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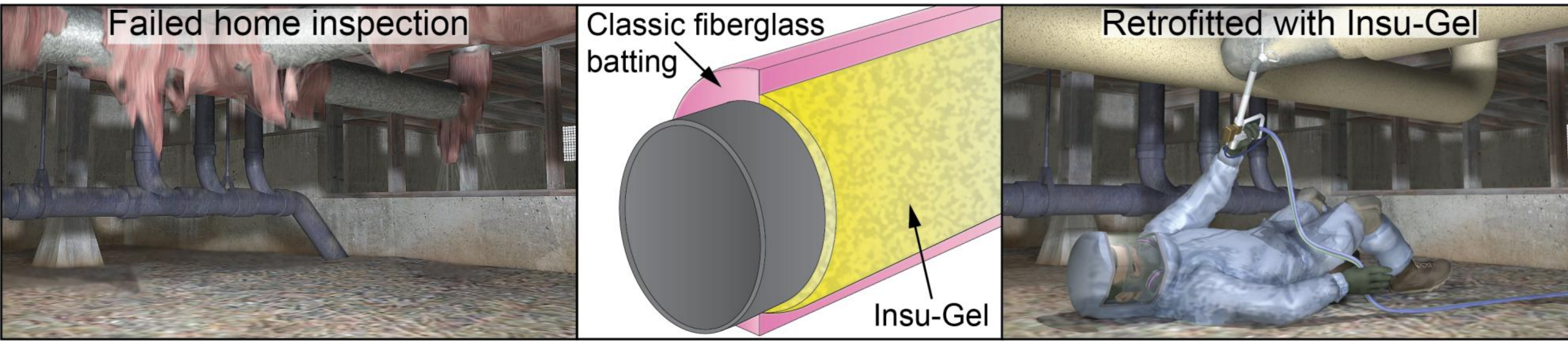

Aerogel Impregnated Polyurethane Piping and Duct Insulation

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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

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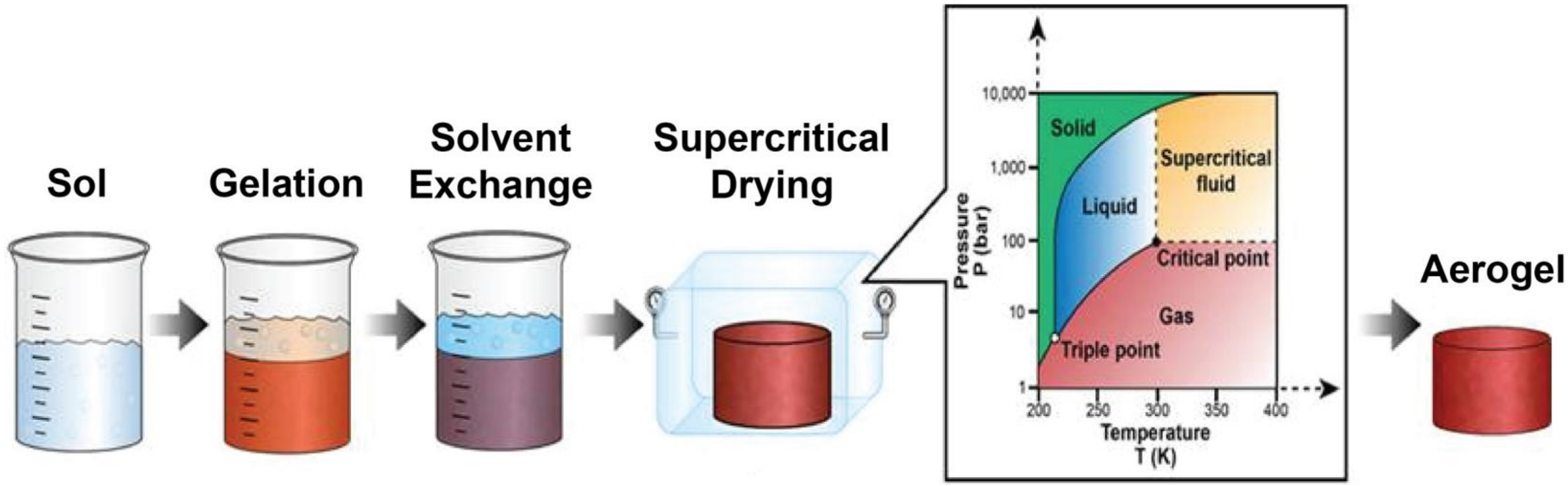
Approach: Incorporate aerogels into existing insulation matrices (e.g. cellulose, polyurethane foam).
We will manipulate the hydrophobic character of the aerogel structure to reduce moisture ingress.

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 CO_2.

Aerogel Properties

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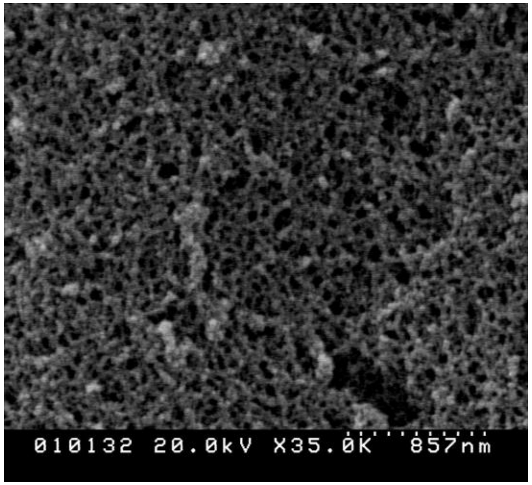
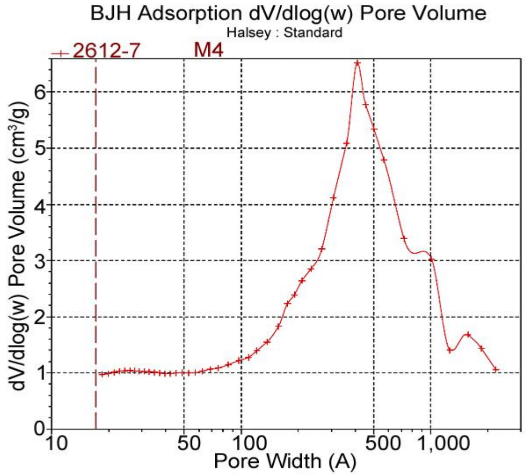
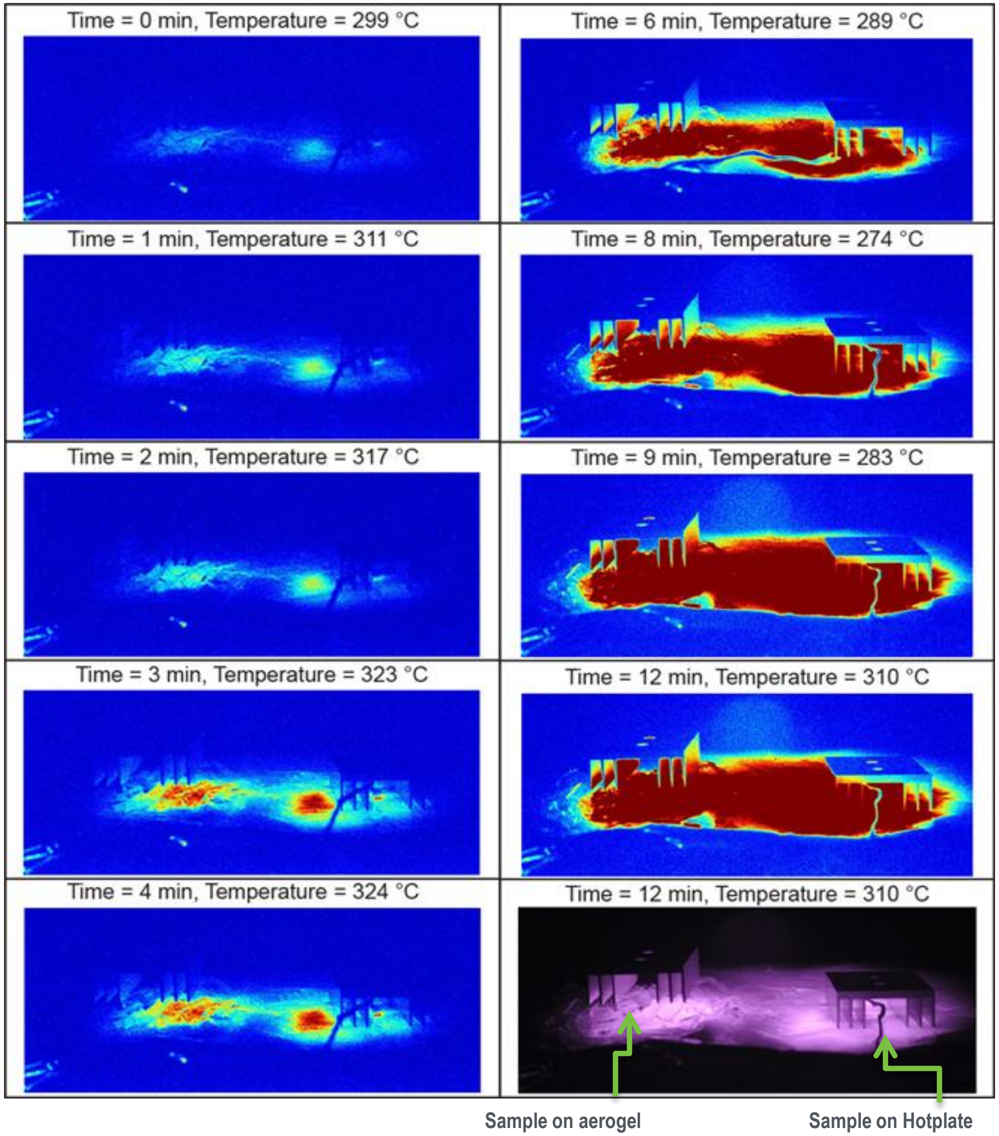
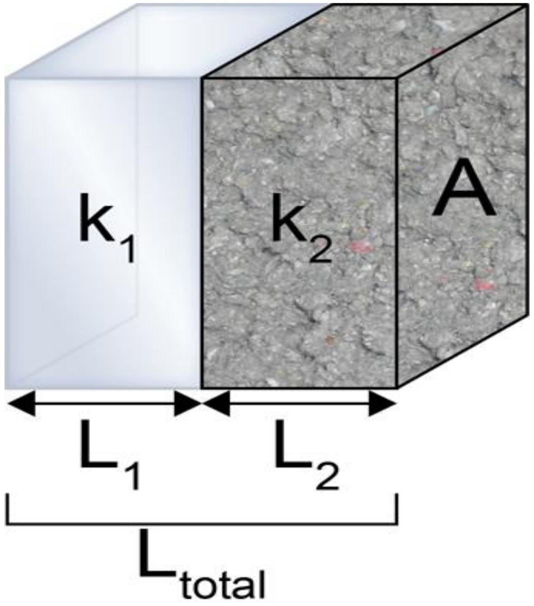


Aerogels have R-values up to 10/inch.





Prediction of Aerogel Additive Concentration



φ = volume fraction

- Assume that we can approximate the aerogel/foam structure as flat slabs.
- We may now assume that thermal resistances (R) are additive.

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

- After some math manipulation:

$$\varphi_1 = \frac{\frac{R_{Total}}{L_{Total}} - \frac{R_2}{L_2}}{\frac{R_1}{L_1} - \frac{R_2}{L_2}}$$

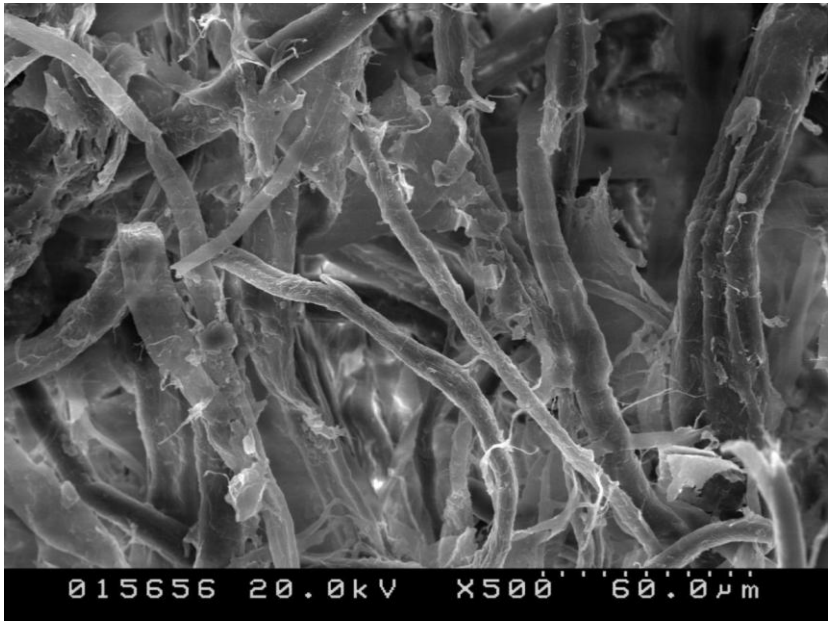
Accomplishments and Progress

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.

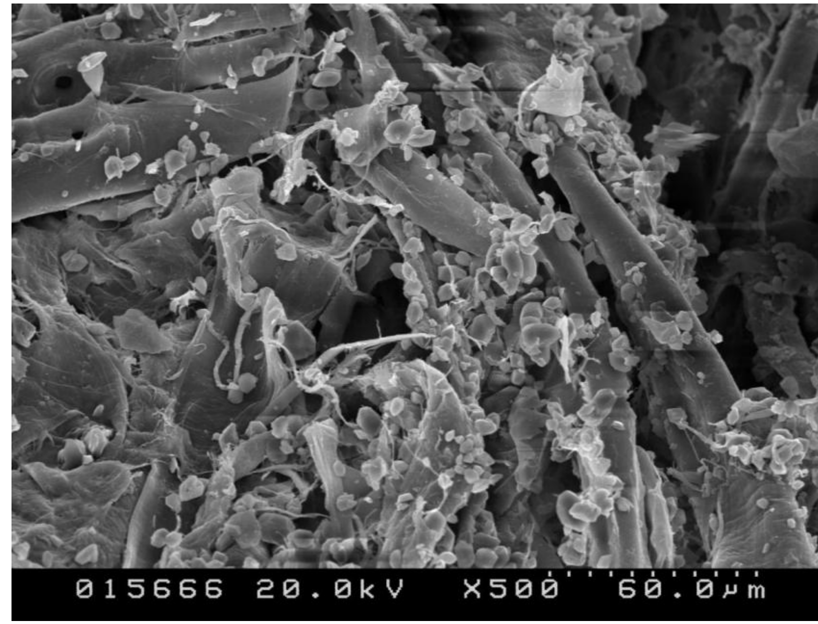
Progress on Goals: Original goal was to increase R-value by at least 30%. We are progressing towards that goal. We are looking to impart other functionalities such as flame resistance to the insulation materials.

Awards/Recognition: None to note as yet.

Cellulose Insulation

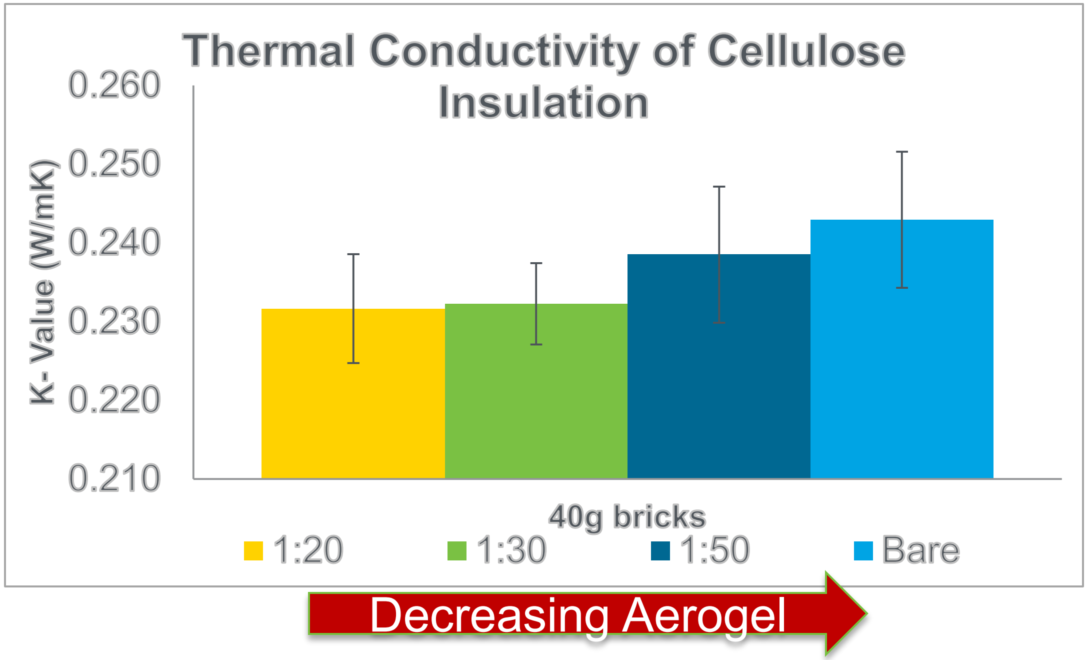


Cellulose
without Aerogel



Cellulose
with Aerogel

Lower k-value with Increasing Aerogel



Density

	1:20	1:30	1:50	Bare
Average Density (g/cm³)	0.1695	0.1767	0.1777	0.1694
Std. Dev (g/cm3)	0.0069	0.0052	0.0086	0.0087

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

Sample	Conductivity		Thickness		R per inch	R-value
	(W/m-K)	(Btu-in/hr-ft²-F)	(mm)	(inch)	(hr-ft²-F/Btu-in)	(hr-ft²-F/Btu)
Bare	0.04478	0.31048	18.9548	0.746	3.2208	2.4035
1-10	0.03837	0.26604	21.3741	0.842	3.7589	3.1631
1-15	0.04159	0.28836	23.0060	0.906	3.4679	3.1410
1-20	0.04145	0.28739	22.9489	0.904	3.4796	3.1438

Soy Based Polyurethane

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Soy-Based Polyurethane without Aerogel

Soy-Based Polyurethane with Aerogel

	Density (g/cm^3)	Std. Dev (g/cm^3)
Soy Based Polyurethane without Aerogel	0.228	0.053
Soy Based Polyurethane with Aerogel	0.158	0.047

Project Plan & Schedule

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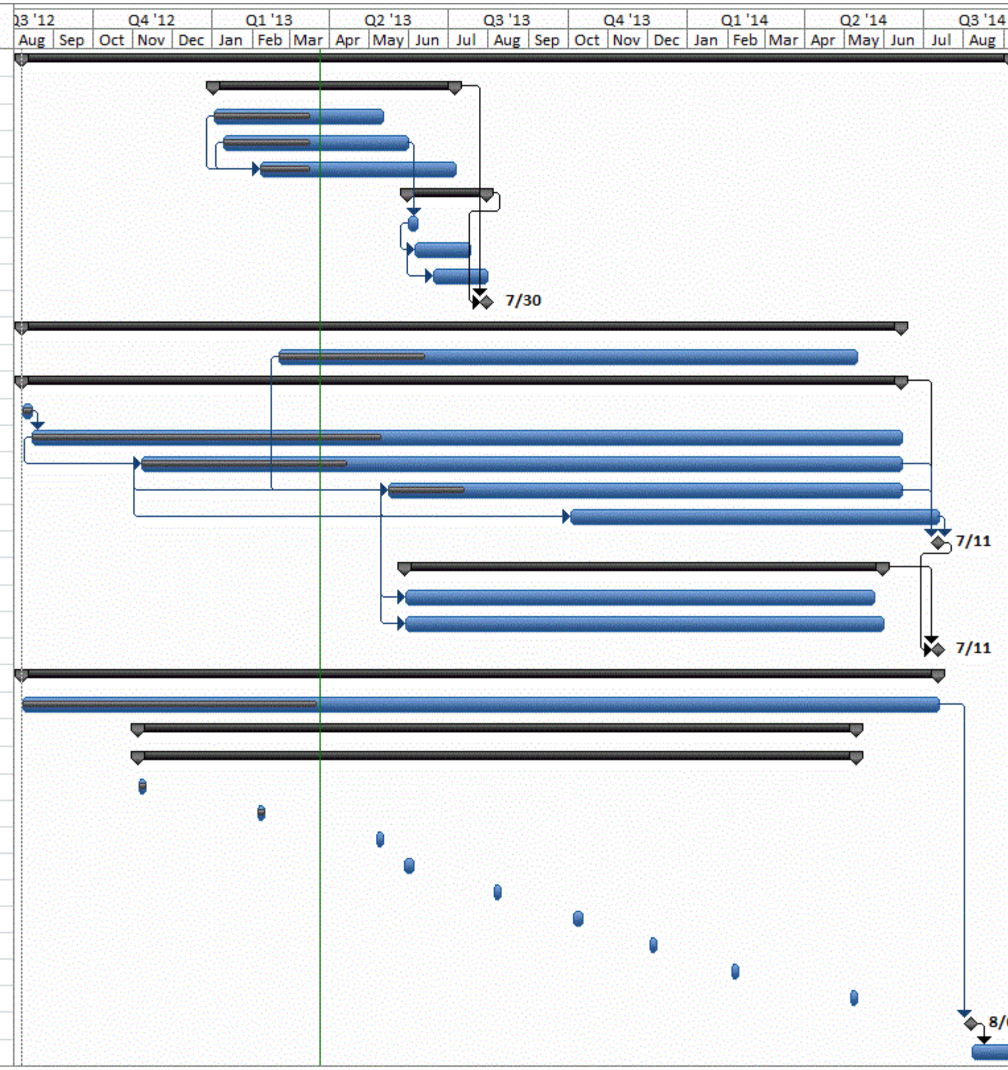
Task Name

- **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
  - **Fabircate 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**
    - **Quaterly Presentations**
      - Update 1
      - Update 2
      - Update 3
      - Annual Progress Report
      - Update 4
      - Update 5
      - Intermin Report
      - Update 6
      - Update 7
  - Contract End Date
  - Final Report



Project Budget

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

Budget History					
FY2010		FY2011		FY2012	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
0	0	110,942	0	308,622	0

Project Integration, Collaboration & Market Impact

Partners, Subcontractors, and Collaborators: We will continue working with with Andre Desjarlais of Oak Ridge National Laboratory to test our samples according to ASTM C518.

Technology Transfer, Deployment, Market Impact:

Participating in Dawnbreaker®,

Presented 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