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Impact of air leakage on hygrothermal and energy performance of buildings in North America. Part III: energy rating of insulated wall assemblies

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NRC - Institute for Research in Construction

PART III: Energy Rating of Insulated Wall Assemblies

Dr. Wahid Meref

Team Work: H.H. Saber, H. Elmahdy, M.C. Swinton, R. Glazer & M. Nicholls

*Workshop on Air Barrier, 13th Canadian Conference on Building Science and Technology (CCBST),
10 May 2011, Winnipeg, MB*



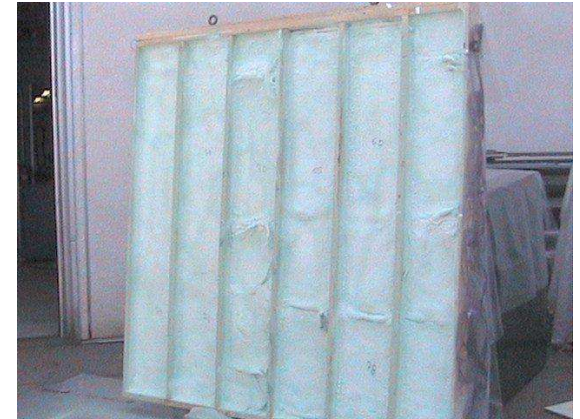
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Council Canada

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de recherches Canada

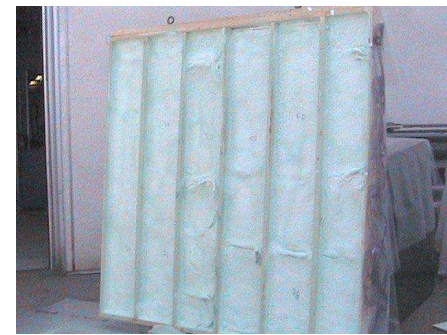
Canada

Outline

- **Background**
- **Project objectives**
- **Scope**
- **Proposed energy rating procedure for insulated wall assemblies**
- **Results of recent research project**
- **Closing remarks**



Background



- **Canadian Building Code Requirements:**
 - Control of air, water, sound, etc.
- **Canadian Construction Materials Center (CCMC) Air Barrier Guide 1996**
- **Move towards Energy Code**
- **Energy rating of building envelope components**
- **Focus on insulated wall assemblies**

Functions and Regulations

- **Some of these functions are regulated by National or Provincial/Territorial Building Codes (e.g., structural, fire,... etc.)**
- **Currently, energy codes and some provincial building codes have requirements related to the thermal performance as related to conduction heat loss (e.g., U-factor or R-value) and air leakage performance of the envelope**
- **The new National Energy Code is expected soon**



Codes and Standards Dilemma

It is difficult to incorporate the effect of air leakage through the envelope on the overall thermal performance of the wall system

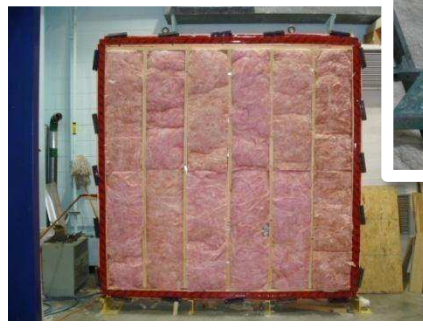


Project Objective:

- **To determine Wall Energy Rating (WER) of walls constructed according to field practices with spray polyurethane foam insulation, by combining measured heat losses due to conduction and air leakage.**
- **The work was extended to cover walls with different types of insulation**

Overview of the WER Project

- **Wall samples built to common construction practices**
- **Testing for thermal resistance and air leakage**
- **Material characterization**
- **Computer simulation**
- **Final results**



This Talk

- **Presents the results of six wall samples: two glass fiber walls (reference walls), and four SPF insulated walls with light density (open cell foam).**
- **Other walls were reported in a series of published papers**
- **A total of 16 walls were tested, modeled and documented so far.**
- **More publications:**

English: <http://www.nrc-cnrc.gc.ca/eng/ibp/irc/publications/index.html>

French: <http://www.nrc-cnrc.gc.ca/fra/idp/irc/publications/index.html>



WER 1 and WER 5

- These 2 walls are intentionally *built not to the requirements of Part 9 of the Canadian National Building Code (NBC)* to introduce a wide range of air leakage rates.
- Part 9 NBC gives 2 options for air barrier continuity:
 - Sealing the joint, or
 - *Lapping the joint by not less than 100 mm and clamping between framing members and rigid panel*
- NBC also requires sealing of windows, piping, ducting and electrical boxes to maintain the integrity of the air barrier (*All penetration were not all sealed to meet the NBC requirements*).

Wall Samples:

Six 2" x 6" spruce stud walls, 16" spacing (nominal)

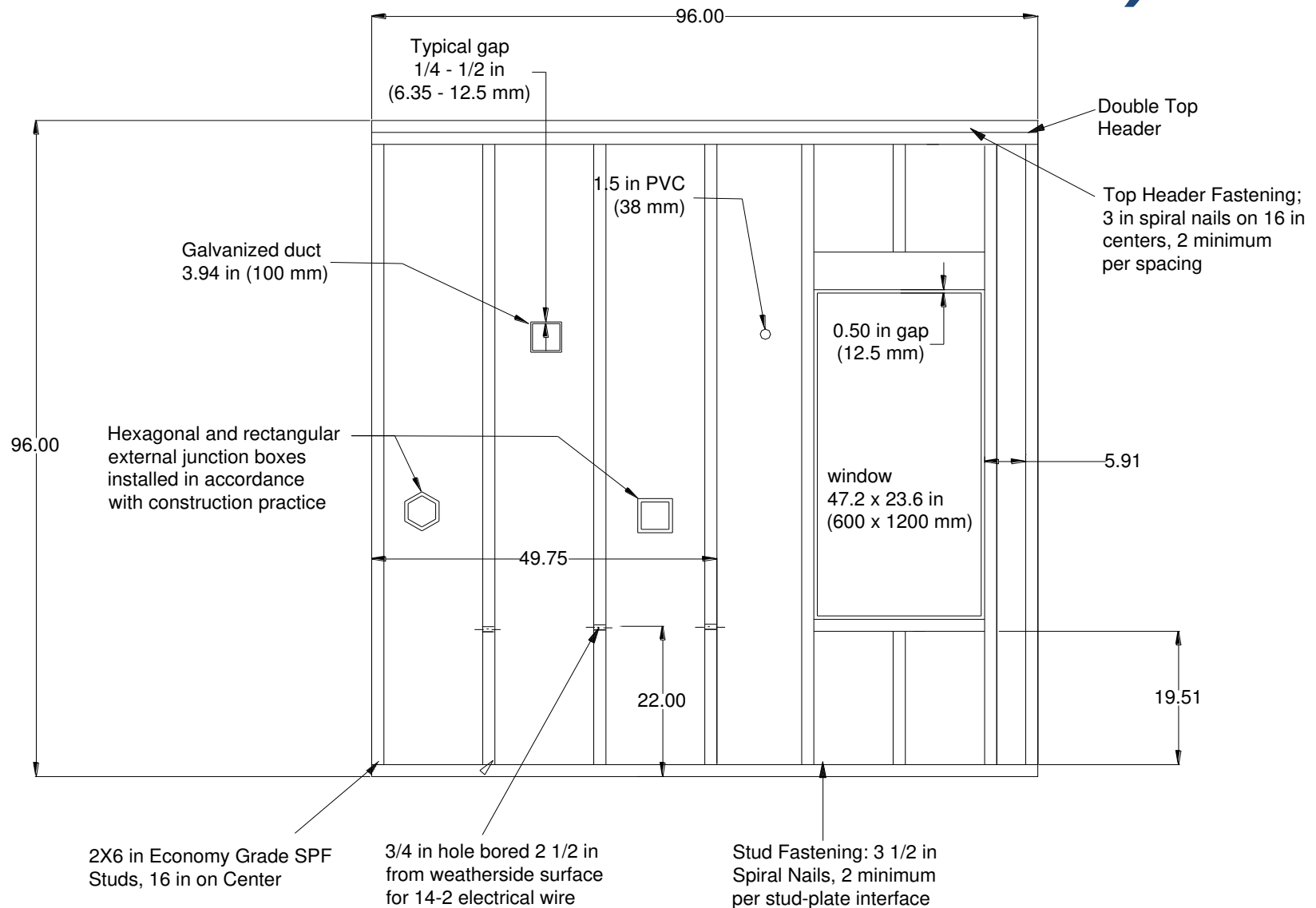
- one sample without penetration, with poly-lapped air barrier (fibrous insulation wall sample WER-1)
- one sample similar to the one above but with penetration (WER-5)
- The spray foam is light density (open cell), four samples, different foams, w/out penetration (WER-AA to DD)

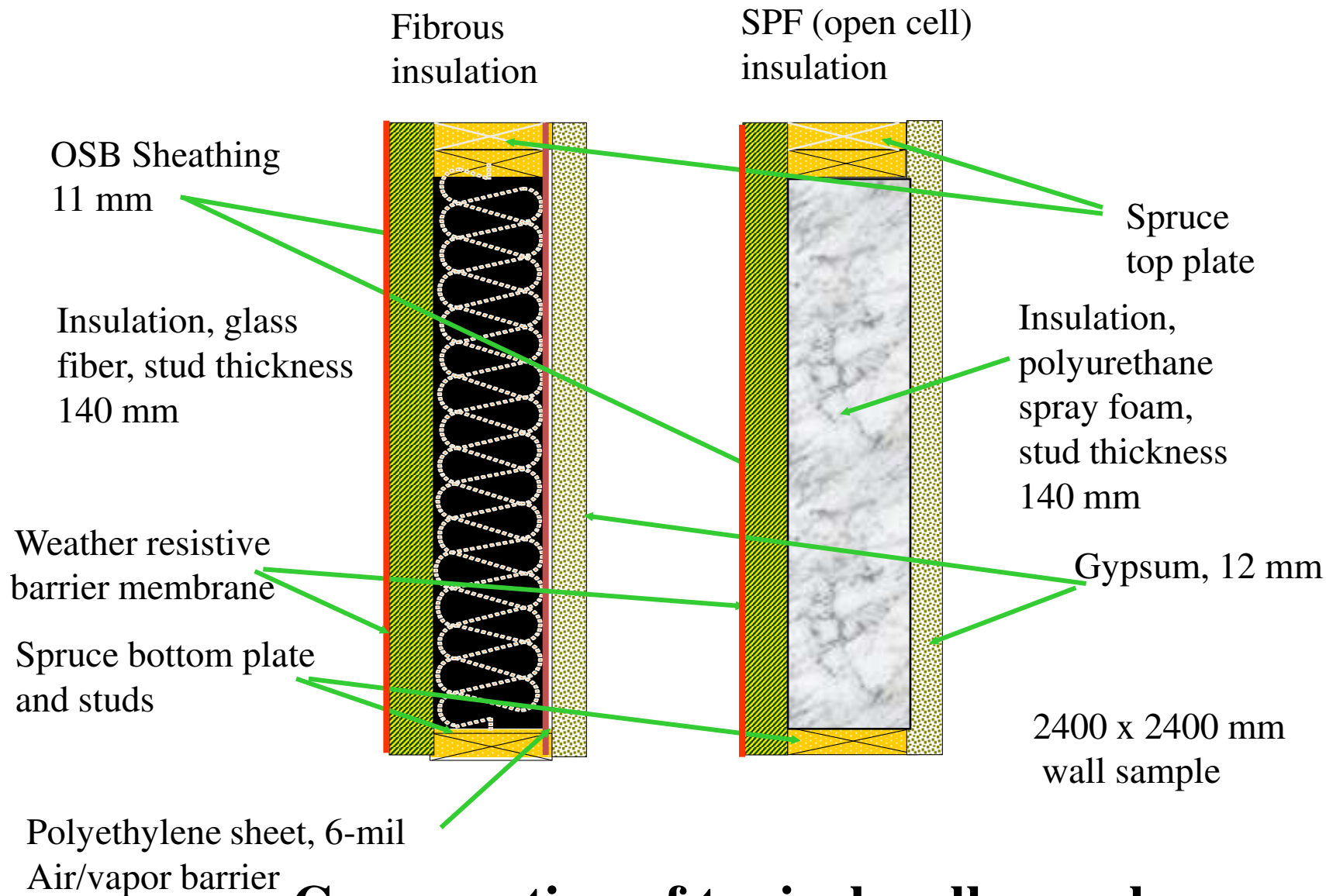


Wall samples:

Wall #	Insulation type	Description
WER-1	Fibrous insulation (poly-lapped air barrier)	Reference wall, without penetrations
WER-5	Same as above	Same as above, but with penetrations
WER-AA	Open cell foam	Blank wall, without penetrations
WER-BB	Open cell foam, same as above	With penetrations
WER-CC	Different brand of open cell foam	Without penetrations
WER-DD	Same as above	With penetrations

Penetrations Layout (CCMC Air Barrier Guide 07272)

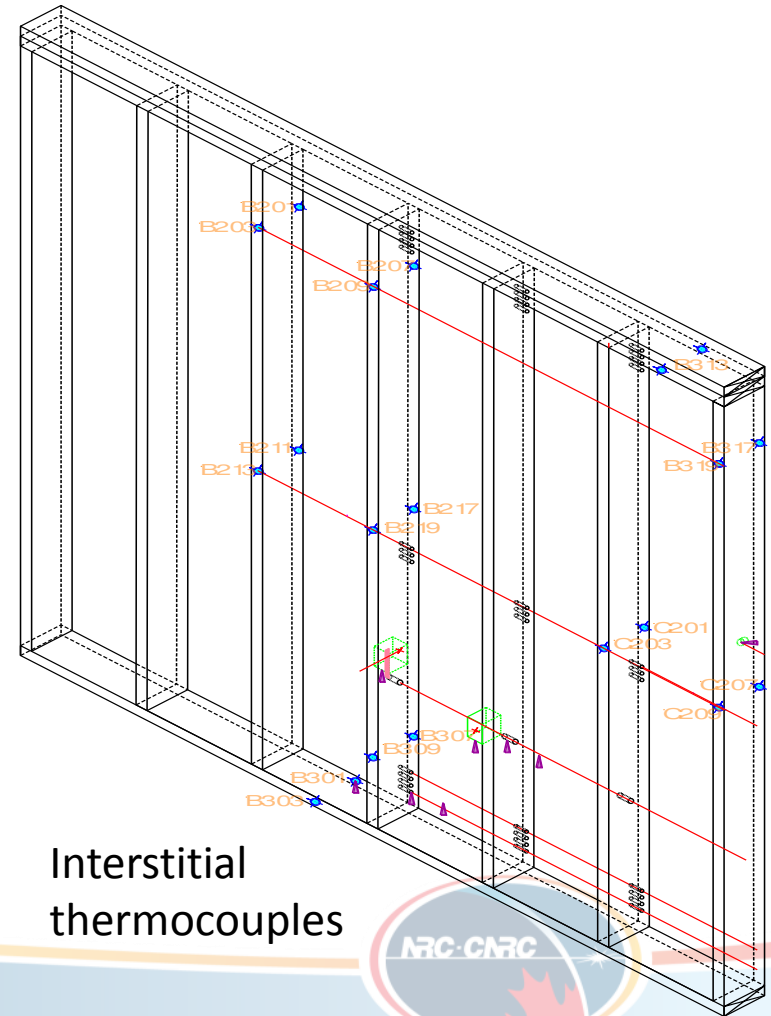




Cross-section of typical wall samples

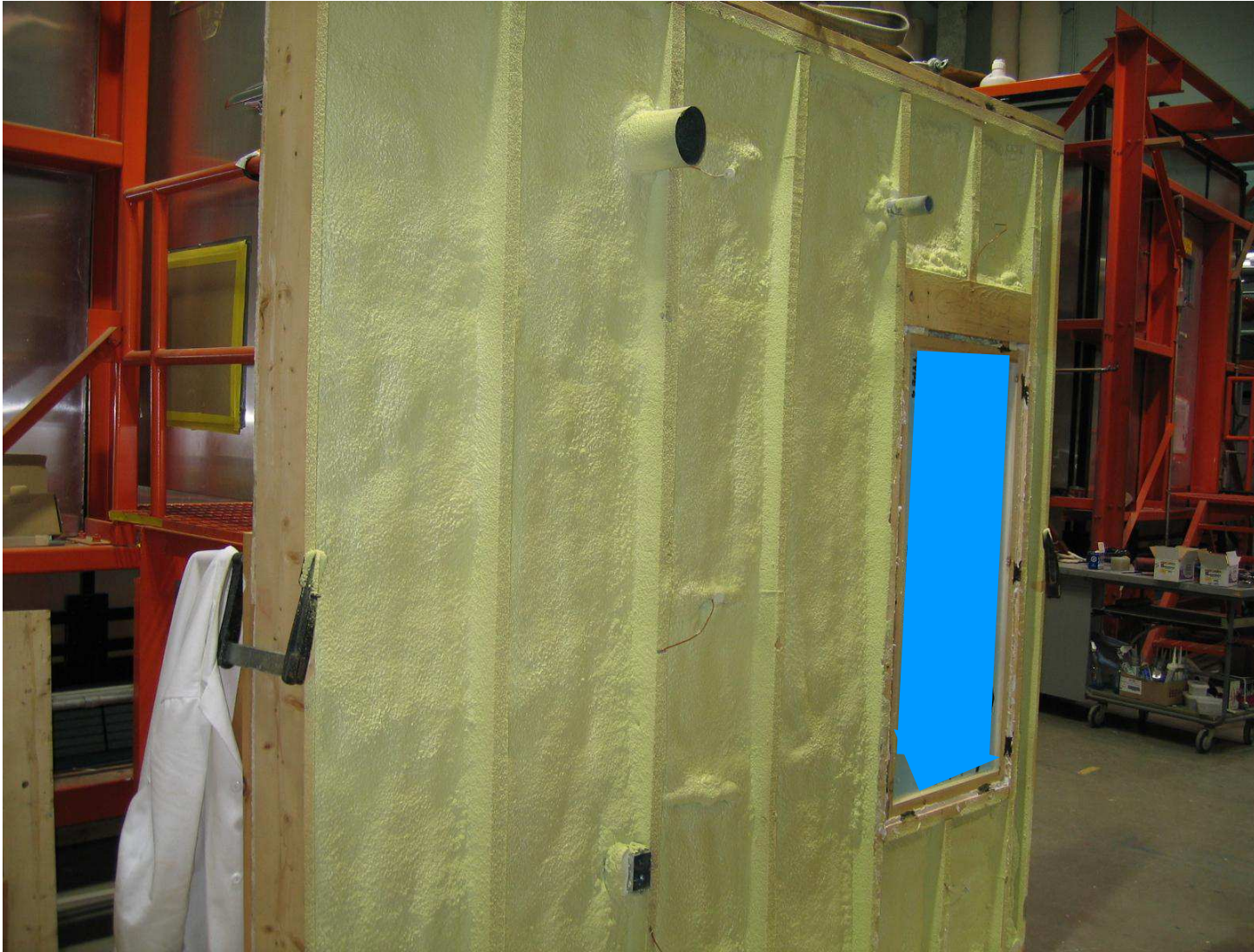


Heat flux
transducer



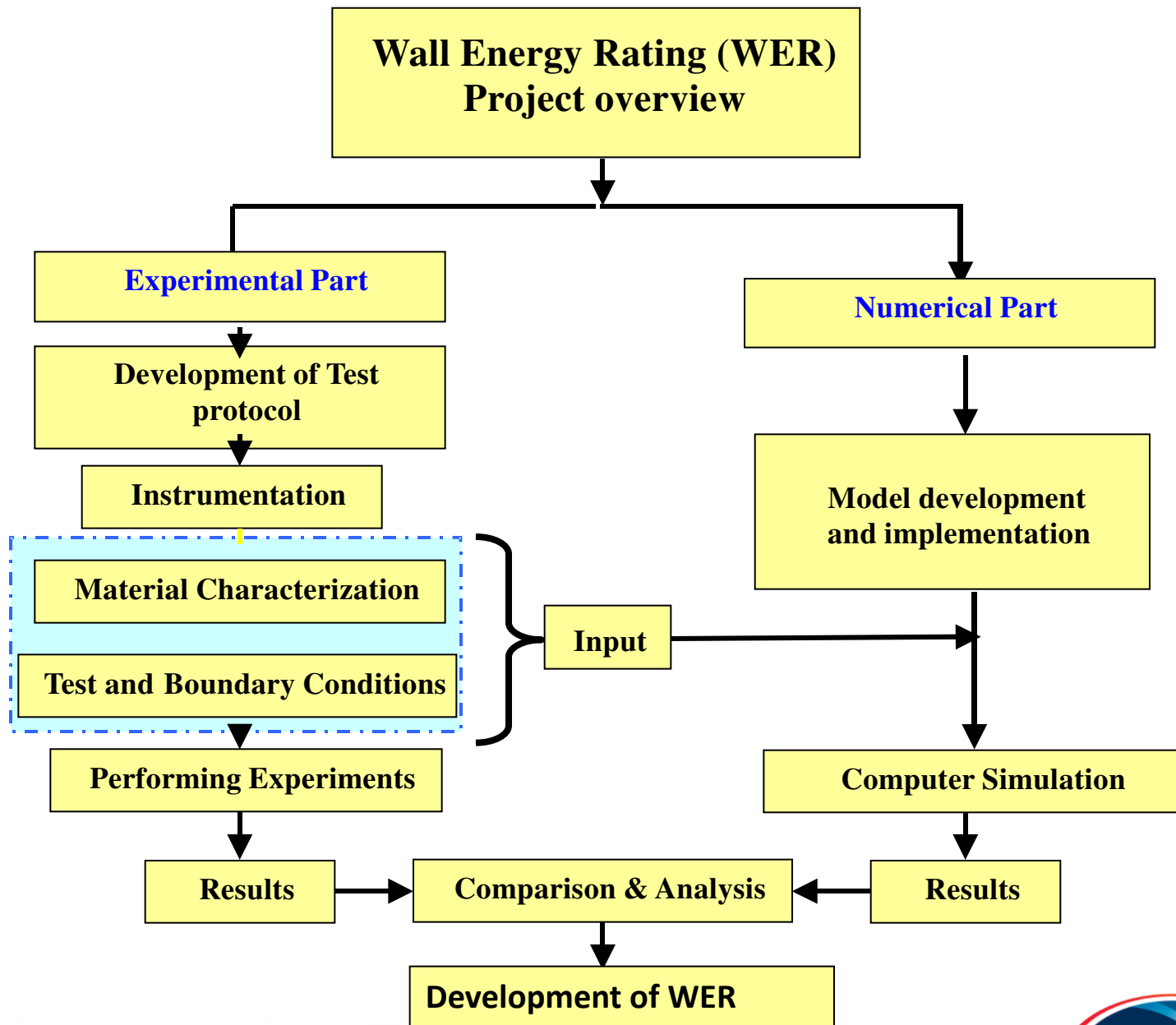
Interstitial thermocouples

SPF wall showing penetrations



Blank wall with fibrous insulation and poly-lapped air barrier





Test Sequence

R-value in GHB

ASTM C1199 and
ASTM E1423

ASTM E283

Air leakage test

GHB

Guarded Hot Box



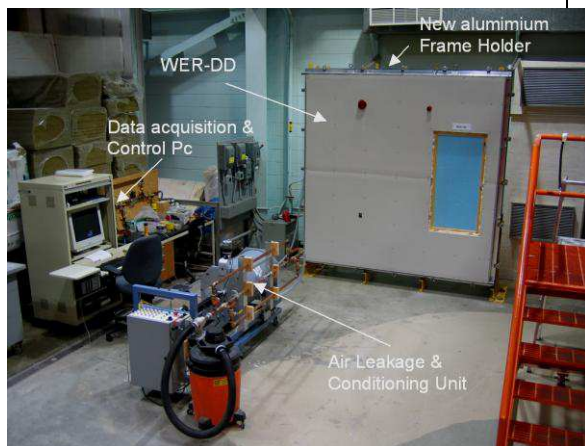
Sample Conditioning

CCMC Air Barrier
Systems Section 07272

Air leakage test

R-value in GHB

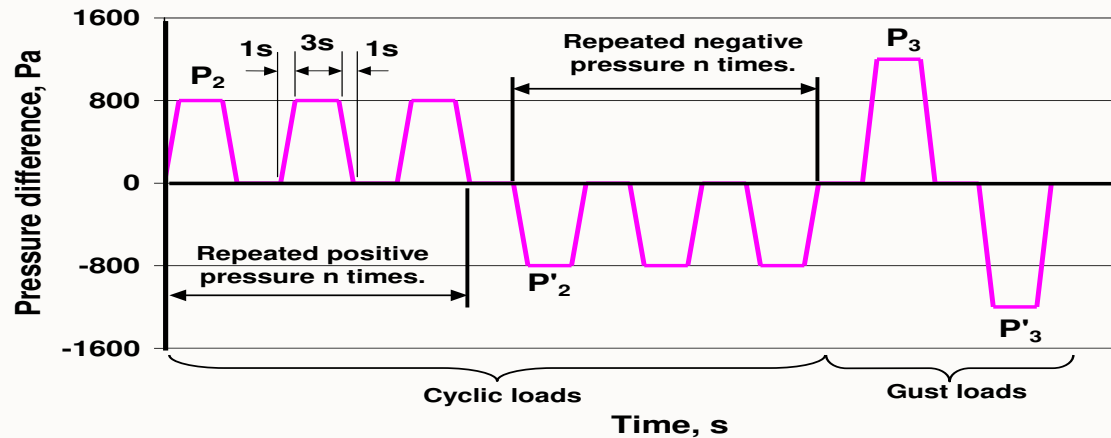
Air Leakage & Conditioning Test Apparatus



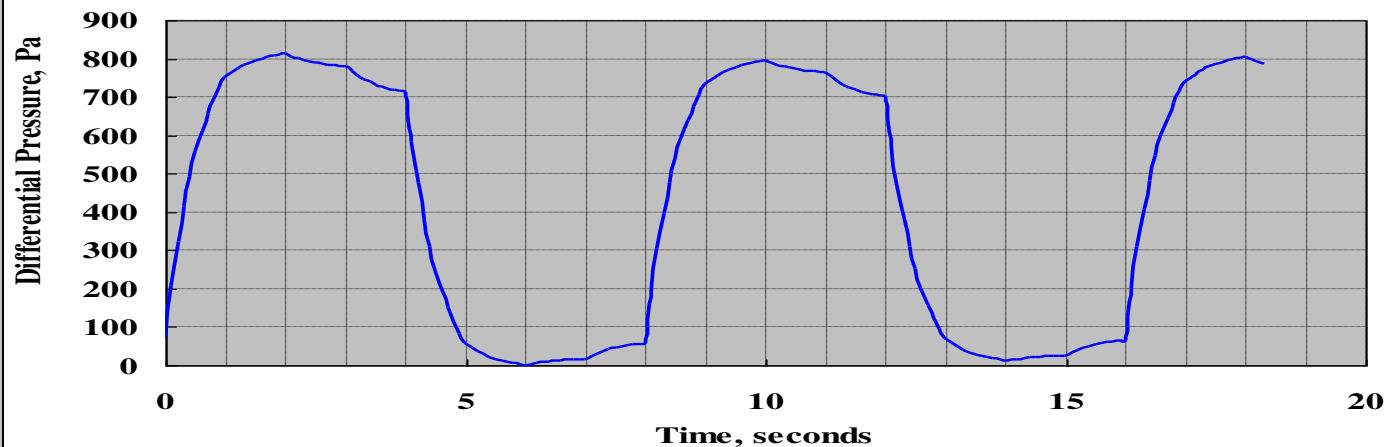
Pressure and gust wind cycles

Sample conditioning

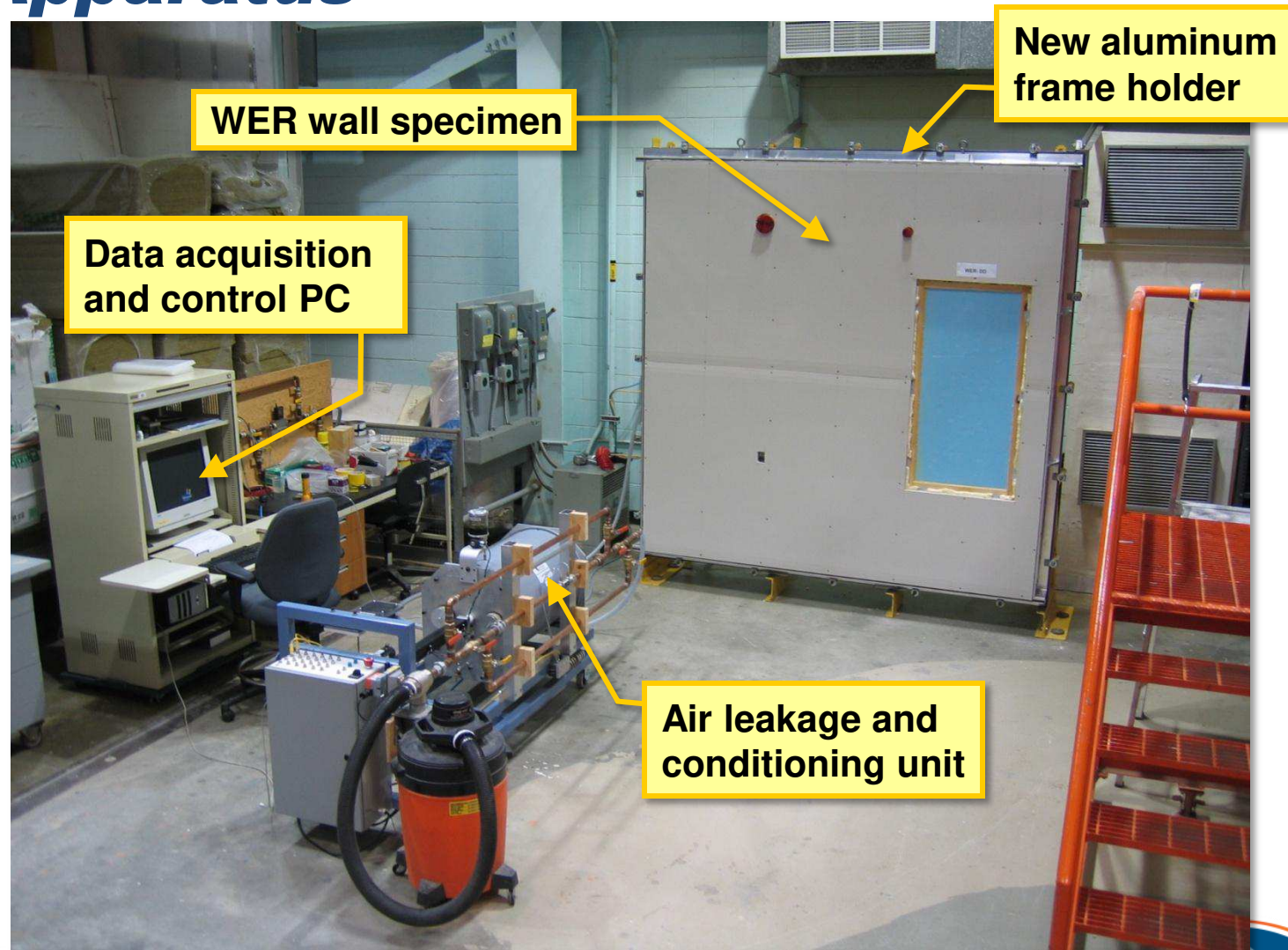
Pressure cycle for sample conditioning



Conditioning (Weathering), +800 Pa, 1000 cycles



Air Leakage and Conditioning Test Apparatus



Guarded Hot Box Apparatus



Test Procedures

- **Air leakage (ASTM E283)**
- **Wall thermal resistance (ASTM C1199 and ASTM E1423)**
- **Material characterization (ASTM C518-98) using heat flow meter**
- **Sample conditioning according to CCMC Technical Guide (Masterformat Section 07272, section 6.62, page 14)**

Results

- **Test results**
 - Air leakage
 - Thermal resistance, R-value
 - Material characterization of foam(s)
- **Simulation results**
- **Comparison of testing and simulation**
- **Development of WER**

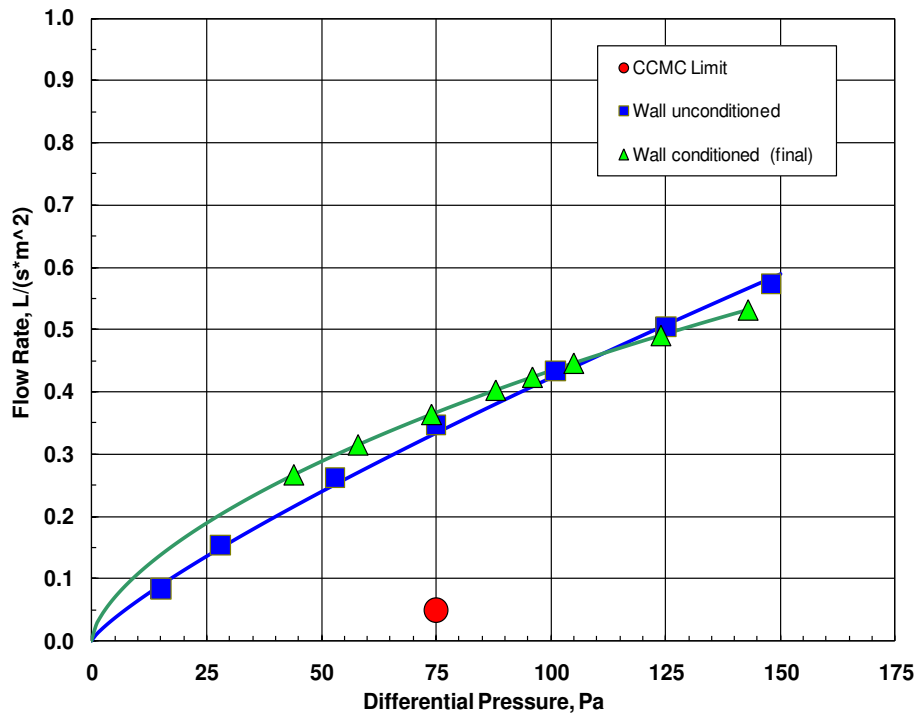


Foam characterization:

Wall Parameter	Symbol	WER-AA & BB	WER-CC & DD
Test Mean temperature	T_m (°C)	0.2	0.3
Material density	ρ (Kg/m³)	12.0	7.8
Thermal conductivity, SI units	λ (W/(m.K))	0.0352	0.0388

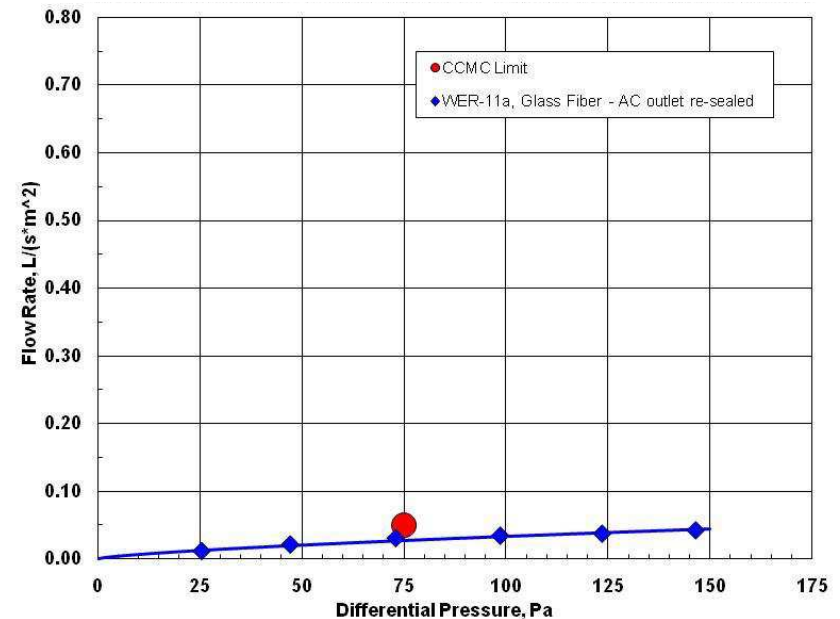
Data for fibrous insulation is obtained from published database

Air leakage test results (WER-1)



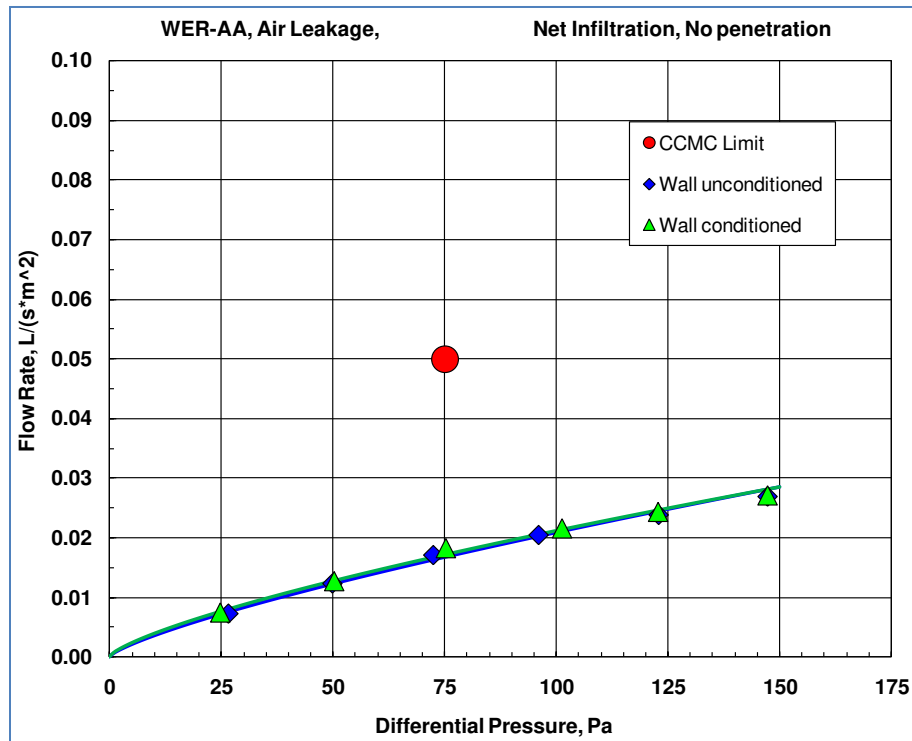
Electric outlet is NOT sealed

Electric outlet is sealed (WER-11a)

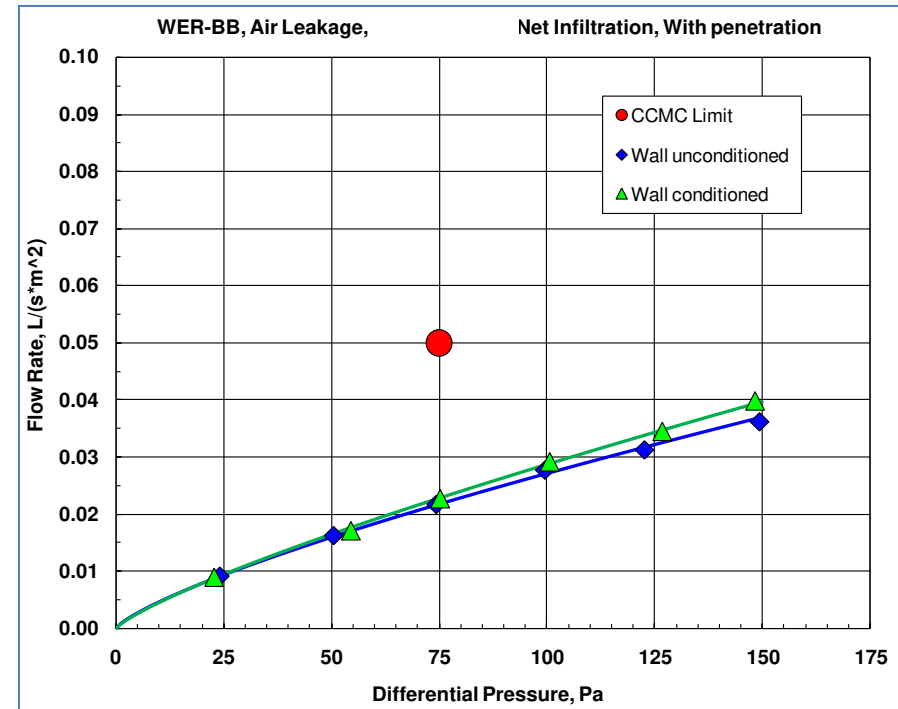


Air leakage test results: WER-AA and WER-BB

WER-AA

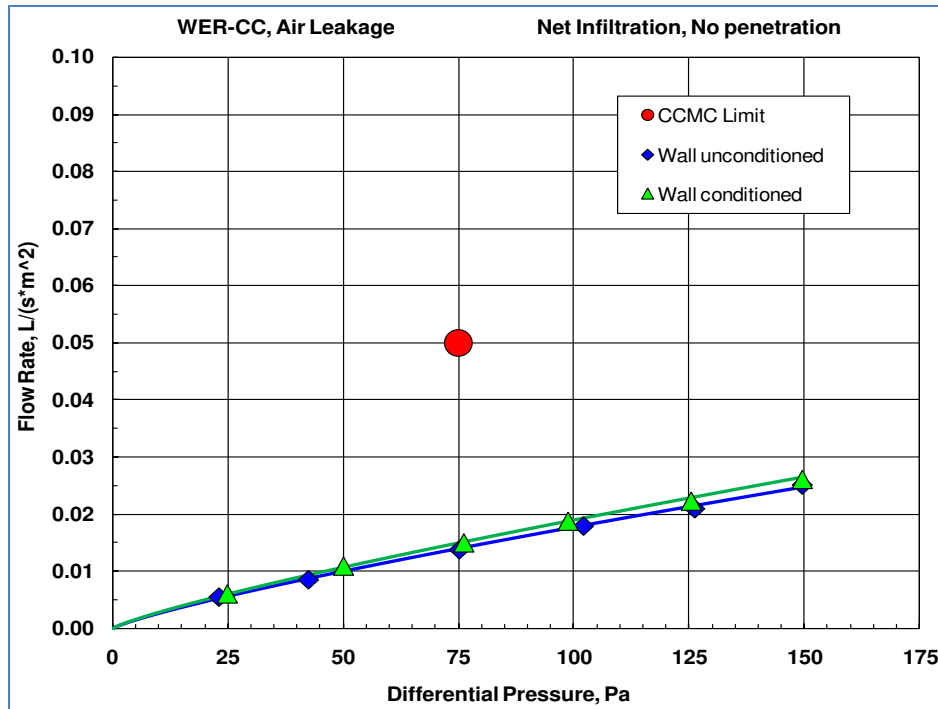


WER-BB

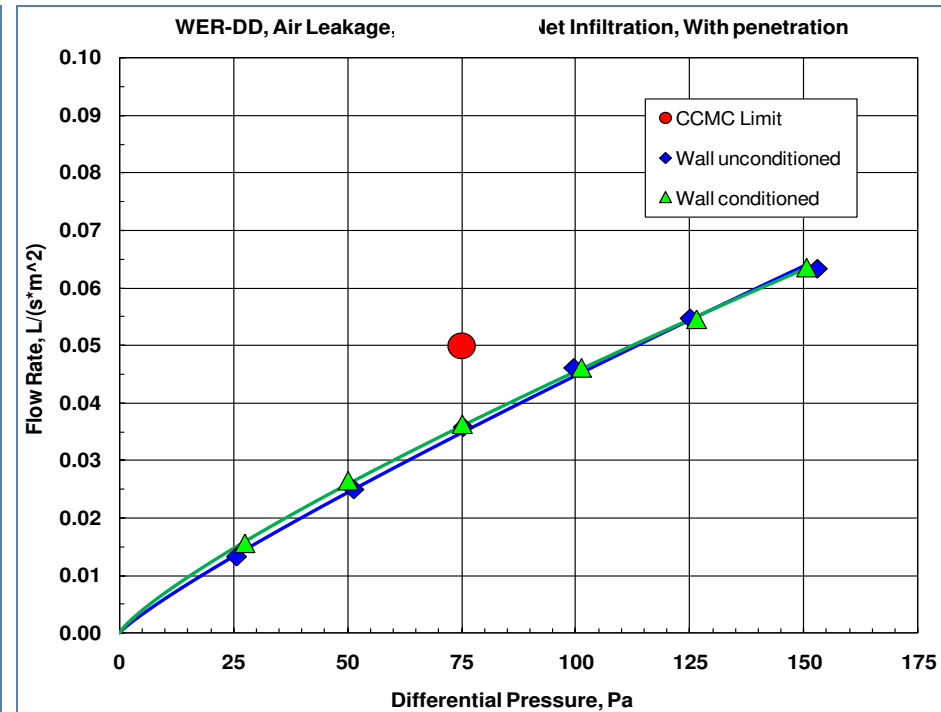


Air leakage test results: WER-CC and WER-DD

WER-CC

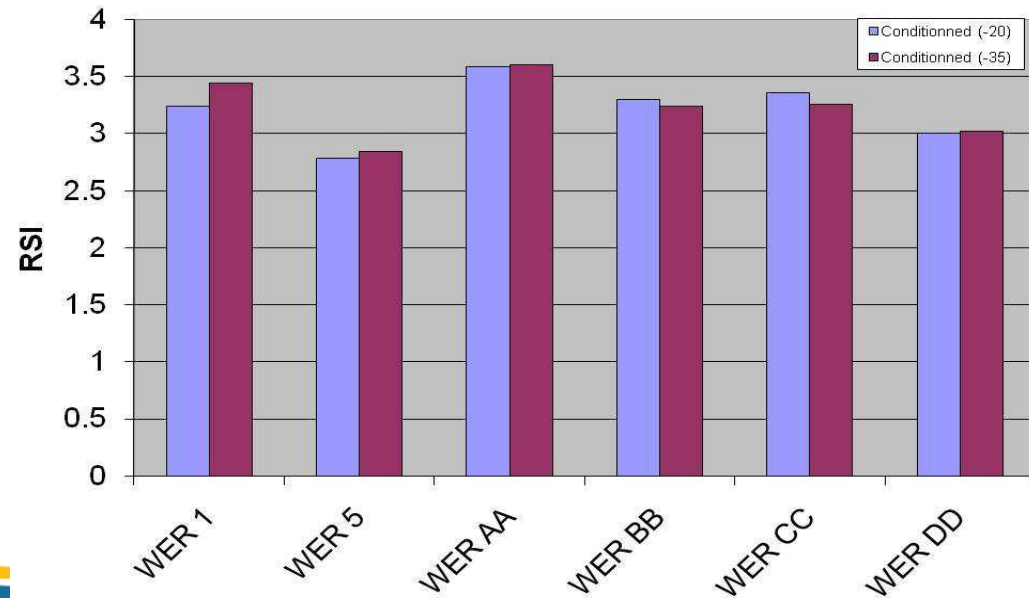


WER-DD



R-value test results

Cold temperature	-20 °C		-35 °C	
	R-value of conditioned walls, m².K/W			
Wall #	m².K/W	°F.ft².hr/BTU	m².K/W	°F.ft².hr/BTU
WER-1	3.25	18.45	3.44	19.53
WER-5	2.78	15.79	2.84	16.13
WER-AA	3.59	20.38	3.60	20.44
WER-BB	3.30	18.74	3.24	18.39
WER-CC	3.36	19.07	3.26	18.51
WER-DD	3.00	17.03	3.02	17.14



Computer Modelling

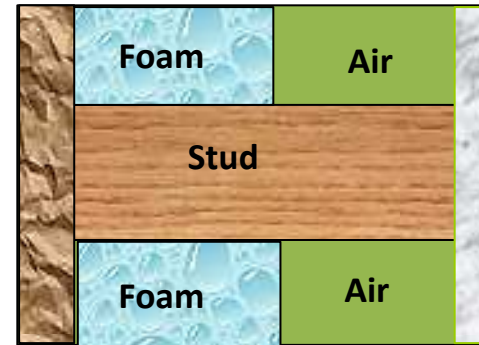
- **Use hyglIRC-C to predict the R-values for the all walls with no air leakage and compare its prediction with measured results**
- **Use hyglIRC-C to predict the R-values at different leakage rates for all walls**
- **Provide a simple correlation to be used for determining the R-values at different leakage rates**



Benchmarking of the Two Models

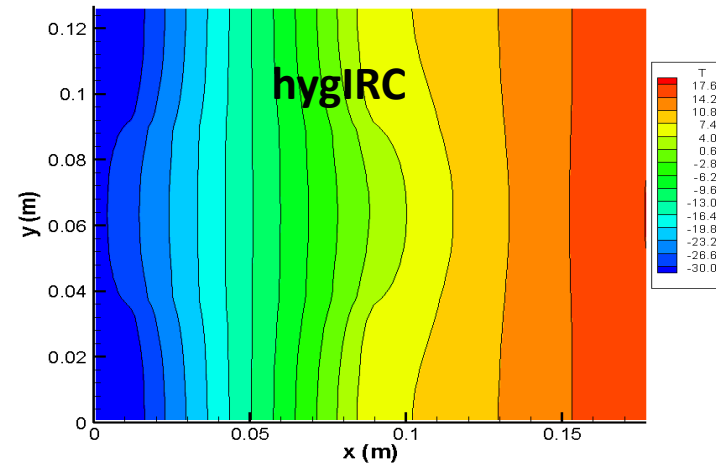
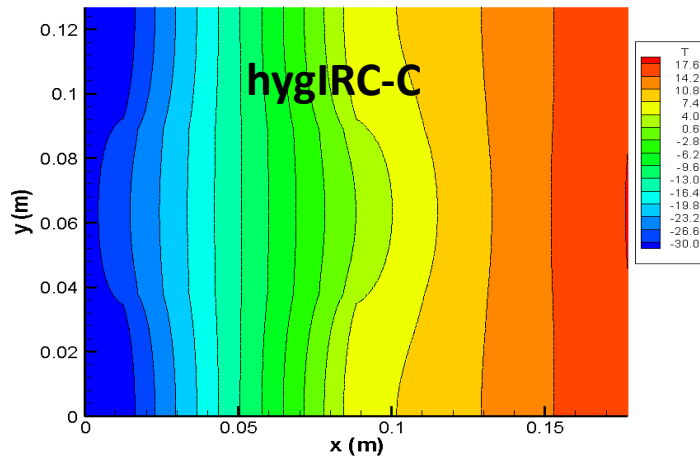
hygIRC 2-D model
hygIRC-C 3-D model

OSB



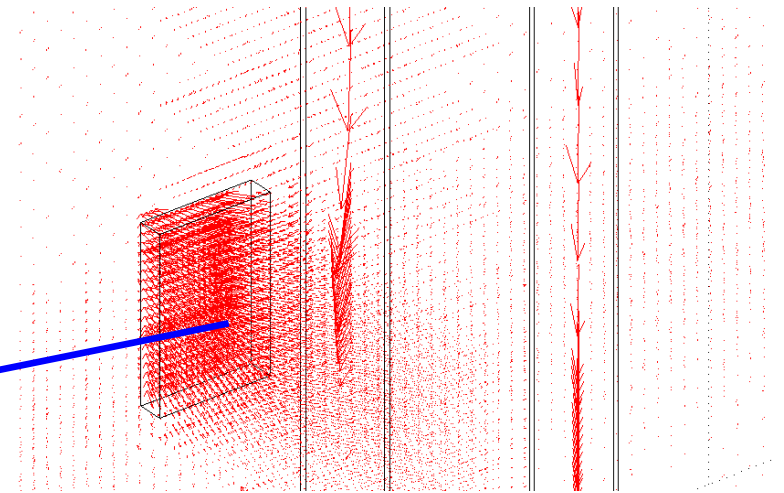
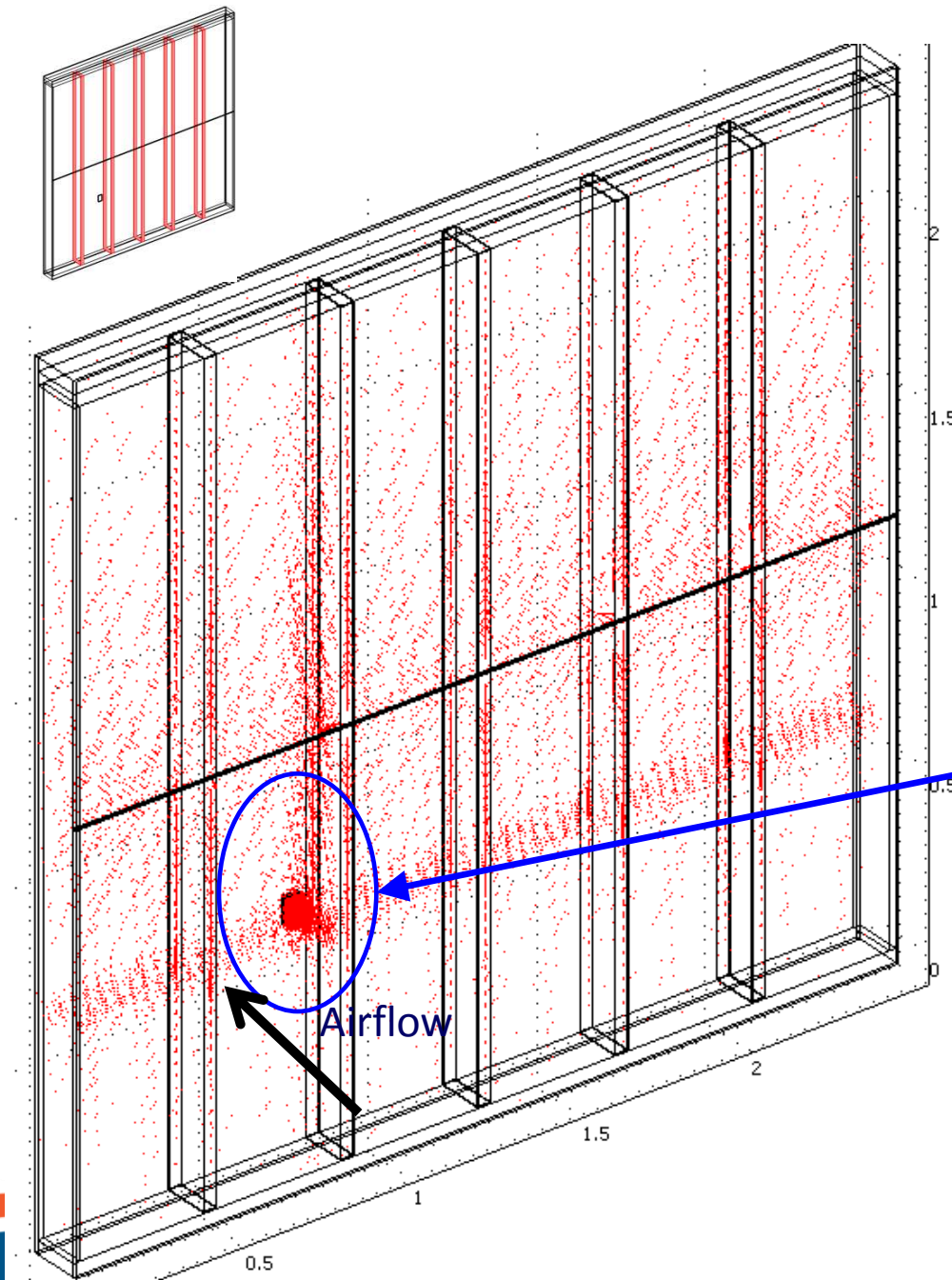
Drywall

Temperature Profiles



Sample of 3D Results (cont'd)

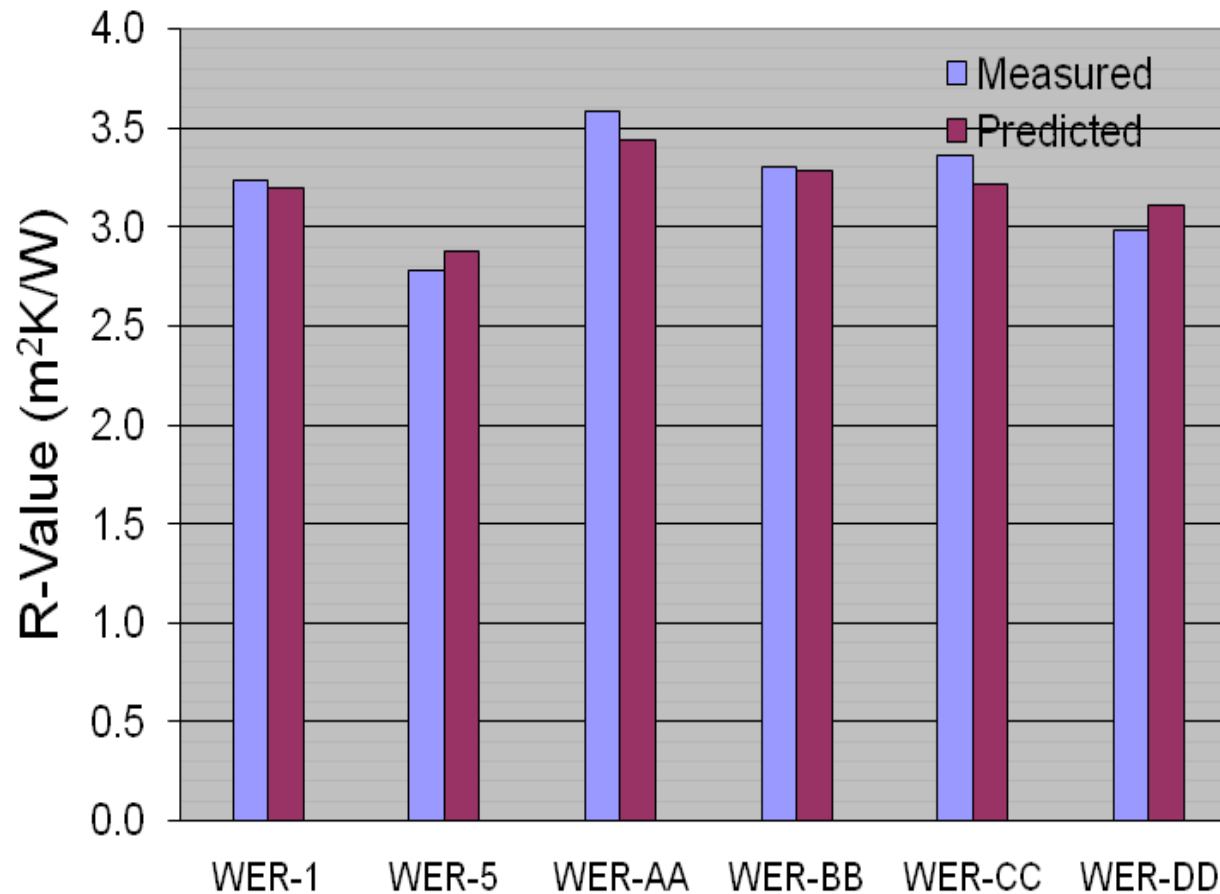
WER-1, $\Delta P = 75$ Pa



Air Velocity Field



Comparison between lab test and simulation results (R-value)



Introduction of R-value Ratio β

$$\beta = \frac{R_L \text{ (R-value with air leakage)}}{R_o \text{ (R-value without air leakage)}}$$

**This factor shows the impact of
air leakage on the wall R-value**

What is Wall Energy Rating (WER)?

- **A tool for energy rating of wall assemblies that addresses the building physics and accounts for:**
 - **Heat loss due to thermal conduction through the system**
 - **Heat loss due to air leakage through the system**
 - **Interaction between the two modes of heat loss. Provides a means to assess the overall performance of the system**

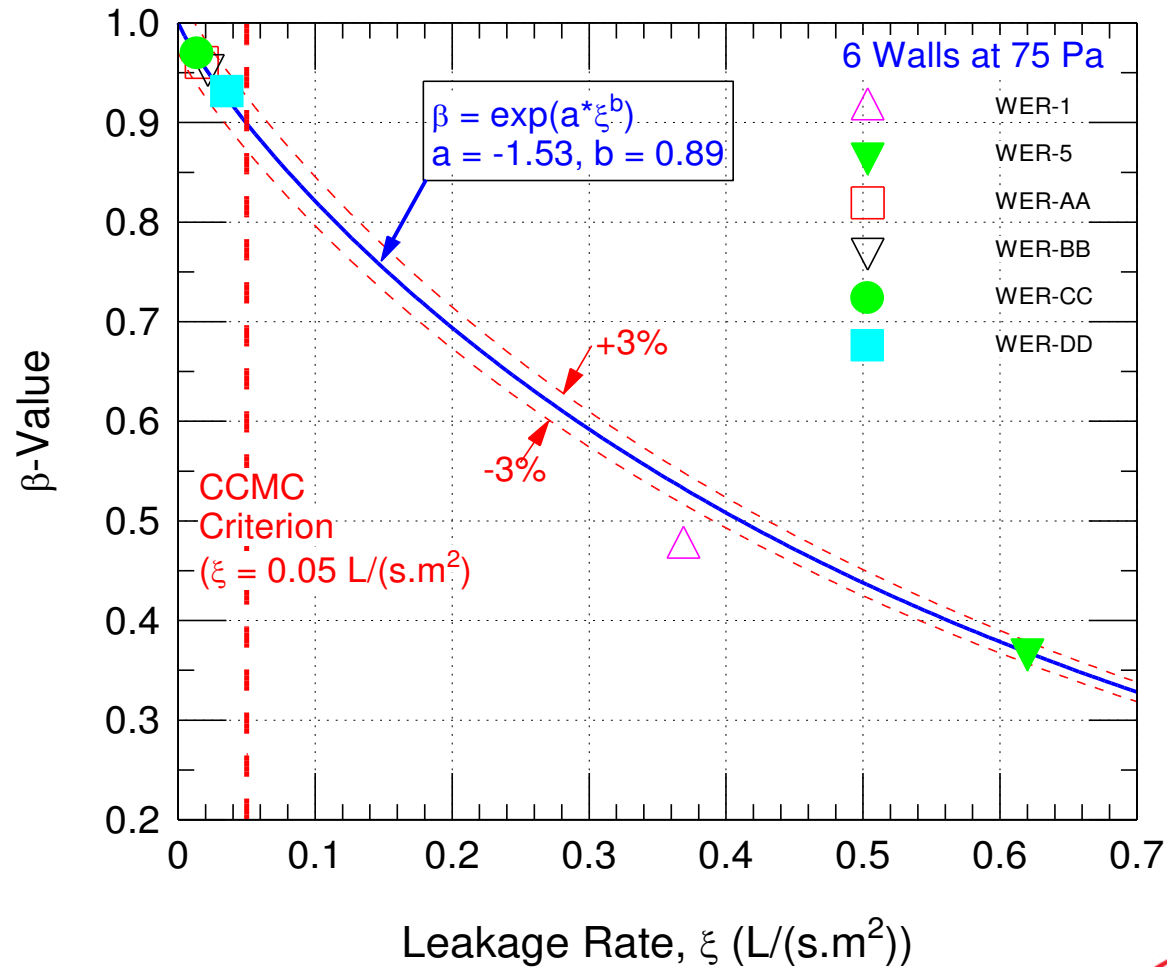


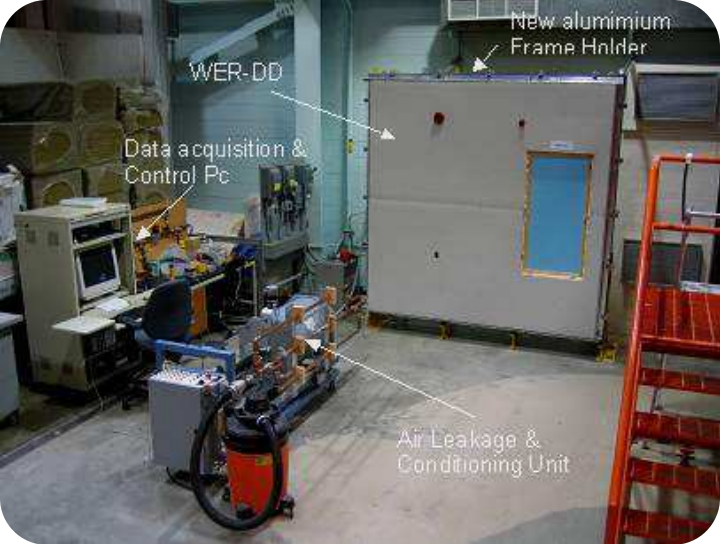
Determination of WER

- **Need**
 - R-value WITHOUT air leakage (GHB), $\text{m}^2\cdot\text{K}/\text{W}$
 - Air leakage rate, ξ , at $\Delta P = 75 \text{ Pa}$, $\text{l}/(\text{s}\cdot\text{m}^2)$
- **Determine wall “apparent” R-value with air leakage at different ΔP values**
- **Determine the apparent R-value ratio, β**
- **Calculate WER**

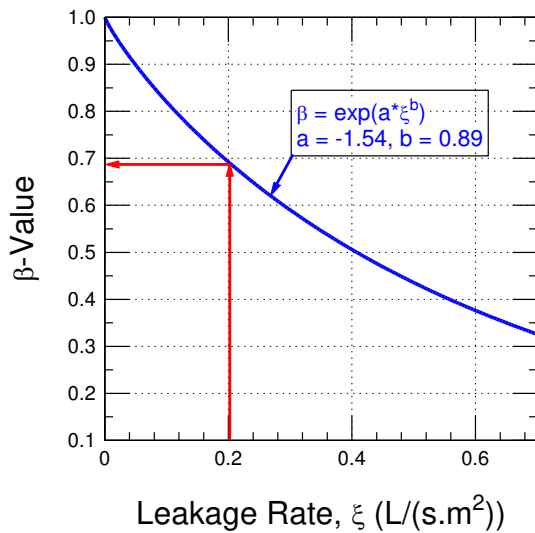


Correlation of β with air leakage rate (6 walls):





LR @ 75 Pa, ξ (L/(s.m²))



Calculation Procedure of Apparent RSI

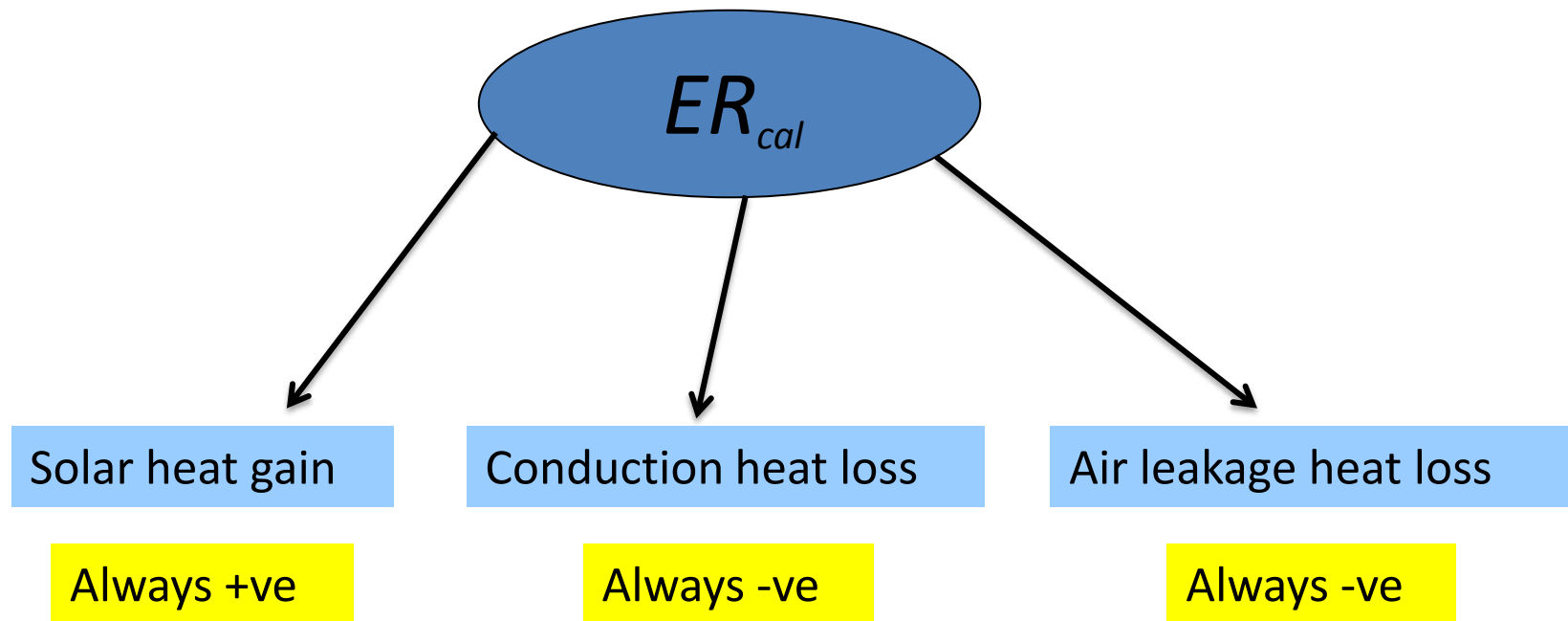
$$\beta = \exp(a \xi^b)$$

$$RSI_L = \beta RSI_0$$

$$WER = 50 - C \left(\frac{\Delta T}{RSI_L} \right)$$

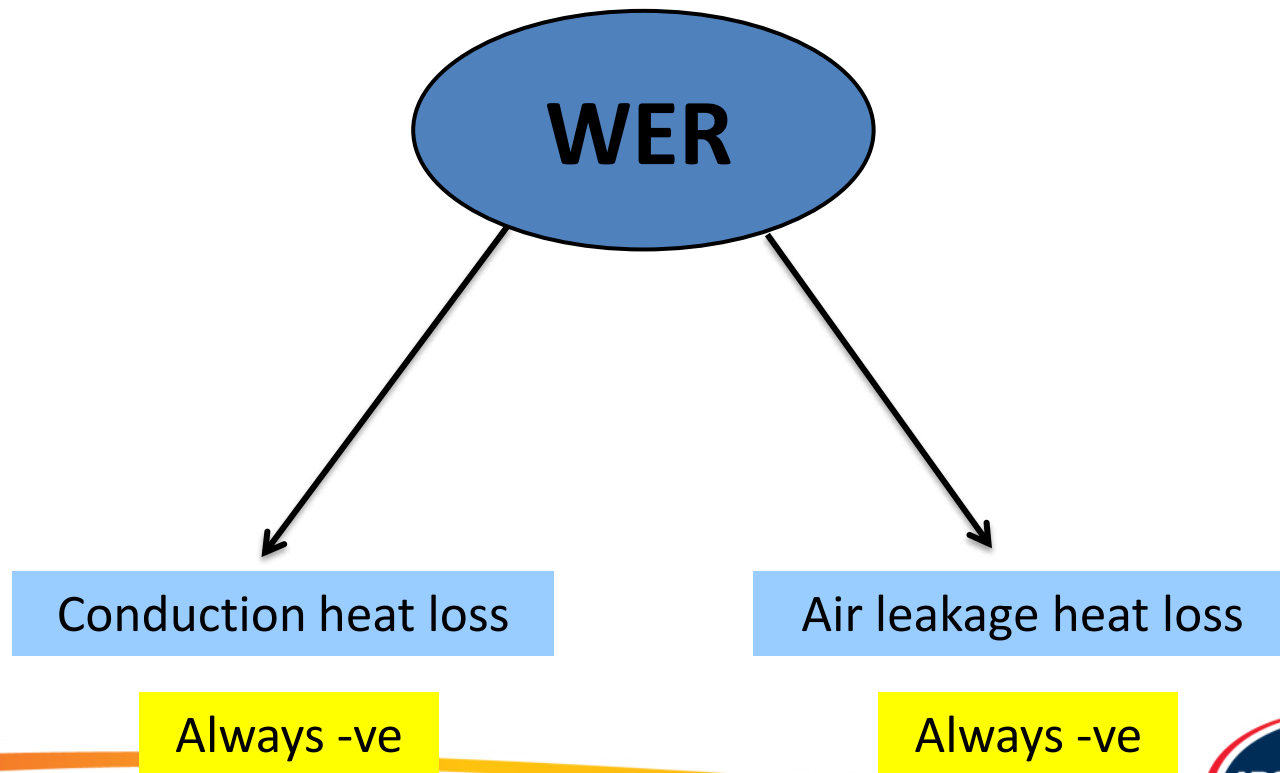
CSA A-440.2 Standard Approach

ER_{cal} Window Energy Rating



WER: A tool for wall energy rating

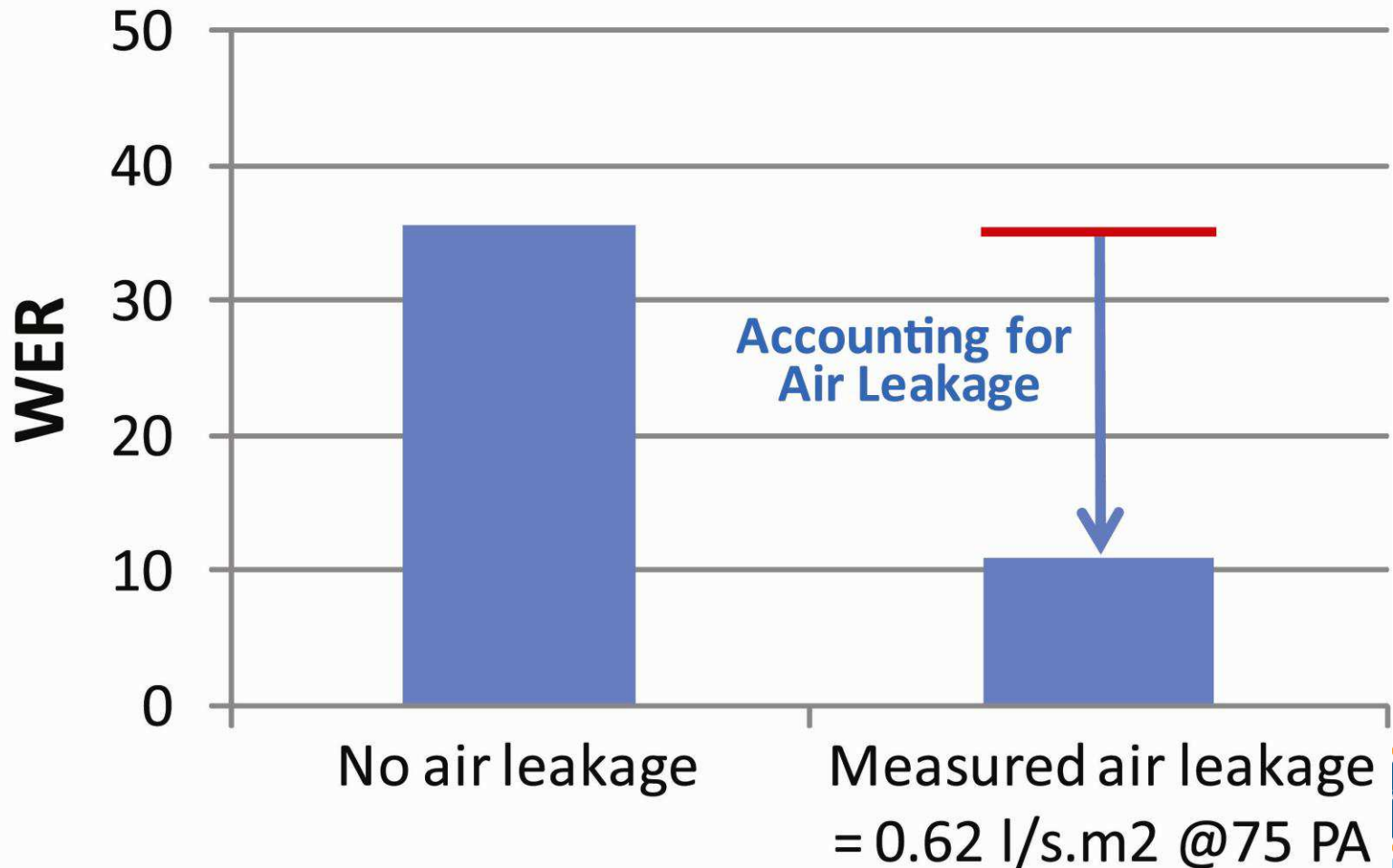
WER Wall Energy Rating



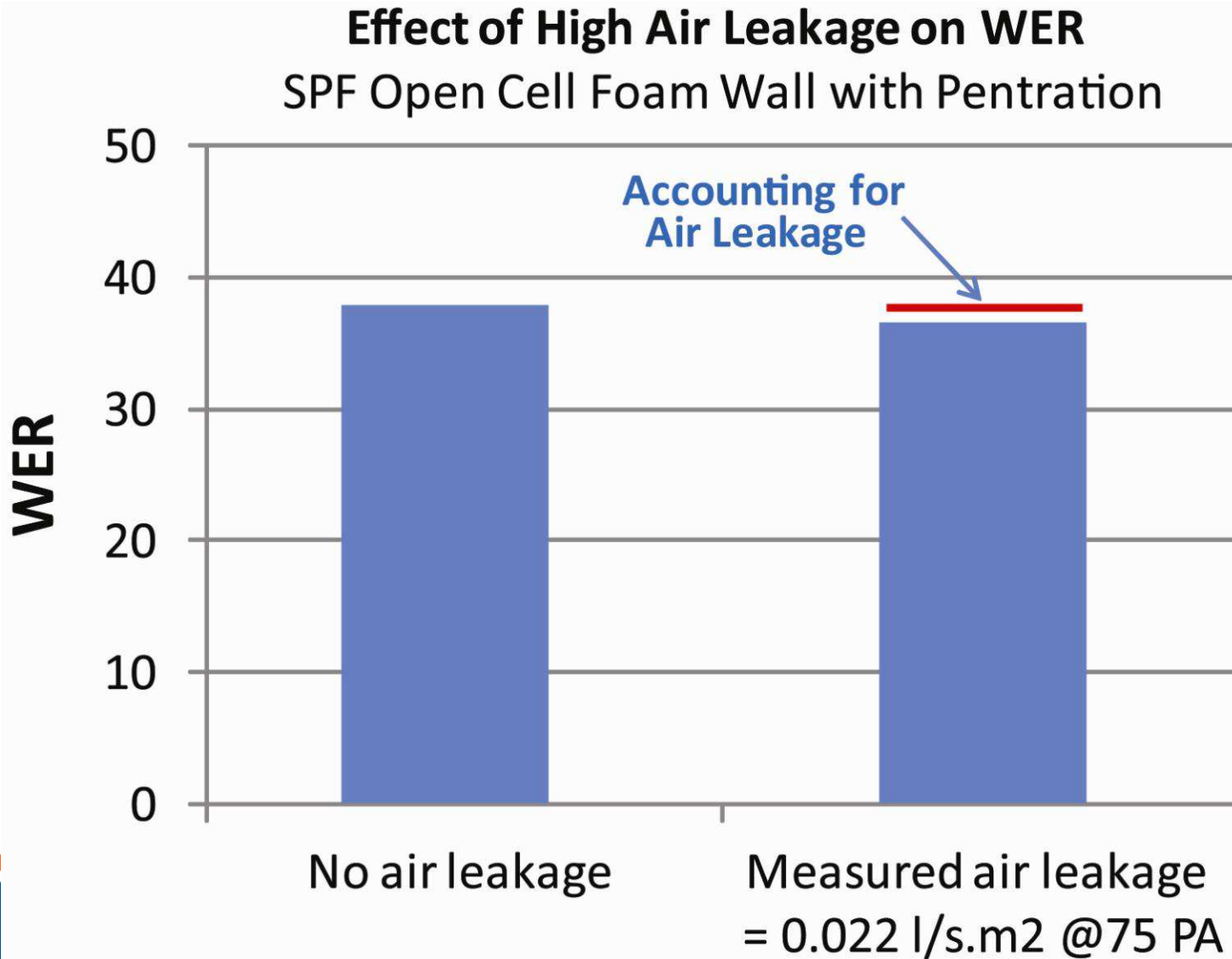
Effect of Air Leakage on WER – Case I

Effect of High Air Leakage on WER

Conventional Wall with Penetrations – Lapped Poly



Effect of Air Leakage on WER – Case II

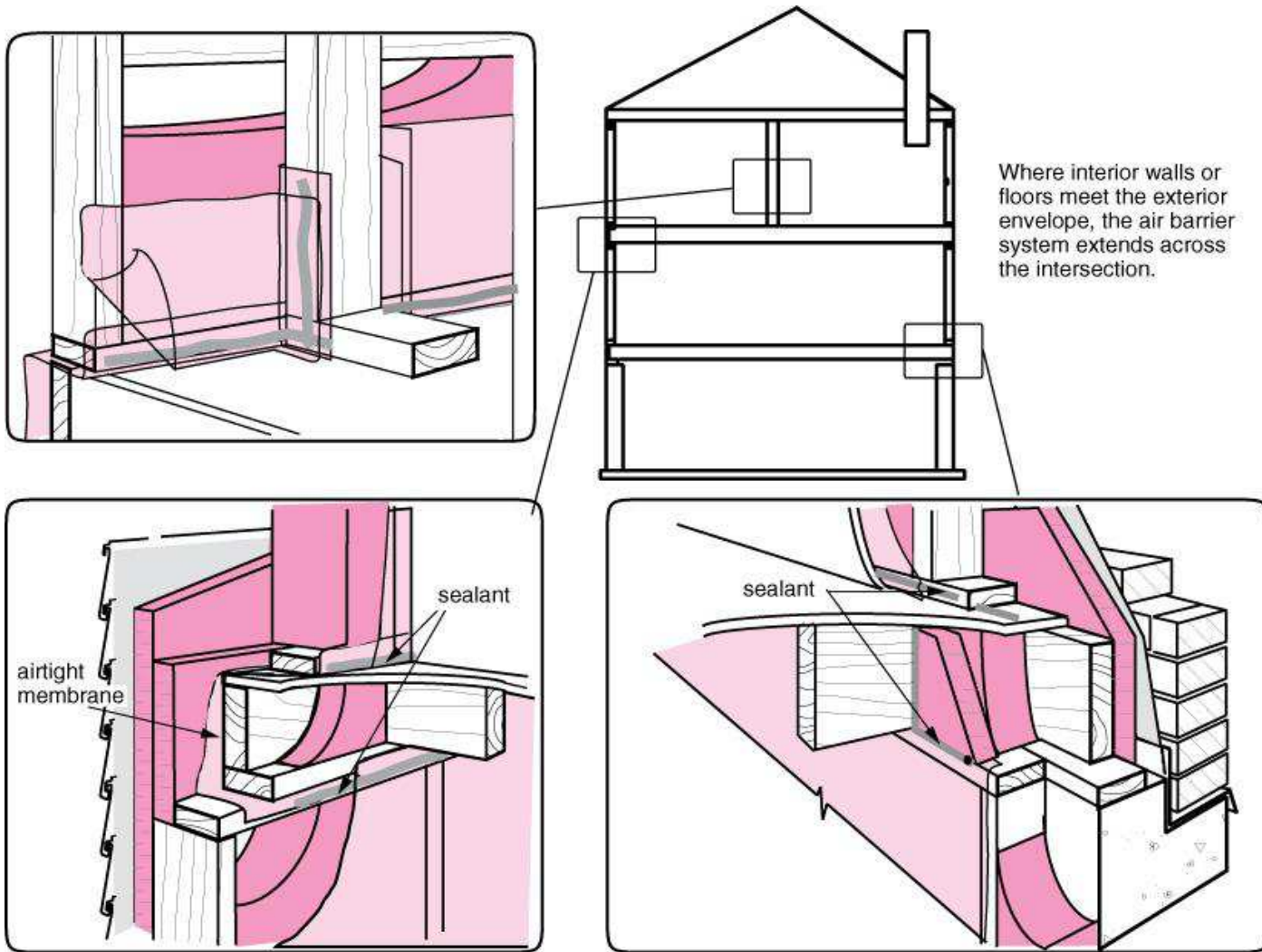


What is next?

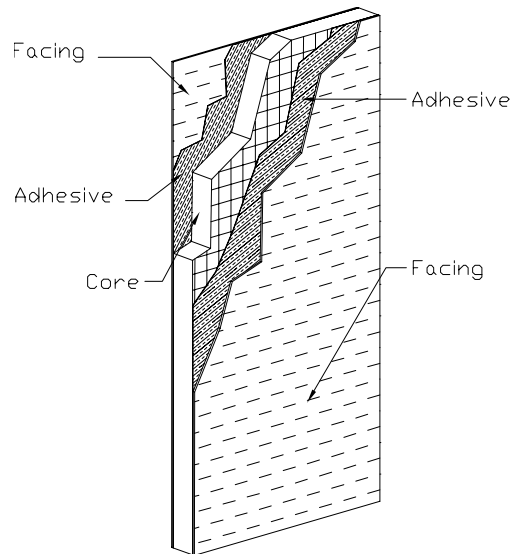
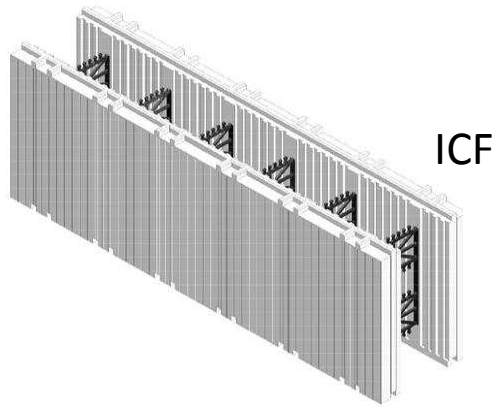
- **Develop energy rating tools for other building components**
- **Combine all the tools in a master protocol to determine the energy rating of the whole building envelope**
- **This will be a step towards energy labeling of buildings**
- **A new consortium will be meeting soon to discuss this new initiative**



Issues for discussion in the future:



Insulated Concrete Forms (ICF's) and Structural Insulated Panels (SIP's):



SIP

Closing Remarks

- **A new procedure is now available to determine the energy performance of insulated wall assembly, with and without penetration**
- **The procedure requires a minimum laboratory testing**
- **Computer simulation proven to be very useful and accurate in predicting the R-value of the wall, with and without air leakage**



Closing Remarks (cont'd)

- **It is necessary to include additional materials and construction practices to generate comprehensive correlation**
- **Efforts are underway to invite others to join this project**
- **Next step is to develop national (and international) standards for that purpose**



Acknowledgement

- **We would like to acknowledge the contribution of the project team and the partners in this project:**
 - **BASF**
 - **CUFCA**
 - **Demilec**
 - **Honeywell**



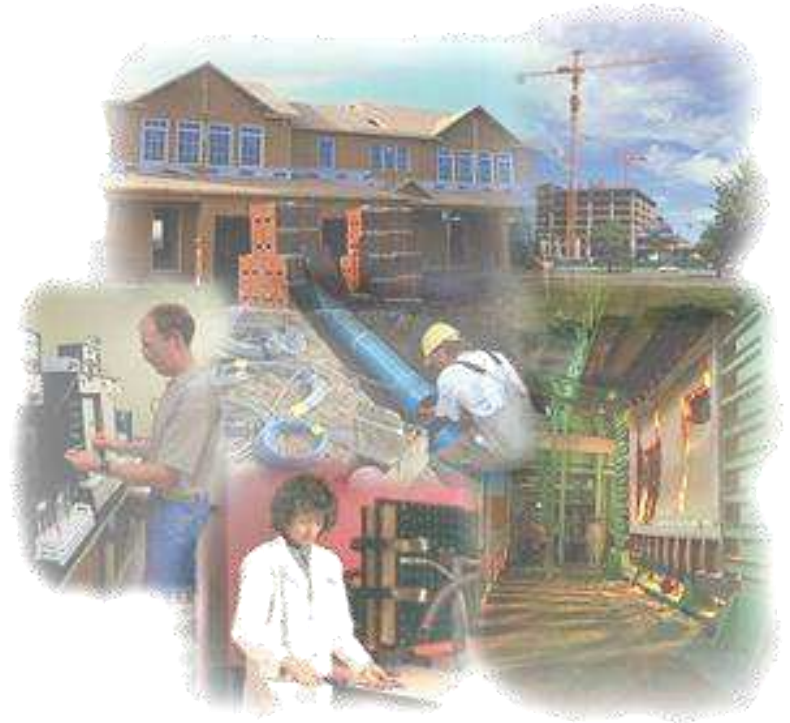


Discussion

Thank you

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