Aerogel Impregnated Polyurethane Piping and Duct Insulation

David M. Hess
InnoSense LLC
david.hess@innosense.us, 310-530-2011
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Purpose & Objectives

Problem Statement: Develop an efficient insulation system that will adhere to housing duct work and pipe structures while conforming to complex geometries. New insulations must increase the R-value of existing materials and be easy to apply or retrofit to existing structures.

Impact of Project: Increased housing heating/cooling efficiency. It is challenging to apply traditional insulation around irregular geometries. It is the goal of this project to increase the R-value over existing insulation to reduce housing energy requirements. Improving energy efficiency will reduce home heating/cooling costs.

Project Focus: To increase the R-value of existing insulation materials through the addition of high R components. Our aerogel technology will reduce cost and energy use in the home. Such an insulation can be retrofitted into older homes and buildings increasing their overall energy efficiency.
Approach: Incorporate aerogels into existing insulation matrices (e.g. cellulose, polyurethane foam). We will manipulate the hydrophobic character of the aerogel structure to reduce moisture ingress.

Key Issues: (1) Additive dispersion, and (2) product attachment to/or inclusion in suitable substrates.

Distinctive Characteristics: Aerogel materials offer the highest R-value of any known material. Addition of aerogels increases flexibility of polymer matrix.
Aerogel Processing

- Gels are made with pre-specified functionality.

- Supercritical drying:
  - Reduces evaporation-induced stresses on gel network, minimizing shrinkage.
  - Selectively removes alcohols due to inherent solubility in CO₂.
Aerogel Properties

Aerogels have R-values up to 10/inch.
Prediction of Aerogel Additive Concentration

- Assume that we can approximate the aerogel/foam structure as flat slabs.

- We may now assume that thermal resistances (R) are additive.

\[ R_{\text{Total}} = R_1 + R_2 = \frac{L_{\text{Total}}}{k_{\text{Total}}} = \frac{L_1}{k_1} + \frac{L_2}{k_2} \]

- After some math manipulation:

\[ \phi_1 = \frac{R_{\text{Total}} - \frac{R_2}{L_2}}{\frac{R_1}{L_1} - \frac{R_2}{L_2}} \]

\( \phi = \text{volume fraction} \)
Accomplishments: We have demonstrated the ability to increase R-value by introducing aerogel additives to both cellulose and polyurethane materials. We have also shown that the density of the insulation is not drastically changed.

Progress on Goals: Original goal was to increase R-value by at least 30%. We are progressing towards that goal. We are looking to impart other functionalities such as flame resistance to the insulation materials.

Awards/Recognition: None to note as yet.
Cellulose Insulation

Cellulose without Aerogel

Cellulose with Aerogel
Lower k-value with Increasing Aerogel

Independent Verification of k-value at ORNL (Phase I)

<table>
<thead>
<tr>
<th>Sample</th>
<th>Conductivity (W/m-K)</th>
<th>Conductivity (Btu-in/hr-ft²-F)</th>
<th>Thickness (mm)</th>
<th>R per inch (hr-ft²-F/Btu-in)</th>
<th>R-value (hr-ft²-F/Btu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare</td>
<td>0.04478</td>
<td>0.31048</td>
<td>18.9548</td>
<td>3.2208</td>
<td>2.4035</td>
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<td>1-10</td>
<td>0.03837</td>
<td>0.26604</td>
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<td>3.7589</td>
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<td>1-15</td>
<td>0.04159</td>
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<td>1-20</td>
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<td>0.28739</td>
<td>22.9489</td>
<td>3.4796</td>
<td>3.1438</td>
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Density

<table>
<thead>
<tr>
<th></th>
<th>1:20</th>
<th>1:30</th>
<th>1:50</th>
<th>Bare</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Density (g/cm³)</td>
<td>0.1695</td>
<td>0.1767</td>
<td>0.1777</td>
<td>0.1694</td>
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<tr>
<td>Std. Dev (g/cm³)</td>
<td>0.0069</td>
<td>0.0052</td>
<td>0.0086</td>
<td>0.0087</td>
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Soy Based Polyurethane

<table>
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<tr>
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<th>Density (g/cm³)</th>
<th>Std. Dev (g/cm³)</th>
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<tbody>
<tr>
<td>Soy Based Polyurethane</td>
<td></td>
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<tr>
<td>without Aerogel</td>
<td>0.228</td>
<td>0.053</td>
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<tr>
<td>Soy Based Polyurethane</td>
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<tr>
<td>with Aerogel</td>
<td>0.158</td>
<td>0.047</td>
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Soy-Based Polyurethane without Aerogel

Soy-Based Polyurethane with Aerogel
Project Plan & Schedule

Fine-Tune and Optimize Processing of Silicate AlcoGels

Refine Aerogel Formulation
- Fine-Tune and Optimize Processing of Silicate AlcoGels
- Optimize Small-Scale Supercritical CO2 Drying Process for Silicate Aerogels
- Evaluate Structural Properties of Silicate Aerogels

Optimize Aerogel Drying
- Initiate Large Scale Toll Supercritical Carbon Dioxide Drying for Silicate Aerogels
- Evaluate Structural Properties of Scaled-Up Silicate Aerogels
- Fabricate Regular-Sized Aerogel Particles
- Milestone 1: Optimized Fabrication of Aerogel Additives

Fabricate Insugel Panel
- Formulate Aerogel-Polyurethane Two-Part Foam Composites
- Formulate Aerogel-Cellulose Loose Fill Composites
  - Procure materials
  - Make Cellulose composite bricks
  - Test bricks
  - Fabricate Sample Panels (Cellulose and Polyurethane) for Insulation Characterization
  - Characterize Structure of Aerogel Composite Insulation Panels
  - Milestone 2: Insugel Panels Fabricated and Characterized

Evaluate Insulation Thermal Properties
- Screen Thermal Properties of Composite Insulation
- Evaluate R-value
- Milestone 3: Development and Characterization Completed

Evaluate Phase III Commercialization Potential
- Continue Gathering Input from Prospective Users

Submit Reports and Other Deliverables
- Quarterly Presentations
  - Update 1
  - Update 2
  - Update 3
  - Annual Progress Report
  - Update 4
  - Update 5
  - Interim Report
  - Update 6
  - Update 7
- Contract End Date
- Final Report
Project Budget:

- **Phase I:** 06/17/2011 – 03/06/2012 $150,000
- **Phase II:** 08/17/2012 – 08/07/2014 $999,999
- **Total:** $1,149,000

**Variances:** Not Applicable

**Cost to Date:** $433,967

**Additional Funding:** None

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<td>DOE</td>
<td>Cost-share</td>
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<td>0</td>
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<td>110,942</td>
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Partners, Subcontractors, and Collaborators: We will continue working with Andre Desjarlais of Oak Ridge National Laboratory to test our samples according to ASTM C518.

Technology Transfer, Deployment, Market Impact:
Participating in Dawnbreaker®, Presenting information to potential end users and collaborators at Greenbuild 2012
Discussing use in refrigerators and as architectural foam with Montalbano Innovation and Development, Inc. (MIDI); very preliminary discussions with Bayer MaterialScience.

Communications: None to date.
Next Steps and Future Plans:

1. Third party evaluation of new insulation formulations.
   - Will send to ORNL for testing.

2. Large scale toll supercritical carbon dioxide processing.
   - Will send samples to Phasex of Lawrence, MA.
   - Will use ISL-fabricated aerogels in insulation structures.

3. Investigate functional additives and their effect on thermal performance.
   - Flame retardants
   - Particle dispersants
Acknowledgements

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- Phase II Program Managers:
  - Dr. Karma Sawyer
  - Dr. Patrick Phelan
  - Mr. Mark LaFrance

- Phase I Program Manager:
  - Ms. Tina Kaarsberg

- Project Assistance:
  - R-value Testing at ORNL
    - Mr. Andre Desjarlais