Energy rating of insulated wall assemblies

Elmahdy, A. H.; Maref, W.; Saber, H. H.; Swinton, M. C.; Glazer, R.; Nicholls, M.

Publisher's version / Version de l'éditeur:

Building Science Insight 2009/10: Energy Efficiency in Buildings: New Tools and Technologies [Proceedings], 2009-01-01

NRC-CNRC

Institute for Research in Construction

Energy Rating of Insulated Wall Assemblies

Hakim Elmahdy

Project team: Wahid Maref, Hamed Saber, Mike Swinton, Rock Glazer and Mike Nicholls

National Research Council Canada

Conseil national de recherches Canada

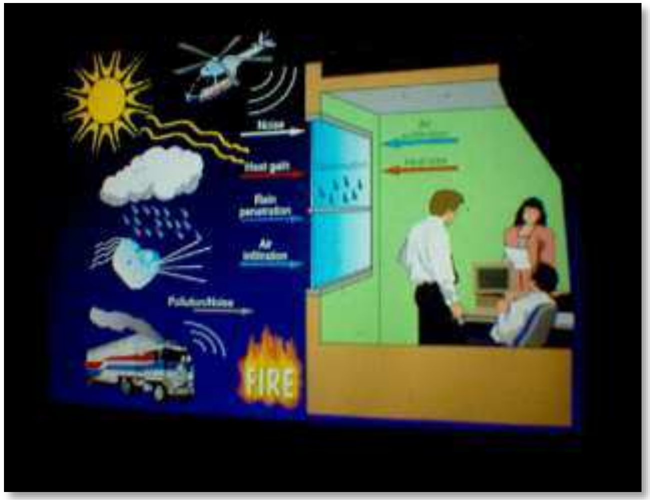
Canada

Outline

- Background
- Window Energy Rating (ER)
- Energy Star labelling
- Proposed energy rating of wall assemblies
- Results of recent research project
- Closing remarks

Background

- Function of building envelope:
  - Control of conduction heat loss (or gain)
  - Control of air penetration
  - Control of water penetration
  - Control of sound transmission
  - Control of solar heat
  - Others ….



Functions and Regulations

- Some of the 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

Code Requirements

- These Codes may call up separate requirements on components or systems
  - Material air tightness (as related to NBC Part 5)
  - System or assembly air tightness (CCMC Air Barrier Guide 07272)
  - Building air tightness (e.g., R-2000)

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 systems of the Building Codes and related Standards

Causes of Failure

- How does the thermal performance of a system vary with the existence of air leakage?
- Air leakage through the system has a negative impact on the overall performance and durability of the assemblies

- Current research work confirms this claim as will be seen later

System Characteristics

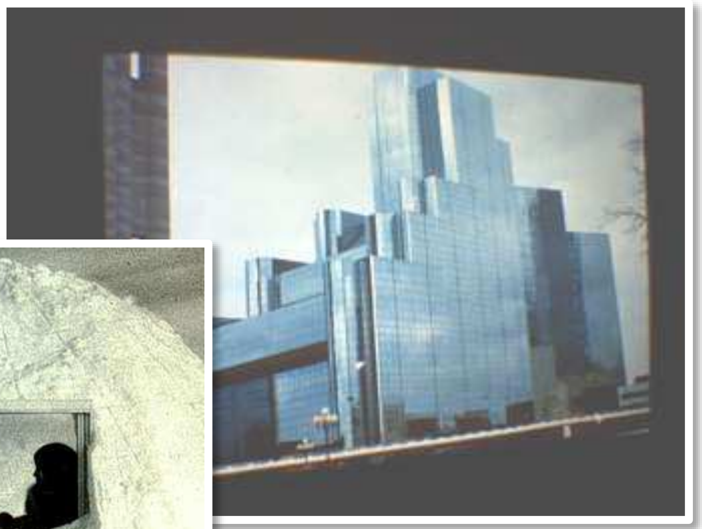
- The material requirements may be sufficient to characterize the material, but may not be enough when it is incorporated in a system
- Meeting the requirements in isolation may lead to improper system performance (e.g., a perfect glazing system in a badly designed sash or frame)

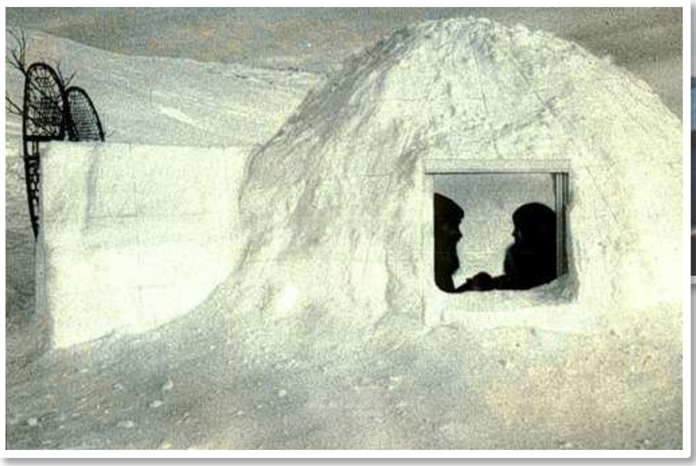
Systems Performing Multiple Functions

- Some products and systems address multiple functions
  - Spray Polyurethane Foam (SPF)
  - Vacuum Insulation Panels (VIP)
  - Insulated Concrete Forms (ICF)
  - Structural Insulation Panels (SIP)
  - High performance roofing systems

Efficient Use of Energy in Buildings

- Requires knowing the system performance
- Requires tools to assess these performance for both large and small buildings





What do we need?

- Energy rating systems (e.g., for windows and walls) to account for the overall performance (specifically thermal and air leakage)
- This will provide a yard stick to measure the overall performance of the system
- It will encourage system designers to promote superior energy efficient systems including high quality joints and around components interface

The Status-quo

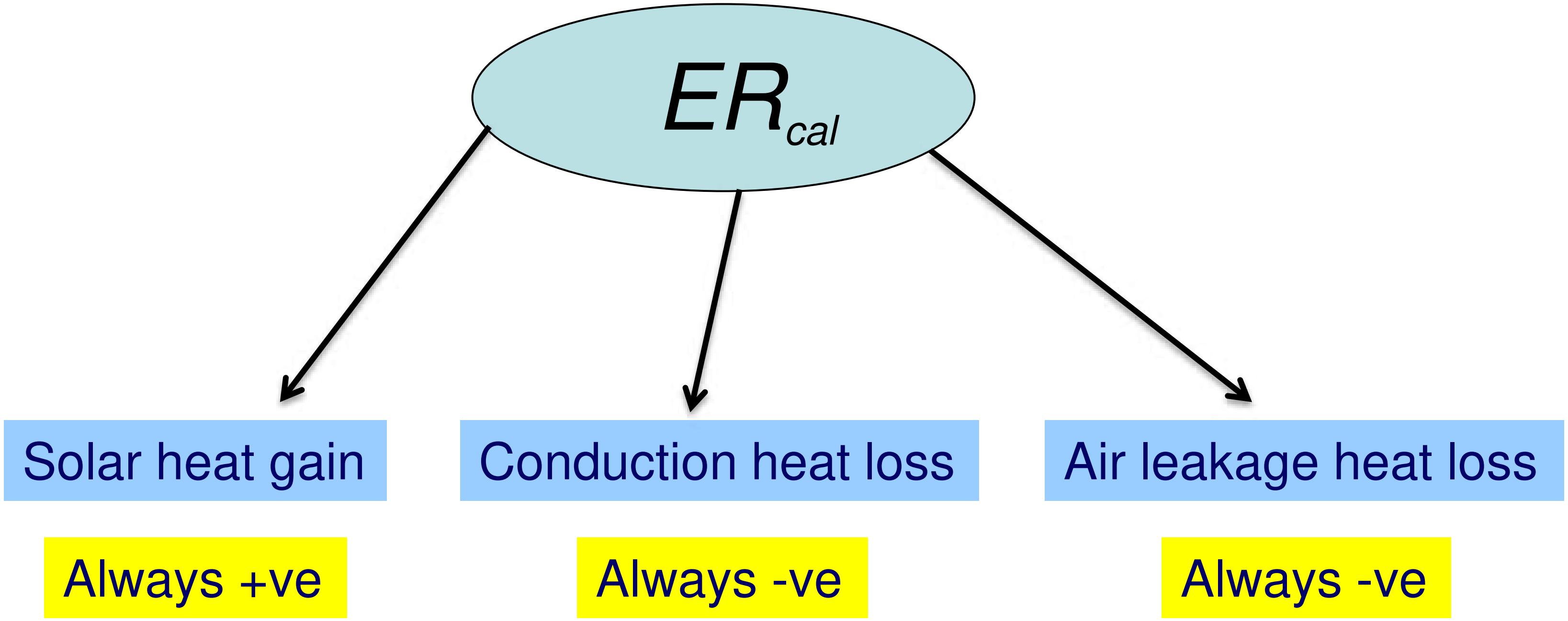
- There exist a few energy rating schemes to determine the energy performance of building components (e.g., CSA A-440.2 for windows ER, and CCMC Air Barrier Guide)
- No similar standard for wall assemblies (opaque or with penetrations)
- Foam insulation industry and NRC-IRC joint project on wall energy rating (WER)

Brief Review of CSA A-440.2 Standard

- Setting the stage for the rest of the presentation
- The purpose is to determine the average energy rating (ER) of window assembly that includes:
  - Heat gain due to solar energy
  - Heat loss due to air leakage
  - Heat loss due to conduction

CSA A-440.2 Standard Approach

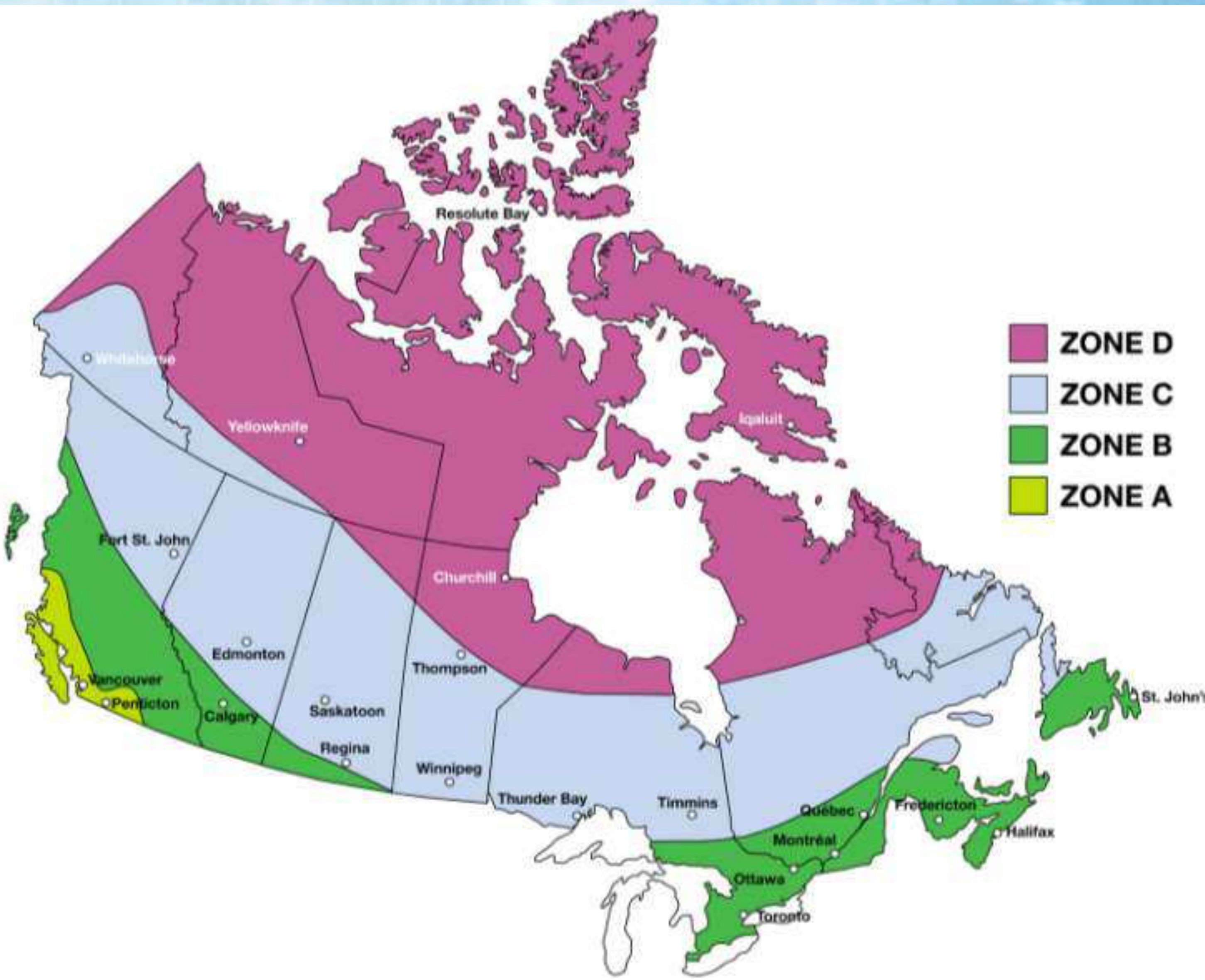
- ER_{cal} Window Energy Rating



ENERGY STAR®

- Voluntary arrangement between NRCan's Office of Energy Efficiency and organizations that build, manufacture, sell or promote products or new homes
- ENERGY STAR® symbol for consumers
- Over 90,000 labelled window products

ENERGY STAR® Zones



Window ENERGY STAR® Requirements

Zone	Heating degree days, below 18 C	Maximum U-factor* W/(m^{2}K)	Minimum Energy Rating (*ER*) Value*
A	<=3500 HDDs	2.0	17
B	>3500 to <=5500 HDDs	1.8	21
C	>5500 to <=8000 HDDs	1.6	25
D	>8000 HDDs	1.4	29

- *Windows can qualify by either their U-factor or their ER value*
- ** Conventional double pane clear glass air-filled window, only used in modeling*

What is Wall Energy Rating (WER)?

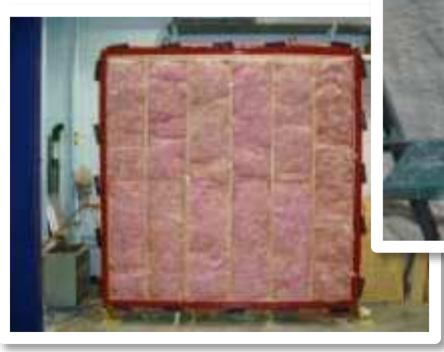
- A tool for energy rating of wall assemblies that addresses the building physics and accounts for:
  - Heat loss due to thermal conduction through the system
  - Heat loss due to air leakage through the system
  - Interaction between the two modes of heat loss. Provides a means to assess the overall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

WER Project Objective

- To determine Wall Energy Rating (WER) of walls constructed, according to field practices, with spray polyurethane foam insulation (with different blowing agent), by combining heat losses due to conduction and air leakage
- Walls with poly-wrapped and sealed insulation were also evaluated as reference walls

Overview of the WER Project

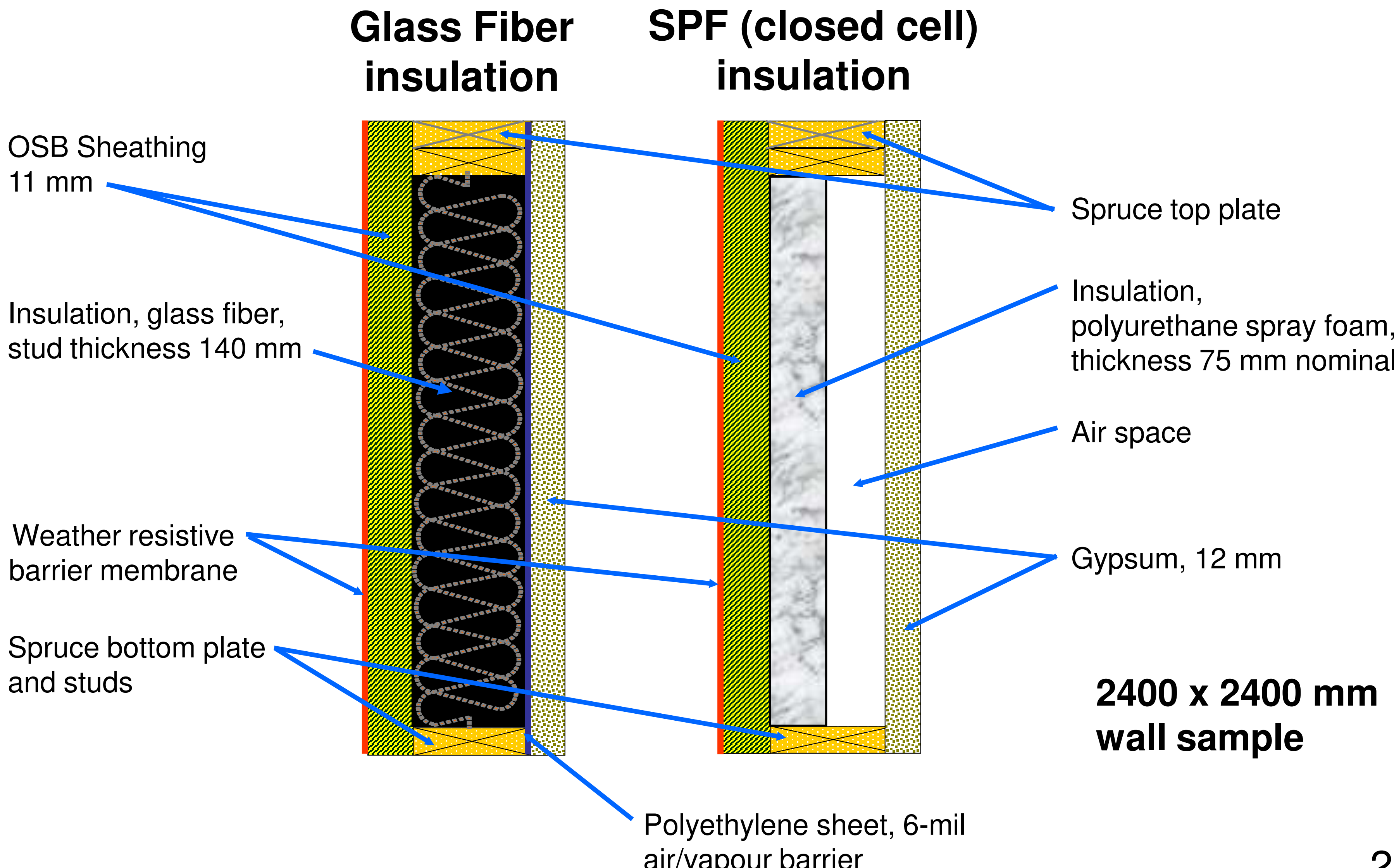
- Wall samples built to common construction practices
- Testing for thermal resistance and air leakage
- Material characterization
- Computer simulation
- Final results



Wall Samples

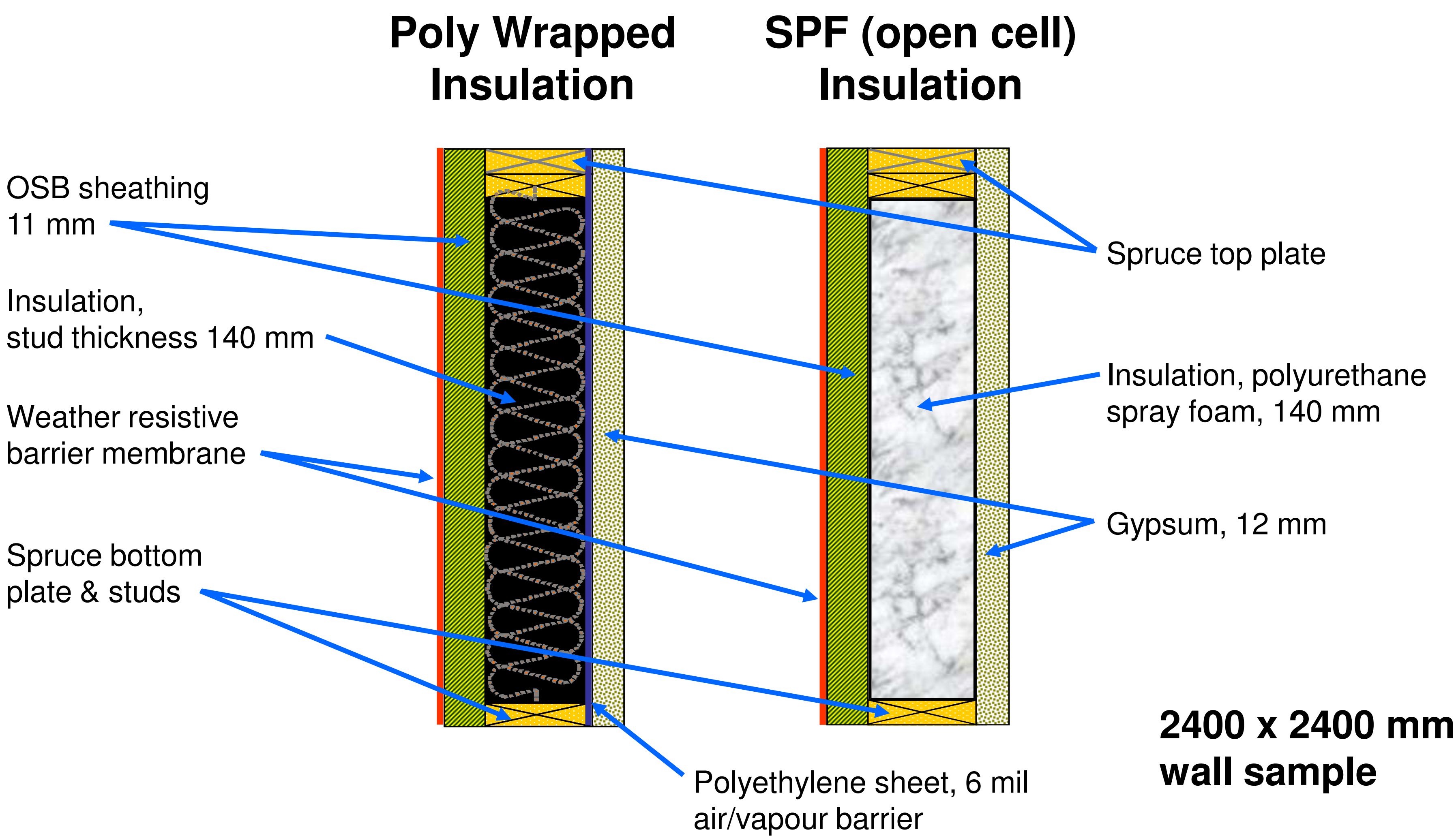
- Six 2” x 6” spruce stud walls, 16” spacing (nominal)
- Insulation materials
  - Poly-wrapped and sealed glass fibre insulation
  - Spray polyurethane foam, HCFC-141b blowing agent
  - Spray polyurethane foam, HFC-245fa blowing agent
  - All foam products (medium and light density) meet ULC S705.1-2001 Standard

Cross-section of typical wall samples



2400 x 2400 mm wall sample

Cross-section of typical wall samples



2400 x 2400 mm wall sample

Wall Description Stage II
Light density (open cell) foam

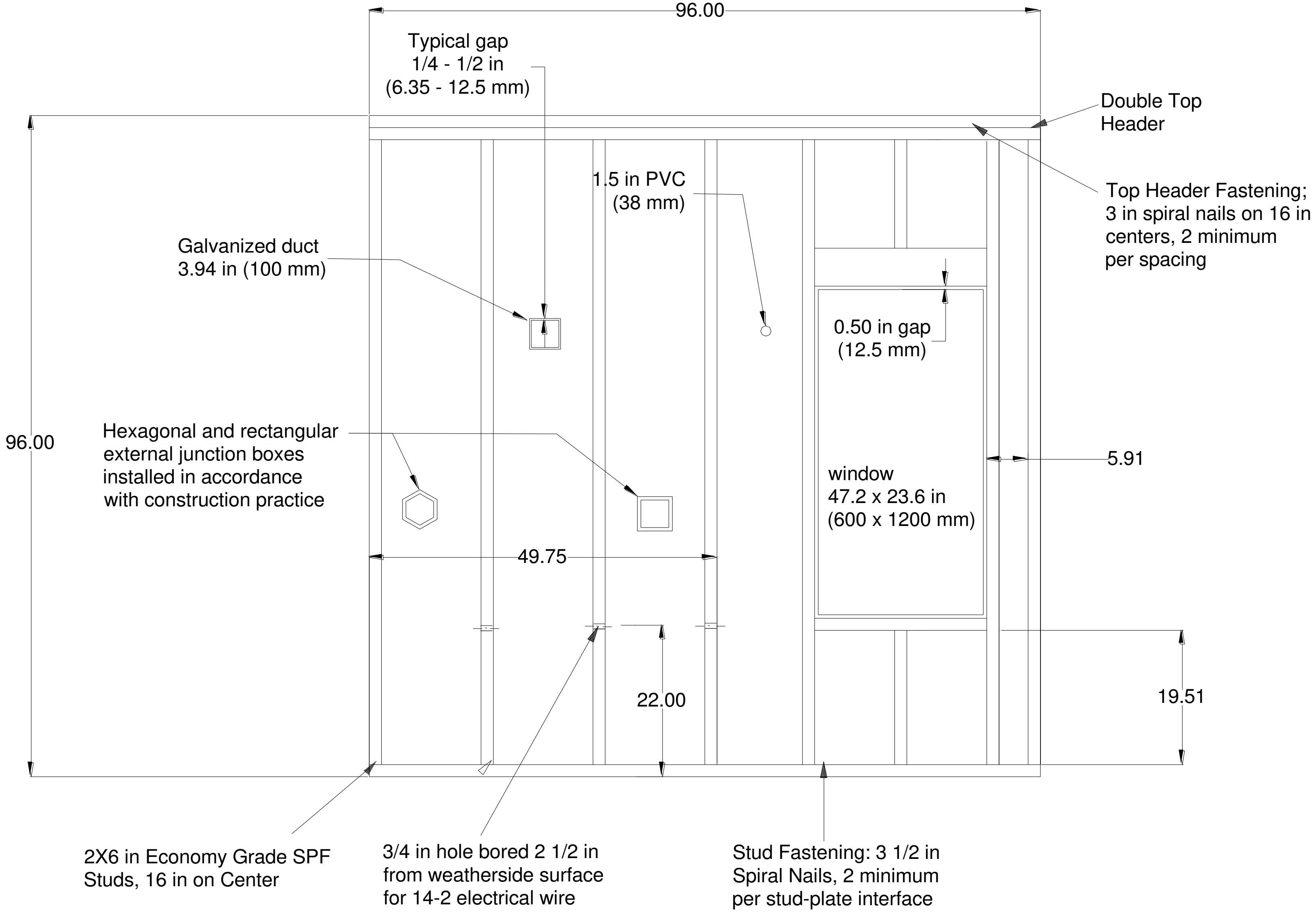
Start with wood frame

Poly-wrapped glass fibre batts

Foaming and finishing

Final foamed wall

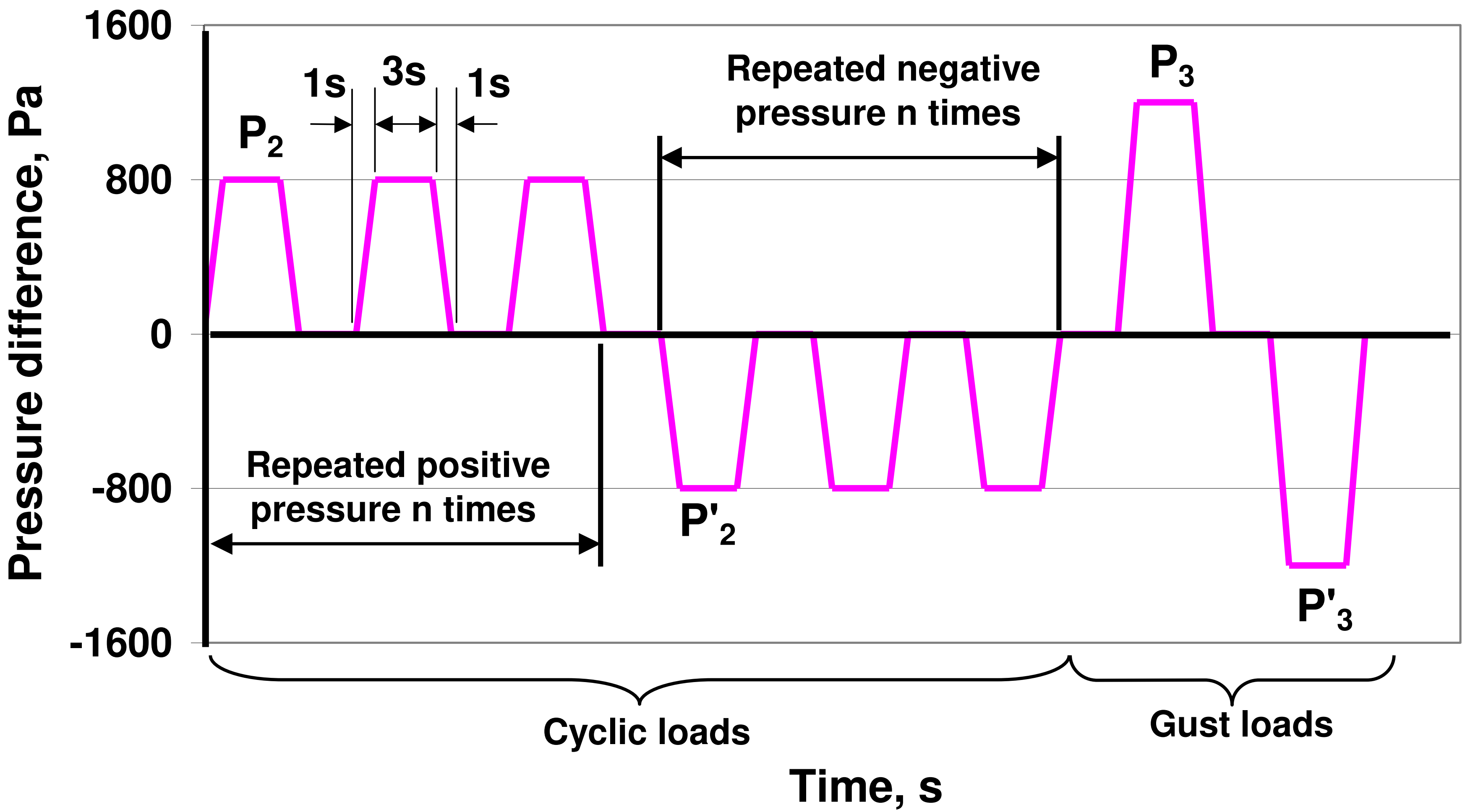
Penetrations Layout (CCMC Air Barrier Guide 07272)



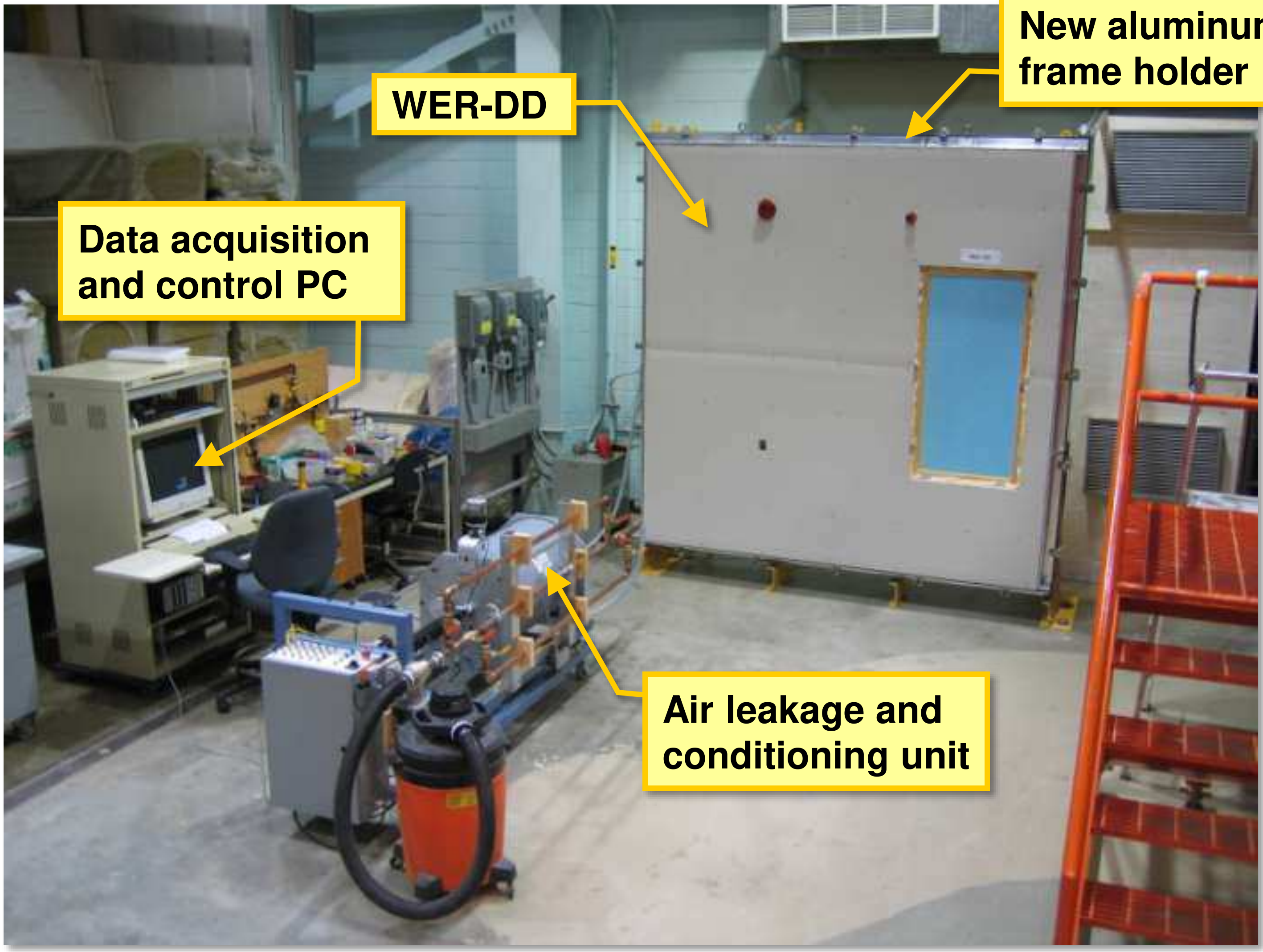
Test Procedures

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

Pressure Cycle for Sample Conditioning



Air Leakage and Conditioning Test Apparatus

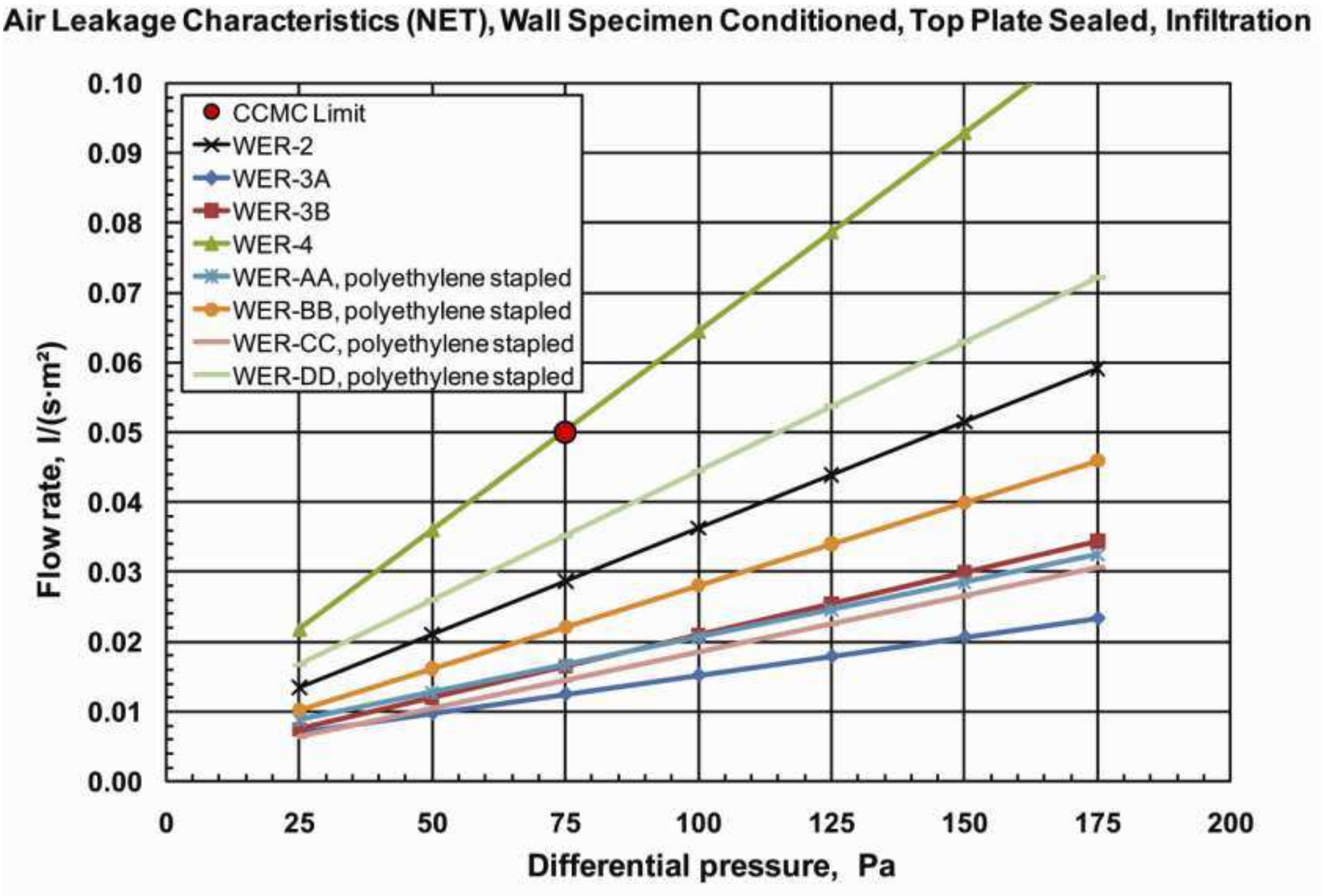


Guarded Hot Box Apparatus

Results

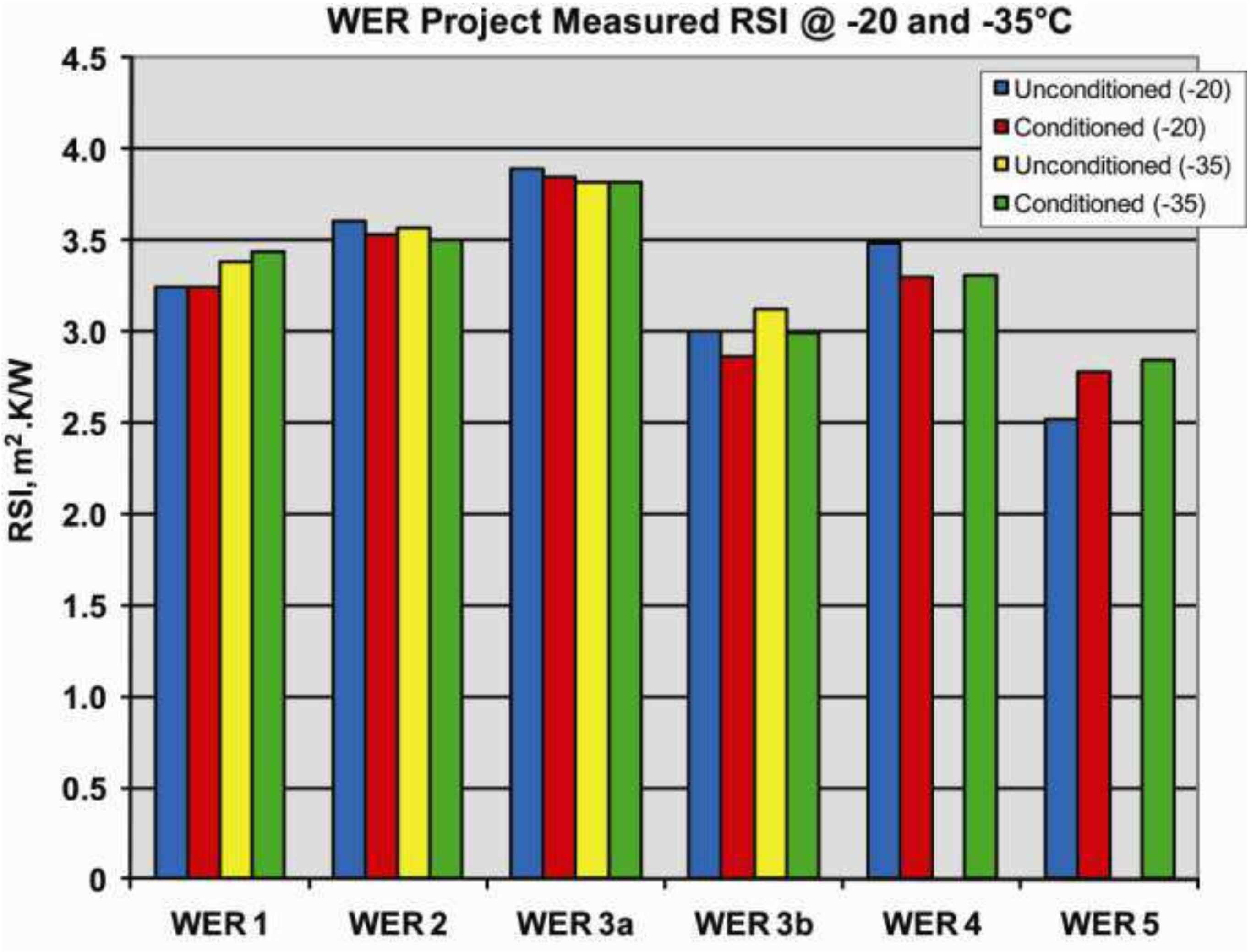
- Test results
  - Air leakage
  - Thermal resistance, R-value
  - Material characterization of foam(s)
- Simulation results
- Comparison of testing and simulation
- Development of WER

Air Leakage Test Results



Test Results: R-value *(cont'd)*

R20 ≅ 3,5 RSI



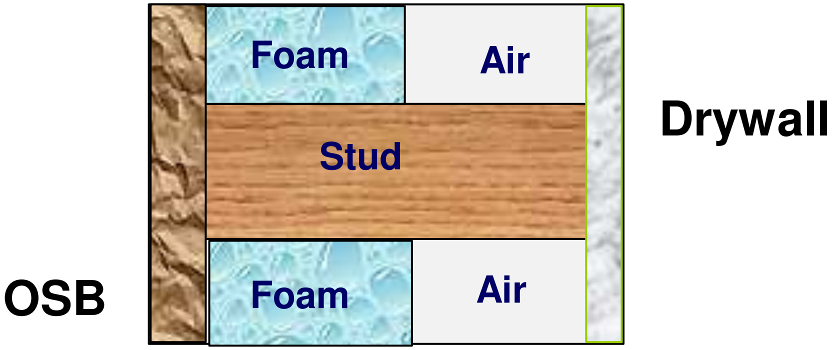
NRC·CNRC

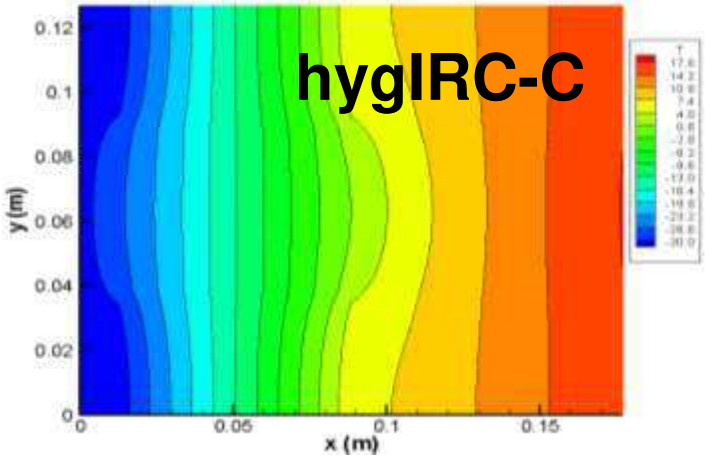
Computer Modelling

- The goal is to benchmark hygIRC (2-D model) and hygIRC-C (3-D model)
- Use hygIRC-C to predict the R-values for the 10 walls with no air leakage and compare its prediction with measured results
- Use hygIRC-C to predict the R-values at different leakage rates for the 10 walls
- Provide a simple correlation to be used for determining the R-values at different leakage rates

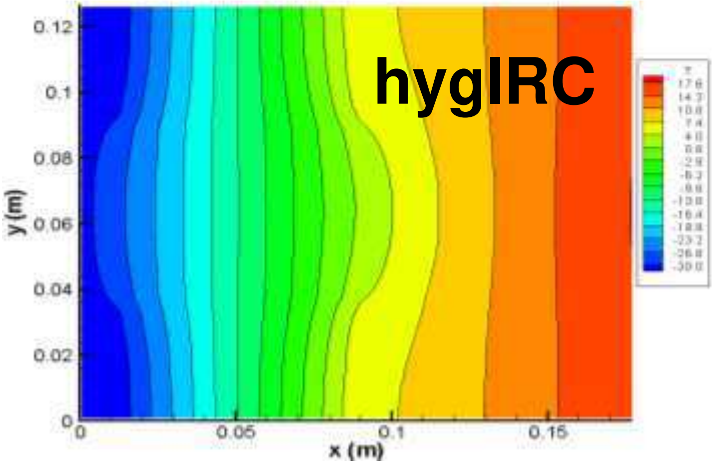
Benchmarking of the Two Models

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



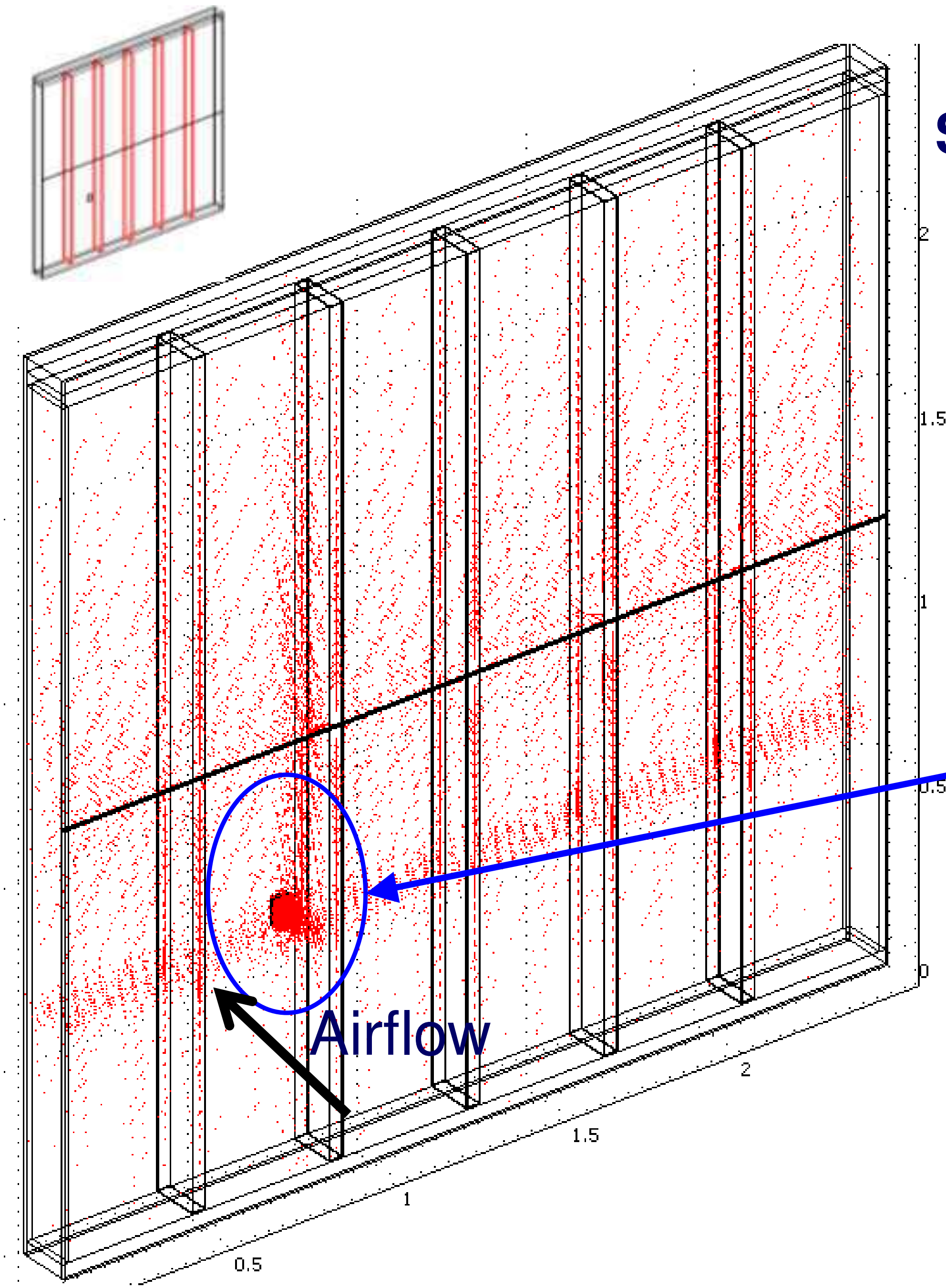


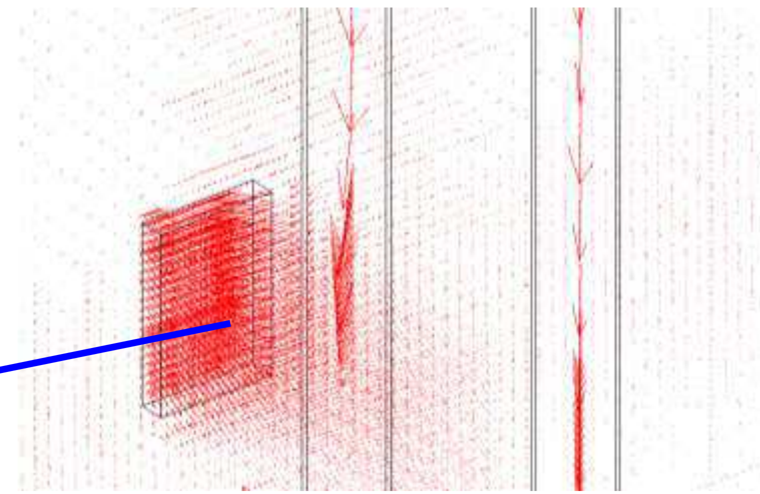
Temperature Profiles



Sample of 3D Results (cont’d)

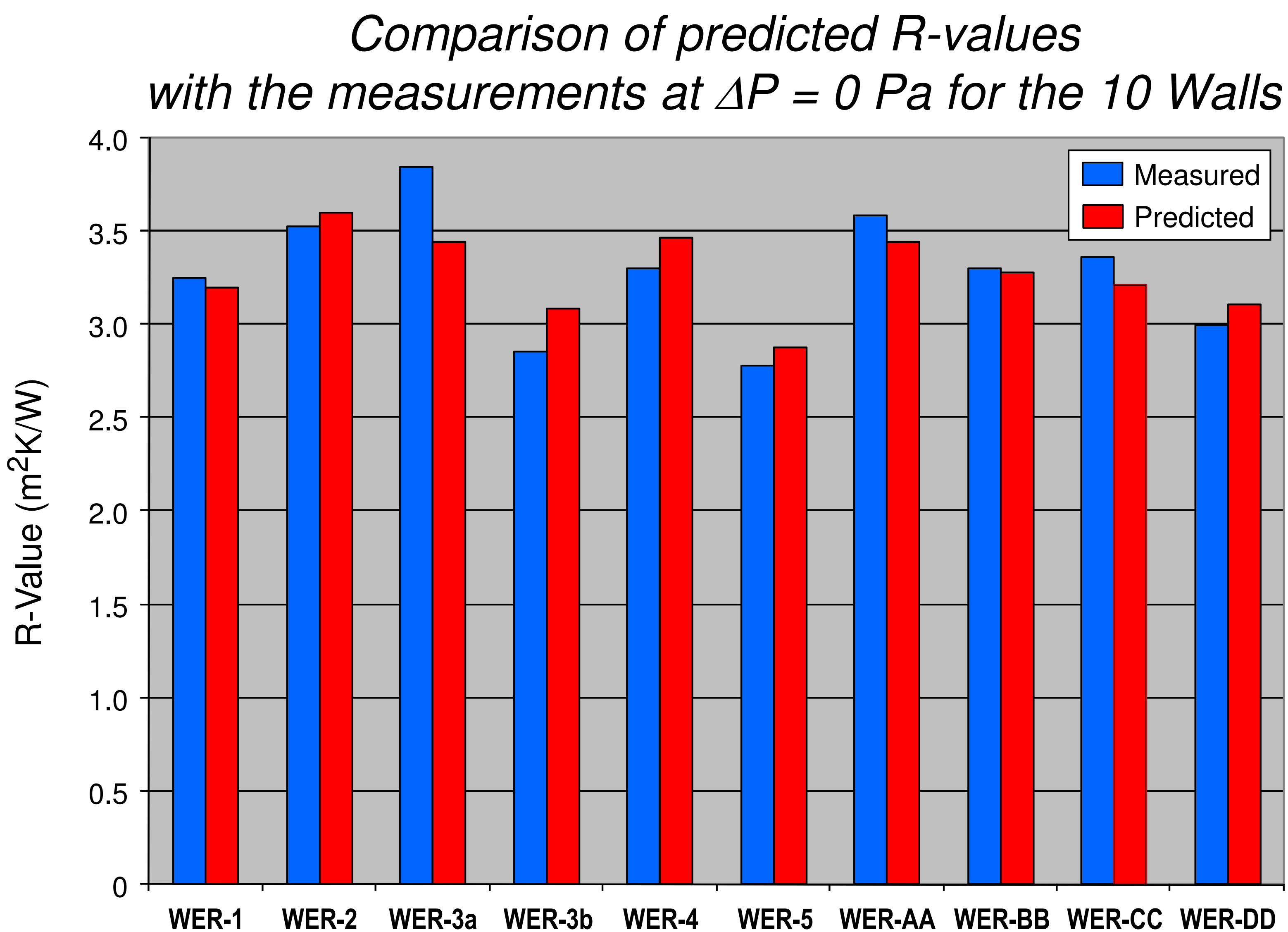
WER-1, ΔP = 75 Pa





Air Velocity Field

R-value Results *(cont'd)*



NRC·CNRC

Introduction of R-value Ration β

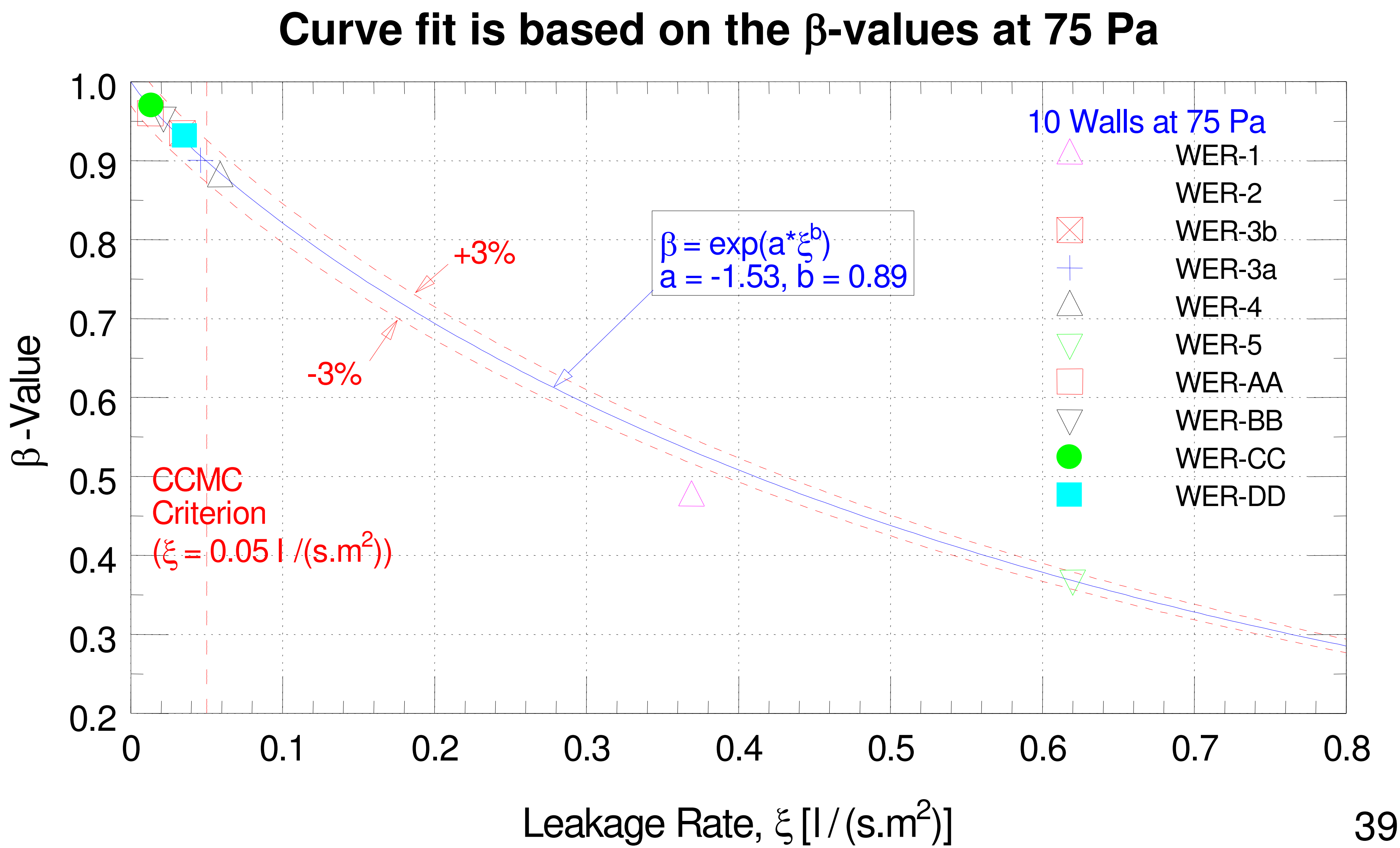
$$\beta = \frac{R_L \text{ (R-value with air leakage)}}{R_o \text{ (R-value without air leakage)}}$$

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

Determination of WER

- Need
  - R-value WITHOUT air leakage (GHB), $m^2.K/W$
  - Air leakage rate, ξ, at ΔP = 75 Pa, $l/(s.m^2)$
- Determine wall R-value with air leakage at different ΔP values
- Determine the R-value ratio, β
- Develop an expression for WER
- Calculate WER

Solution: Ratio of R-values Correlates Well



Calculation Procedure of Apparent RSI

Start → For a given wall

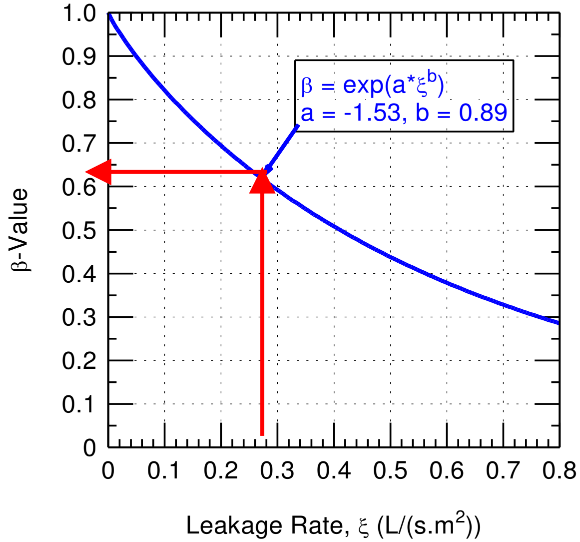
Obtain R-value at no leakage, RSI_0, experimentally in the GHB

↓

Conduct leakage test to obtain the leakage rate, ζ at ΔP = 75 Pa, $l/(s.m^2)$

↓

Calculate the β-value using:
$\beta = \exp(a^*\zeta^b)$, a = -1.53, b = 0.89



↓

Calculate R-value with leakage, RSI_L as:
$RSI_L = \beta * RSI_0$

→ End

WER Calculation: New Proposal for Standardization

RSI_0 = Guarded hot box test result @ $\Delta T = 40°C$

ξ = Air leakage test result, $l/(s.m^2)$ @ 75 Pa

$\beta = \exp(-1.53 * \xi^{0.89})$ or use the graph

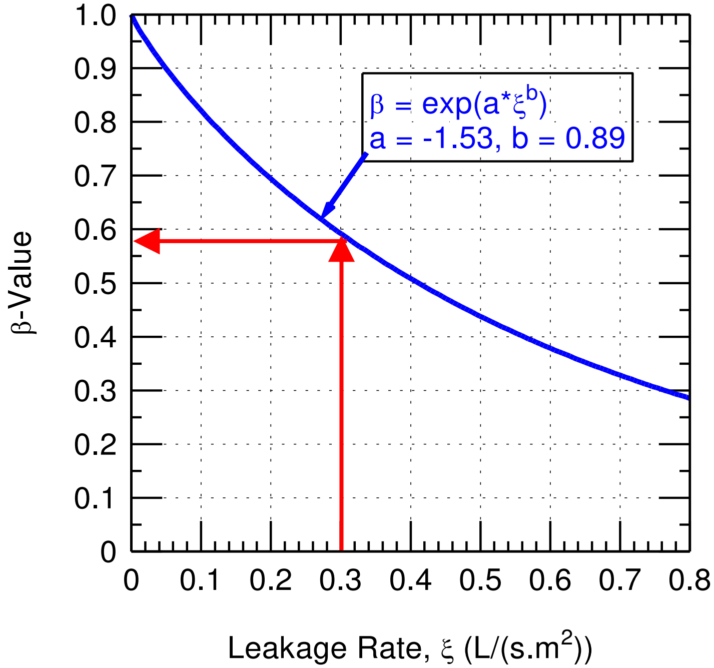
$RSI_L = \beta * RSI_0$

$WER = -\Delta T / RSI_L$, $W/(m^2)$

$$WER_{Cal} = 50 - C\,(\Delta T / RSI_L)$$

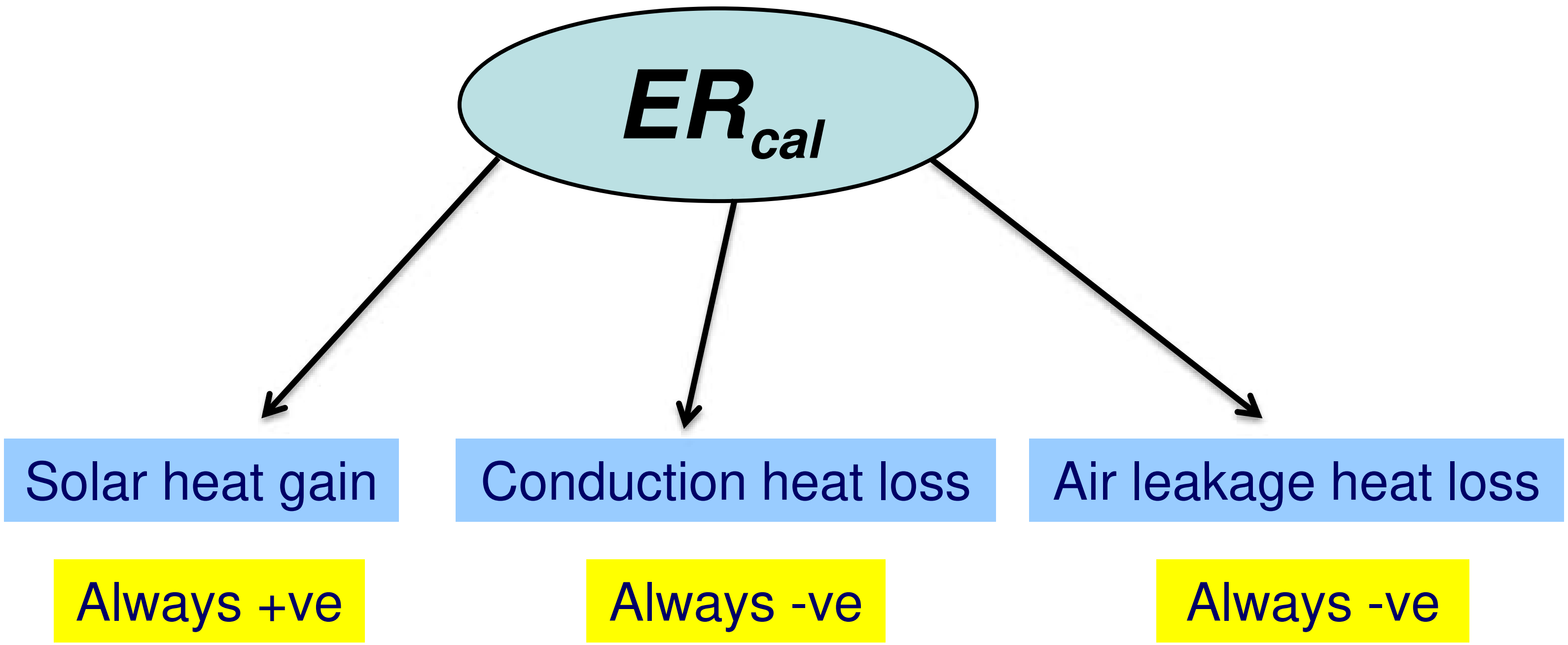
$C = 1$, m^2/W to normalize WER

WER_{Cal} is dimensionless



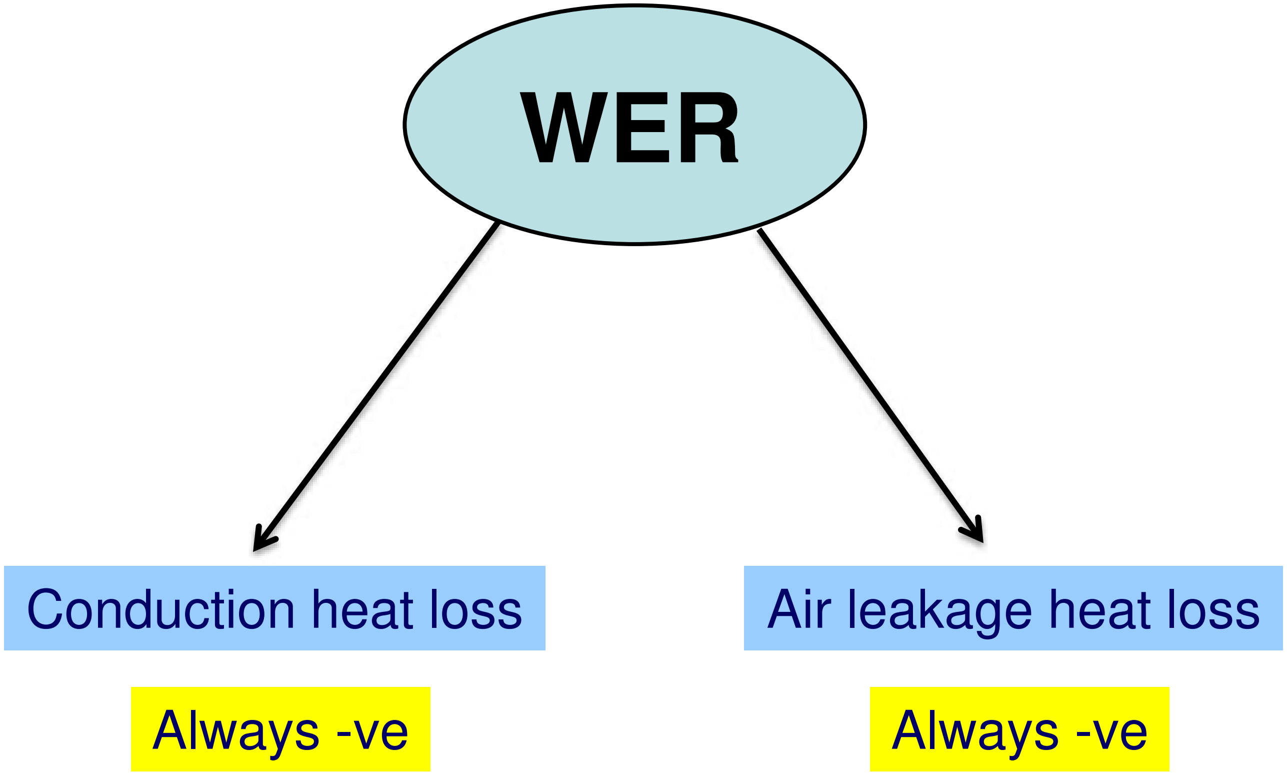
CSA A-440.2 Standard Approach

- ER_{cal} Window Energy Rating (W/m^2)

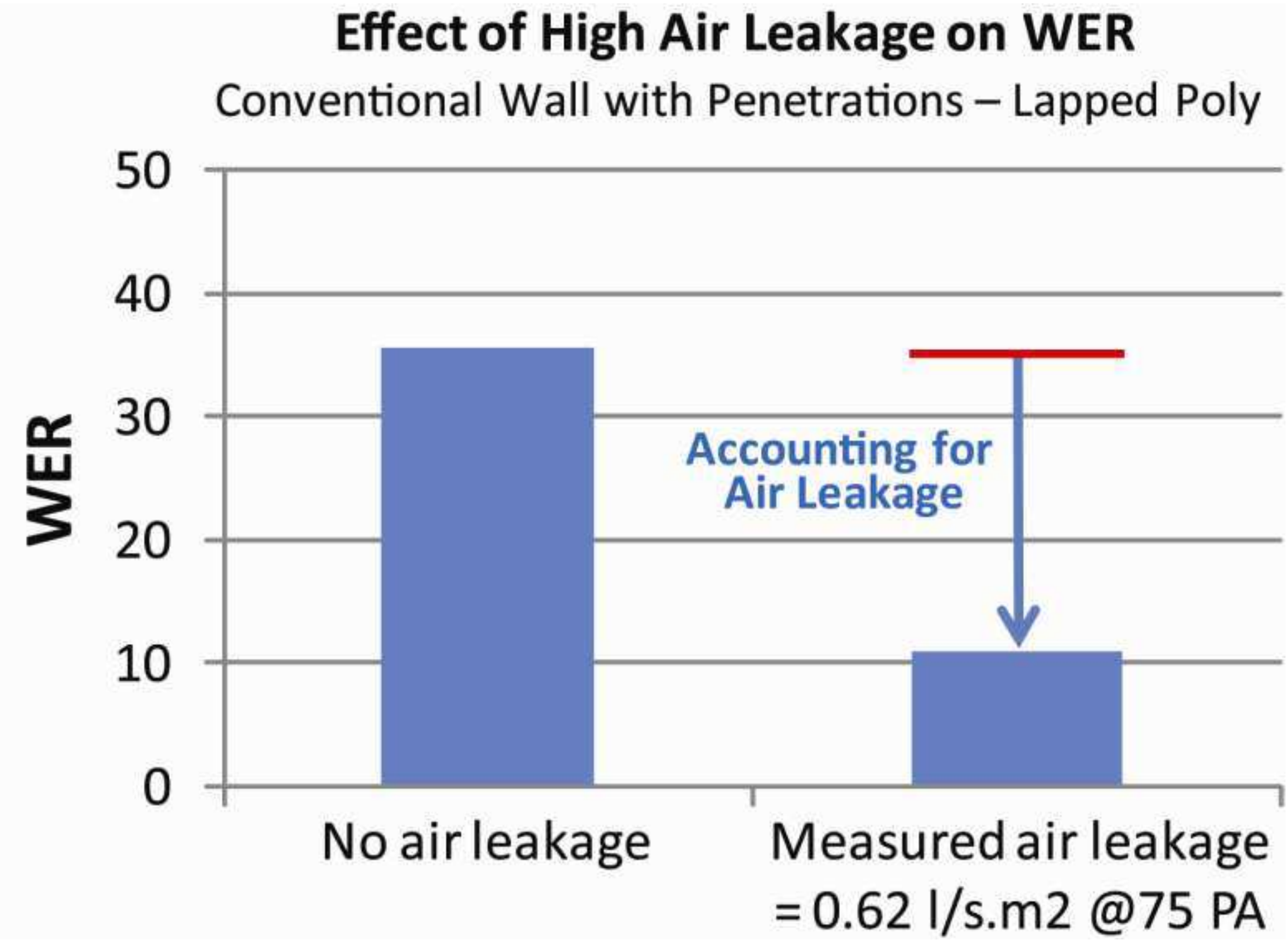


WER: A tool for wall energy rating

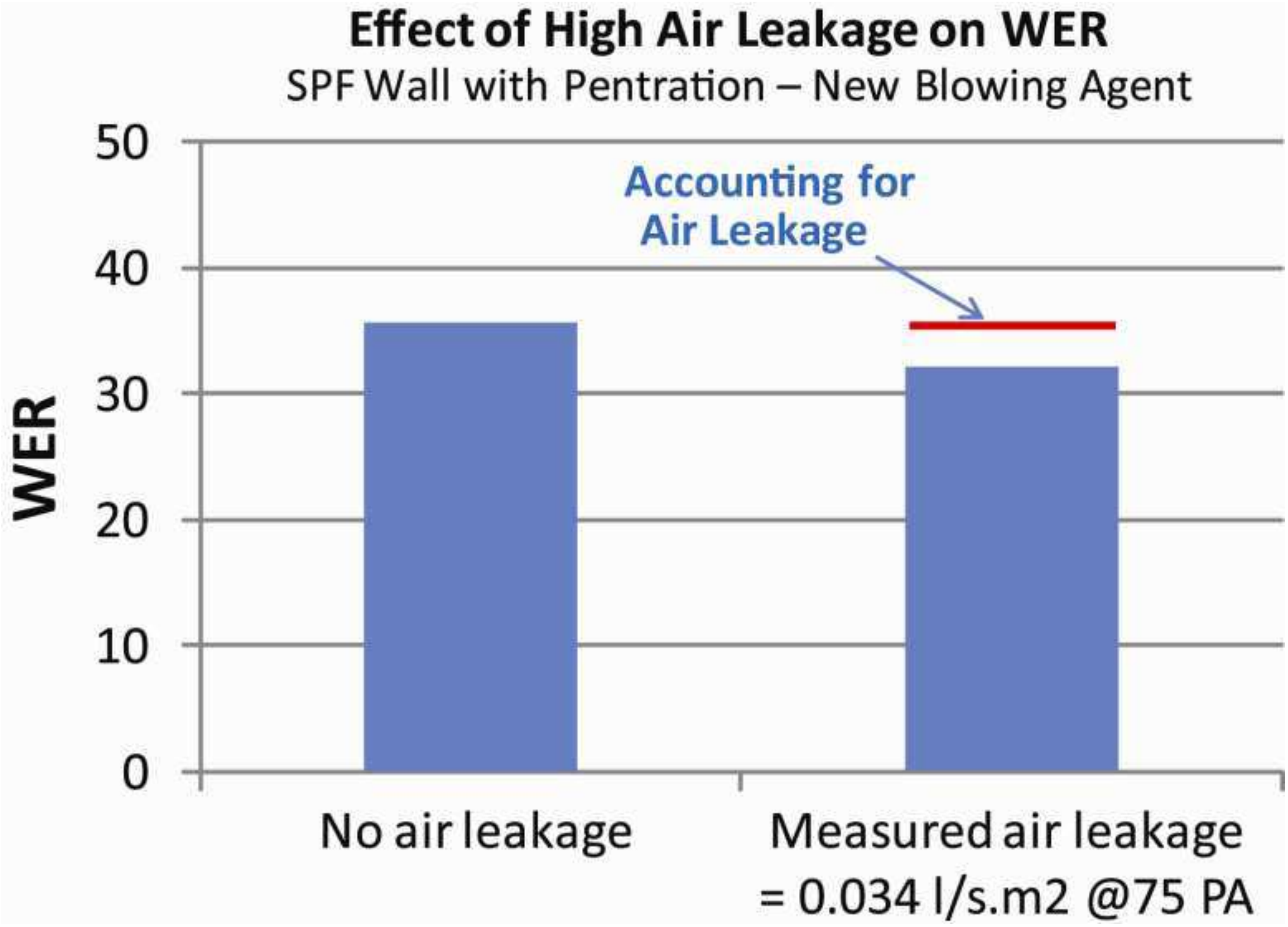
- WER Wall Energy Rating (W/m^2)



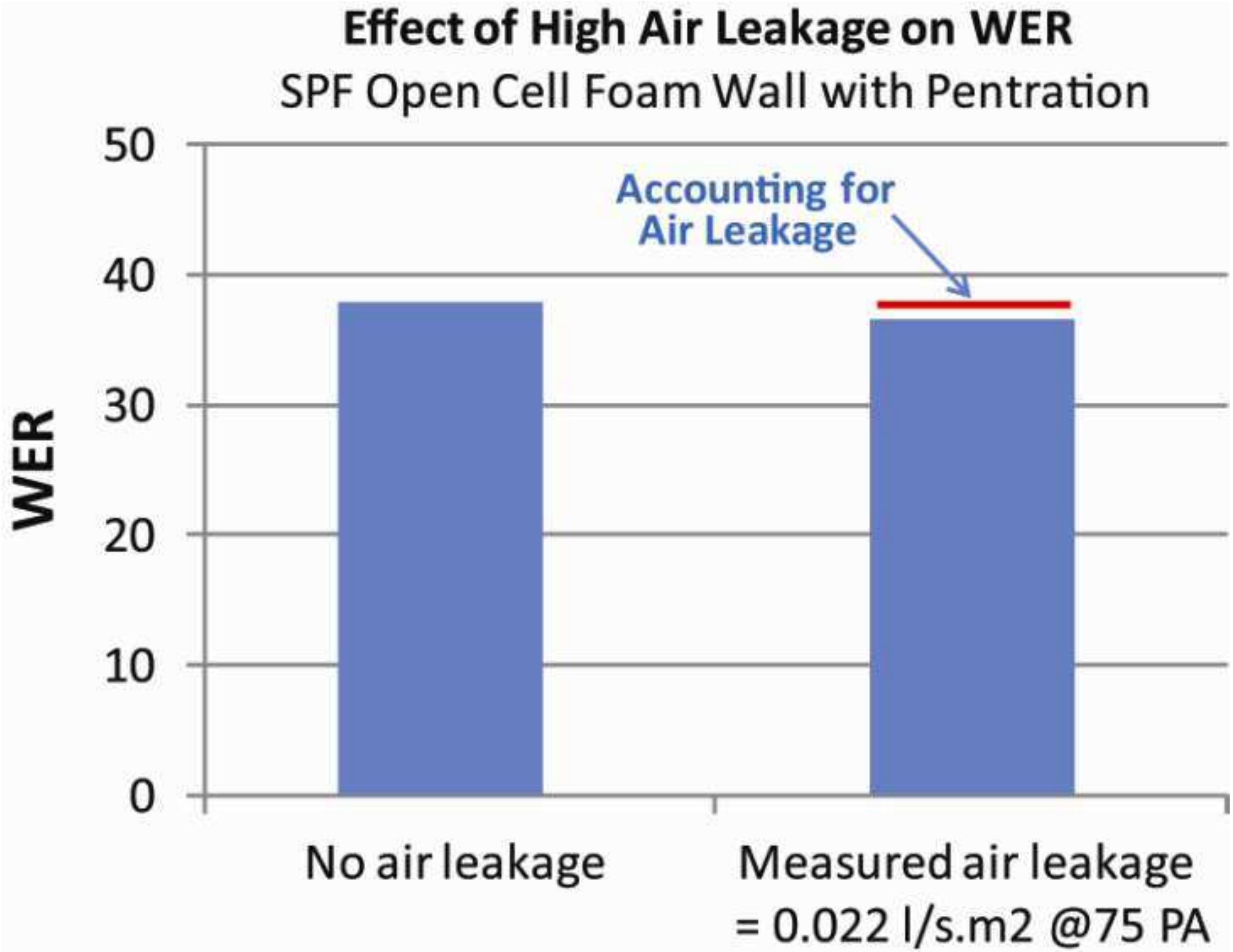
Effect of Air Leakage on WER – Case I



Effect of Air Leakage on WER – Case II



Effect of Air Leakage on WER – Case III



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 partners in this project
  - BASF
  - CUFCA
  - Demilec
  - Honeywell

NRC·CNRC

Institute for Research in Construction

Bringing quality to the built environment

www.nrc-cnrc.gc.ca/irc