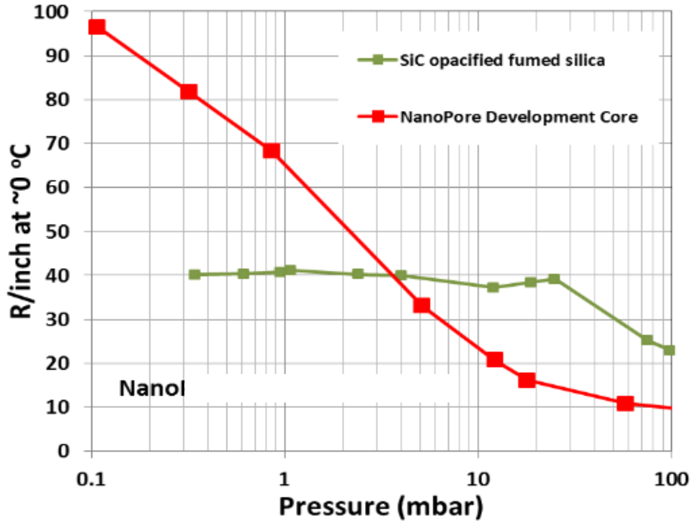
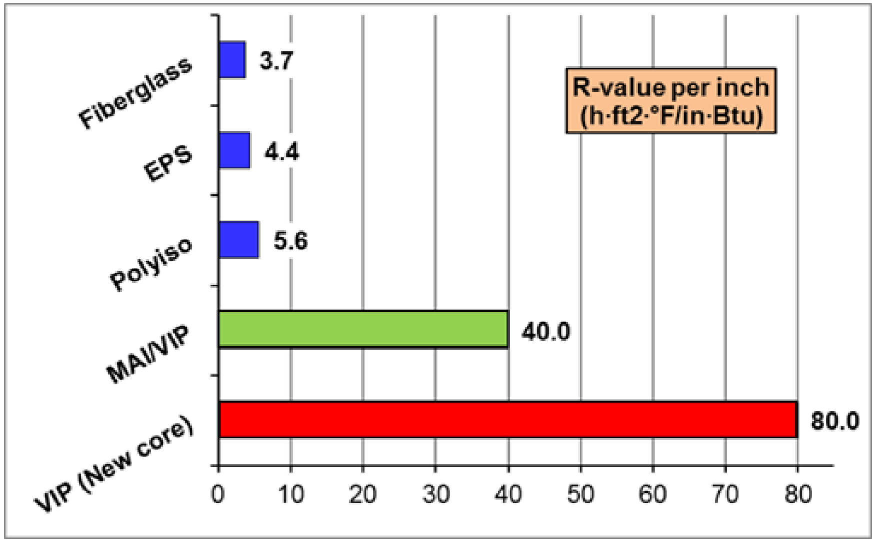
Ultra-high R/inch VIP with new developmental core material





Oak Ridge National Laboratory

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Project summary

Timeline:

Start date: October 1, 2017
Planned end date: September 30, 2019

Key Milestones

1. Complete installation of R25 foam-VIP composite insulation on a low-slope commercial roof (9/30/2018)
2. Develop new barrier material that is capable of maintaining low gas pressure for extended periods of time (3/31/2018)
3. Measure R-value of fibrous core materials over a range of pressures to demonstrate feasibility of R70-80/inch (9/30/2018)

Budget:

Total Project $ to Date:

- DOE: $1,300,000
- Cost Share: $0

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Key Partners:

NanoPore Incorporated
Firestone Building Products Company

Project Outcome:

Two focus areas: (i) install and evaluation of fumed silica-based foam-VIP composite insulation boards, and (ii) develop ultra-high R/inch VIPs with low-cost core materials. The overall goal is developing cost-effective insulation systems with at least twice the thermal performance of current building insulations. The new high R/inch insulations will enable easier retrofits of existing buildings.

Team

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE U.S. DEPARTMENT OF ENERGY

NanoPore

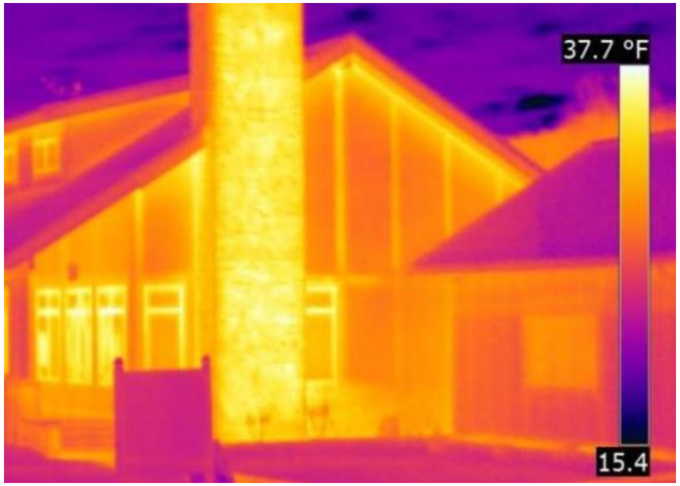
Firestone BUILDING PRODUCTS

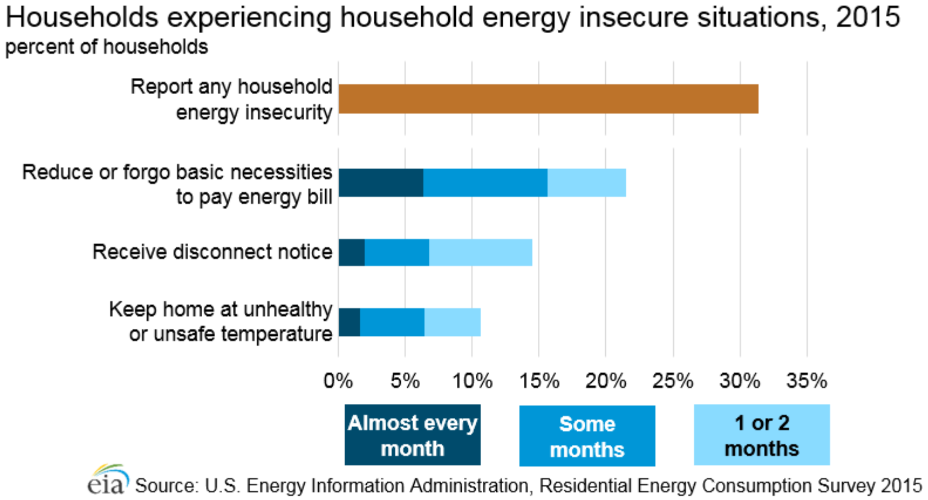
- **Kaushik Biswas, PhD & Andre Desjarlais (ORNL):** Project management, experimental and numerical evaluations, and reporting.
- **Douglas Smith, PhD (NanoPore):** Micro-/Nanoporous insulation expert, VIP manufacturer.
- **John Letts, PhD (Firestone):** Foam manufacturing expert, foam-VIP composite manufacturing.

ORNL has decades-long building science expertise. ORNL researchers are well-versed in experimental and numerical evaluations of insulation materials and systems, including vacuum insulation. NanoPore has 100+ patents on porous insulation materials and has spun-off the largest VIP producers in the US and UK. Firestone is an industry leader for building materials and foam insulation, with over $1.4 billion in annual sales. The team of ORNL, NanoPore and Firestone successfully developed an R12/inch foam-VIP composite in 2017.

Challenge

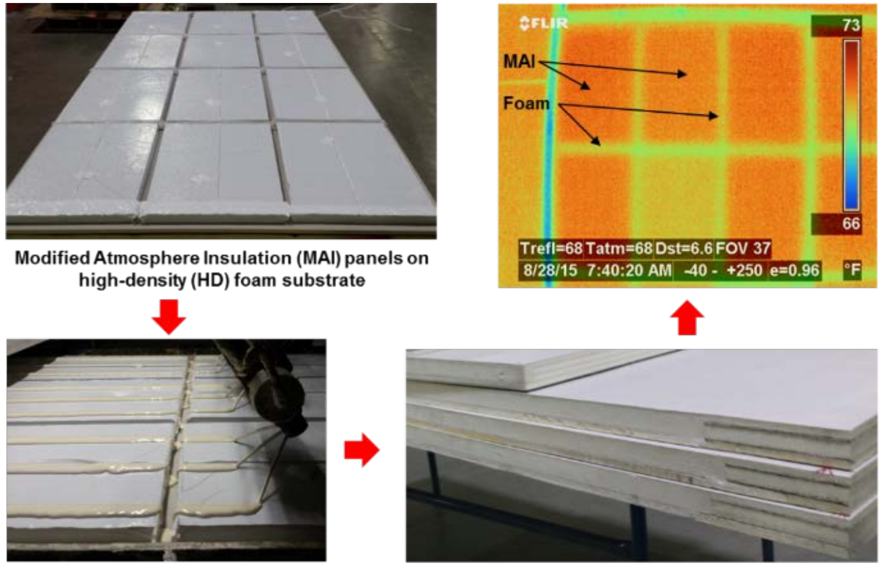
- In 2010, the primary energy consumption attributed to building envelope (roofs and walls) was 5.8 quadrillion BTUs (*~6% of entire US consumption*).
- 2014 DOE Roadmap depicts need for high-performance, cost-effective insulation systems.
- Economic implications: More than 20% of US households face hardships due to high energy costs.
- Cost effective envelope upgrades/retrofits have proven ineffectual with existing insulations that can achieve R6/inch or less.
- Vacuum insulation-based systems are potential solutions, but cost reductions are needed.





Approach

- The team has successfully developed foam-VIP composites that can achieve R25 at 2 inch thickness, or R12/inch.*
  - Existing state-of-the-art building insulation is polyurethane and polyisocyanurate foam insulations that can achieve R6/inch.
- R25 composite contains low-cost VIPs called Modified Atmosphere Insulation (MAI) with fumed silica core.



Modified Atmosphere Insulation (MAI) panels on high-density (HD) foam substrate

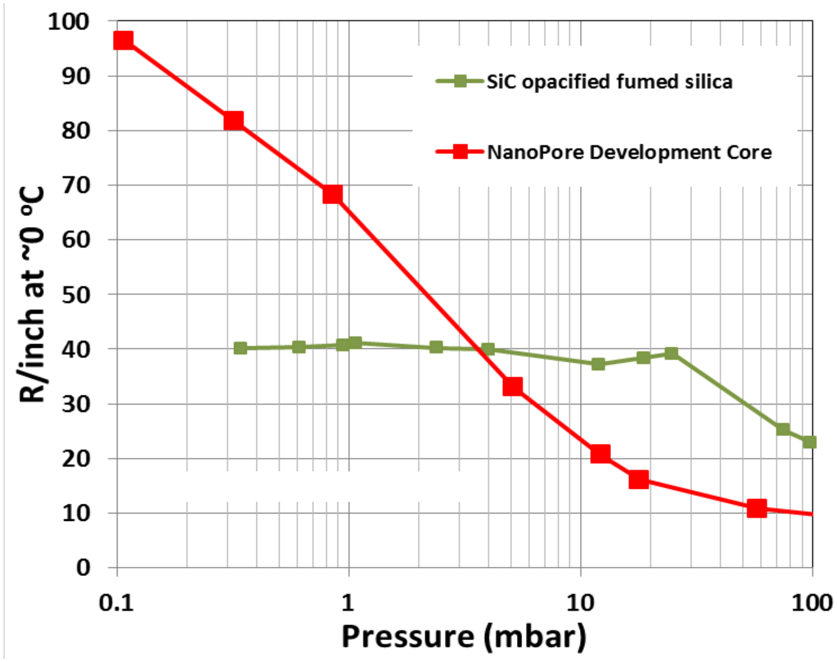
Foam application on manufacturing line

Finished composite insulation boards

* https://www.energy.gov/sites/prod/files/2017/04/f34/5_31395_Biswas_031617-1100.pdf

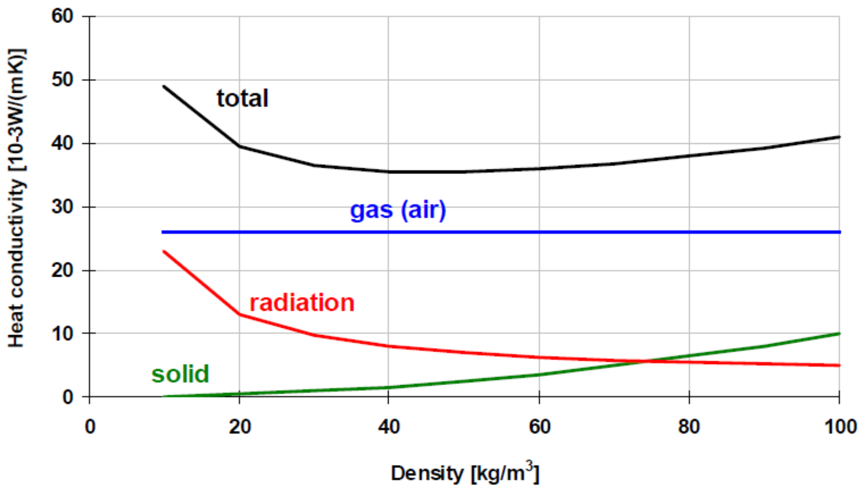
Approach (contd.)

- Two main focus areas in current project:
  - Evaluating the R25 composite insulation in real building and evaluating long-term performance via natural and accelerated aging.
  - Developing higher R/inch VIPs at lower cost than MAI.
- Fumed-silica based MAI panels can achieve R40/inch and are projected to cost $0.05/ft^2/R-value at large-scale production.
- The new core-based VIPs are projected to cost $0.02/ft^2/R-value (assuming R80/inch).
- Added cost advantage: Same performance with thinner panels will allow lower material and shipping costs and reduce installation thickness.



Approach (contd.)

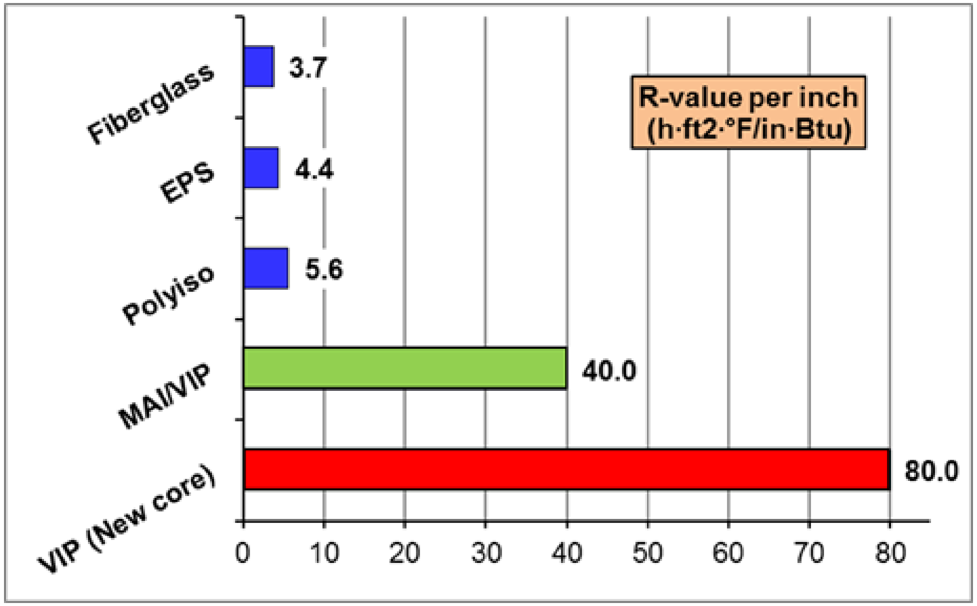
- Perform a full-scale installation of the R12/inch composites on a low-slope roof of an occupied commercial building.
  - Contractor feedback will enable further technology development/ optimization.



- Investigation includes:
  - Barrier films to maintain the low internal pressure (0.1-1 mbar).
  - Optimization of the core to minimize solid conduction and infrared radiation.
  - Project costs of the VIP/MAI-foam composite with the new core material.

Impact

- Developing R12/inch insulation is a stated goal of the 2014 DOE Envelopes Roadmap.
- 2030 primary energy savings potential of R25 insulation is 1.6 quads, based on the DOE Market Calculator.
  - Applications include low-slope commercial roof and residential walls.

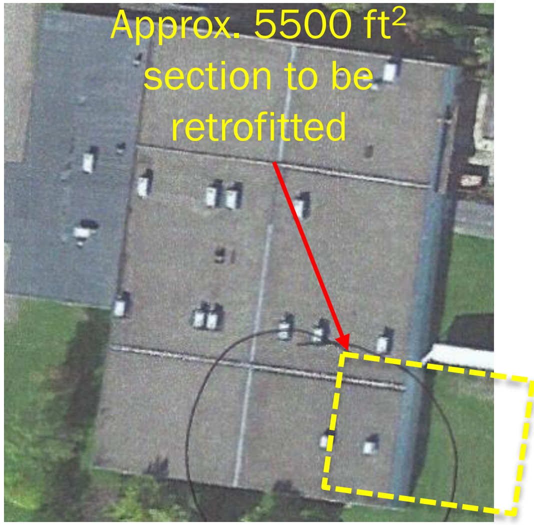


Progress

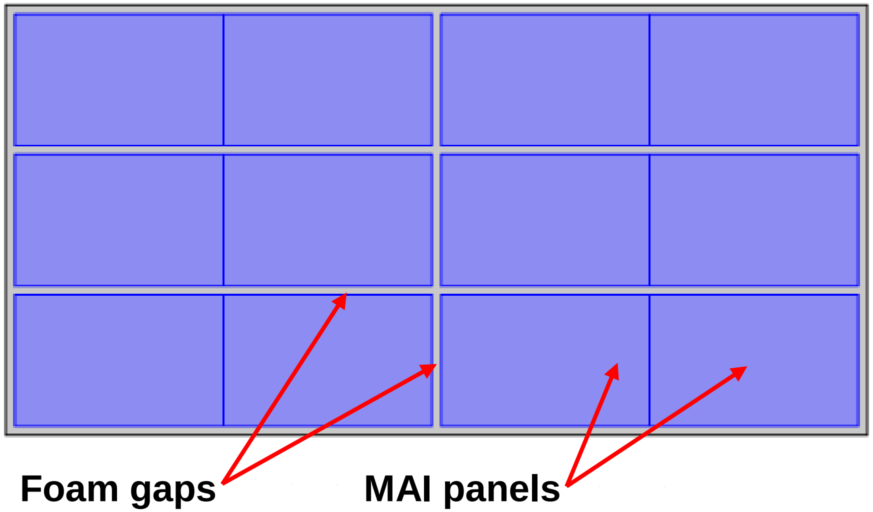
- New project started on October 1, 2017, but builds on previous research on MAI and R25 composite insulation development.
- Focus area 1 – Installation and long term performance of R25 composite insulation.
  - Identified an occupied commercial building; and
  - Scaled up and manufactured R25 composite insulation boards containing fumed silica-based MAI panels.
- Focus area 2 – Development of new core to achieve R80/inch.
  - Developed vacuum pump system to rapidly make VIPs with internal pressures of 0.1 mbar; and
  - Identified and evaluated barrier films that can maintain low internal pressure and their impacts on thermal bridging/edge effects.

Reroof validation of R25 composite boards

- Building and site:
  - Caribou, ME (climate zone 7)
  - 5500 ft^2 section with gravel-covered built up roof.
  - Slope: 2:12
- Three sections (for comparison):
  - 2” R25 composite, fully adhered
  - 2” R25 composite, mechanically attached
  - 4” polyiso (same R-value)
- Reroof construction:
  - Steel deck > 0.5” coverboard > insulation > membrane (EPDM).

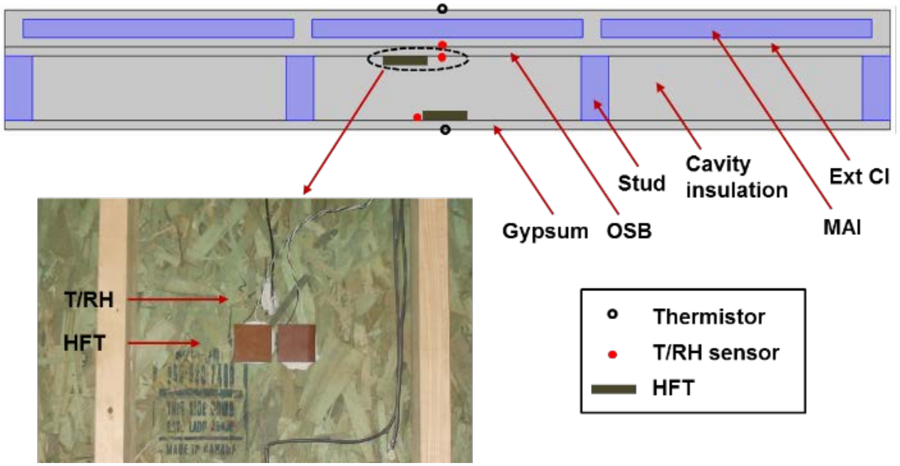


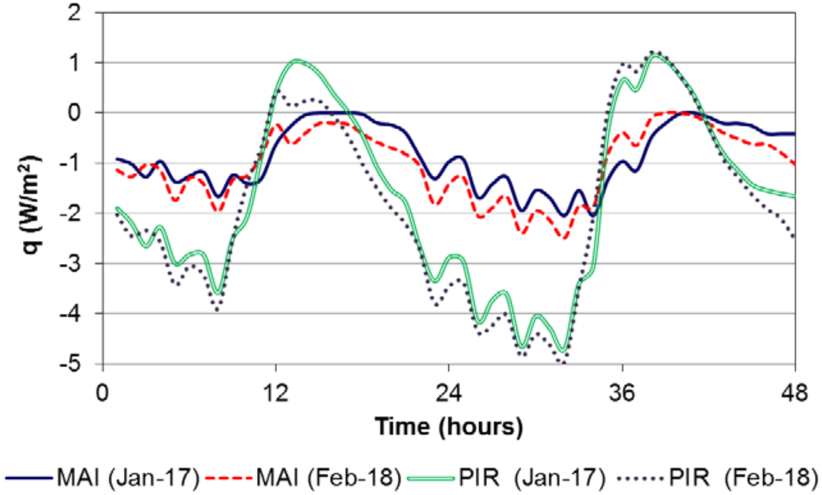
4’ x 8’ composite board



Natural aging of R25 composite insulation

- Natural-aging test being done in Charleston, SC.
- Side-by-side walls with regular 2” polyiso and the R25 composite as exterior continuous insulation (CI).
- No degradation in thermal performance during 1.5 years of testing based on and measured heat flux data.

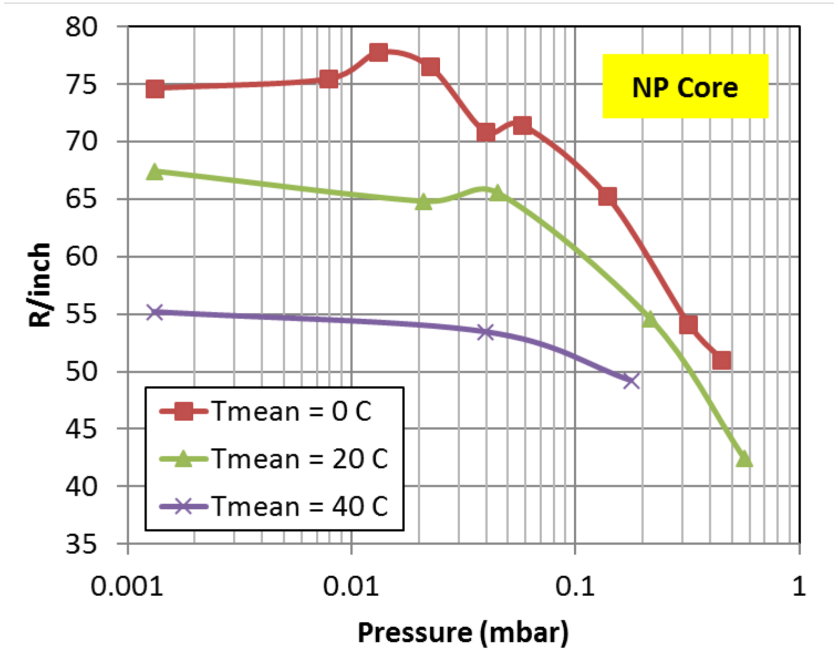


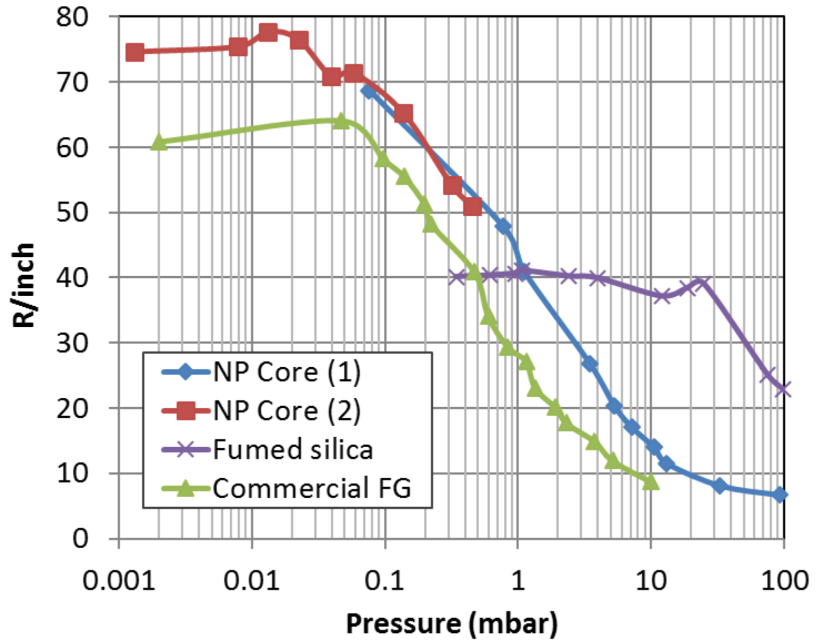


Comparison of heat fluxes through R25 and polyiso CI during Jan 2017 and Feb 2018.

Development of high R/inch VIPs

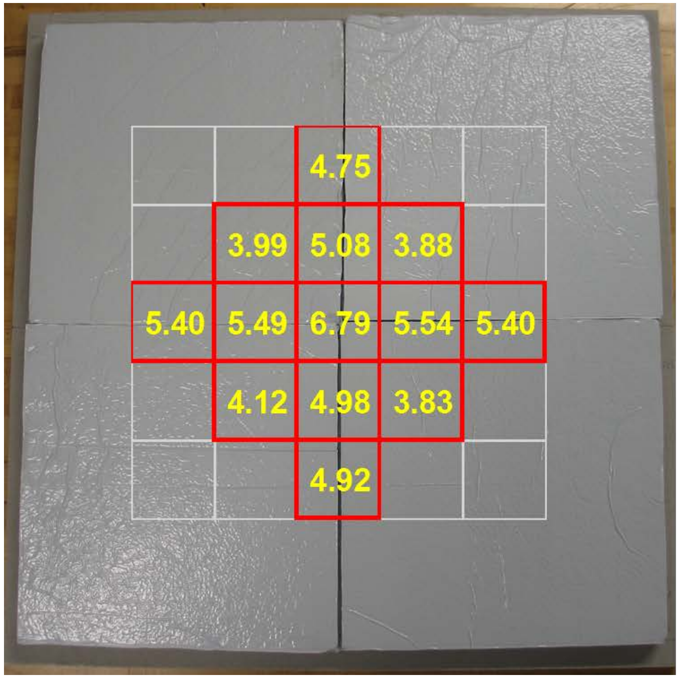
- Evaluation of new core materials (NP Core) at different temperatures and pressures.
  - For comparison, fumed silica and fiberglass (FG) cores are being tested.
- New core is not yet optimized to reduce radiation heat transfer.
- A high vacuum chamber that can rapidly achieve VIP low pressures of < 0.001 mbar is under construction.



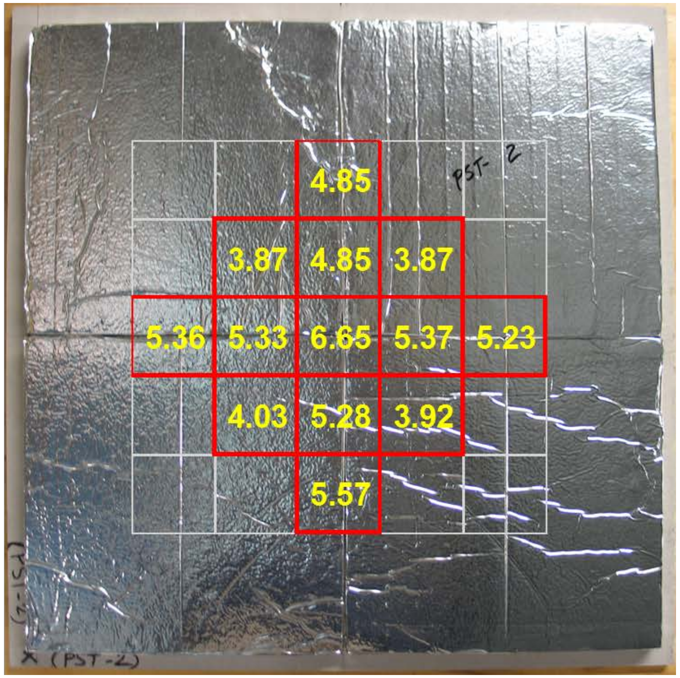


Test of edge effect with different barrier films

- Polymeric barrier films were used on MAI panels for the R25 boards.
  - MAI panels contained fumed silica core at ~10 mbar.
- New core-based VIPs will contain a lower internal pressure (~0.1 mbar) and metallized films may be needed for longer lifetime.
- Measured heat fluxes with polymeric (left) and metallized (right) films.



140 µm PE/EvOH/PE film



104 µm metallized PET film

- PE – Polyethylene
- EvOH - Ethylene vinyl alcohol
- PET – Polyethylene terephthalate

Stakeholder engagement

- Collaboration between government (DOE), research organization (ORNL) and industry (NanoPore and Firestone).
- ORNL has access to test beds for evaluations of prototypes of VIP-based insulation systems.
- Firestone has access to roofing contractors and commercial buildings that can act as test beds for installation evaluations.
  - Contractor feedback is critical for product development and optimization
- Publications and presentations at technical meetings/conferences will enable dissemination of information to relevant stakeholders.
  - K. Biswas, A. Desjarlais, D. Smith, J. Letts, J. Yao and T. Jiang. *Development and thermal performance verification of composite insulation boards containing foam-encapsulated vacuum insulation panels*, Applied Energy, submitted April 2018.

Remaining project work

- Remaining FY18 work
  - Complete roof installation of the R25 composite boards.
  - Design an accelerated aging protocol for laboratory aging of silica-based MAI panels and the R25 composite.
  - Test the efficacy of barrier films to maintain low internal pressure in the new core-based VIPs.
  - Optimize the new core material with respect to gas and solid conduction and radiation heat transfer.
- FY19 & long-term future work
  - Develop and evaluate full-scale (4’ x 8’) composite insulation boards with the new R80/inch VIPs.
    - Evaluate impact of metallized films on overall R-value.
  - Evaluate long-term performance of the R80/inch VIPs.
  - Determine pathways to scaled-up production of the R80/inch VIP and strategies for introduction to the building insulation market.

Thank You

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REFERENCE SLIDES

Project Budget

Project Budget: FY18-FY19: $1,300,000
Variances: None
Cost to Date: $500,000 (includes full cost of FY18 commitments)
Additional Funding: None

Budget History					
FY 2017 (past)		FY 2018 (current)		FY 2019 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
N.A.	N.A.	$1,300,000	0	0	0

Project Plan and Schedule

- Delays in issuing a subcontract to an industry partner caused the first milestone to slip; it was completed in early February
- Go/No-Go milestone: Demonstrated R/inch of 70-80 with the selected fibrous core material

Project Schedule				
Project Start: Oct 1, 2018		Completed Work		
Projected End: Sep 30, 2019		Active Task (in progress work)		
		Milestone/Deliverable (Originally Planned)		
		Milestone/Deliverable (Actual)		
	FY2018			
Task	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
Past Work				
Identification of test roof for the R25 MAI composite performance verification				
Propose accelerated test methodology for silica-based MAI panels based on literature review				
Develop new barrier material that is capable of maintaining low gas pressure for extended periods of time				
Current/Future Work				
Develop a model to evaluate the effect of radiation heat transfer within the core and prepare test panels to test the effect of radiation				
Test roof is installed, data collection is initiated, and feedback from contractors is compiled and reported				
Report initial accelerated aging test results on MAI panels and compare with field data gathered in field exposure facility in South Carolina				
Develop a dry compaction process which includes the fibers and opacifier and produces the final core material in the correct board size.				
Updated cost analysis report for the fiber-based MAI to include the impacts of the new core and barrier materials, and any process changes compared to silica based MAI.				
Measure the R-value of a variety of fibrous core materials over a range of internal pressures to demonstrate the feasibility of obtaining a core R-value of at least R70-80/inch.				