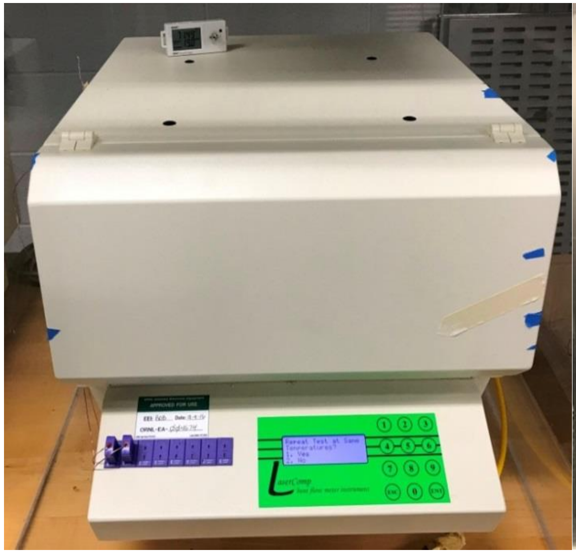
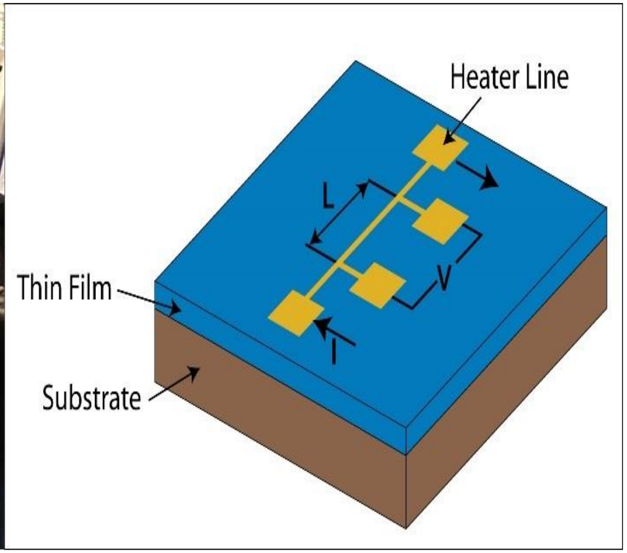
Developing the Metrology for Accurately Assessing the R-value of Super Insulation





Oak Ridge National Laboratory
André Desjarlais, Program Manager
desjarlaisa@ornl.gov

Project Summary

Timeline:

Start date: June 2018

Planned end date: September 2021

Key Milestones

1. Define the relationship between sample size, accuracy, and precision (12/19).
2. Obtain NIST Standard of 0.015 W/m·K (06/20).
3. Demonstrate accuracy of 5% and precision of 3% at a target of 0.015 W/m·K (03/21).

Budget:

Total Project $ to Date:

- DOE: $278K
- Cost Share: $0

Total Project $:

- DOE: $975K
- Cost Share: $0

Key Partners:

NIST	FIW München
Georgia Tech	LBNL
NREL	UC Berkeley

Project Outcomes:

- Develop experimental techniques that can satisfy the need for testing small sections of highly thermally resistive materials.
- Develop a new thermal reference material.
- Produce a suitable consensus test method.
- Accelerate test equipment availability to researchers.

Team





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

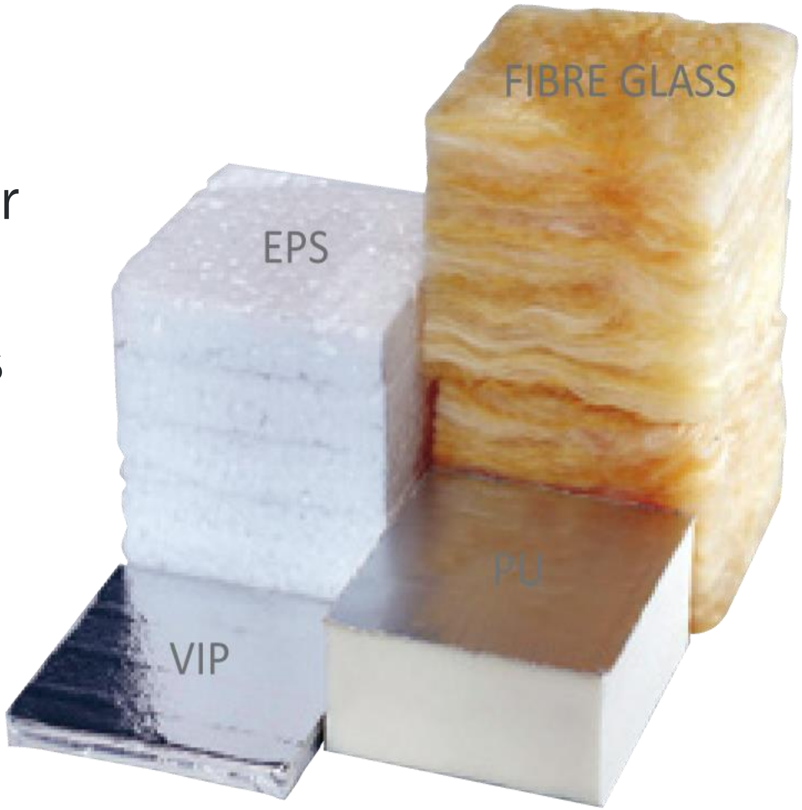
NIST

- Kaushik Biswas, PhD (ORNL): Numerical evaluations
- André Desjarlais (ORNL): Insulation testing expert and project management
- Ralph Dinwiddie, PhD (ORNL): Transient thermal testing expert
- Som Shrestha, PhD (ORNL): Heat transfer testing and modeling specialist
- Robert Zarr (NIST): Thermal measurements and transfer standards expert

- Team includes researchers with extensive experience in thermal measurements
- Consortia members add further depth to thermal testing expertise
- Inter-lab round robins possible with some consortia members
- US standards developer part of the team
- ORNL has acquired specialized test apparatus for project

Challenge

- Developing insulation materials with R>12/inch is of interest to BTO.
  - Several projects funded in this space including LBNL, Virginia Commonwealth University, Fraunhofer CSE, and ORNL.
- Existing equipment and test methods do not align with researcher needs.
  - Making large samples is difficult and expensive (8 by 8 inch or larger required).
  - Apparatus uncertainty not defined (equipment verified at R-4.5/inch reference materials).



Approach

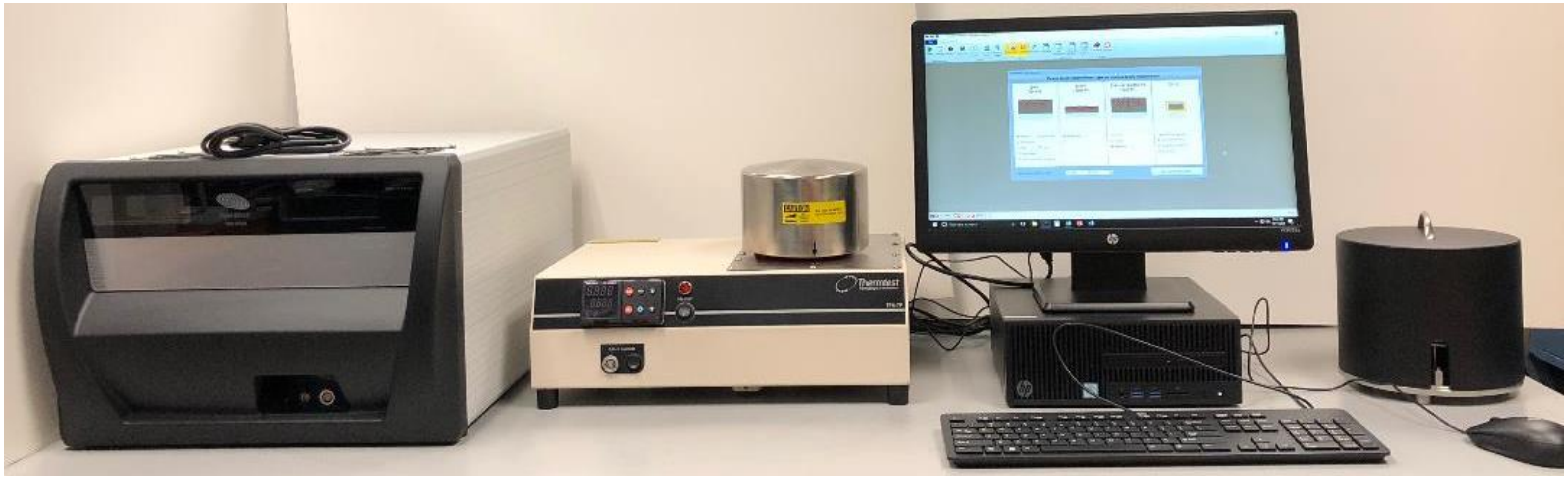
- Develop experimental methods and instrumentation that can test small sections of high R/inch materials.
  - Candidate procedures and hardware will be evaluated in terms of their ability to satisfy the project criteria of sample size, accuracy, and speed of testing.
- Develop working group with researchers to assure that activities are consistent with their needs.
- Produce a suitable consensus reference material and test method.
- Encourage equipment suppliers to produce and sell the final designs.

Approach

- Tasks
  - Identify researcher needs for improved test metrology.
  - Explore the use of the heat flow meter apparatus (HFMA) method.
  - Evaluate the transient plane source method.
  - Review of alternate methods.
  - Develop draft consensus standards for proposed test methods.
  - Work with test equipment manufacturers to introduce improved version of the test equipment.

Approach

- Potential Barriers
  - Is the accuracy of existing equipment sufficient to be employed?
  - Can test equipment be improved to accurately measure low heat fluxes?
  - Is there a suitable material that can be used as a reference standard?



Impact

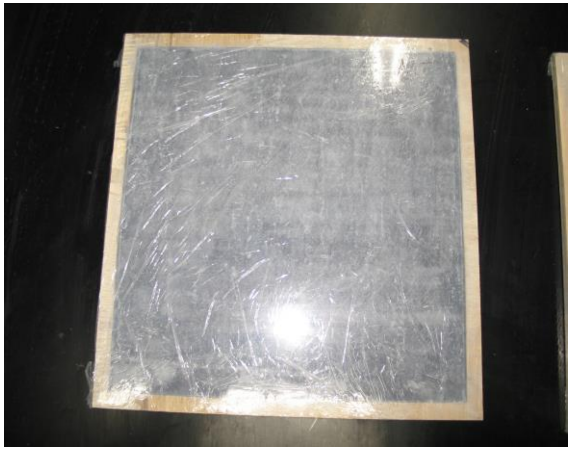
- Highest envelope priority listed in Windows and Building Envelope Research and Development Roadmap (February 2014).
  - Faster and more economic development of materials
  - Faster prototyping
  - Faster experimentation
  - Greater confidence in small incremental differences

Table 22. Roadmap Target Prioritization Tool Analysis Results for Building Envelope Technologies, Including Thermal Insulation Materials, Air-Sealing System Technologies, and Commercial Roofing Technologies

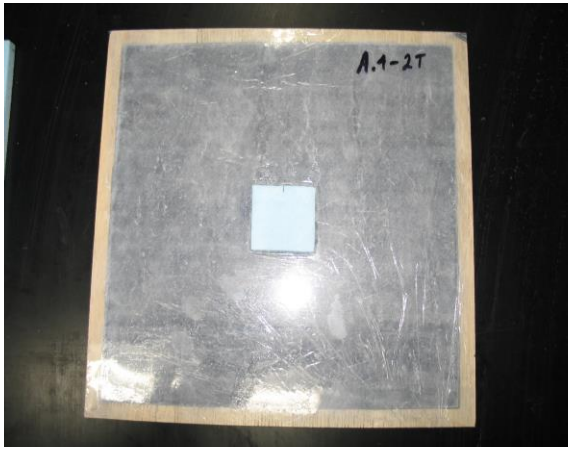
Building Envelope Technologies					
Roadmap Target Technology Description	Market Size[34] (TBtu)	Technical Potential[35], 2030 (TBtu)	Unstaged Max Adoption Potential[36], 2030 (TBtu)	Payback in 2030 (years)	Prioritization Tool Measure Number[37]
Building Envelope Material					
R-12/in building envelope thermal insulation material, with an installed cost premium ≤$0.25/ft^2 (R)	1,610	836	267	3.2	658

Progress (ASTM C 518)

- Use standard apparatus to undertake 150 measurement test matrix.
- Three different materials analyzed: plywood (R1.6/in.), XPS (R5.0/in.) and aerogel batt (R8.6/in.).
- Evaluate full size materials, then prepare specimens with 6-, 4-, 3-, 2-, and 1-inch apertures in center.
- Test with apertures filled with other materials (i.e., 6-inch aerogel in XPS ring).
- Use data from full size tests to estimate uncertainty in testing smaller sections.
- Repeat test matrix varying heat flux transducer cross-section and sensitivity.



Solid specimen of aerogel in wooden ring and film.



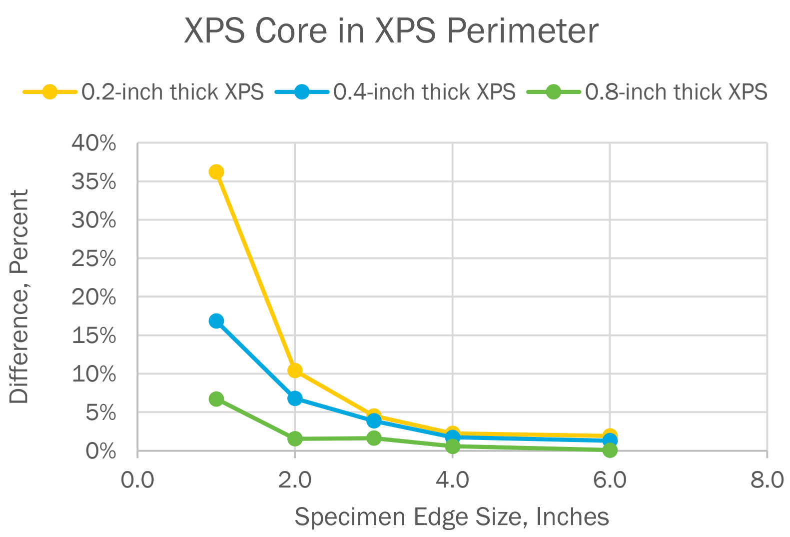
Specimen of XPS core in aerogel surround.

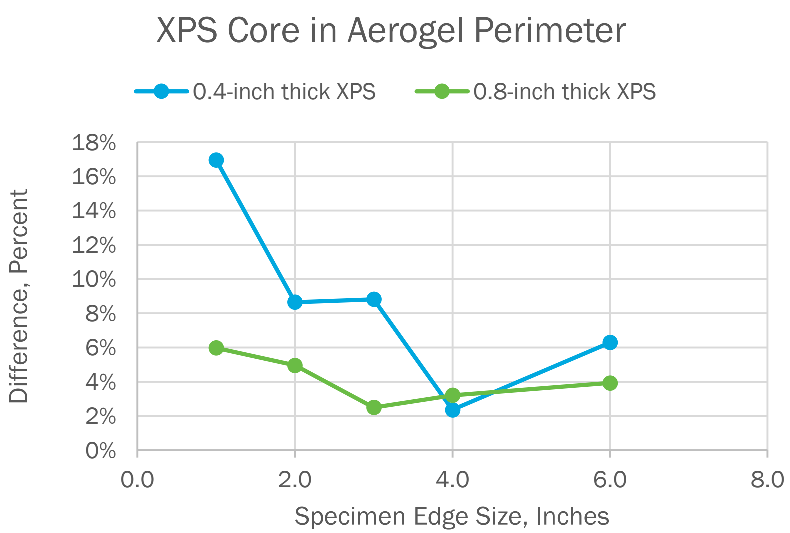
Progress (ASTM C 518)

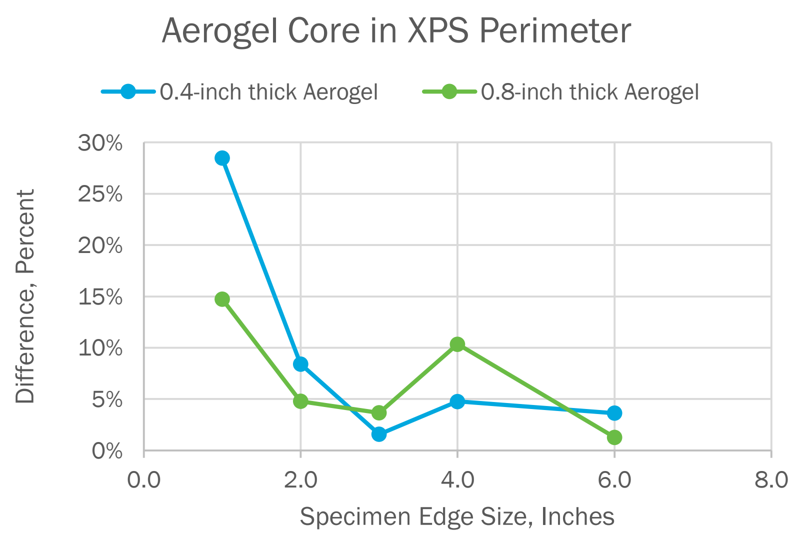
Core Material	Solid		With Plywood Surrounds		With XPS Surrounds		With Aerogel Surrounds	
	R/in.	STD	R/in.	STD	R/in.	STD	R/in.	STD
Plywood	1.62	0.14	1.66	0.14	2.72	1.02	3.50	1.95
XPS	5.08	0.10	3.09	1.28	5.00	0.07	6.19	1.34
Aerogel	8.57	0.17	3.84	2.40	6.77	1.49	8.43	0.17

Note: R/in. and standard deviation (STD) data are the averages of all samples with varying cross-sections (1- to 6-inch square) and thicknesses (0.2 to 0.8 inches).

Progress (ASTM C 518)





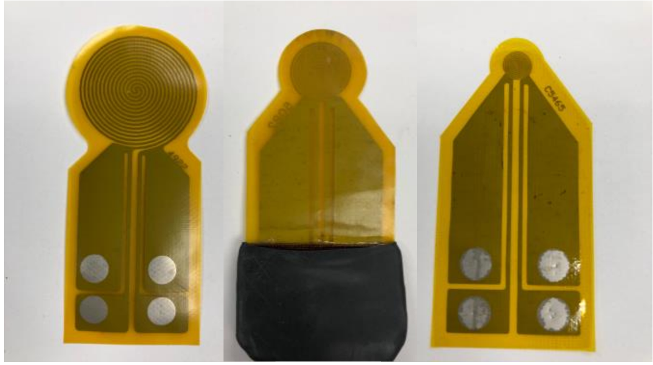


Progress (ASTM C 518)

- Takeaways
  - Uncertainty increases as difference in R-value between core and surround materials increase.
  - Uncertainty increases as core gets smaller.
  - Thicker specimens appear to exhibit less uncertainty.
  - Plywood not a good material choice due to variations in the R-value of the different layers within the plywood.
  - Aerogel blanket a difficult material to use due to its propensity to compress.

Progress (ISO 2207-2)

- Progressing with 150 experiment test matrix varying the specimen thermal resistivity, thickness and size.
- Exploring the parameter space of the measurement (Scan time, power, sensor size) for low thermal conductivity specimens.
- Need to replace plywood with bulk wood.
- Test experimental sensor with low heat loss design.



Progress (General)

- Expert meeting teleconference held in October 2018.
  - Consensus is to pursue modifying existing methods first; pursue alternate procedures only if existing methods unsatisfactory.
  - Try to reduce specimen size to 1-inch square.
- Met with NIST about developing reference materials.
  - Examining possibility of using SRM 1449 as a reference material.
- Introduce topic to ASTM C 518 task group at Spring 2019 Meeting at ASTM C 16.
- Discussions started with TA Instruments and Thermtest about possible instrument modifications.

Stakeholder Engagement

- Project consortium
  - Forschungsinstitut für Wärmeschutz e.V. München
  - Georgia Institute of Technology
  - Lawrence Berkeley National Laboratory
  - National Renewable Energy Laboratory
  - University of California Berkeley
- Consortium activities
  - Critique research being performed
  - Identify additional experimental protocols
  - Define equipment and test method requirements
  - Monitor progress quarterly

Stakeholder Engagement

- NIST
  - Experts in standard reference material development
  - Utilize experience and history
  - Support financially to provide guidance and measurements
  - Initial plan is to use SRM 1449 (fumed silica)
    - Microporous block insulation commercially available.
    - Thermal resistivity is about 7.2 hr ft^2 F/Btu.
    - Machining may be an issue (silica, fragility)

Remaining Project Work

- Address sample size issue.
  - Develop algorithms for thermal resistivity, specimen thickness and cross-section.
  - Replace plywood and aerogel blanket materials with poplar and SRM 1449.
- Address calibration issue.
  - Get subcontract in place with NIST.
  - Finalize SRM selection.
- Address heat flux measurement issue.
  - Understand impact of HFT sensitivity and size, power and scan time on uncertainty.
- Draft ASTM test method or practice.

Thank you

Oak Ridge National Laboratory
André Desjarlais, Program Manager
desjarlaisa@ornl.gov

REFERENCE SLIDES

Project Budget

Project Budget: $300K per year for 3 years. Some funds from FY18 from other project to get an early start.
ORNL purchased specialized test equipment.
Variances: None.
Cost to Date: $139K ($64K from FY19 funding).
Additional Funding: Possible cost share from NIST (not yet confirmed).

Budget History					
FY 2018		FY 2019 (current)		FY 2020 – FY 2021 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$175K	$0	$200K	$0	$600K	$0

Project Plan and Schedule

Task	Milestones	FY19				FY20				FY21			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1.1	ASTM C518 address sample size issue												
1.2	ASTM C518 address calibration issue												
1.3	ASTM C518 address heat flux measurement issue												
1.4	ASTM C518 improved heat flux meter apparatus demonstrated												
2.1	Transient plane source address sample size issue												
2.2	Transient plane source address thermal conductivity issue												
2.3	Transient plane source address calibration issue												
2.4	Transient plane source improved transient plane source apparatus demonstrated												
3	Address alternate methods and issues												
4	Identify researcher needs for improved test metrology												
5	Develop draft consensus standards for proposed test methods												
6	Work with test equipment manufacturers to introduce improved version of the test equipment methods												
1	Improve the precision of thermal measurements and demonstrate this capability												