- Non-toxic
- Used in hot- and cold-weather clothing
- Blanket used for project encased in nylon

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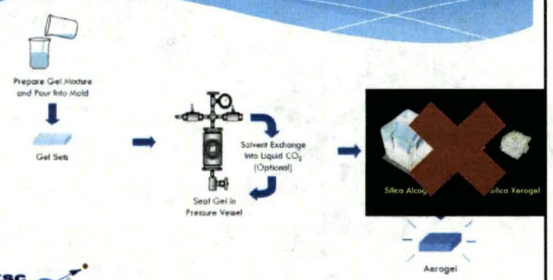
How Aerogel is Made



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Images from www.aerogel.org

Design Requirements

- Perspiration control
- Stay cool in FL heat
- Distribute load evenly
- Prevent injury
- Prevent skin irritation
- Accommodate volume fluctuation in residual limb
- Easy to don and doff

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Test Methods

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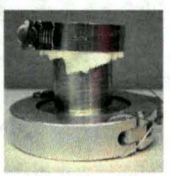
Moisture Vapor Permeability

- No ISO standards for interface materials
- Literature search: one study using distilled water
- Adapted test for wound dressings
  - BS EN 13726-1:2002
  - Artificial sweat solution from ISO 3160-2:2003



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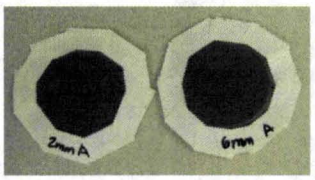
Moisture Vapor Permeability

- Samples prepared in the Prototype Lab
- Circular samples to fit test assembly (4 cm diameter)
- Encased in nylon to prevent skin irritation
- Sealed with waterproof First Aid tape



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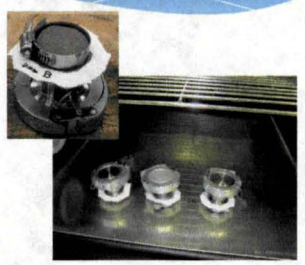
Moisture Vapor Permeability

- Test assembly with sample and fluid weighed
- Incubated inverted
  - 24 hours
  - 37°C, 5% relative humidity
- Test assembly removed and reweighed
  - Difference in mass is the fluid that has transpired



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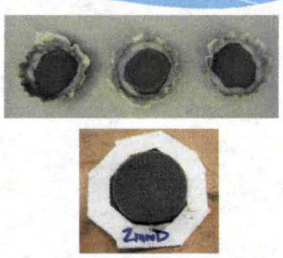
Moisture Vapor Permeability

- Aerogel beads
  - Difficult to use
  - Concerns about force transmission
- Comparison of Pyrogel® (2.0 mm and 6.0 mm) and 10.0 mm Spaceloft®
  - Spaceloft® difficult to use
  - Testing continued with the two Pyrogel® thicknesses



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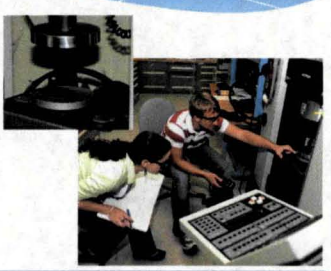
Compression

- 1.5" square samples of Pyrogel®
- Tested on Instron
  - Max load: 1000 lbf
  - Compression rate: 0.1" per minute
- Thickness measured before and after



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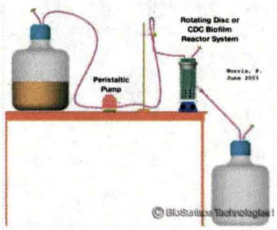
Biofilm Formation

- 12 mm diameter coupons of Pyrogel ®
- Tested on CDC Biofilm Reactor
  - ASTM E 2562-07
  - Challenge organism: *Pseudomonas aeruginosa*
  - 24 hour batch mode
  - 24 hour CSTR mode



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Results and Discussion

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Moisture Vapor Permeability

Material	Moisture Vapor Lost (g)	Moisture Vapor Lost (%)
Nanogel®	-12.8	84.7
	-12.3	86.9
	-12.9	85.7
2.0 mm Pyrogel ®	-13.4	88.4
	-5.19	34.8
	-6.55	43.8
6.0 mm Pyrogel®	-2.43	16.1
	-3.48	23.0
	-10.1	67.3
10.0 mm Spaceloft®	-6.27	41.4

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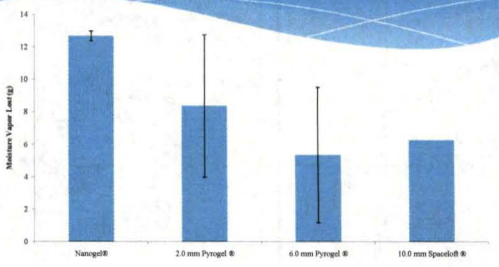
Moisture Vapor Permeability



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Why such high variance?

- Non-uniform performance of the test fixtures
- Leaking was noted in two trials
  - Last two trials
  - Where failure was noted, data points were eliminated
- May have leaked in other trials
  - Fluid may have evaporated before it was detected
  - Did not keep track of which test fixture went with which sample for each trial

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Comparison with Existing Materials

- Existing materials allow little to no moisture to pass through
- Further testing is needed
  - No test standards
  - Only study published has used distilled water
  - Comparison with GORE-TEX®, also breathable

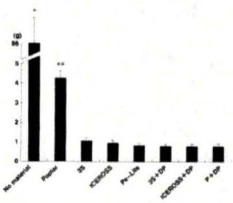

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Chart from Hachisuka, K., Matsushima, Y., Ohmine, S., Shitama, H., and Shinkoda, K., "Moisture permeability of the total surface bearing prosthetic socket with a silicone liner: is it superior to the patella-tendon bearing prosthetic socket?" *Journal of UOEH*, Vol. 23, No. 3, 2001, pp. 225-232.

Compression

Material	Initial Thickness (mm)	Compression at 1000 N (mm)	Strain at 1000 N (%)	Loss in Thickness (mm)	Loss in Thickness (%)
2.0 mm Pyrogel ®	2.11	1.74	77.4	-0.432	-20.5
	2.18	1.32	51.9	-0.483	-22.1
	2.39	1.45	44.6	-0.483	-20.2
6.0 mm Pyrogel ®	5.94	3.78	64.5	-0.356	-5.98
	6.02	3.64	60.2	-0.737	-12.2
	6.22	3.47	52.2	-0.889	-14.3

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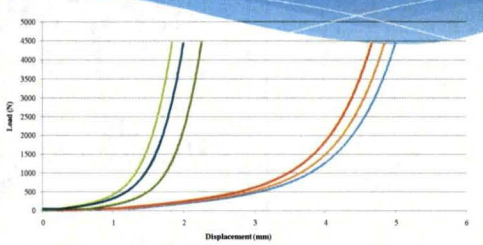
Compression



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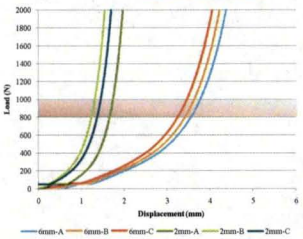
Comparison with Existing Materials

- Gait analysis: maximum axial force is between 800 and 900 N
- Previous studies: 550 N
- This study: over 4400 N
- Performed comparable to or better than existing materials, even under eight times the load



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Conclusions

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Suitability for Prosthetic Liners

- Breathability
  - Permeable to vapor
  - Further testing needed with existing materials
- Load bearing
  - Performed comparably under higher loads
  - Further testing needed with existing materials

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Future Development

- Biofilm testing
- Comparisons with existing materials
- Uniformly performing test fixtures
- Repeated or cyclic load bearing tests
- Friction load bearing tests
- Liner prototype

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THANK YOU SO MUCH!

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Questions

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