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**4th
IBPC**4th International
Building Physics
ConferenceIstanbul
15-18 June 2009

Istanbul Technical University

MOISTURE MANAGEMENT AND ENERGY ANALYSIS IN BUILDINGS

***Part I- A FIELD MONITORING STUDY OF INTERSTITIAL
CONDENSATION IN WOOD-FRAME WALLS IN COLD CLIMATE***

W. Maref, M. Armstrong , M. Rousseau

4th IBPC, Istanbul, Turkey, 14 June 2009

National Research
Council CanadaConseil national
de recherches Canada**Canada**

Team



K. Abdulghani



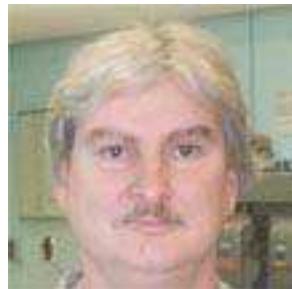
W. Lei



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W. Maref



M. Nicholls



T. Aubin



M. Rousseau

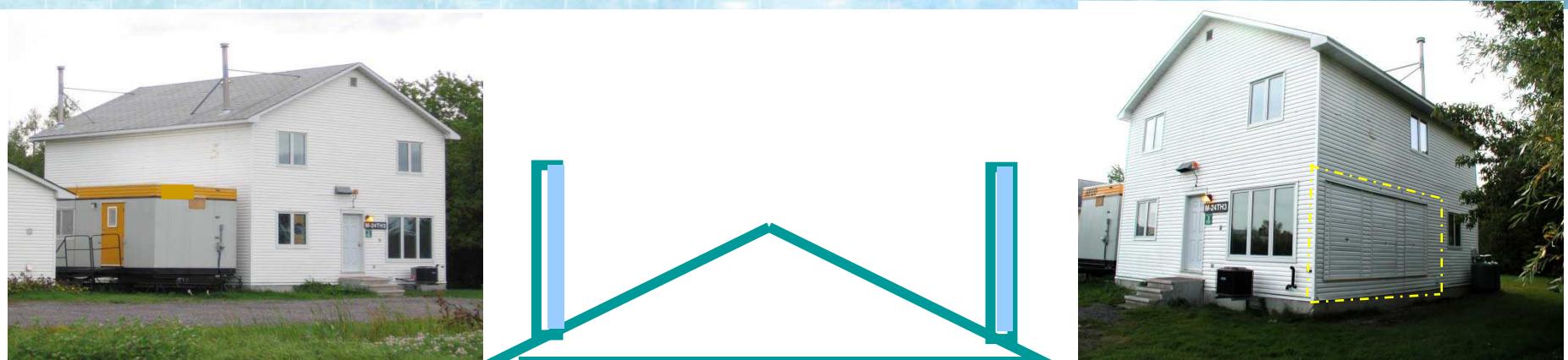


R. Berzins

Outline

- Background & Objectives
- Field Exposure of Wall Facility (FEWF) **Part I**
 - Experimental Approach
 - Construction Details
 - FEFW Instrumentation
 - Results and Discussion
 - Summary

Ventilation and Wall Research House Facility



1. VENTILATION, HEATING AND COOLING FACILITY - IE



Study & compare traditional & innovative ventilation, heating & cooling strategies

2. FIELD EXPOSURE OF WALL FACILITY – (FEWF) BES



Study & compare traditional & innovative BE strategies



Field Exposure of Wall Facility (FEWF)



Objectives

- Compare performance of different side-by-side wall assemblies
- improve understanding of HAM response of wall and window assemblies exposed to naturally occurring climate loads of Ottawa as well as to indoor environment loads of T, RH and P defined by occupancy and HVAC systems.
- Research the interaction between the building envelope and the indoor environment
- Complement IRC's controlled laboratory test and modeling simulations

Roadmap

IRC Field Exposure of Wall Facility (FEWF)

- **Year 1 (2006-2007)** Commission the facility by monitoring three identical test specimens of traditional construction (2x6) through Fall, Winter and Spring. **(Part I)**
- **Year 2 (2007-2008)** Partnership with CMHC & NRCan to investigate the effects of two energy retrofit strategies on the wetting and drying potential of wall assemblies. **(Part II)**
- **Year 3 (2008-2009)** Partnership with FPIInnovation (Forintek) to investigate the effects of the interior air/vapour barrier polyethylene membrane on the wetting and drying potential of wall assemblies and extending the project with CMHC & NRCan for one retrofit strategy.
- **Year 4 (2009-2010)** Partnership with CMHC & NRCan to investigate the dynamic heat transmission characteristics through Insulated Concrete Form (ICF) wall assemblies over a full year cycle of weather exposure
- **Year 5 (2010-2011)** PERD Project to Test the Next Generation Envelope Systems (i.e. Vacuum Insulated Panel)
- **Year 6 and beyond** Investigate the performance of wall specimens of different innovative designs based on industrial collaboration/partnership.

Part I - Commissioning

■ Objectives

- Validate: identical test specimens, protocol and instrumentation
- Characterize heat and moisture response

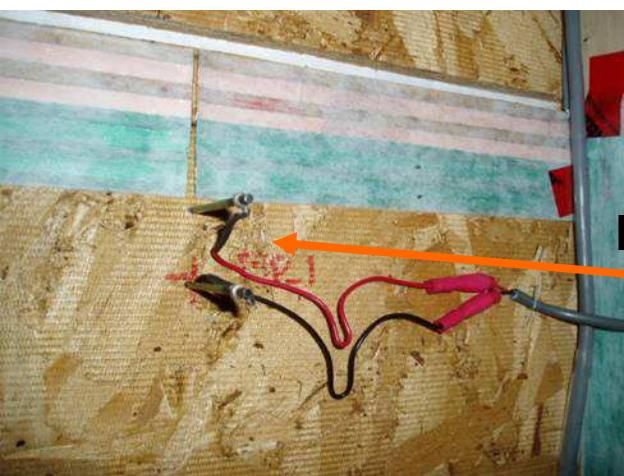
IRC Field Exposure of Wall Facility (FEWF)



LAYER 4 - Interior Face of OSB



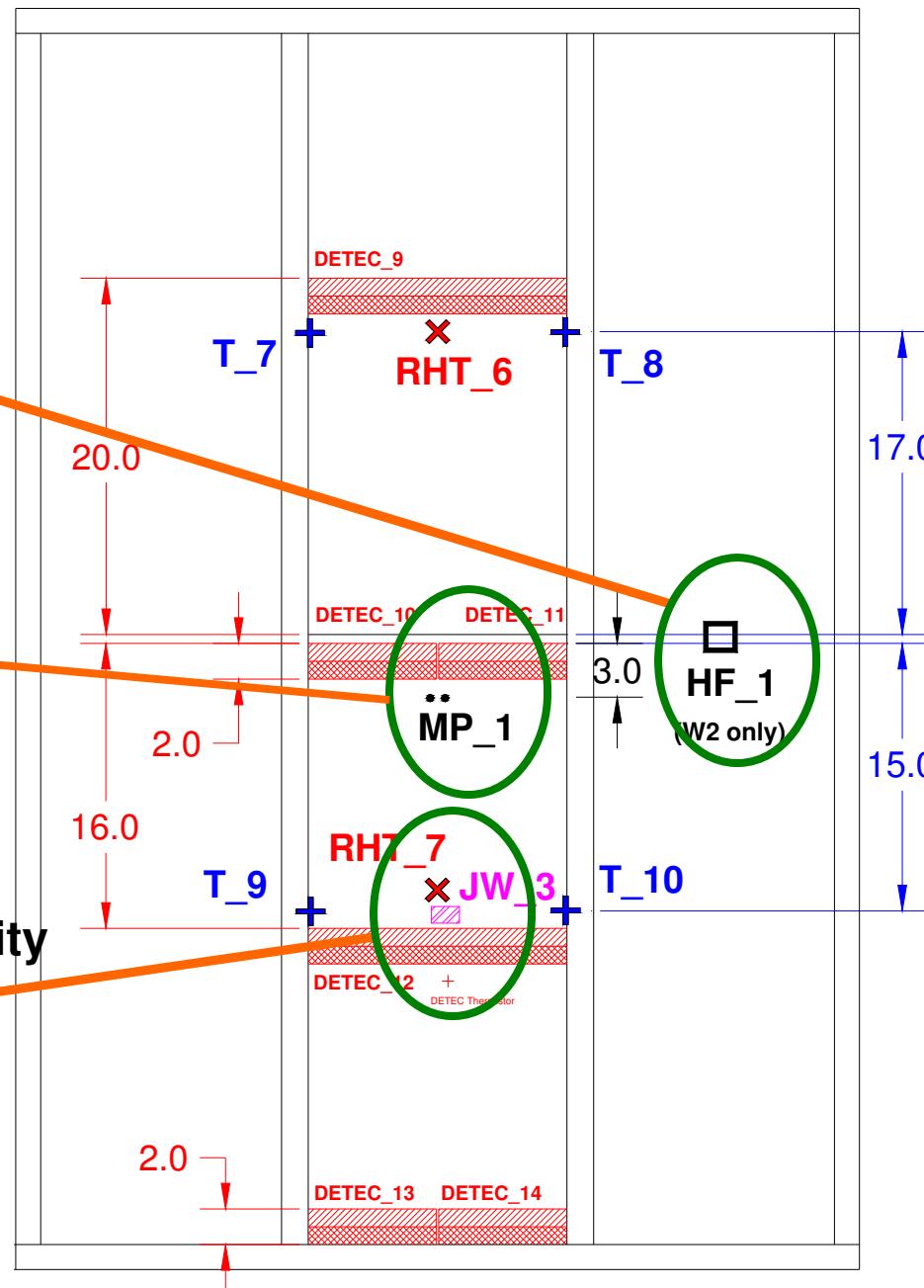
Heat Flux



Moisture Pin



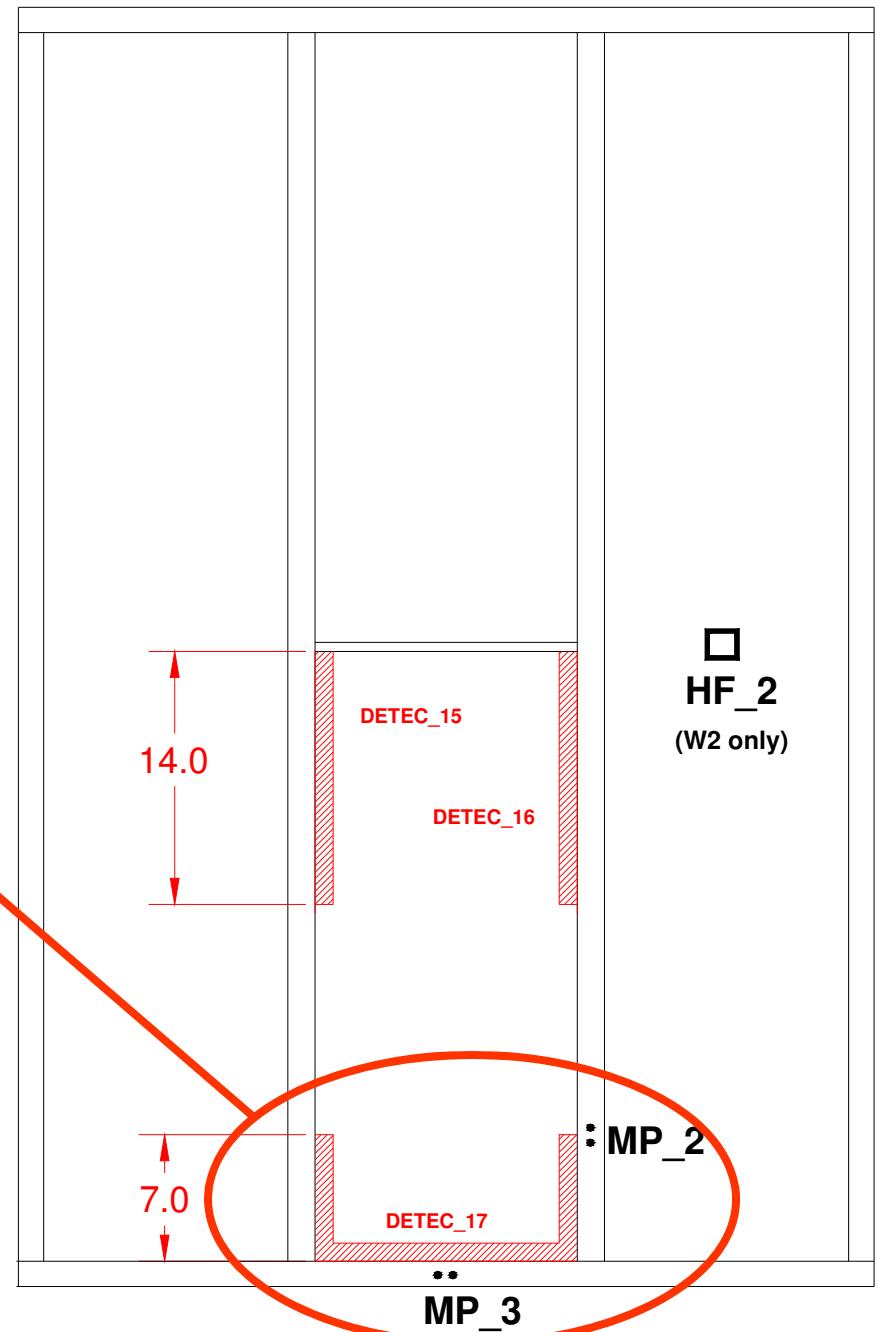
**Wireless
Relative Humidity**

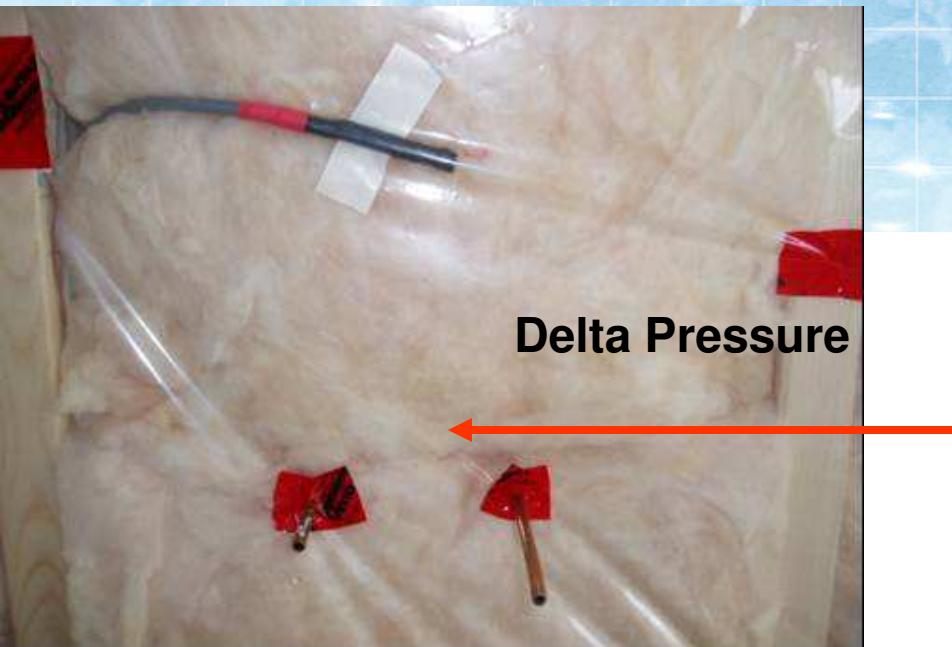


LAYER 5 - Stud Cavity

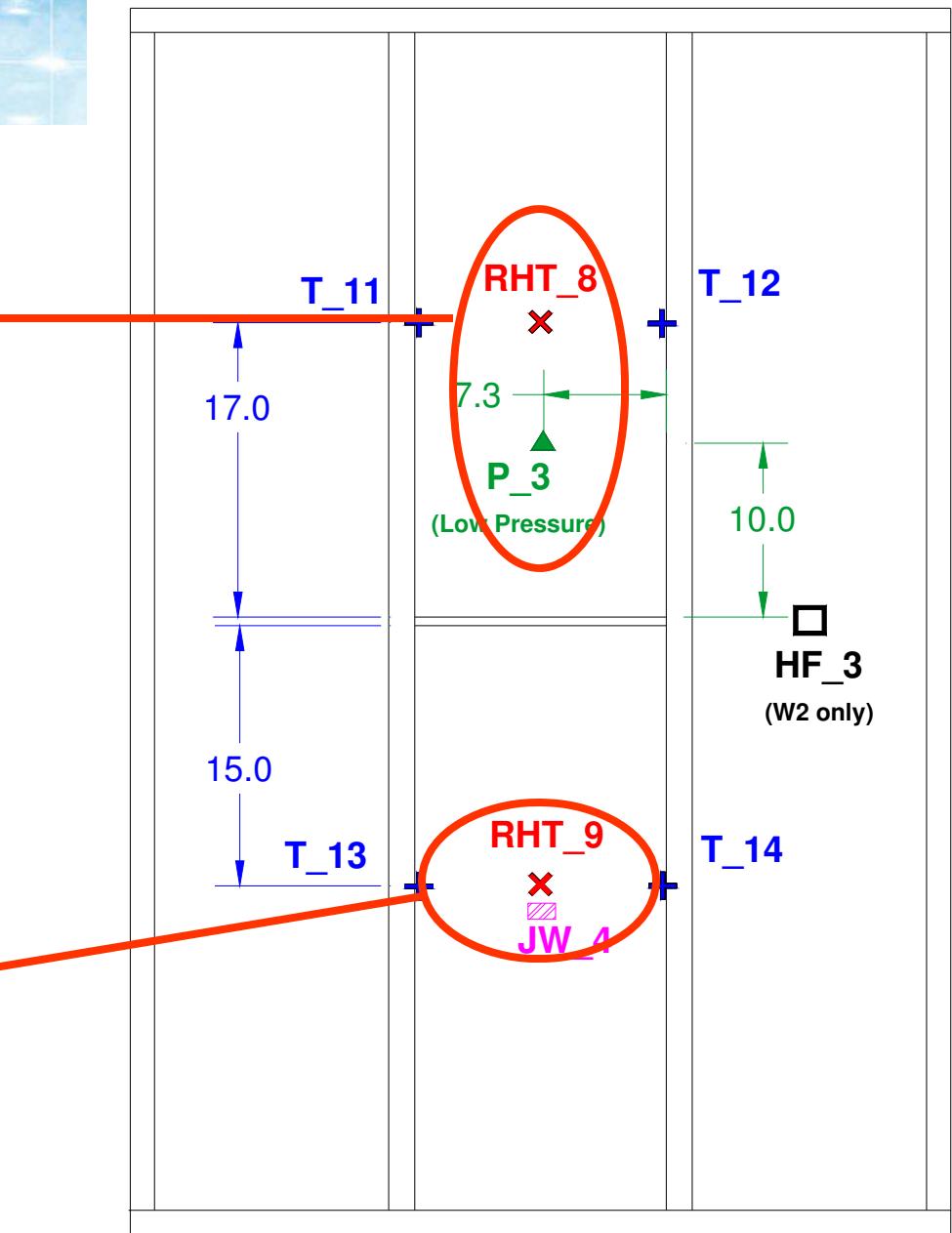


Moisture Pin



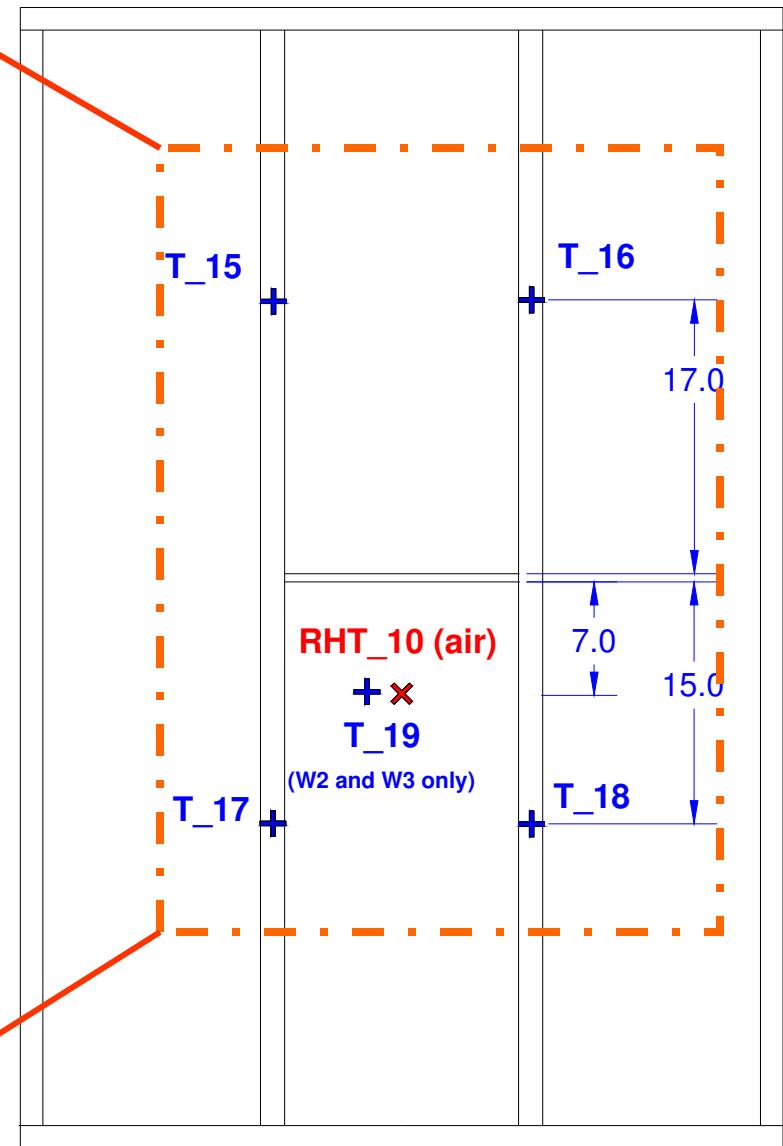


LAYER 6 - Interior Face of Insulation & Stud Cavity (Exterior side of Vapour Barrier)





LAYER 7 - Interior Face of Drywall



FEWF Instrumentation

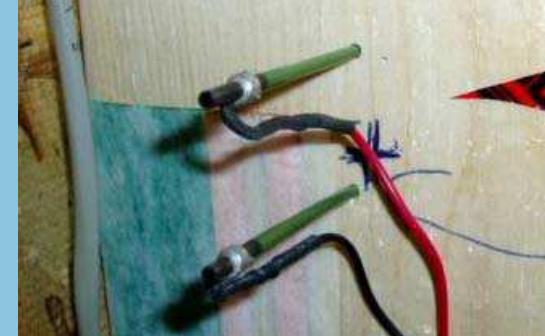
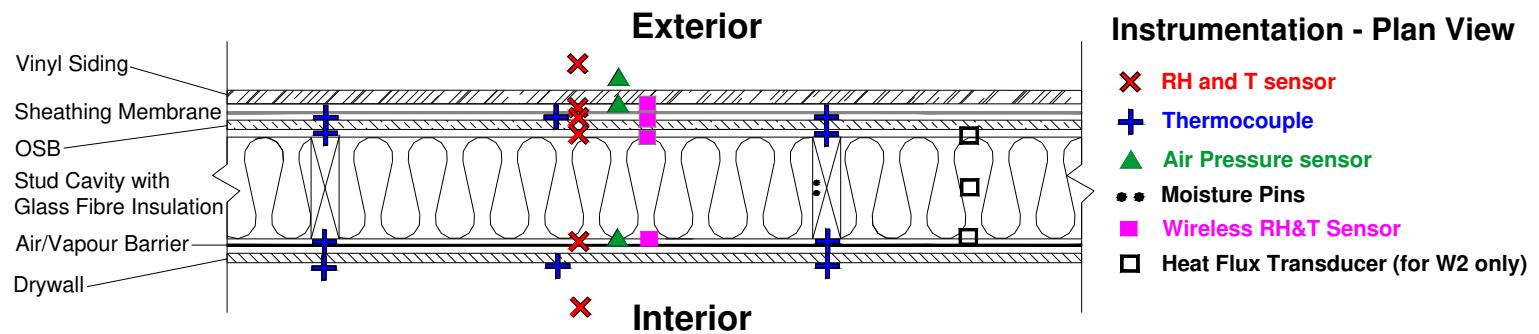


W3

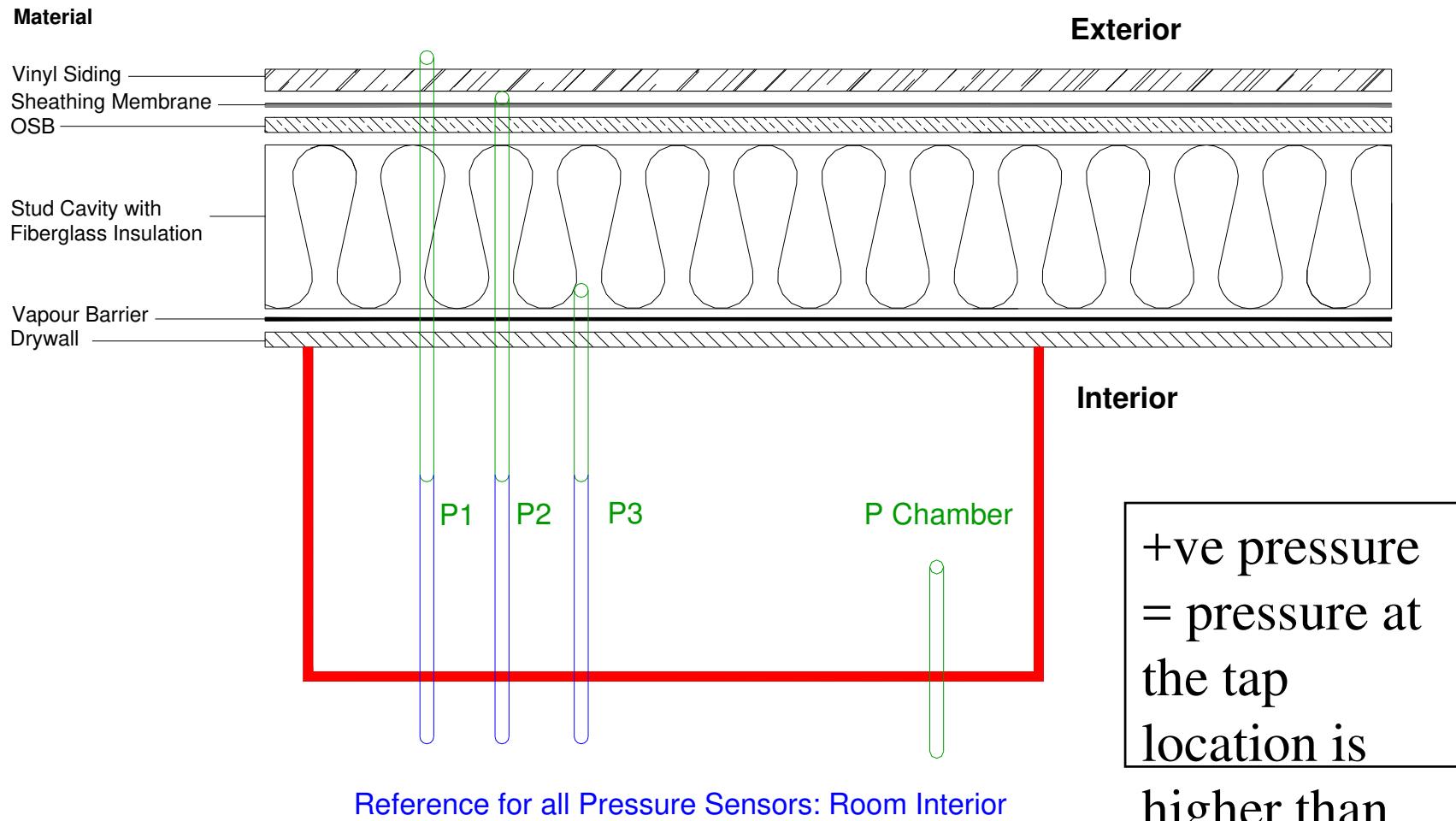
W2

W1

Methodology - Instrumentation



Pressure Tap Locations



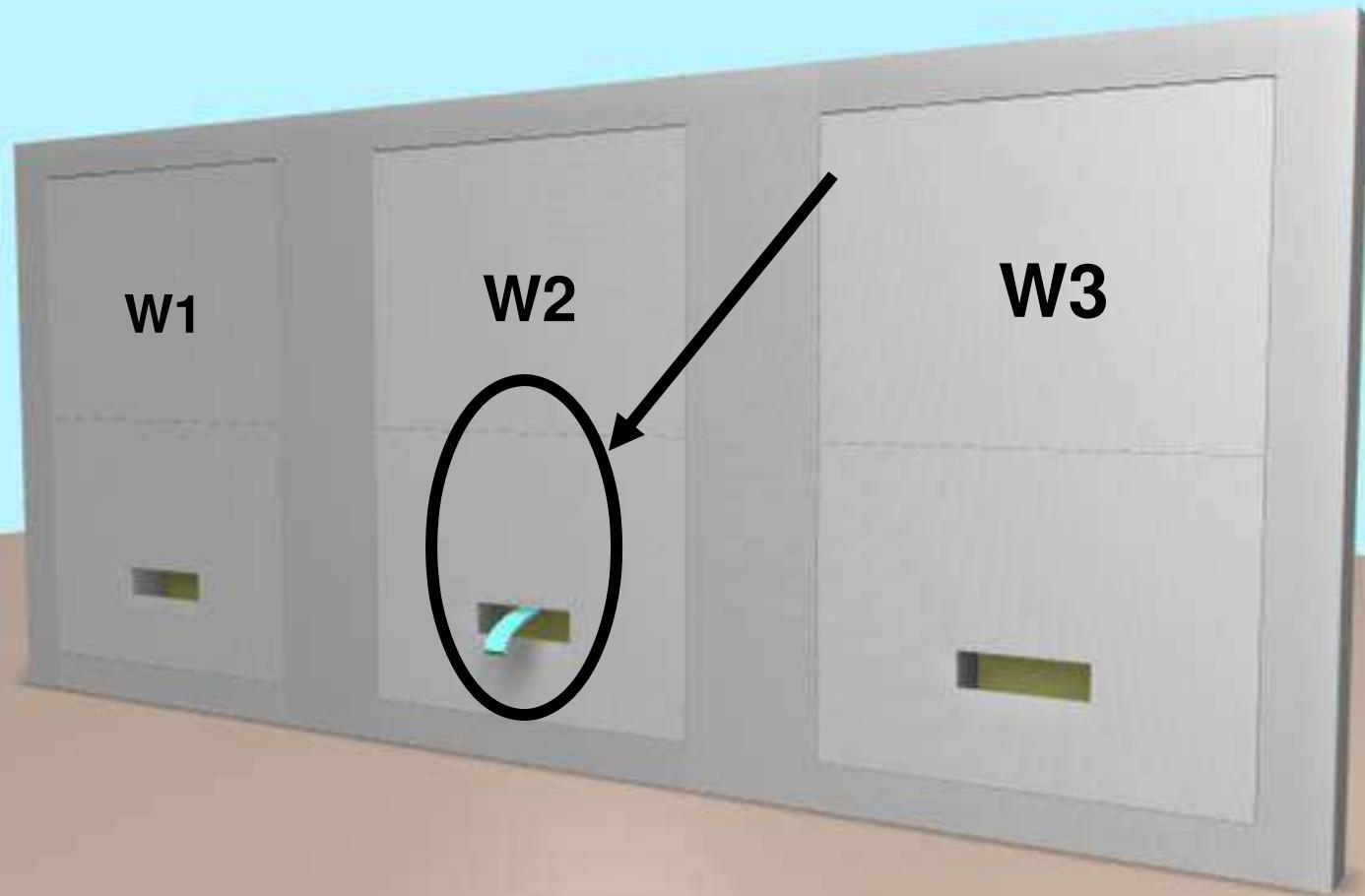
+ve pressure
= pressure at
the tap
location is

higher than
the pressure
in the room



Experimental Approach

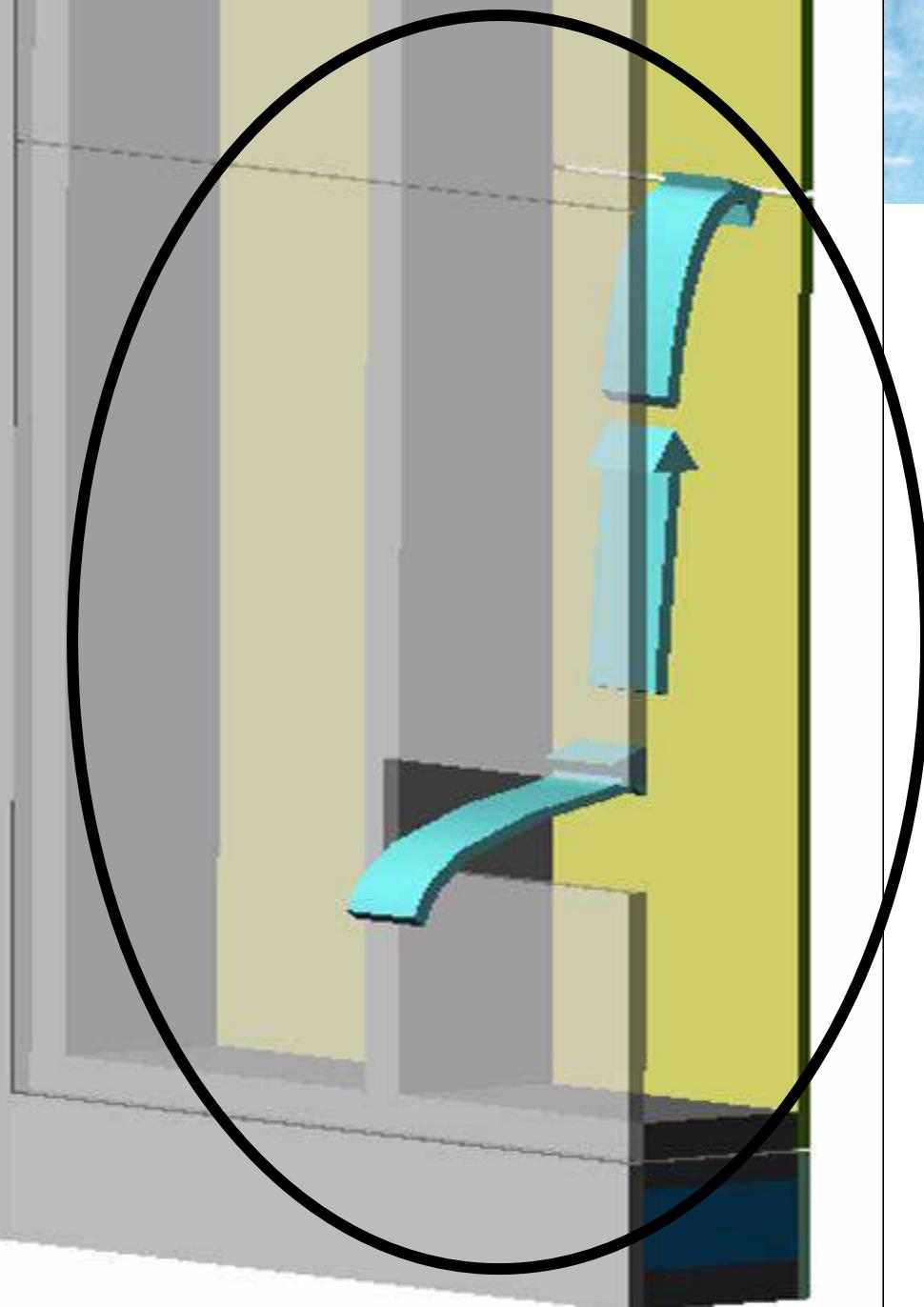
- Challenging the wall experimental begins:
 - Stage 1- Create air leakage path and monitor under naturally occurring int. and ext. conditions on two of three specimens (1 week)



W1

W2

W3



Experimental Approach (Cont'd)

- Challenging the wall experimental begins:
 - Stage 1- Create air leakage path and monitor under naturally occurring int. and ext. conditions on two of three specimens (1 week)
 - Stage 2- Increase indoor RH to 70% and induce 5 Pa positive pressure while air leak is present in two specimens, for a certain period of time

Conditioning Chamber on the Room Side



- Walls 2 and 3 exposed to chamber conditions
- Control T, RH, Pressure
- Deficiency in air barrier (Wall 2 and 3 only)

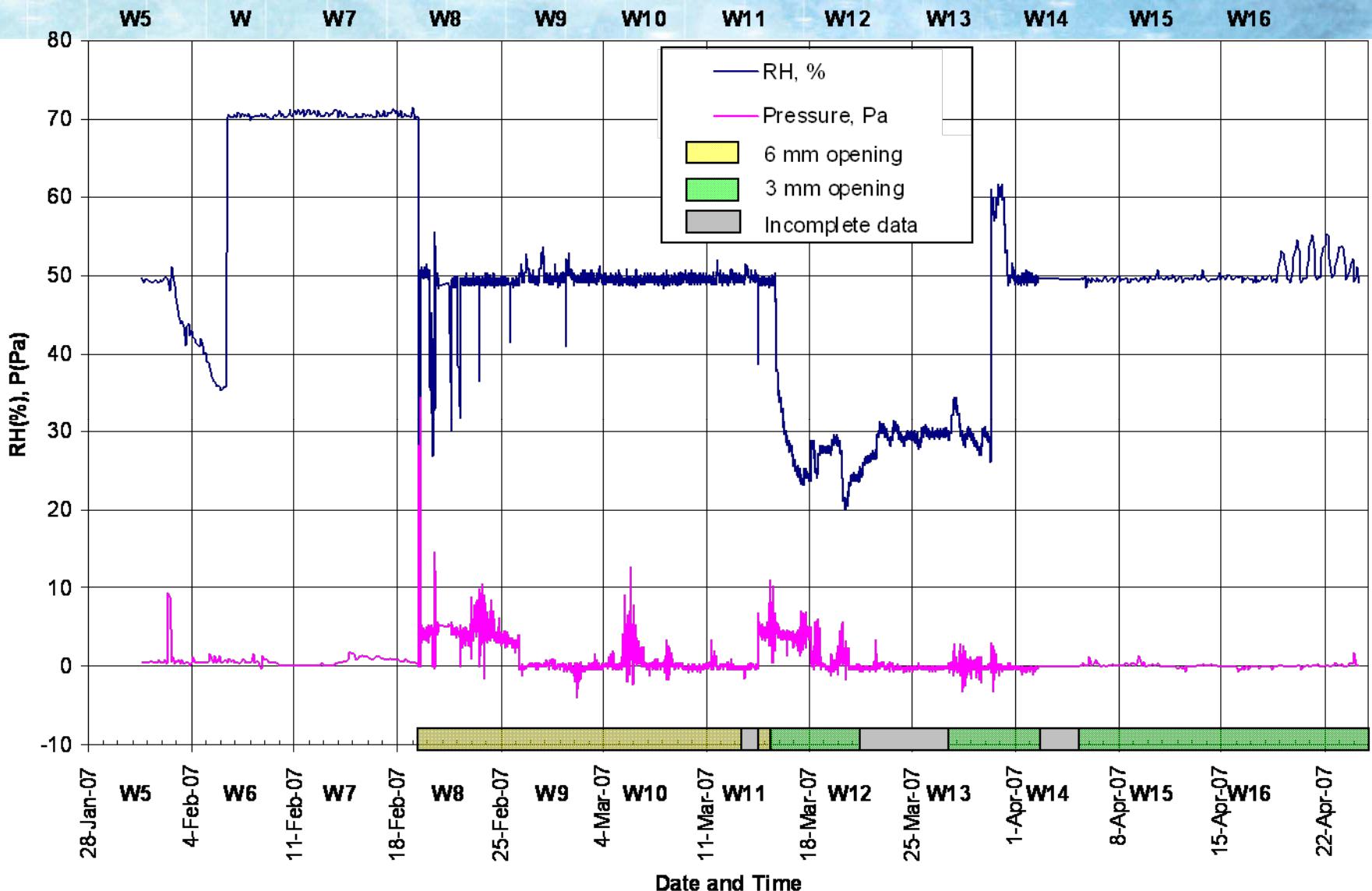


Experimental Approach (Cont'd)

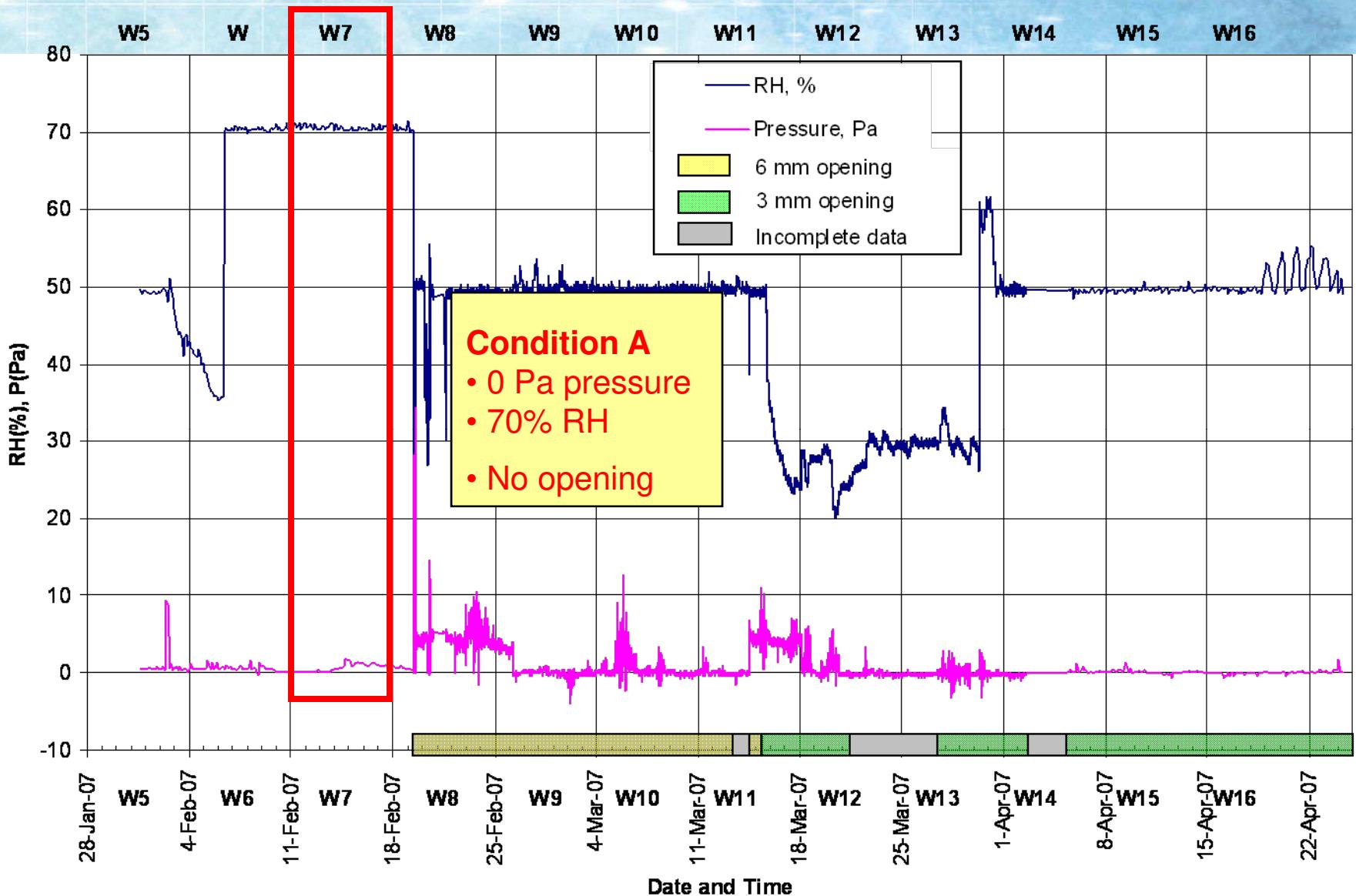
- Challenging the wall experimental begins:
 - Stage 1- Create air leakage path and monitor under naturally occurring int. and ext. conditions on two of three specimens (1 week)
 - Stage 2- Increase indoor RH to 70% and induce 5 Pa positive pressure while air leak is present in two specimens, for a certain period of time
 - Stage 3- Return to naturally occurring conditions to monitor drying. Disassemble the indoor chamber

Results

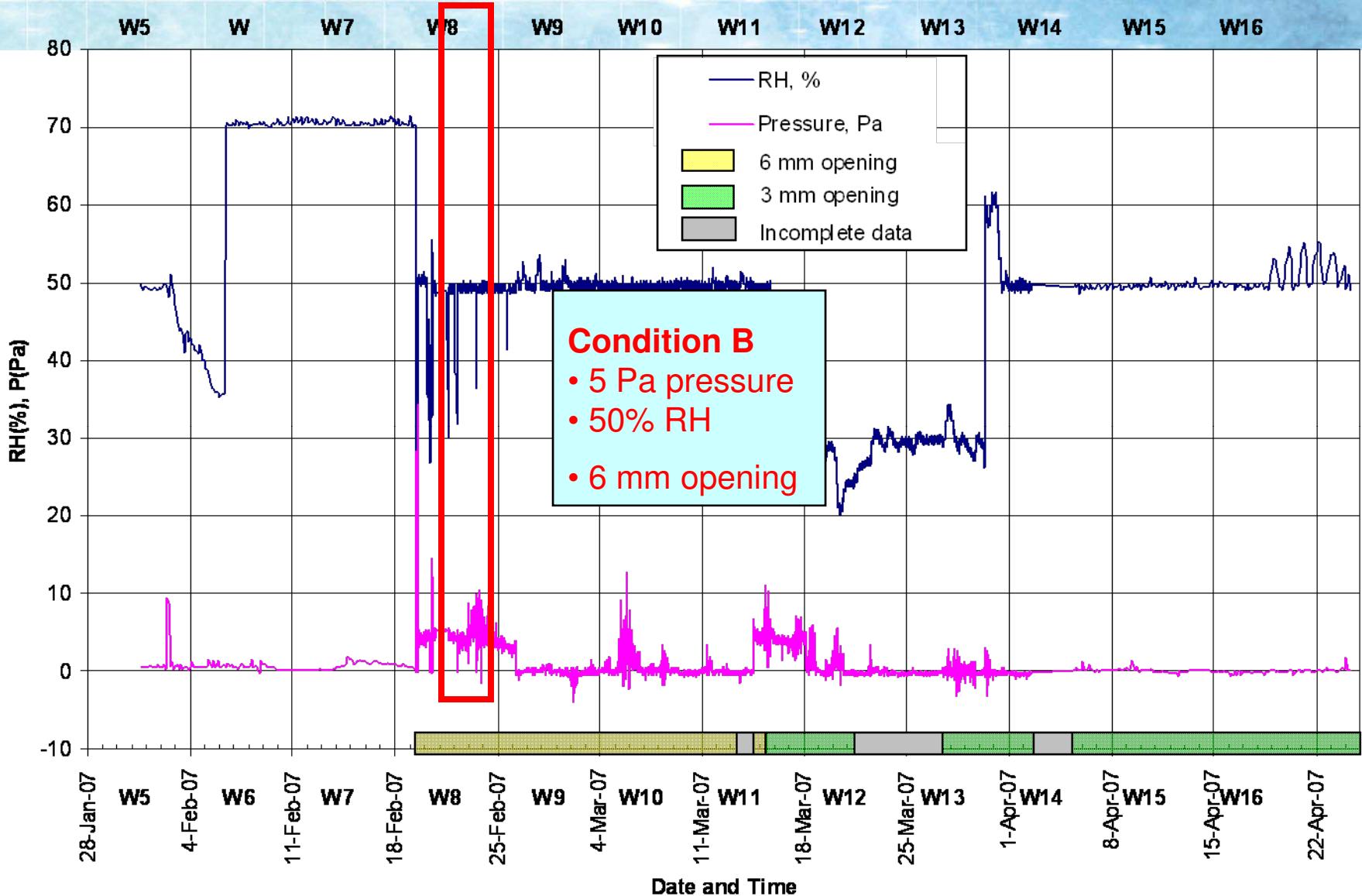
FEWF Chamber RH%, Pressure Vs Time



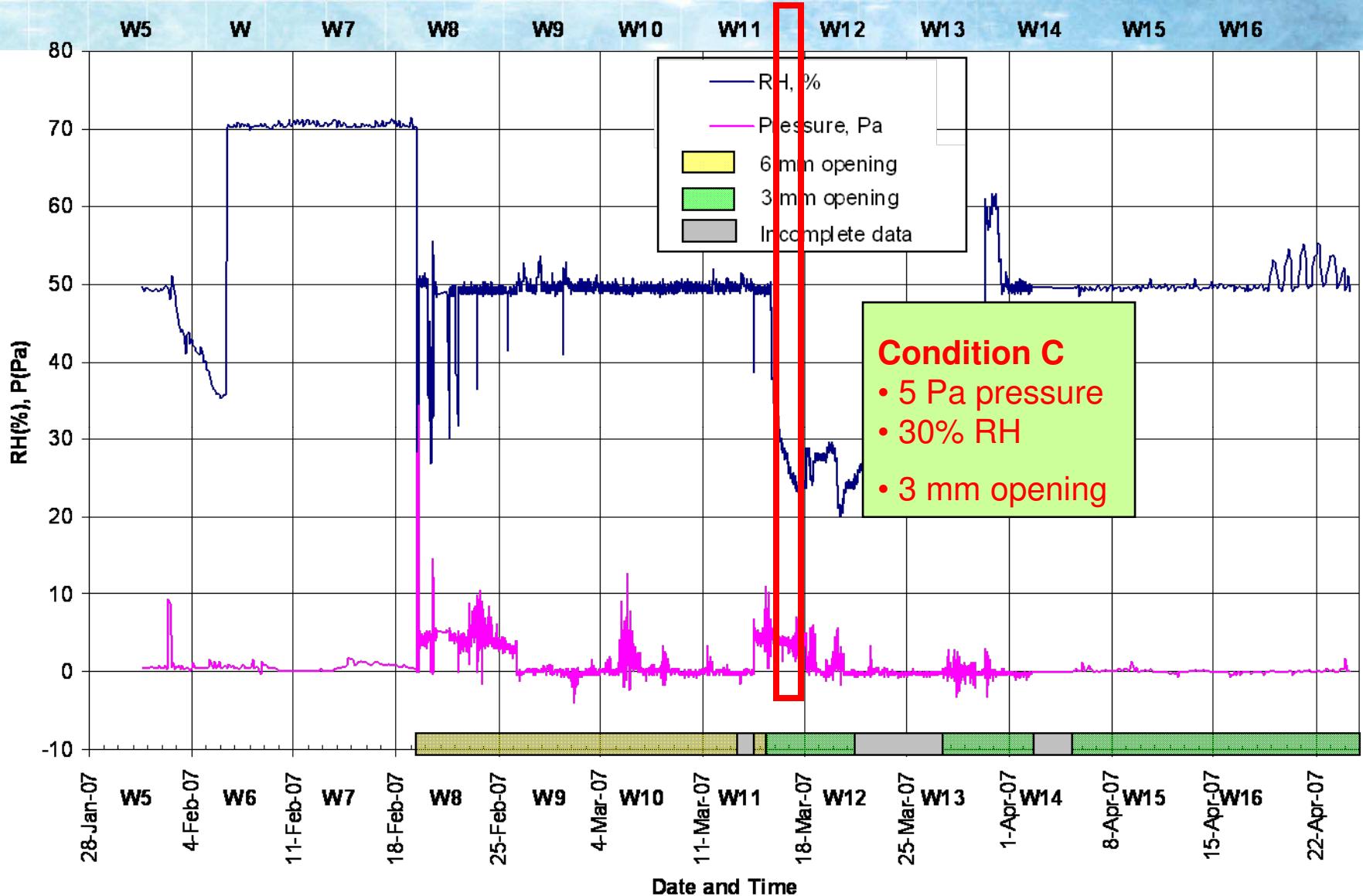
FEWF Chamber RH%, Pressure Vs Time



FEWF Chamber RH%, Pressure Vs Time



FEWF Chamber RH%, Pressure Vs Time



FEWF Chamber RH%, Pressure Vs Time

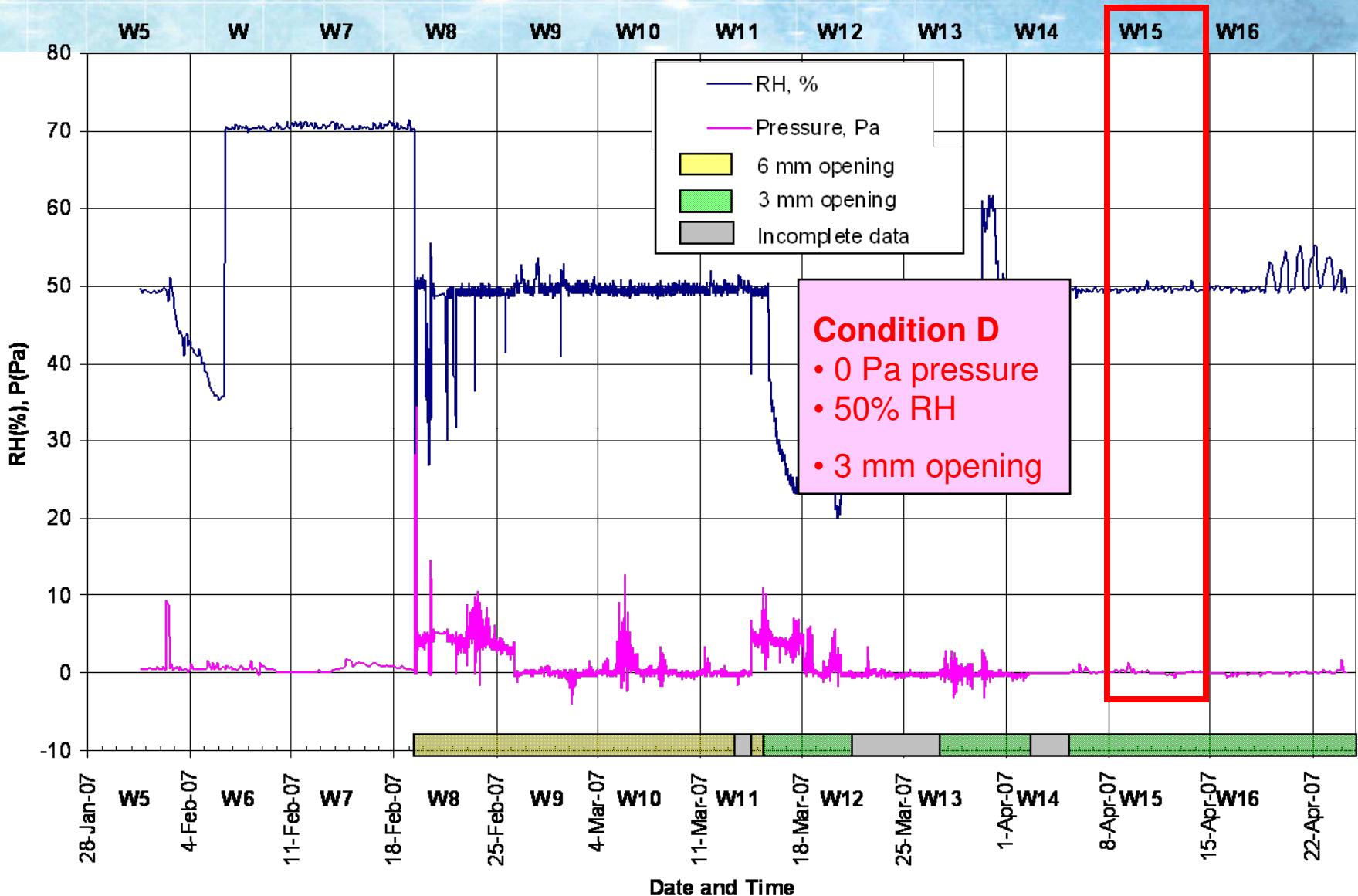
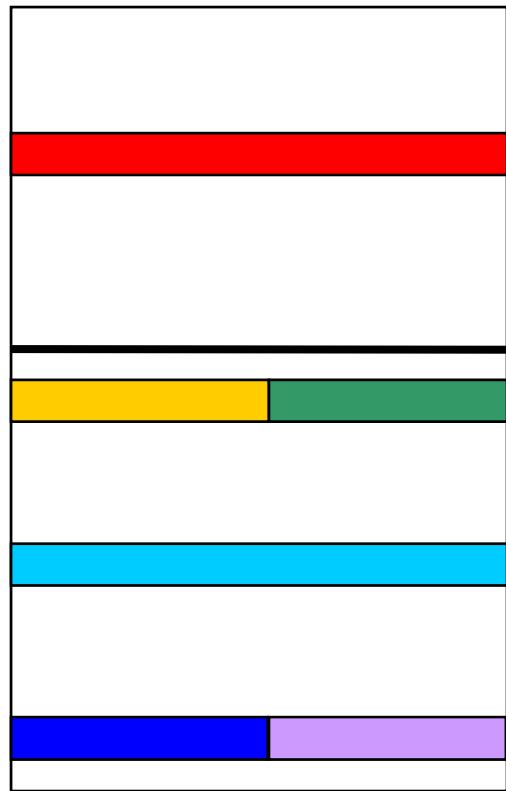






Diagram for Moisture Detection Tape Locations on the interior of the OSB



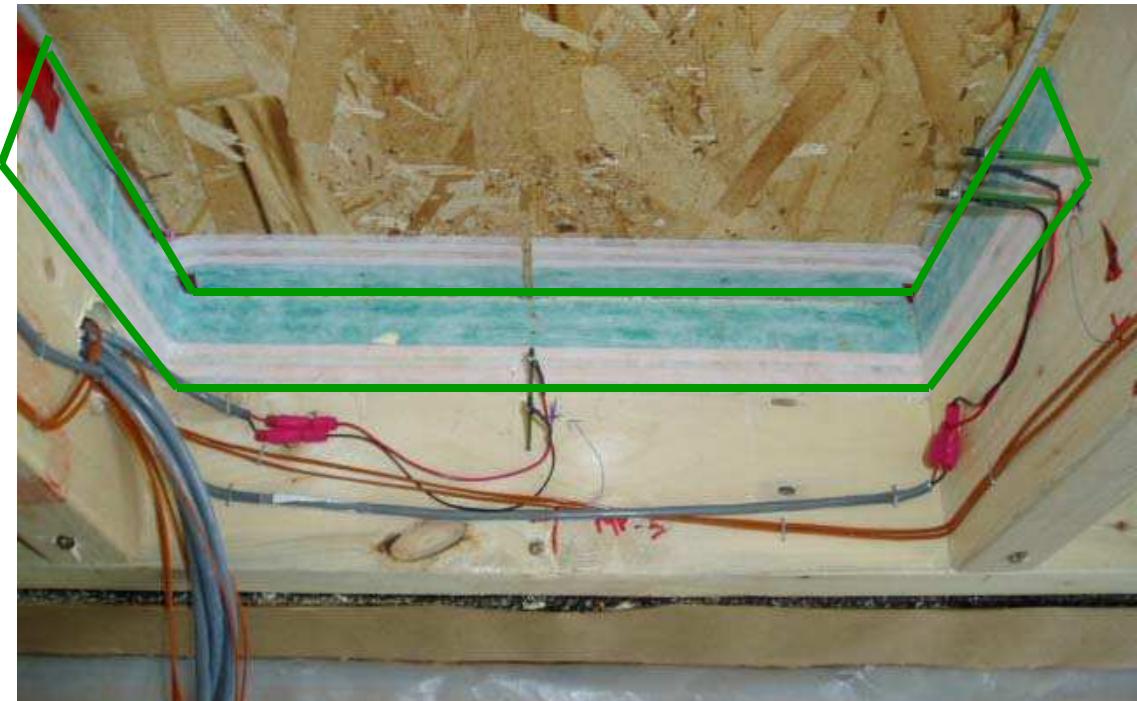
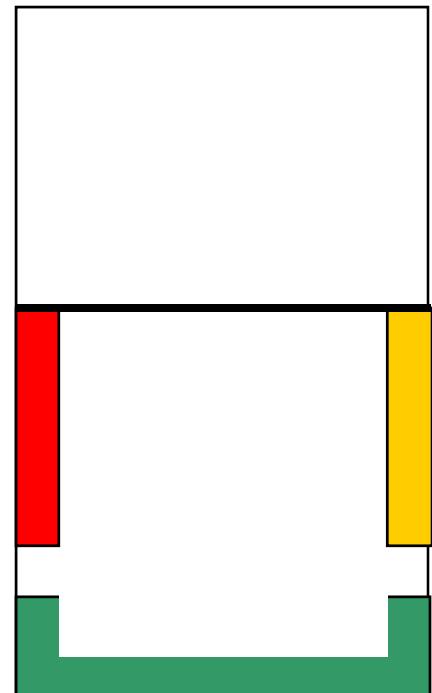
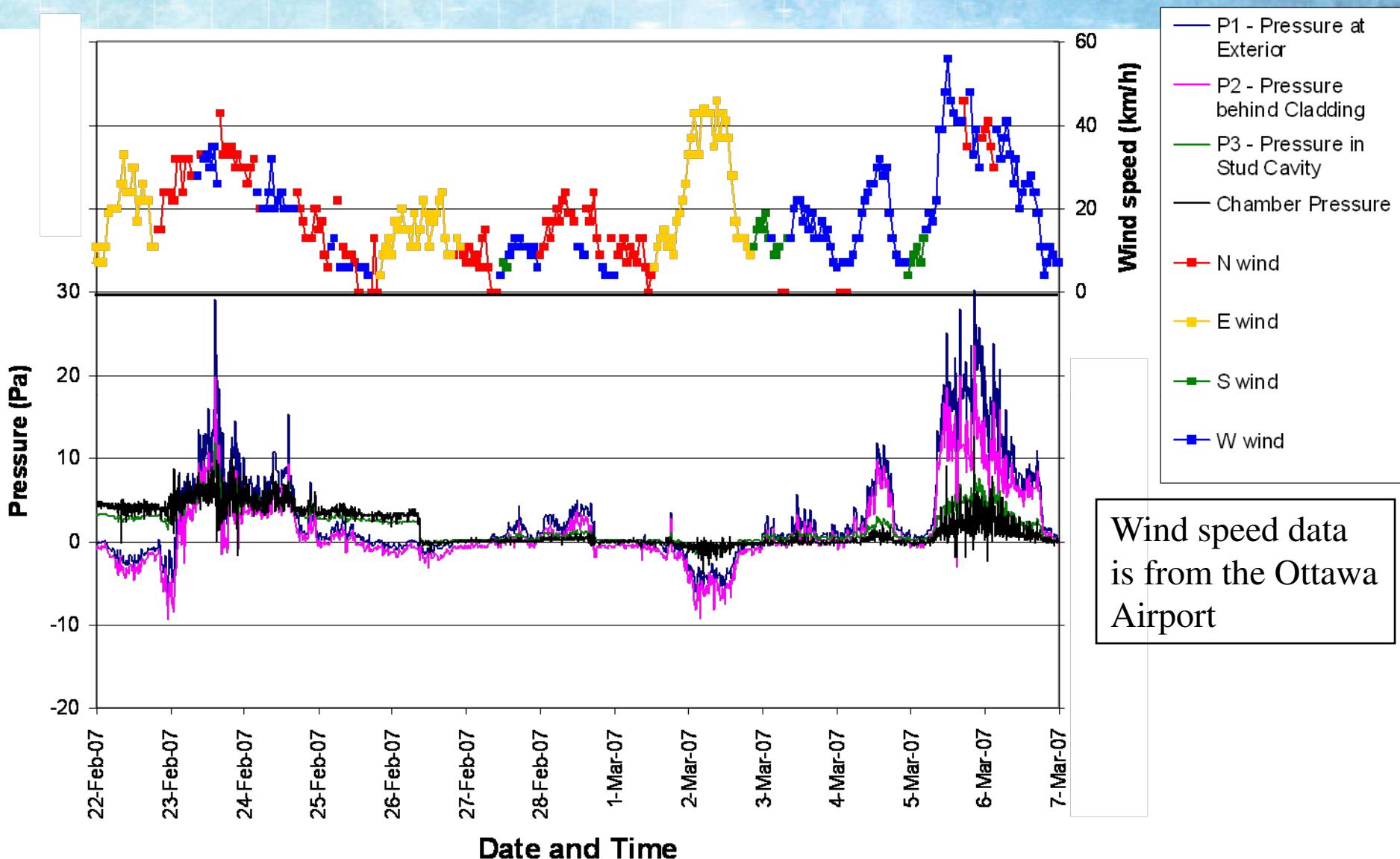


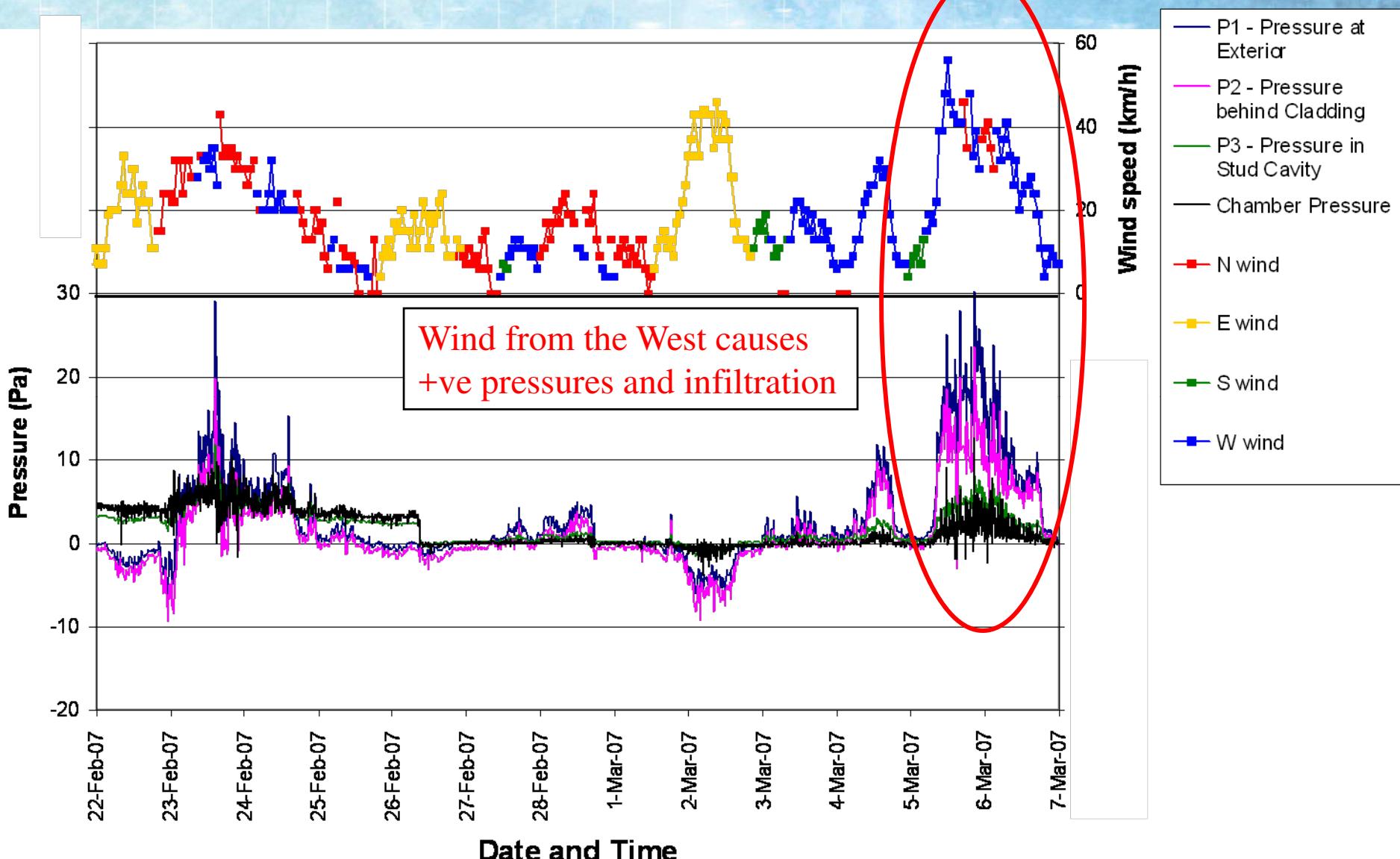
Diagram for Moisture Detection Tape Locations in the Stud Cavity



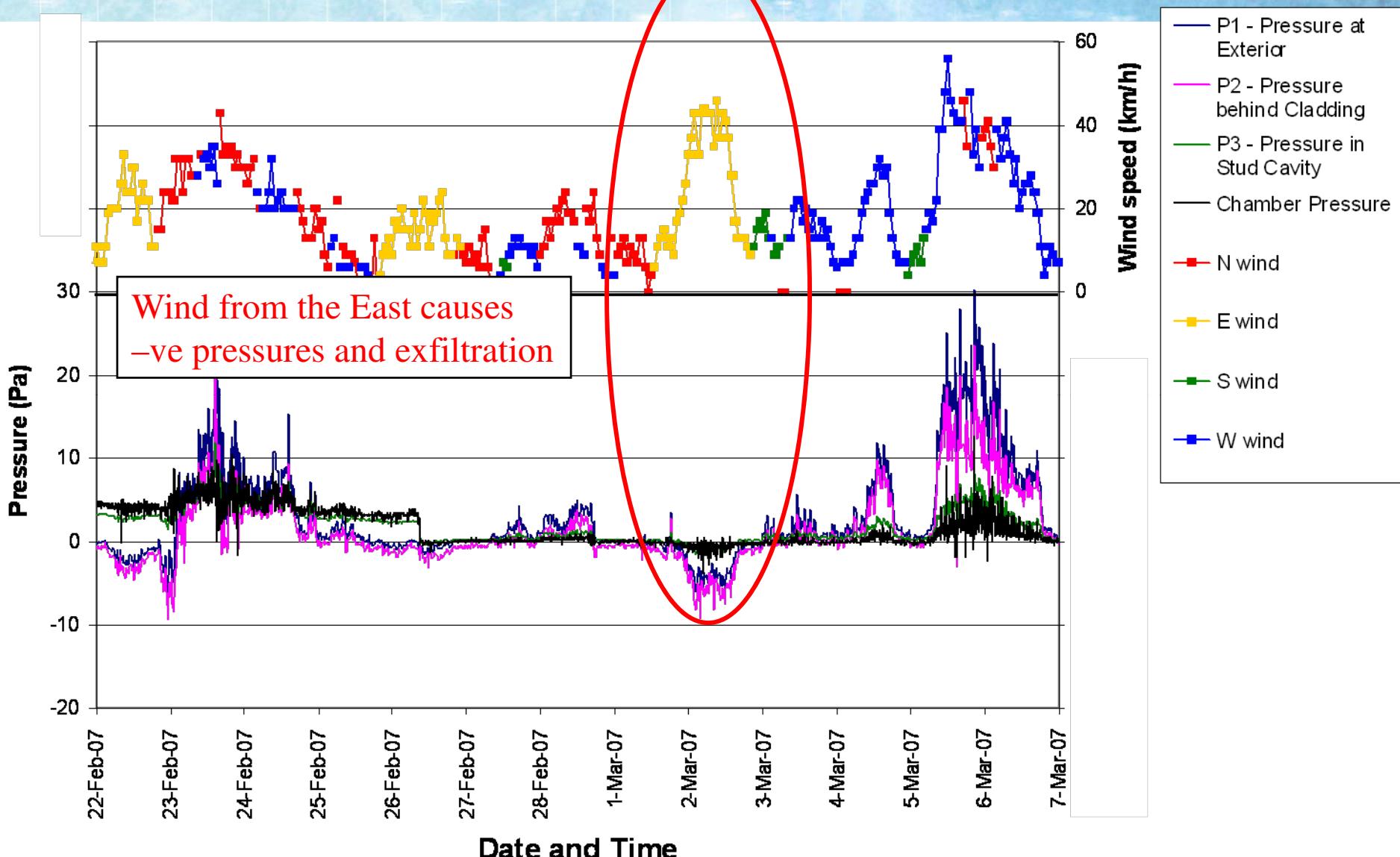
Pressure, Wind speed and direction



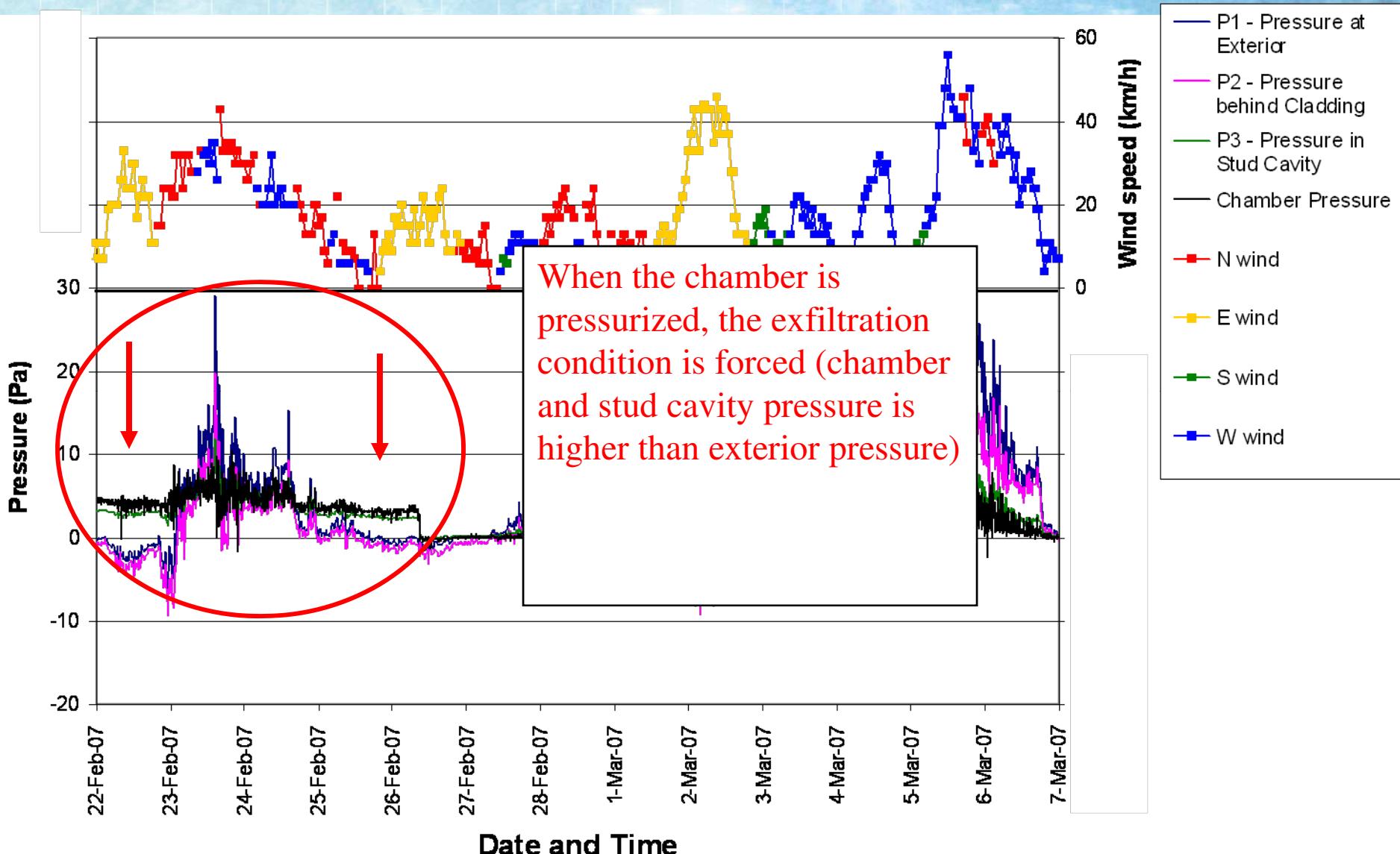
Pressure, Wind speed and direction



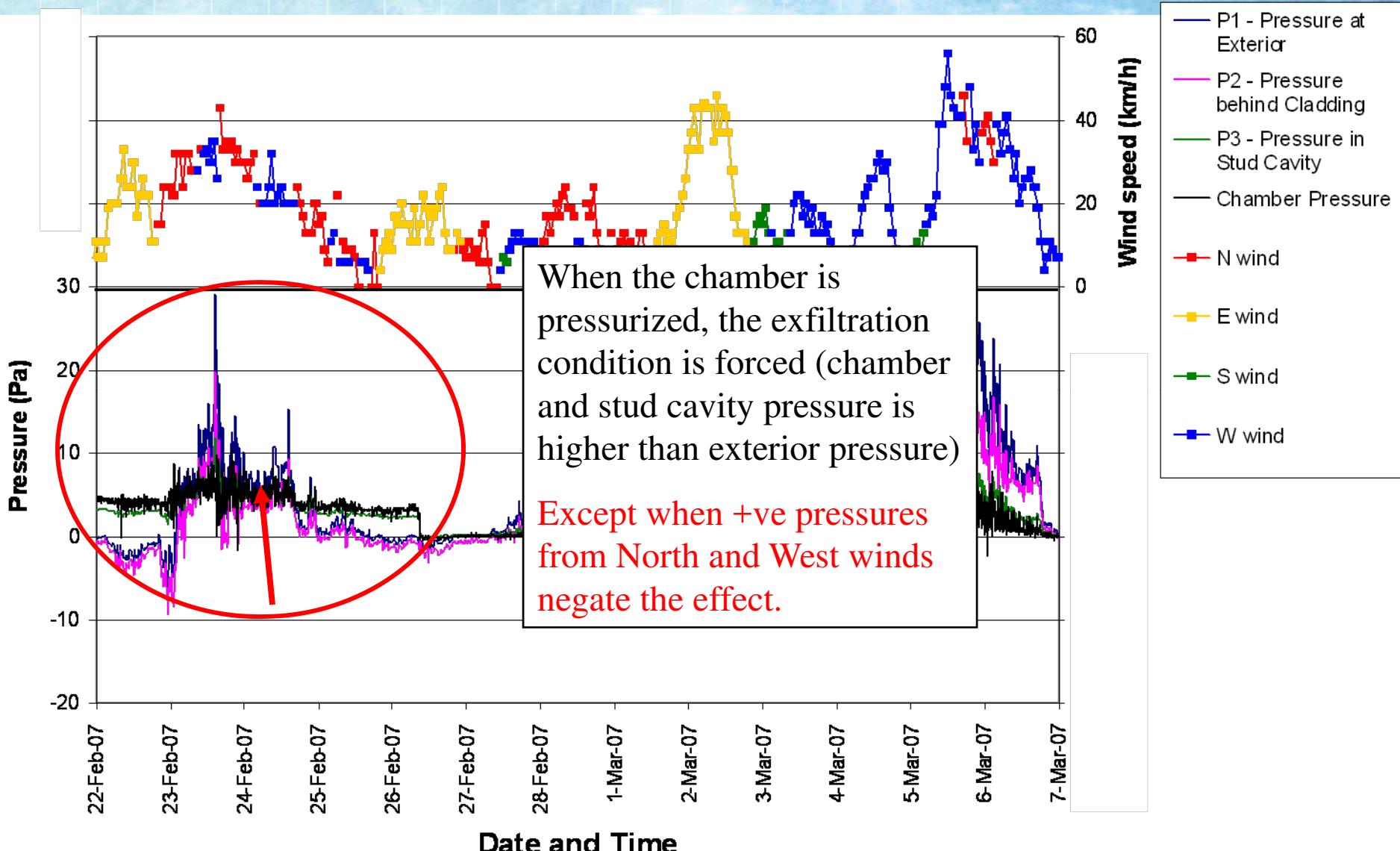
Pressure, Wind speed and direction



Pressure, Wind speed and direction



Pressure, Wind speed and direction

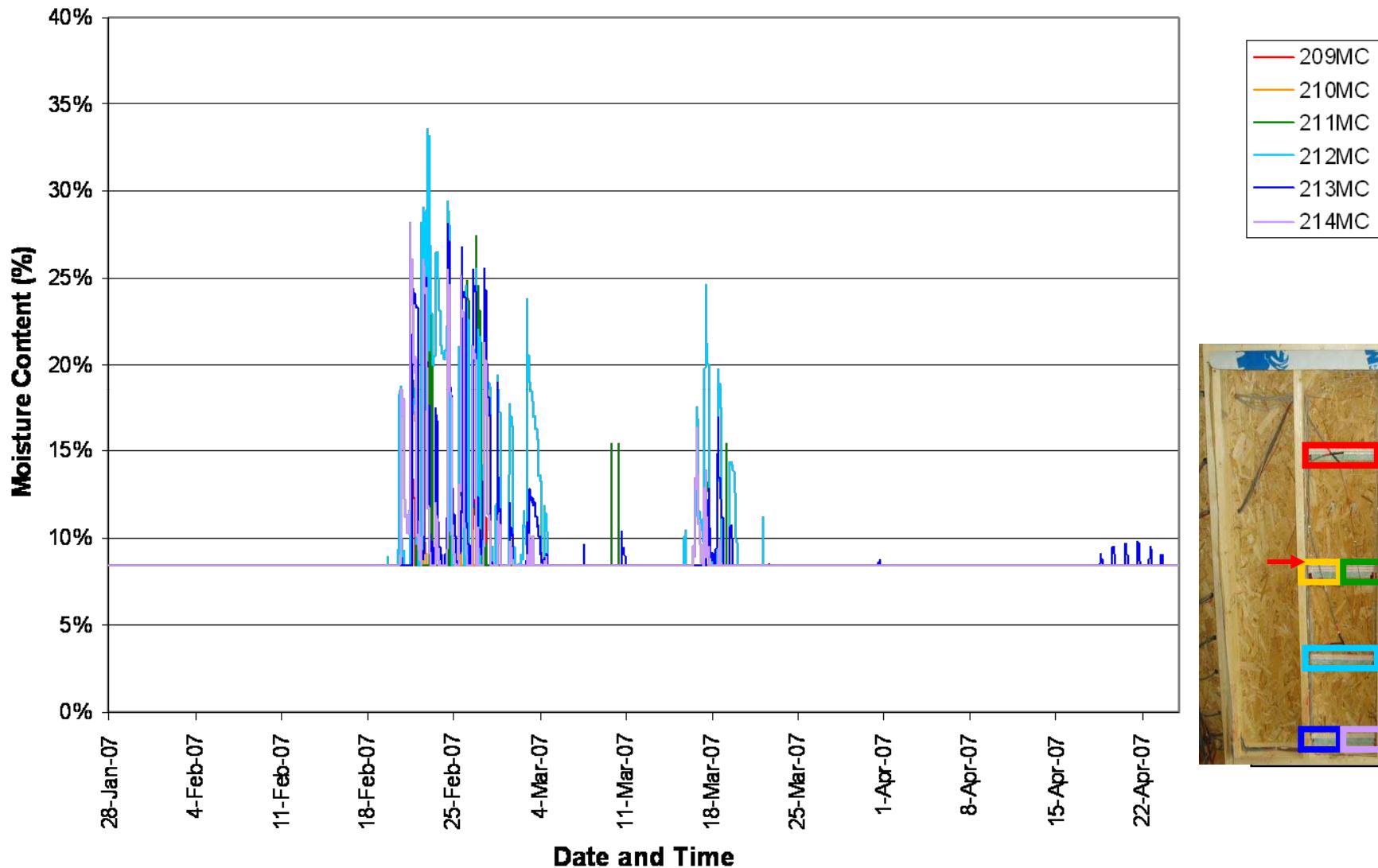


Conditions

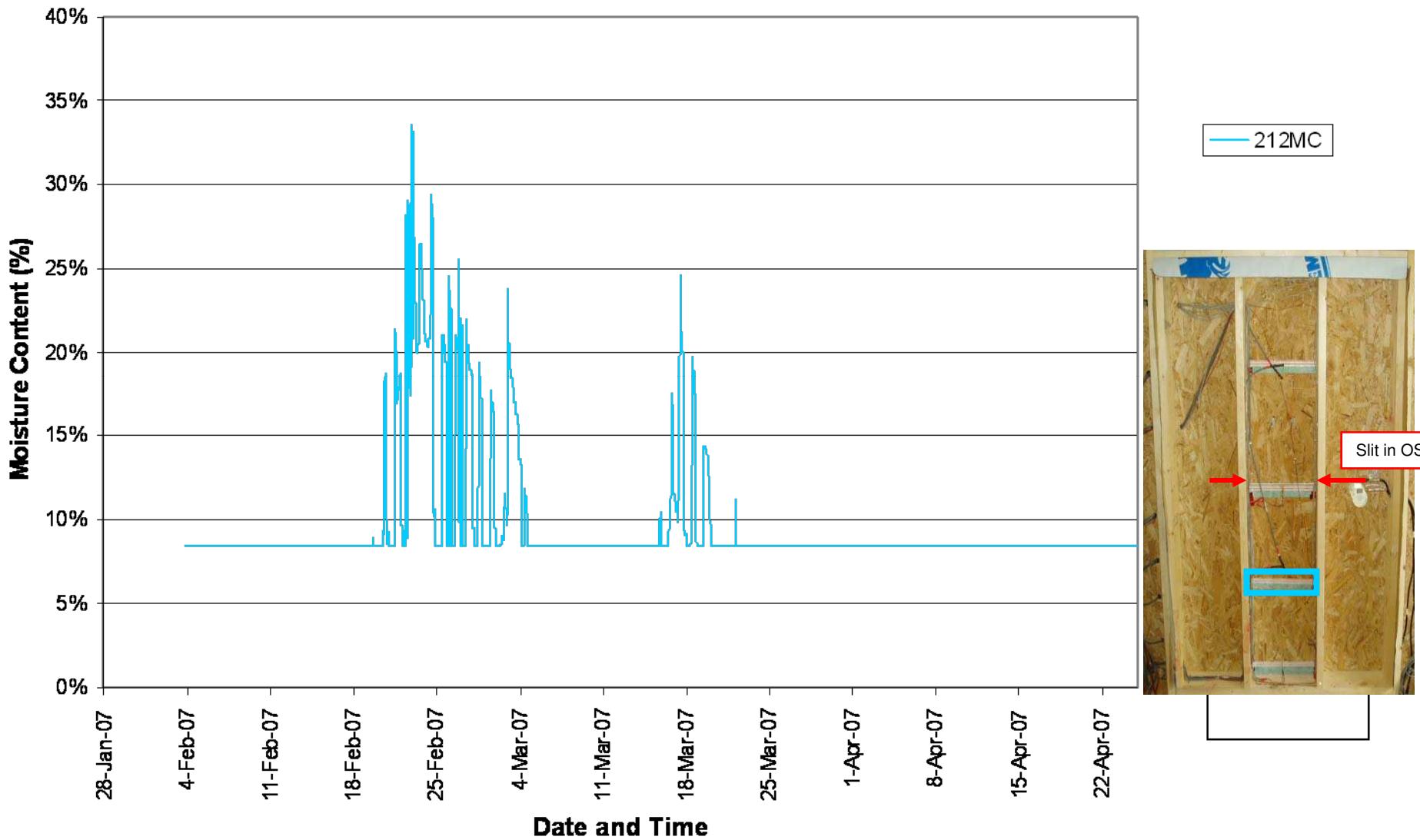
Condition	Pressure	RH	Opening	Week
A	0 Pa	70%	None	7
B	5 Pa	50%	6 mm	3 days in week 8 (22 to 24 Feb)
C	5 Pa	~30%	3 mm	2 days in week 11 (16 to 17 Mar)
D	0 Pa	50%	3 mm	15

All data presented are averaged over the test period indicated above

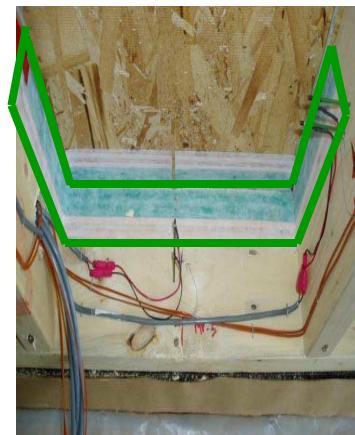
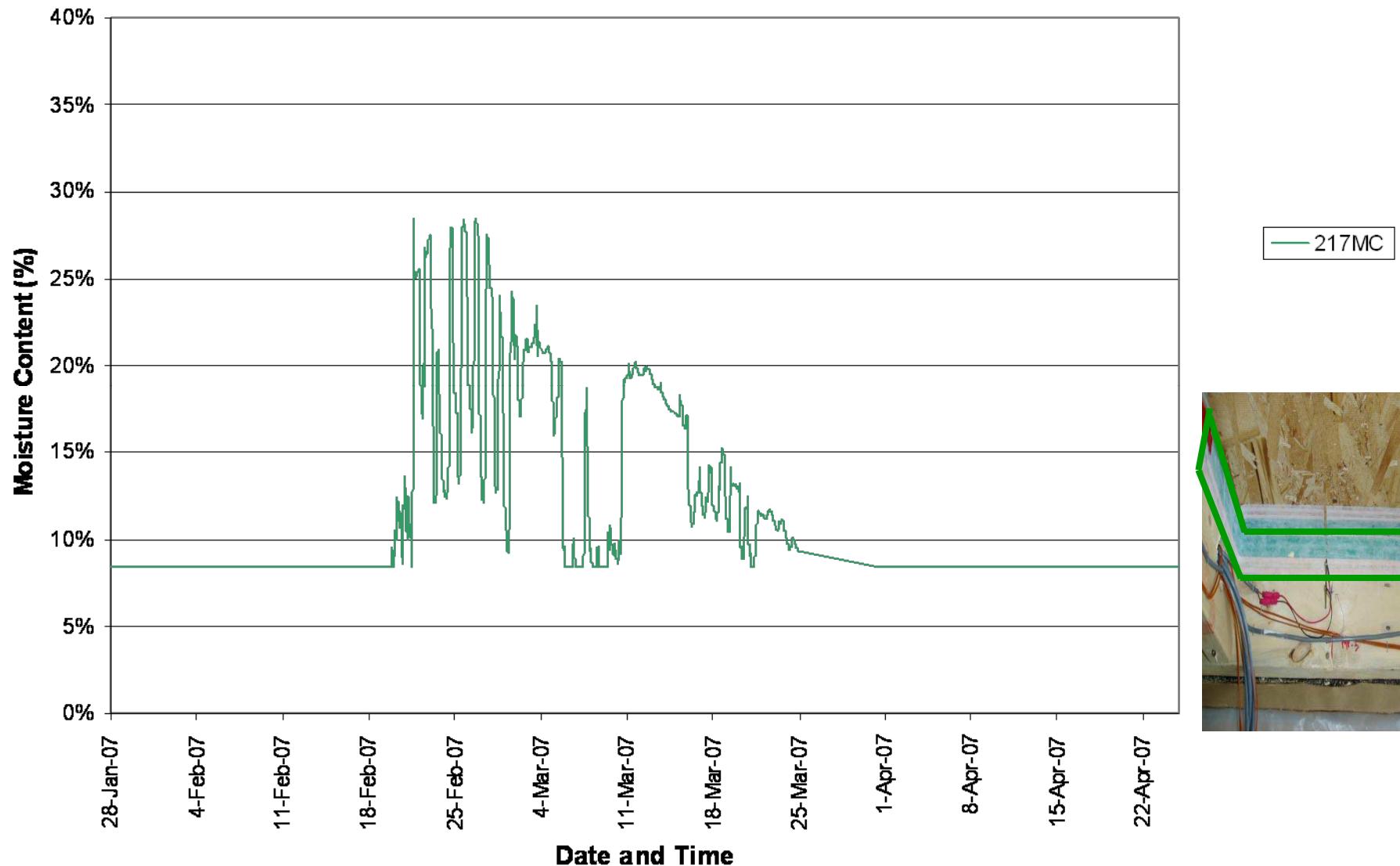
Moisture Content - Wall 2 Interior OSB



Moisture Content - Wall 2 Interior OSB



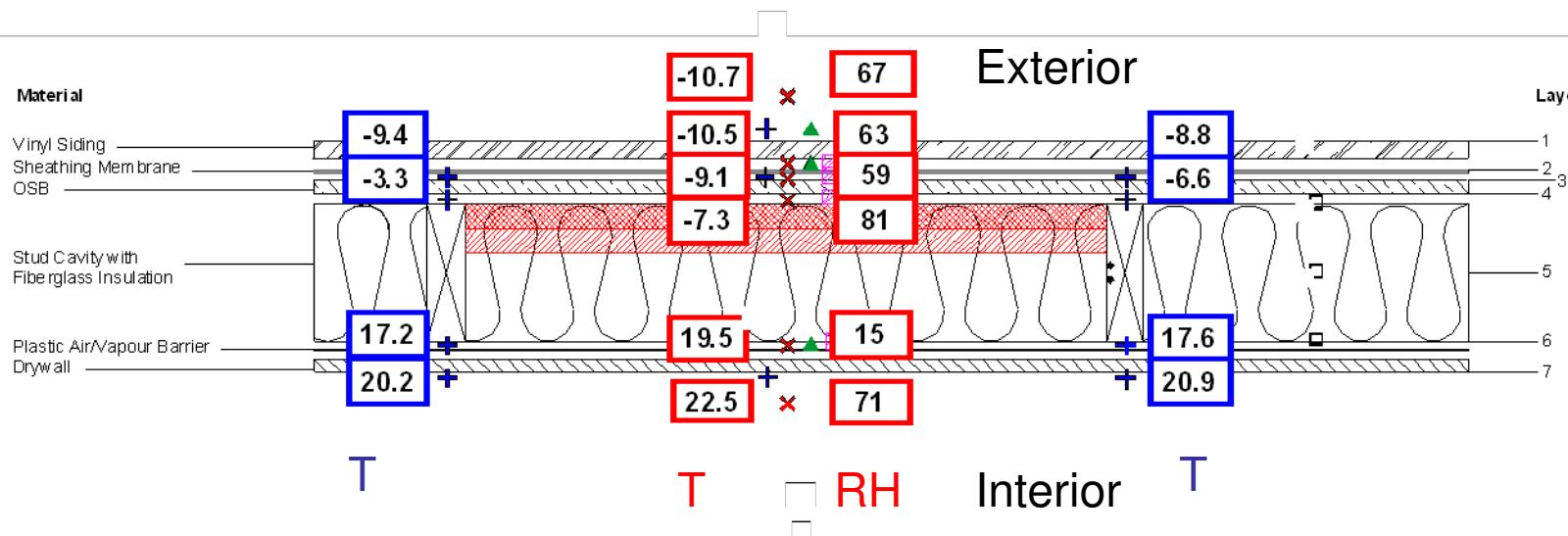
Moisture Content - Wall 2 Stud Cavity



Condition A: 0 Pa, 70% RH, no opening

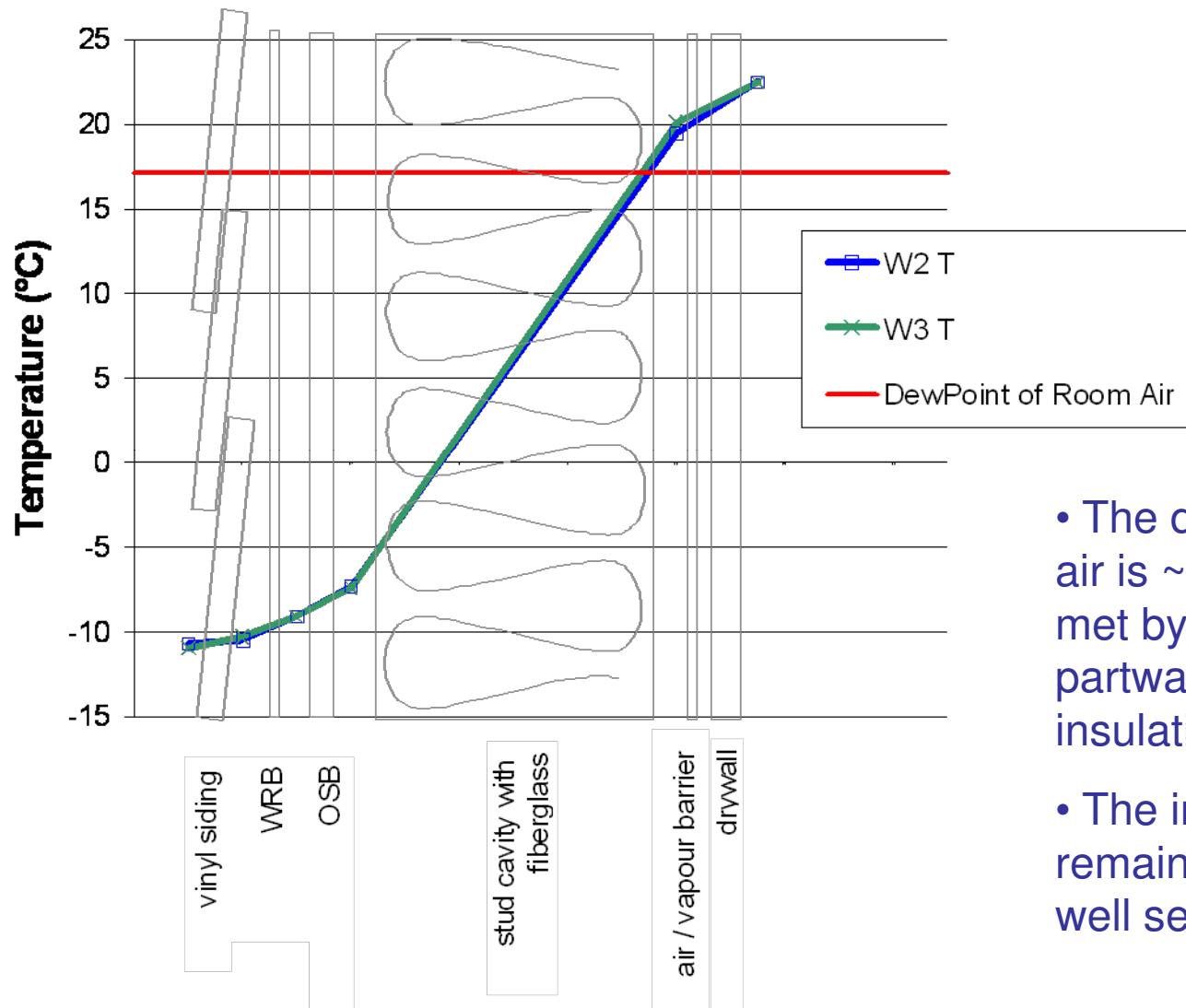
Wall 2 Horizontal Cross Section

Week 07 11-Feb-07



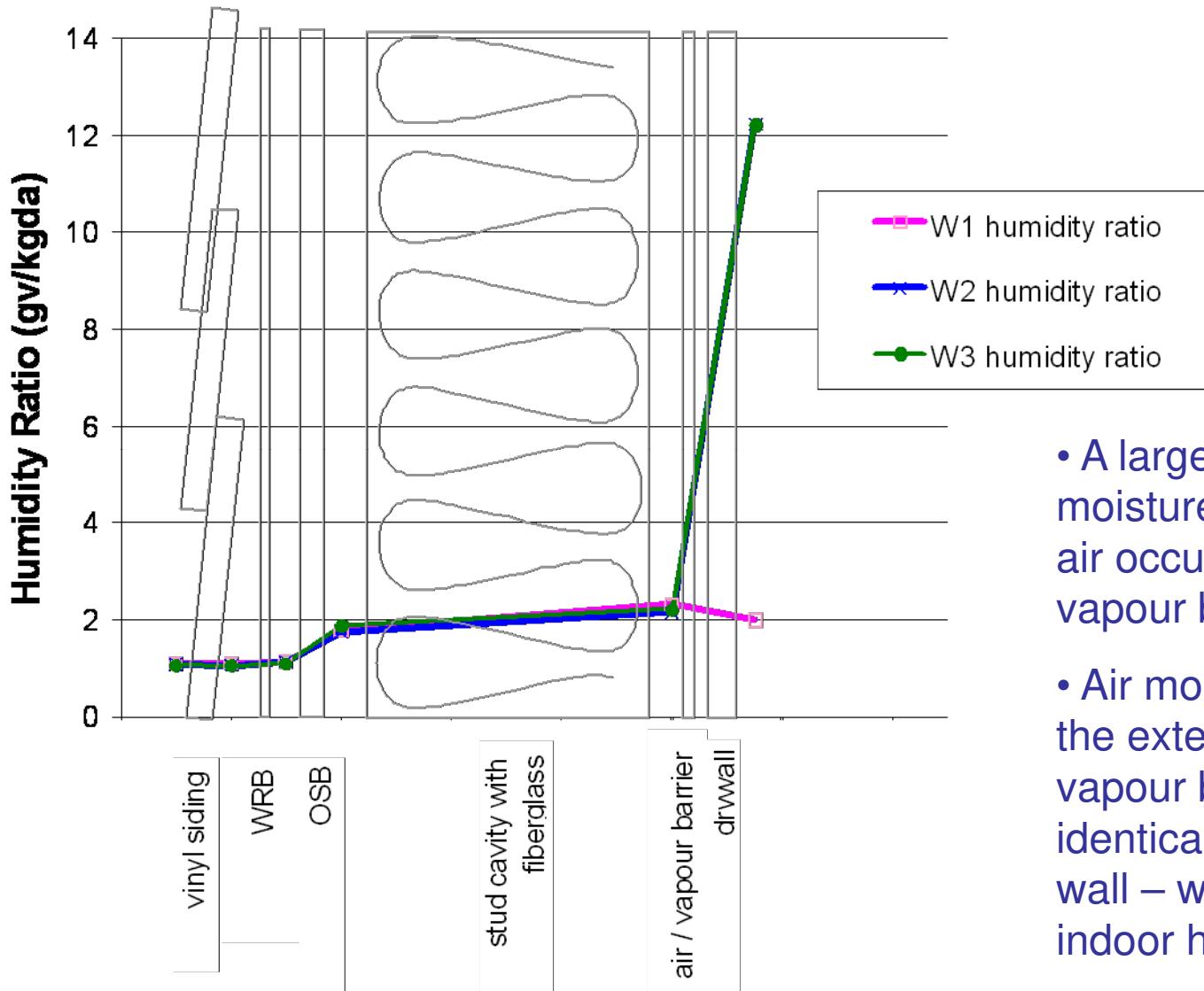
- Despite the high humidity on the interior of the room (71%), the humidity behind the air/vapour barrier is low, 15%
 - The location with the highest RH is the interior of the OSB, at ~81% - still below dewpoint

Condition A: 0 Pa, 70% RH, no opening



- The dewpoint of room air is $\sim 17^{\circ}\text{C}$, a condition met by temperatures partway through the insulation
- The interior of the wall remains dry due to being well sealed

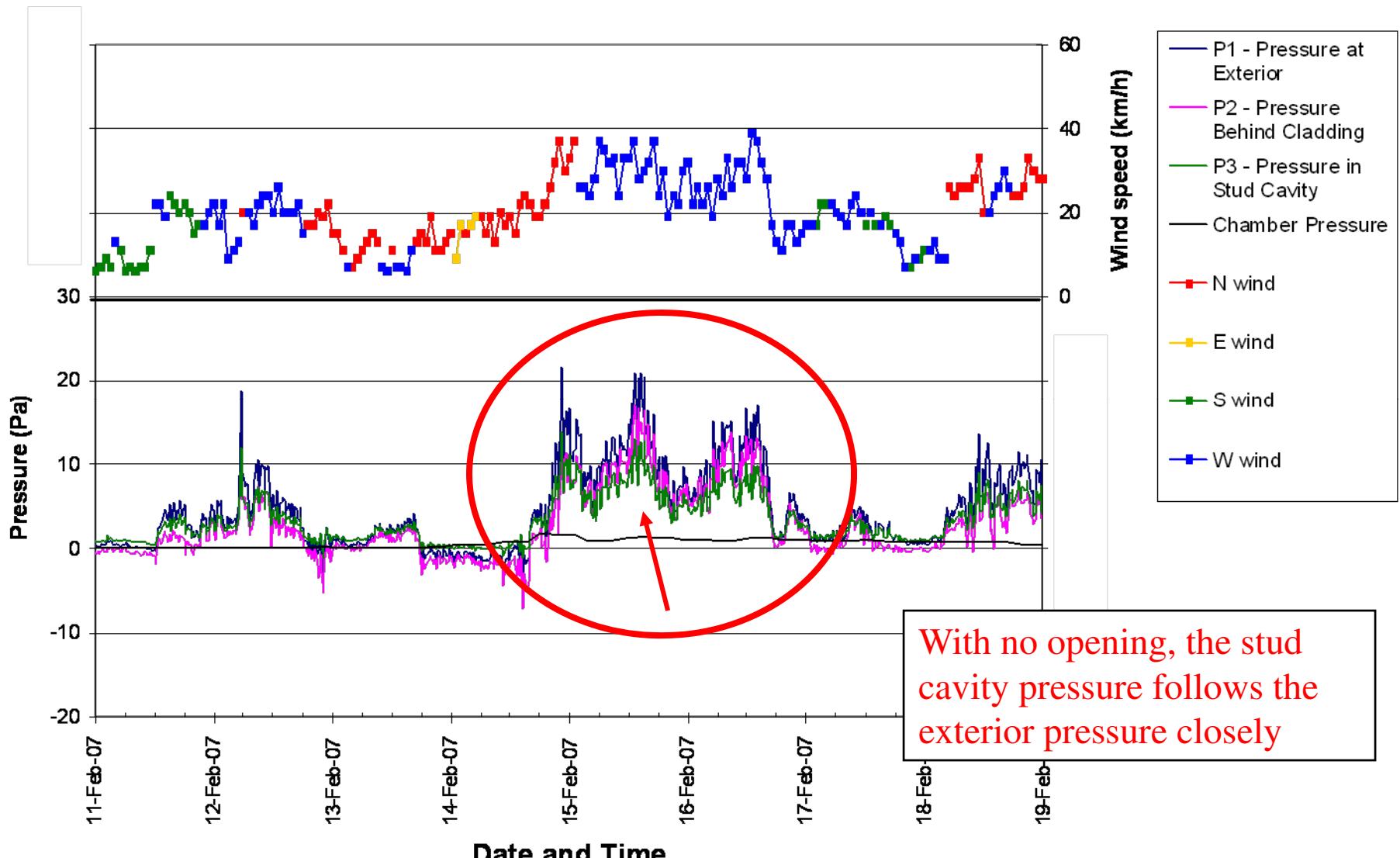
Condition A: 0 Pa, 70% RH, no opening



- A large drop in the moisture content of the air occurs across the vapour barrier
- Air moisture content on the exterior side of the vapour barrier is nearly identical to the reference wall – with no added indoor humidity loads

Condition A: 0 Pa, 70% RH, no opening

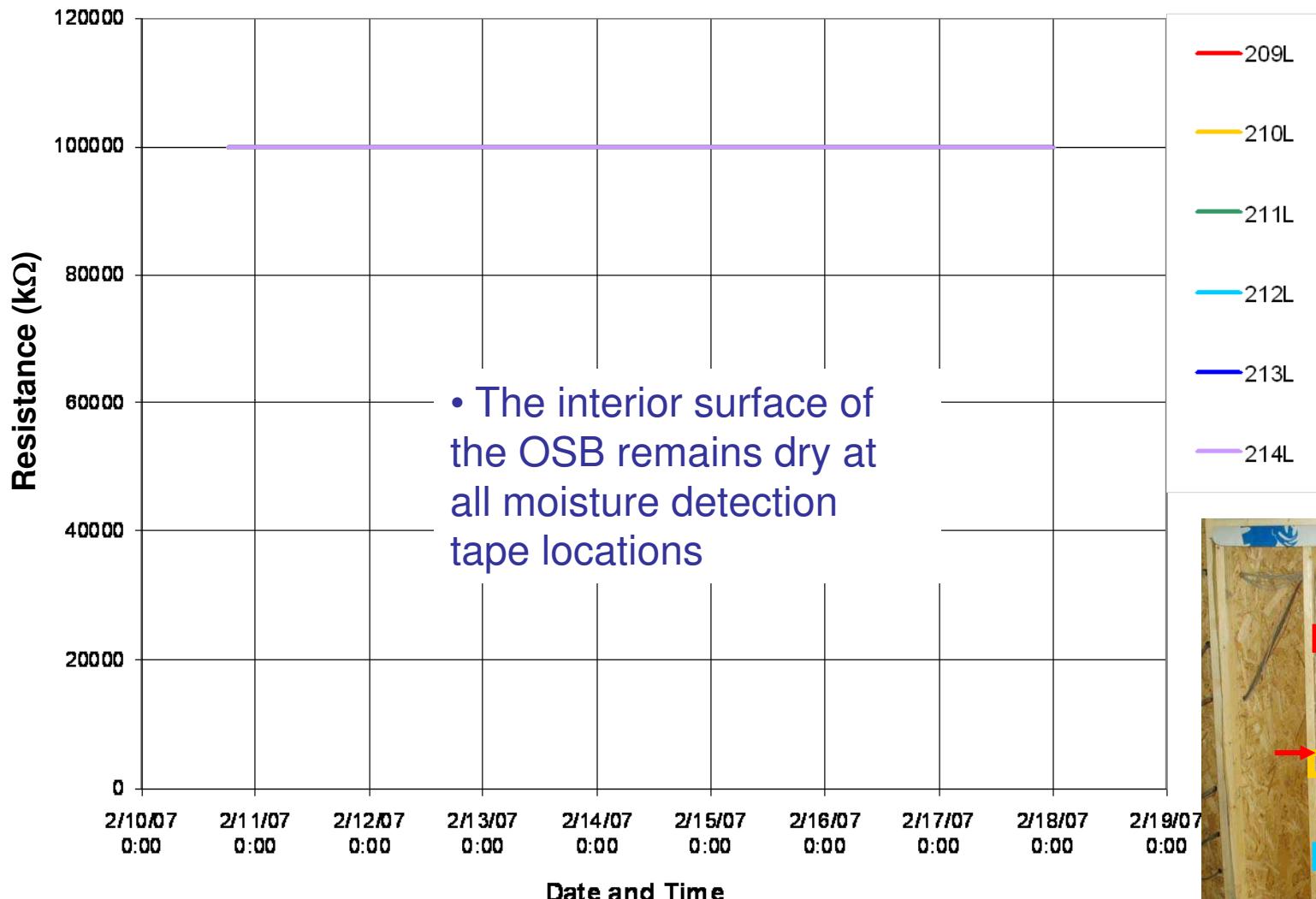
Pressure, Wind speed and direction



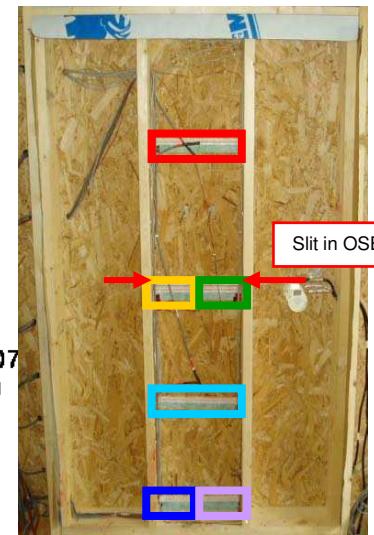
Condition A: 0 Pa, 70% RH, no opening

11-Feb-07

FEWF Wall 2 - Interior of OSB - Layer 4 - Liquid



- The interior surface of the OSB remains dry at all moisture detection tape locations

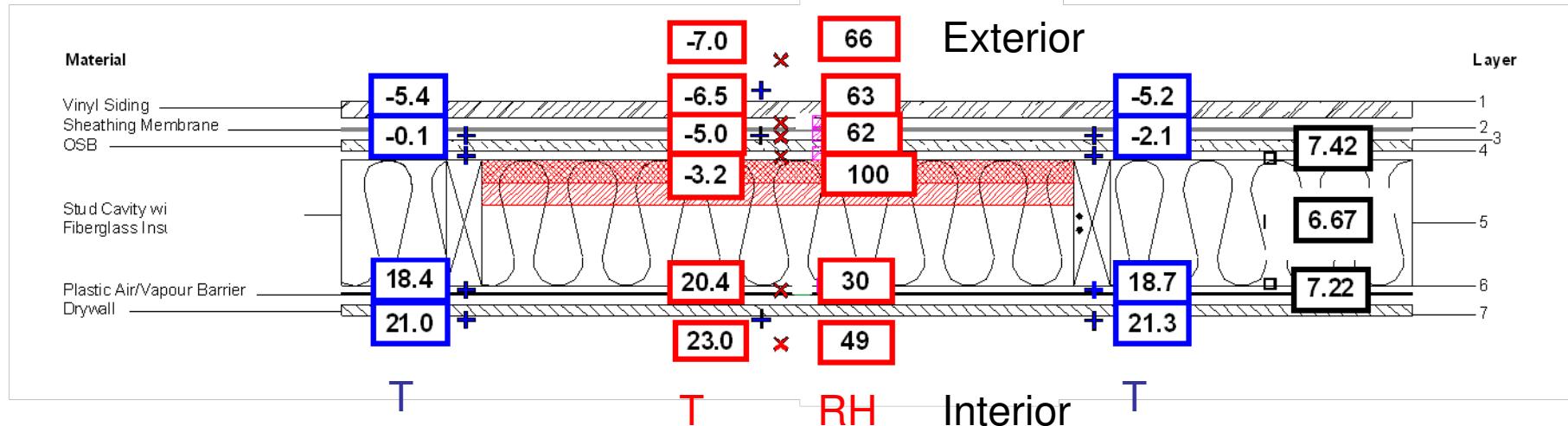


Condition B: 5 Pa, 50% RH, 6mm opening

Wall 2 Horizontal Cross Section

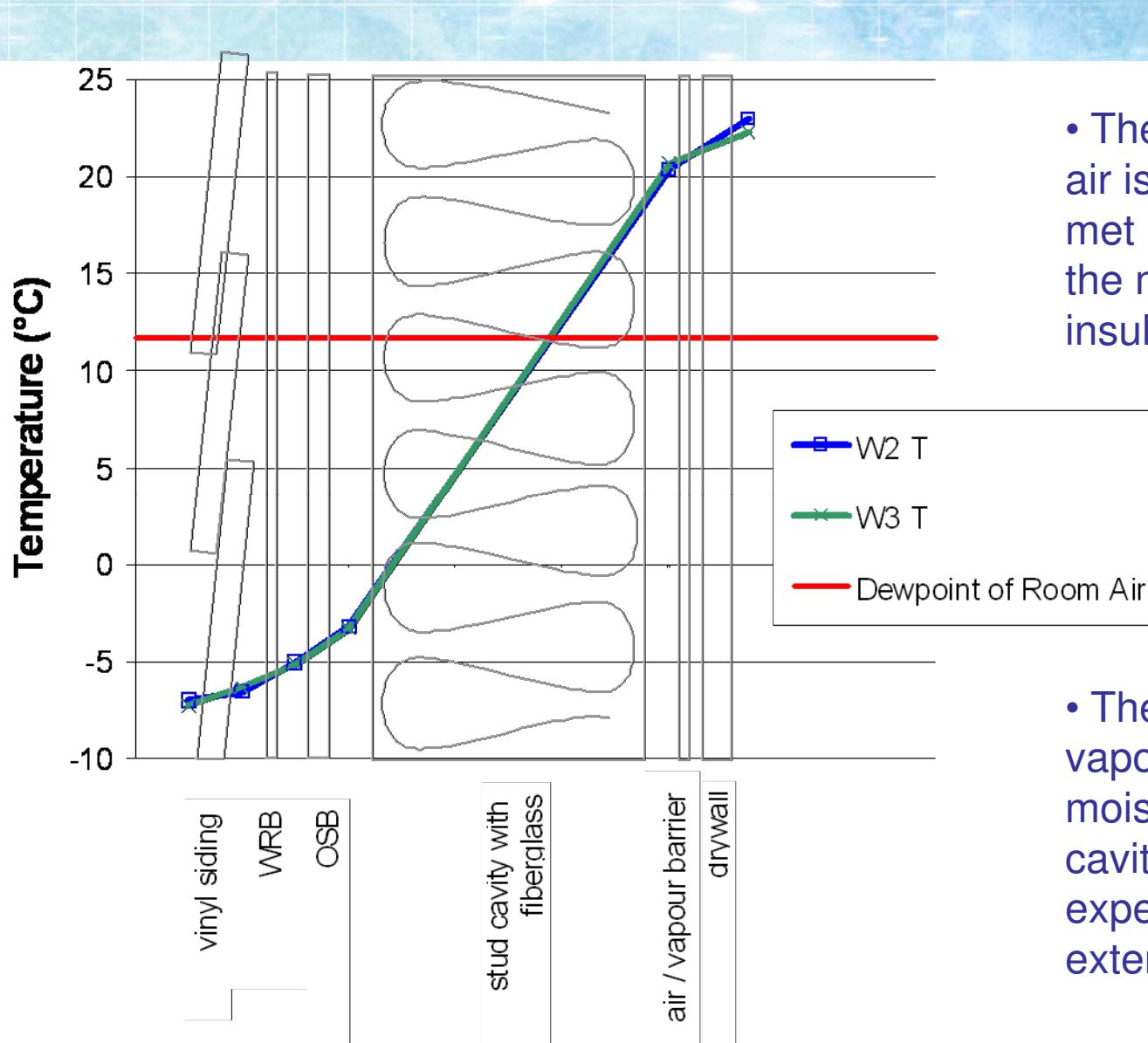
Week 08

22-Feb-07



- The interior of the room is at 49% RH, the humidity behind the air/vapour barrier is 30% RH – indicating that moisture is being introduced through the opening
- The location with the highest RH is the interior of the OSB, at 100% - condensation would be expected

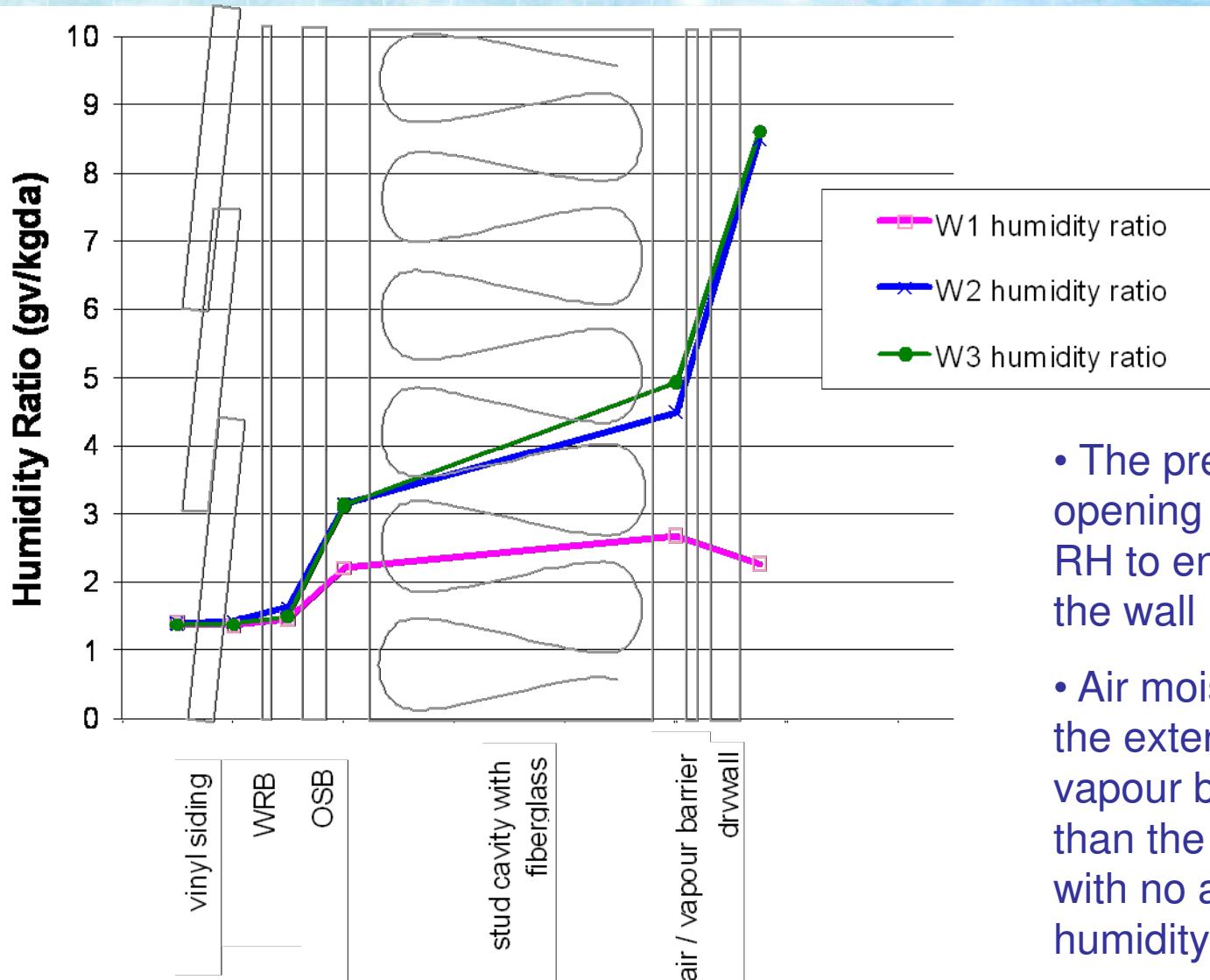
Condition B: 5 Pa, 50% RH, 6mm opening



- The dewpoint of room air is $\sim 12^{\circ}\text{C}$, a condition met by temperatures at the middle of the insulation

- The opening in the vapour barrier allows moisture to enter the cavity, condensation is expected anywhere to the exterior of the insulation

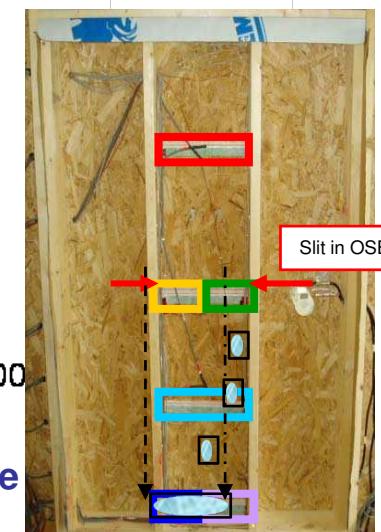
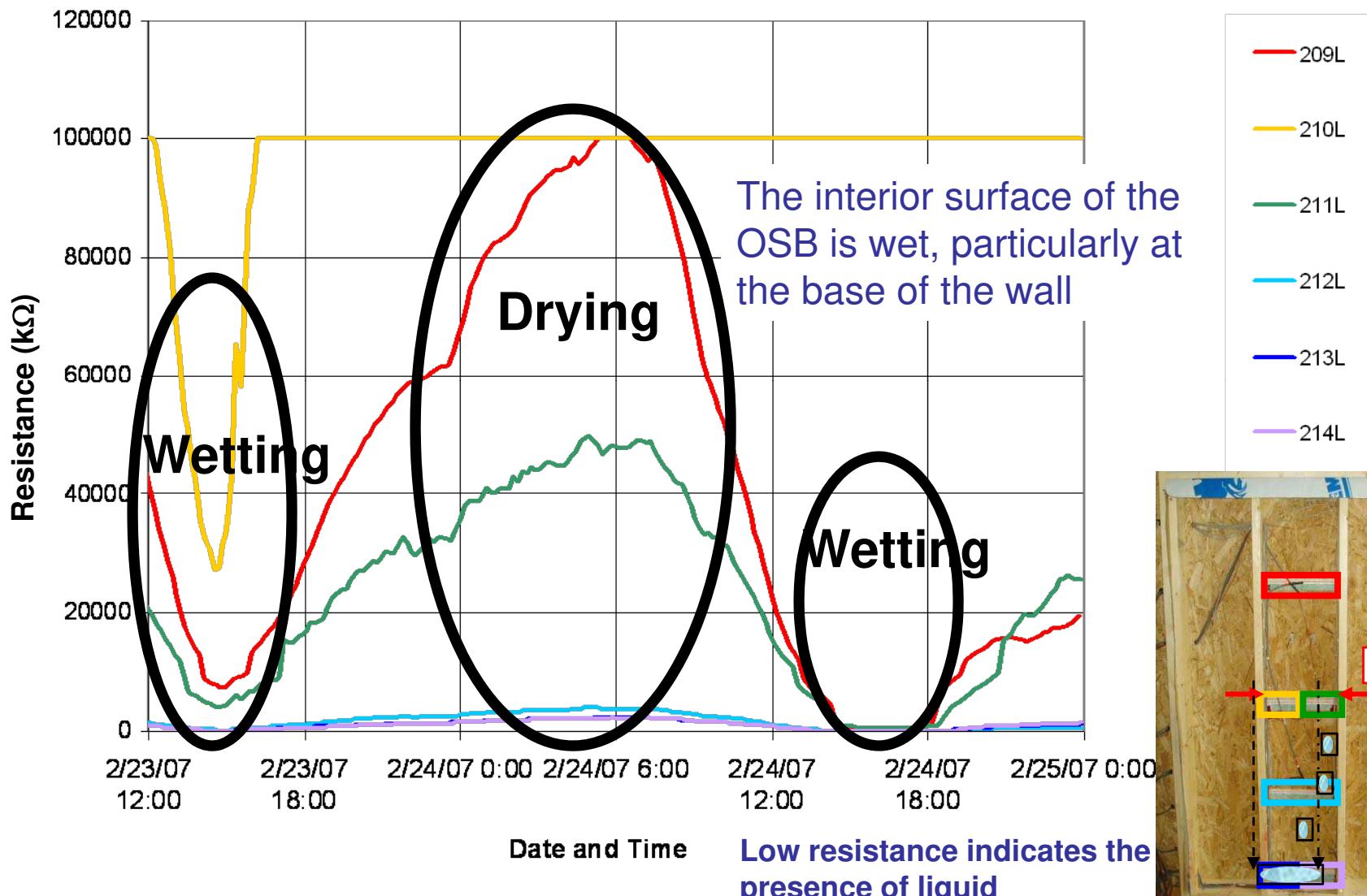
Condition B: 5 Pa, 50% RH, 6mm opening



- The pressure and opening allow the high RH to enter the interior of the wall
- Air moisture content on the exterior side of the vapour barrier is higher than the reference wall – with no added indoor humidity loads

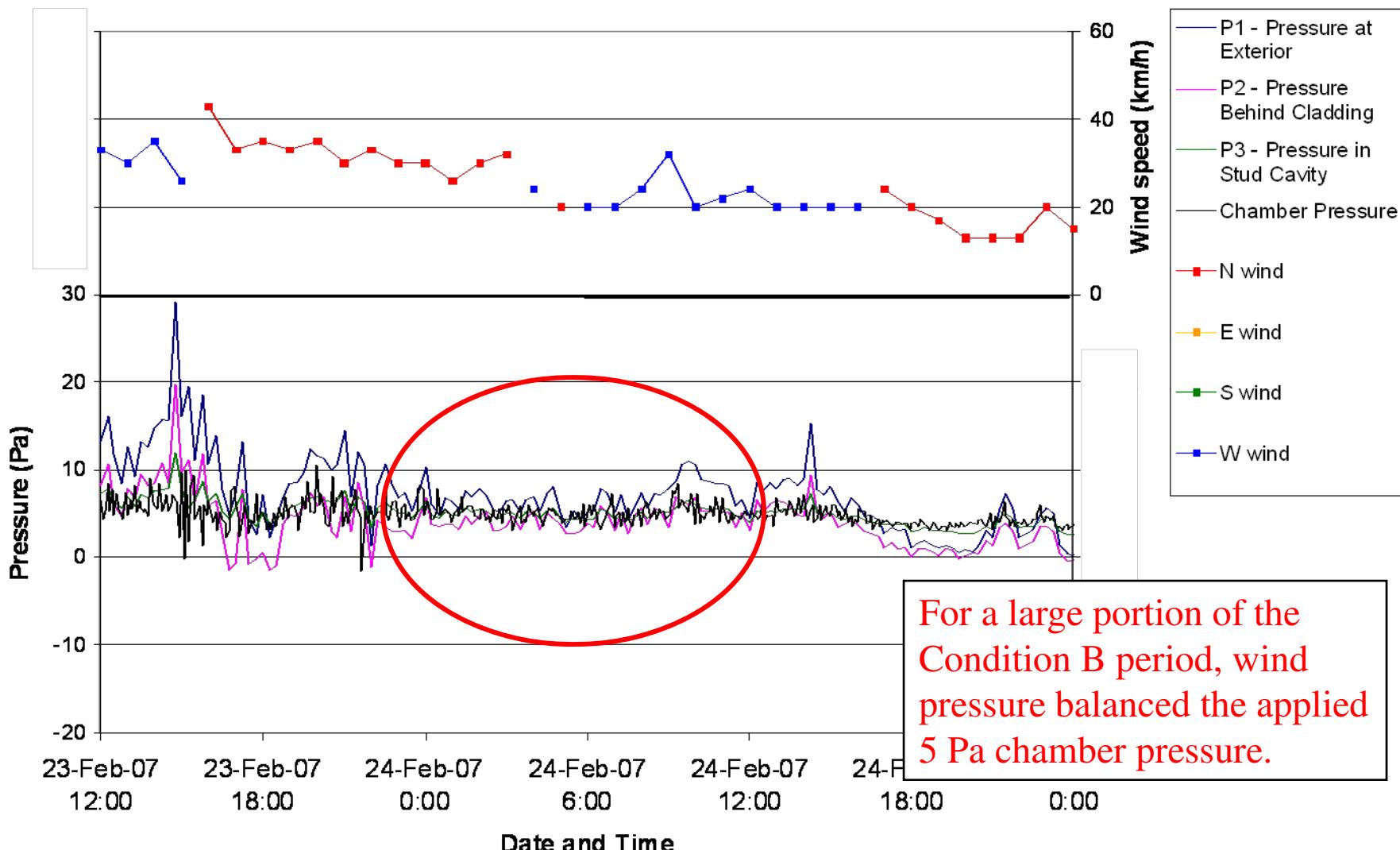
Condition B: 5 Pa, 50% RH, 6mm opening

FEWF Wall 2 - Interior of OSB - Layer 4 - Liquid



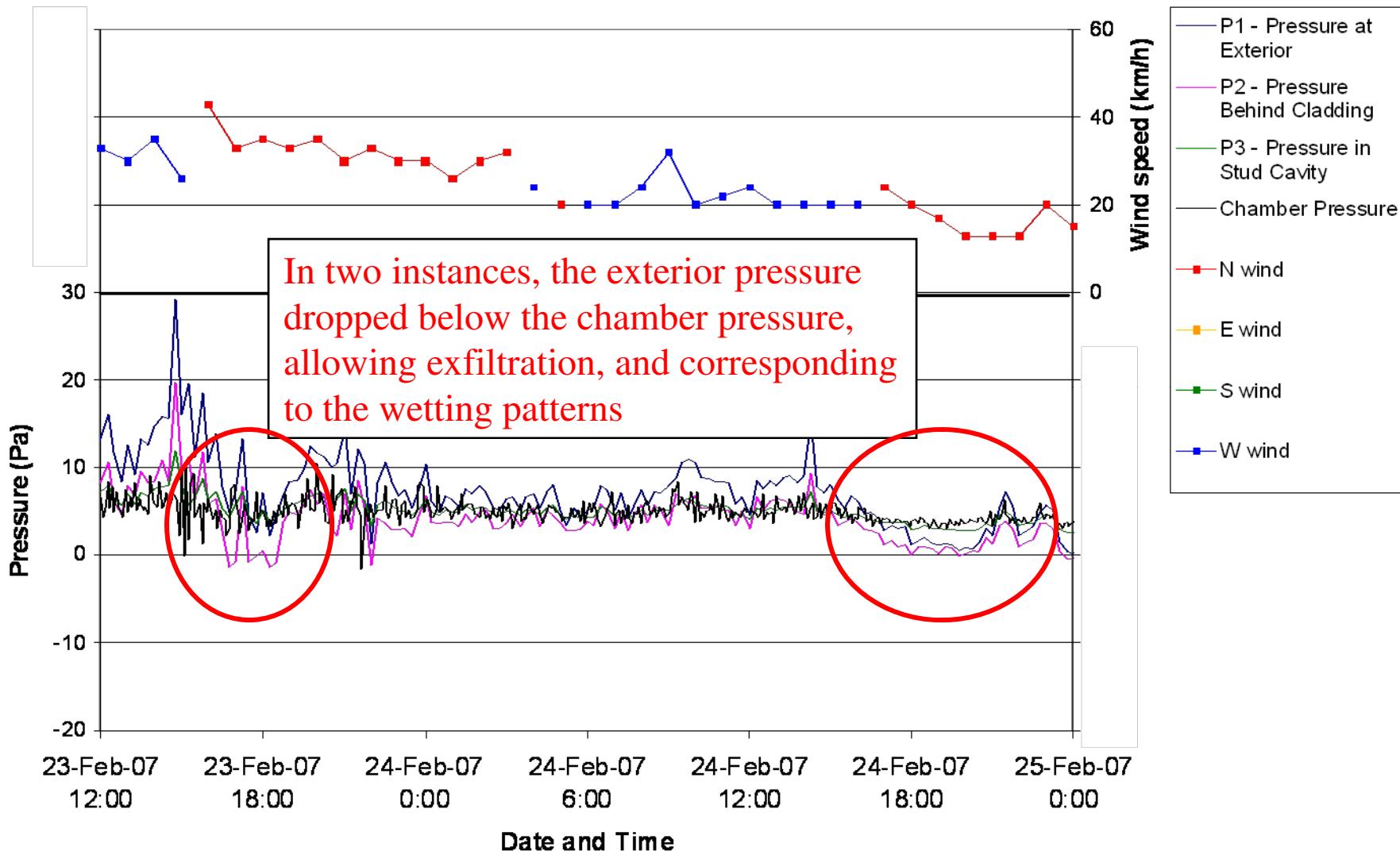
Condition B: 5 Pa, 50% RH, 6mm opening

Pressure, Wind speed and direction



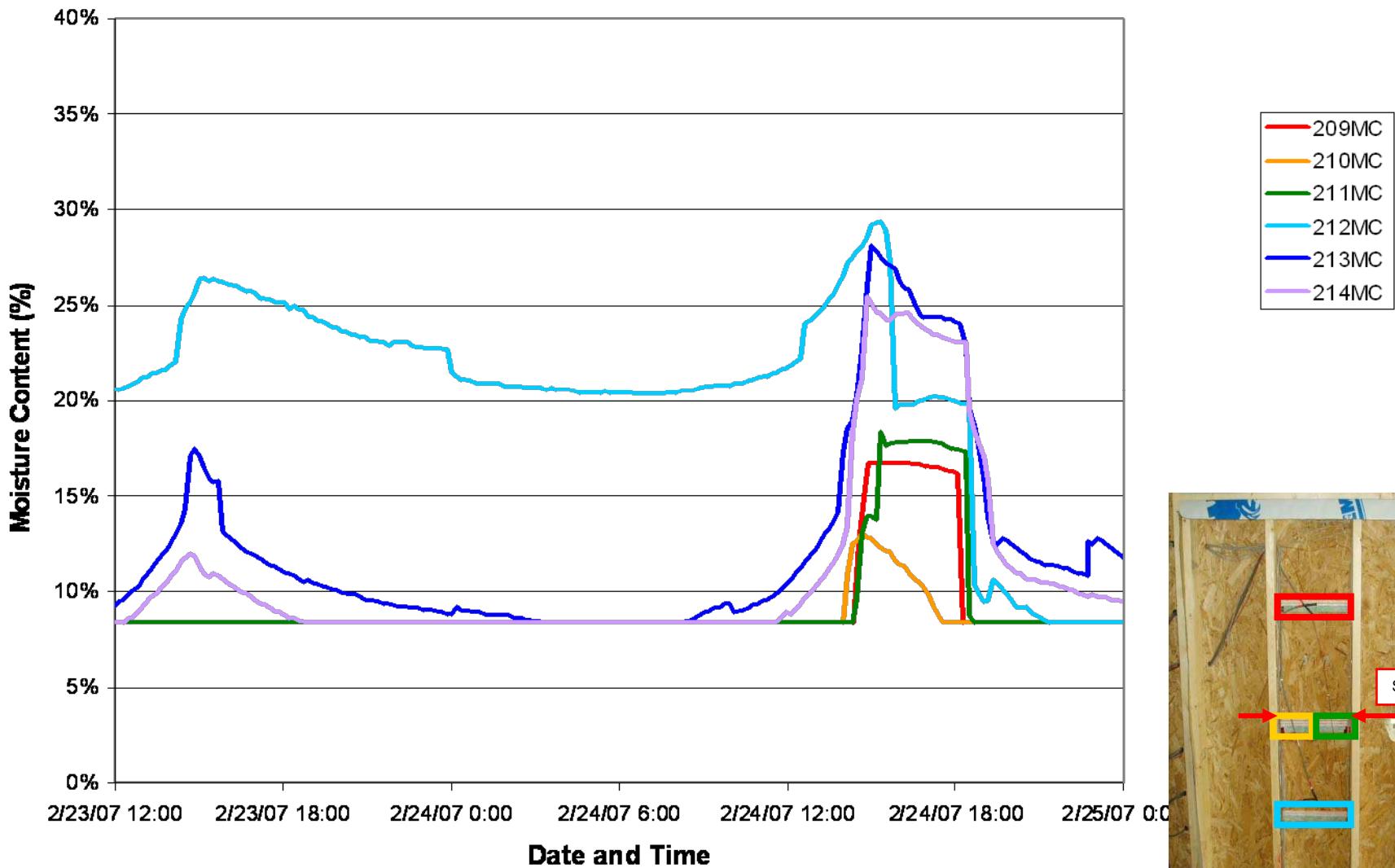
Condition B: 5 Pa, 50% RH, 6mm opening

Pressure, Wind speed and direction



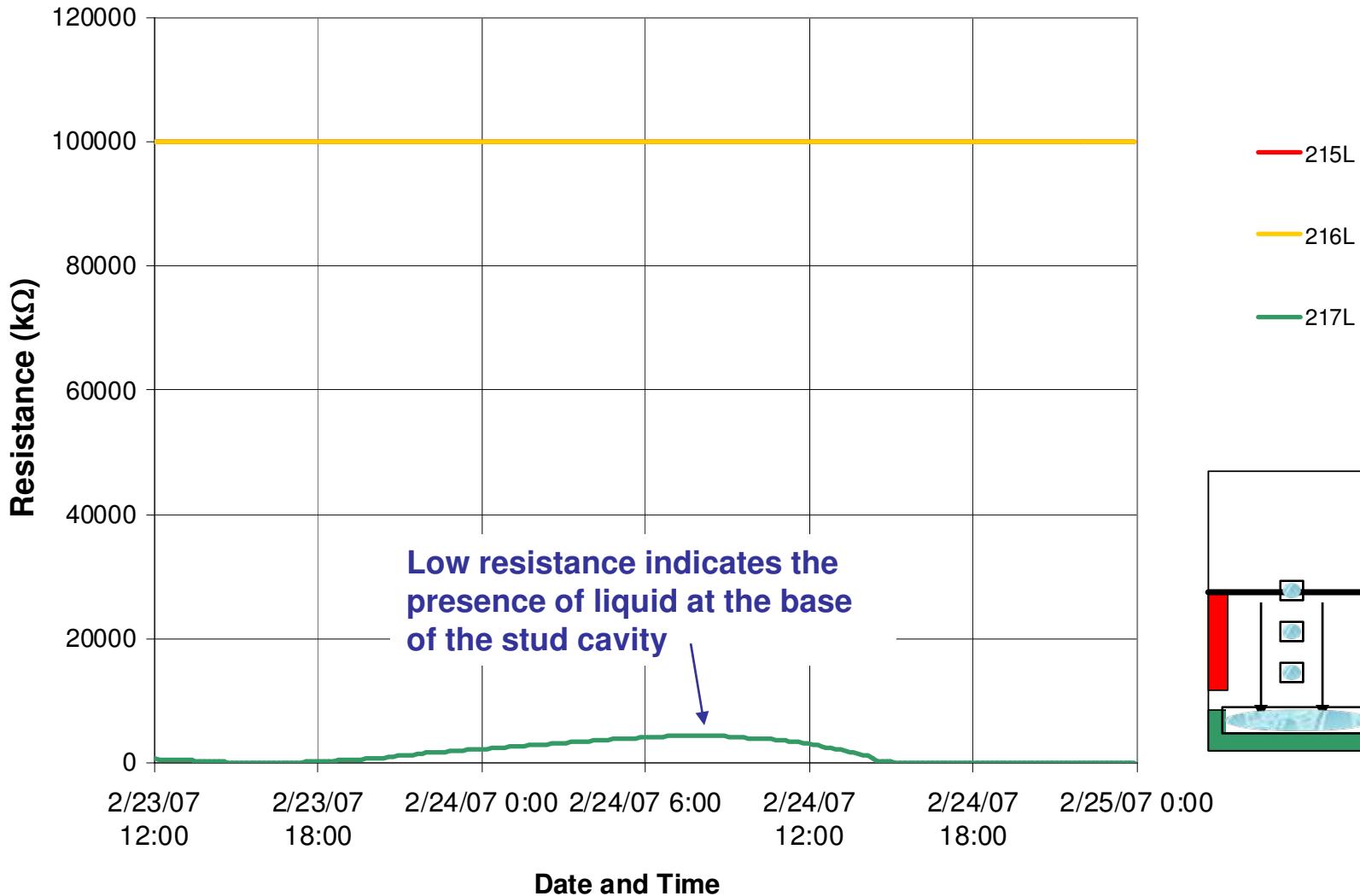
Condition B: 5 Pa, 50% RH, 6mm opening

Moisture Content - Wall 2 Interior OSB



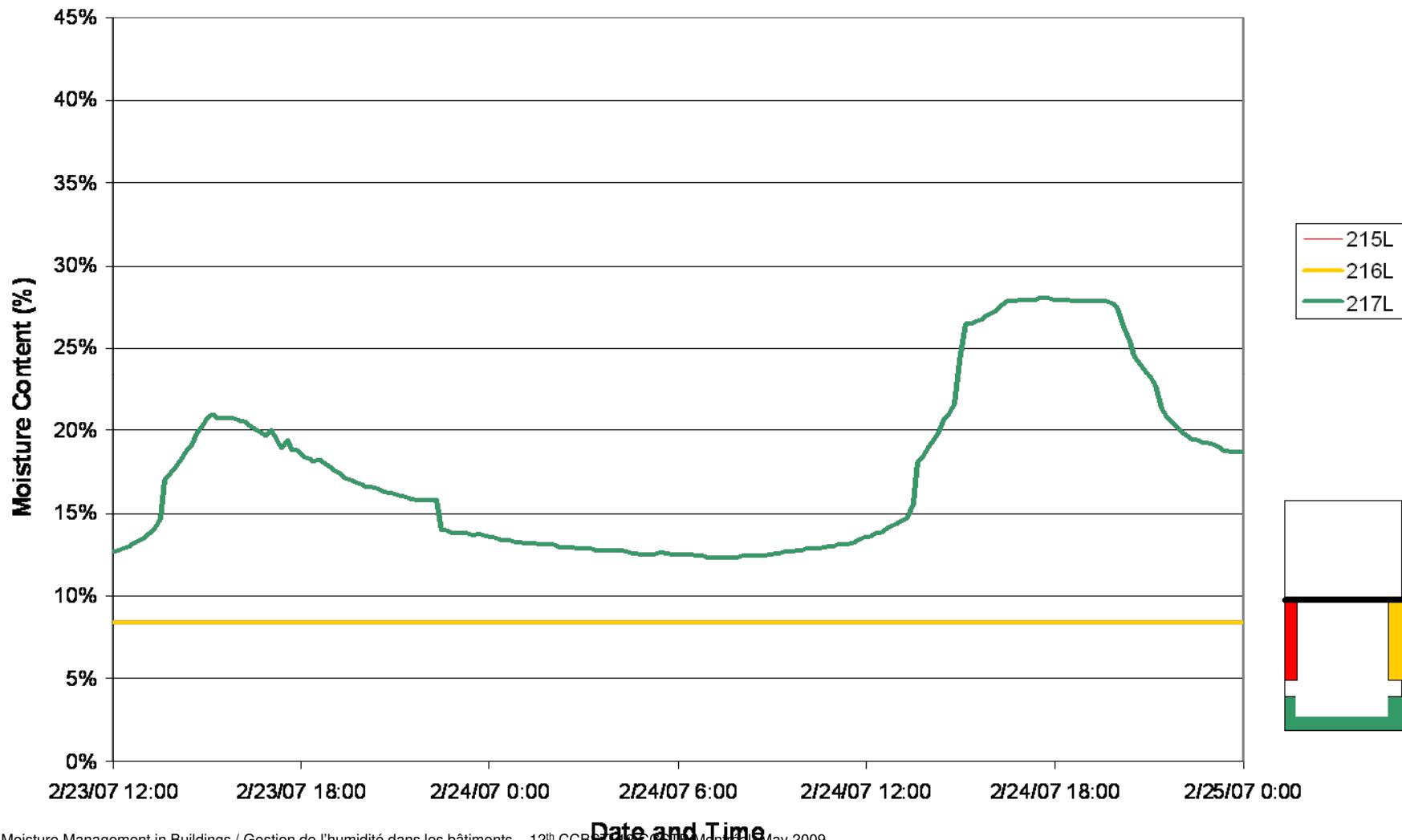
Condition B: 5 Pa, 50% RH, 6mm opening

FEWF Wall 2 - Stud - Layer 5 - Liquid

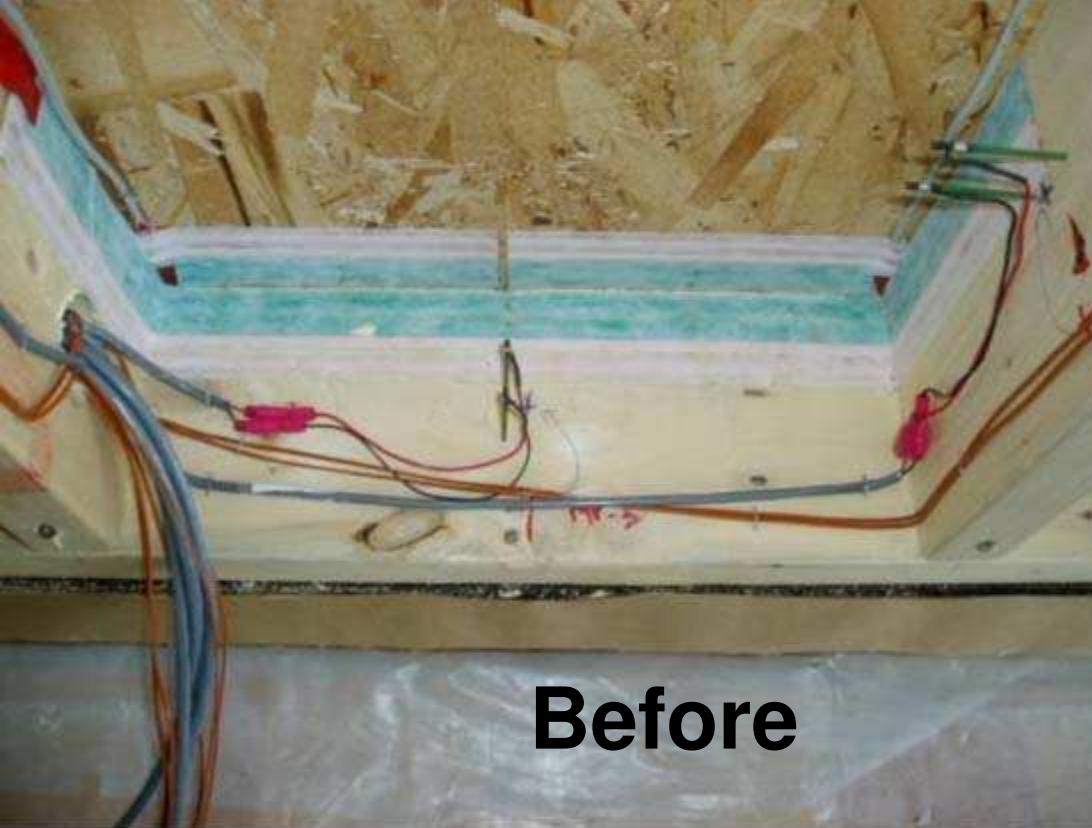


Condition B: 5 Pa, 50% RH, 6mm opening

Moisture Content - Wall 2 Stud Cavity



Results



If you leave it too wet for too long, then....

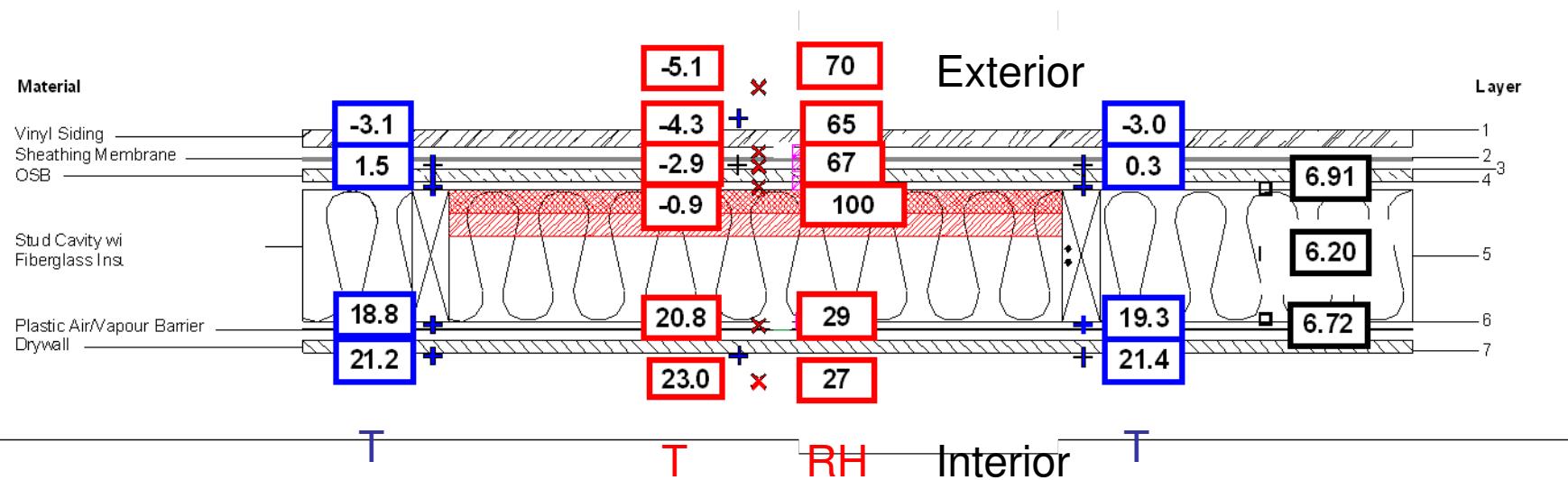


Condition C: 5 Pa, 30% RH, 3mm opening

Wall 2 Horizontal Cross Section

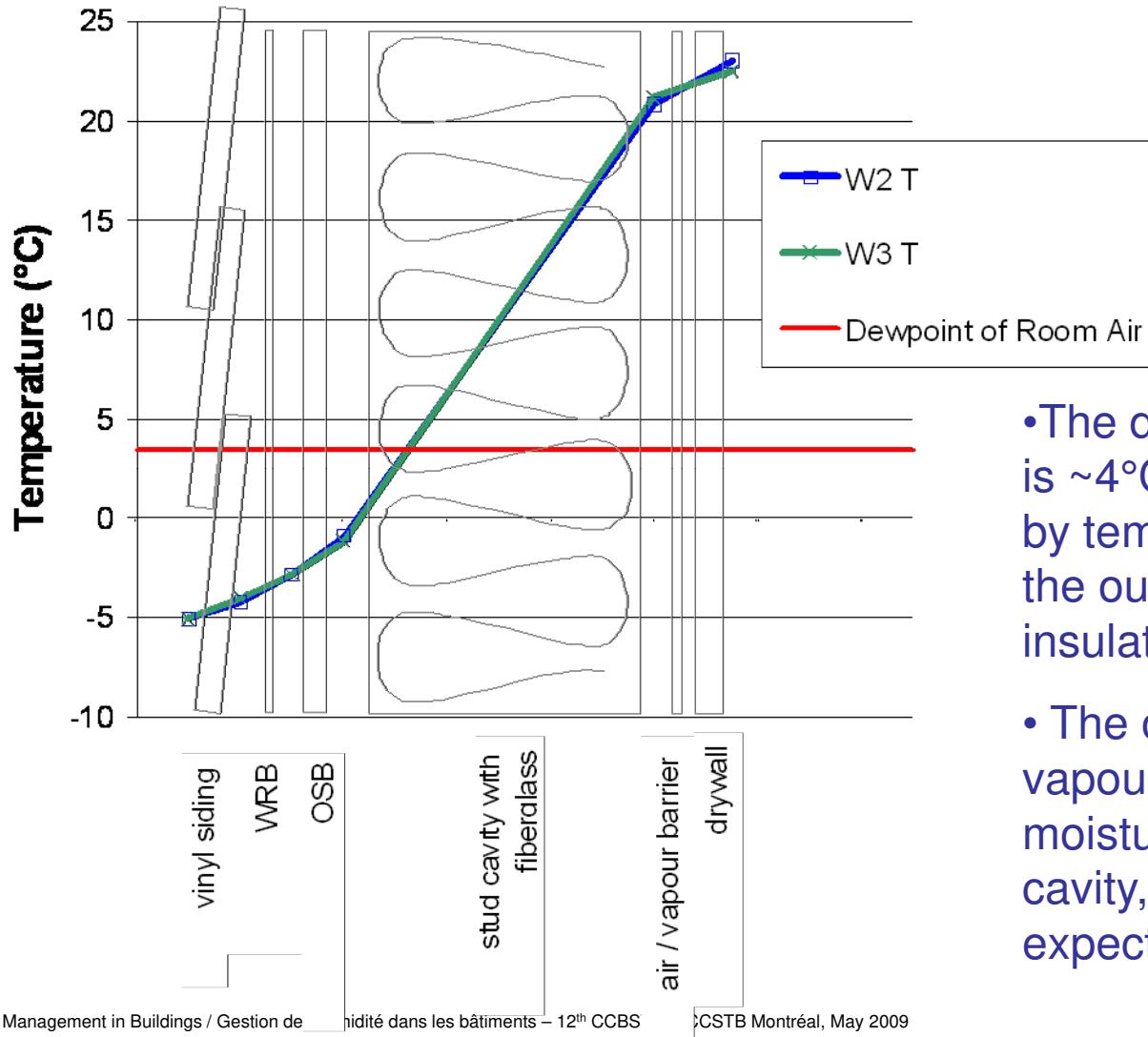
Week 11

16-Mar-07



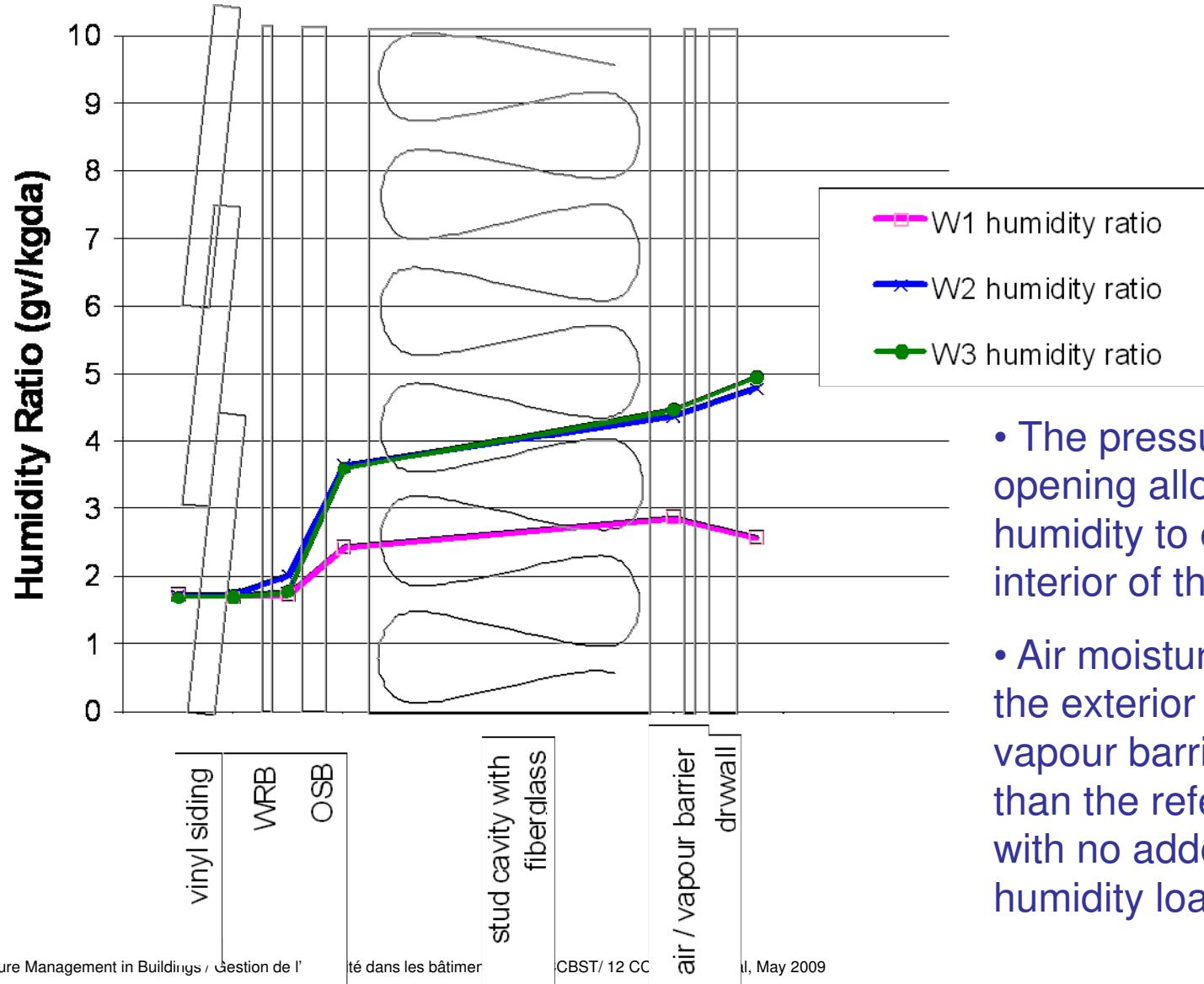
- The interior of the room is at 27% RH, the humidity behind the air/vapour barrier is 29% RH – indicating that moisture is being introduced through the opening
- The location with the highest RH is the interior of the OSB, at 100% - condensation would be expected

Condition C: 5 Pa, 30% RH, 3mm opening



- The dewpoint of room air is ~4°C, a condition met by temperatures towards the outside of the insulation
- The opening in the vapour barrier allows moisture to enter the cavity, condensation is expected at the OSB

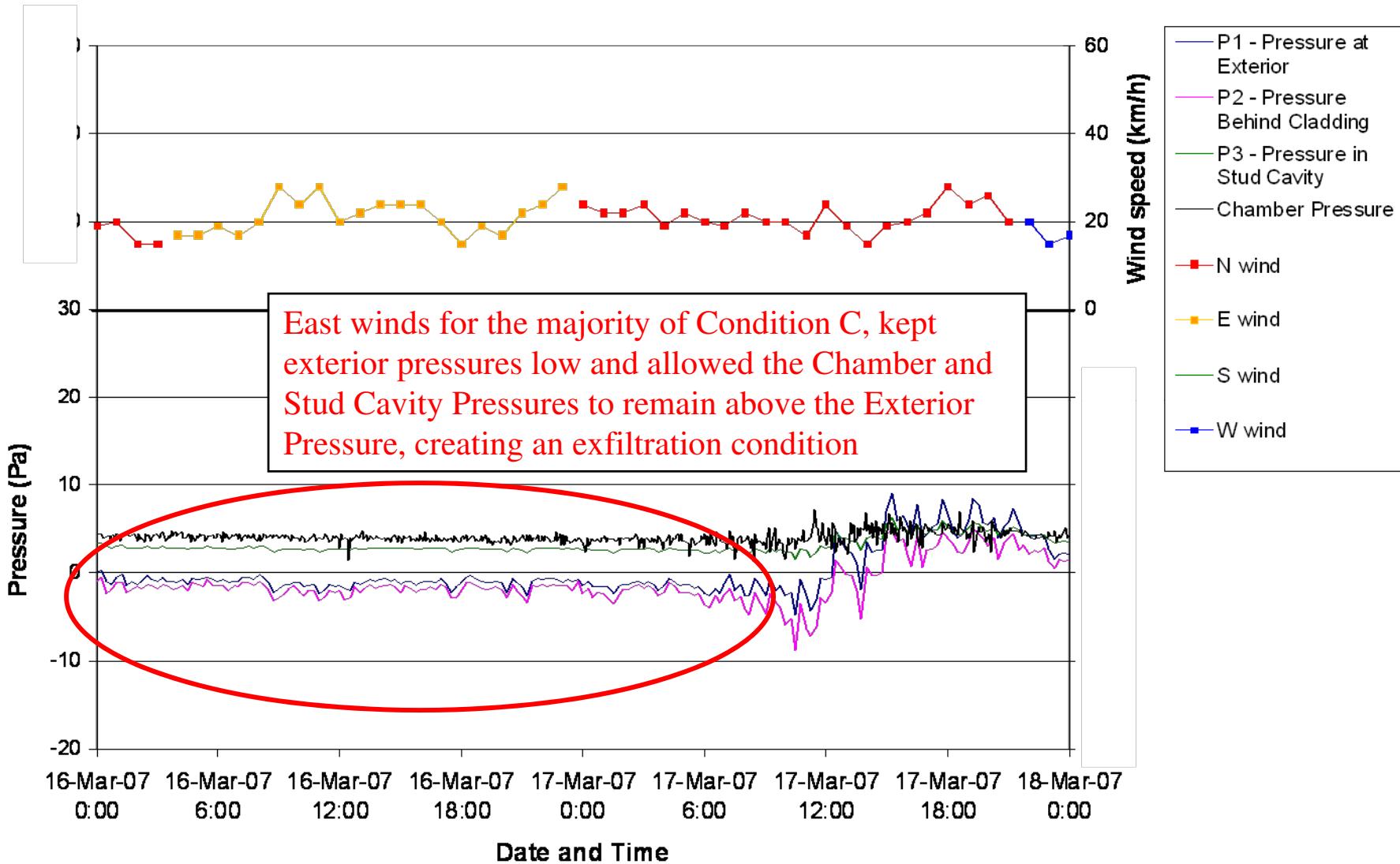
Condition C: 5 Pa, 30% RH, 3mm opening



- The pressure and opening allow the humidity to enter the interior of the wall
- Air moisture content on the exterior side of the vapour barrier is higher than the reference wall – with no added indoor humidity loads

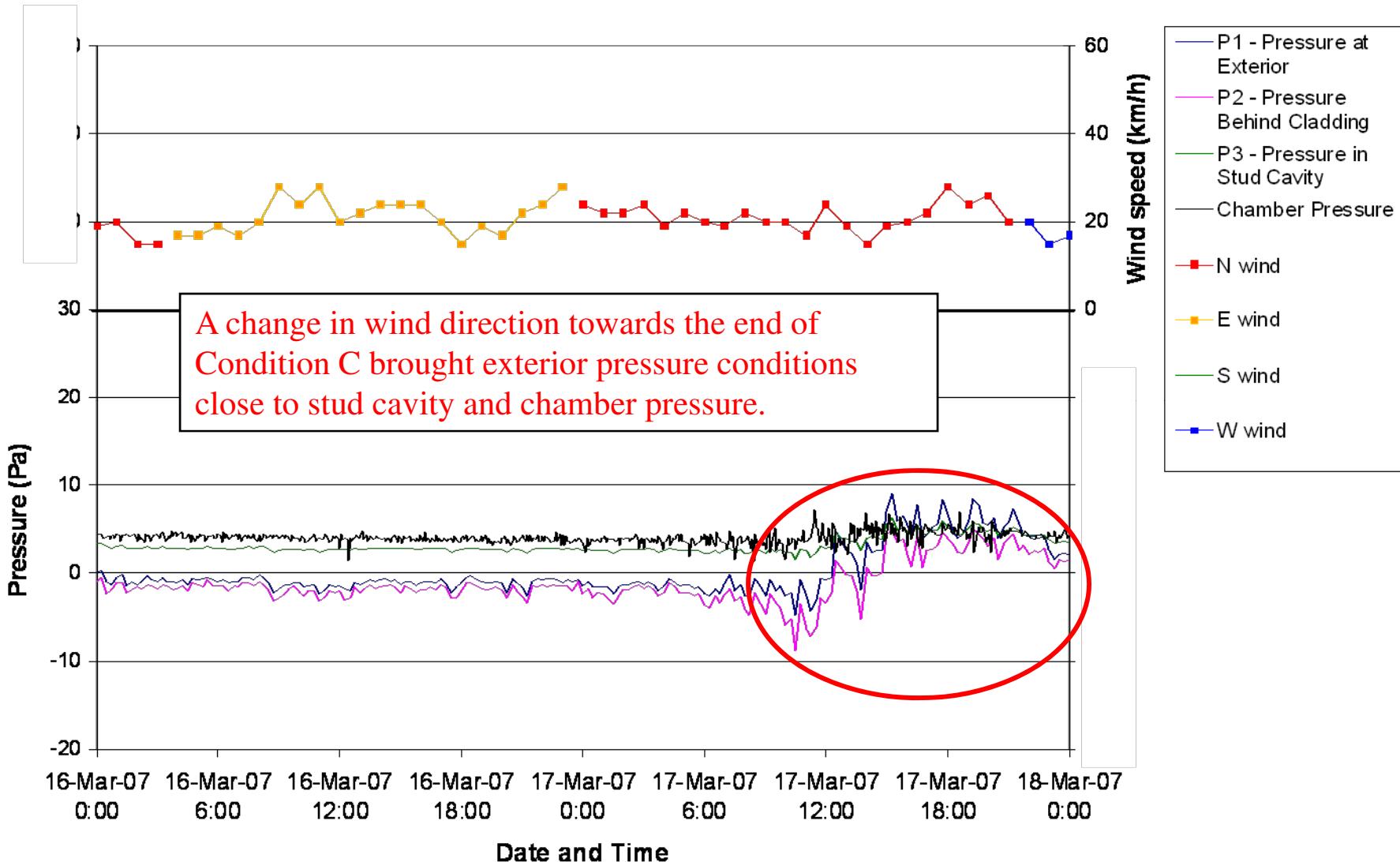
Condition C: 5 Pa, 30% RH, 3mm opening

Pressure, Wind speed and direction



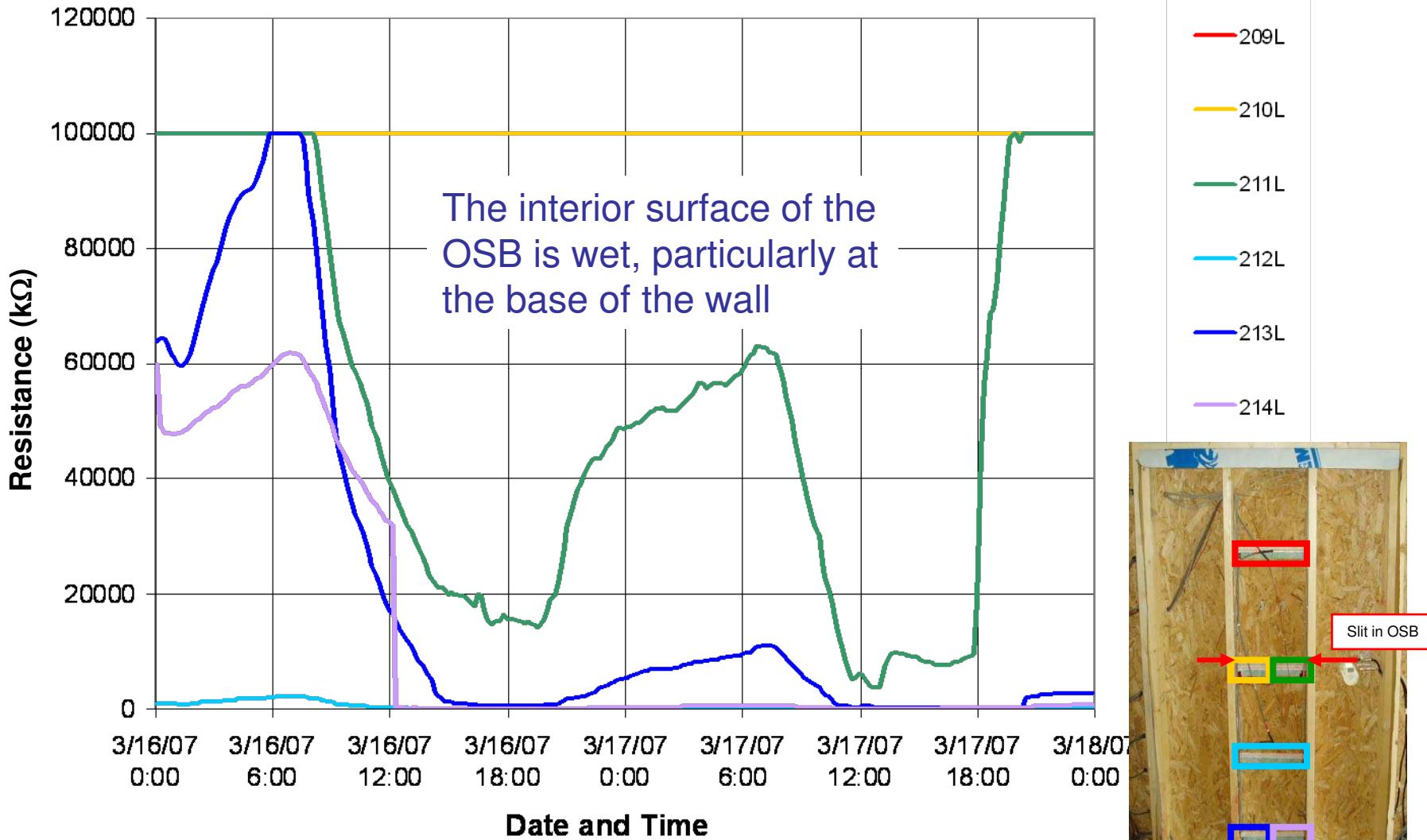
Condition C: 5 Pa, 30% RH, 3mm opening

Pressure, Wind speed and direction



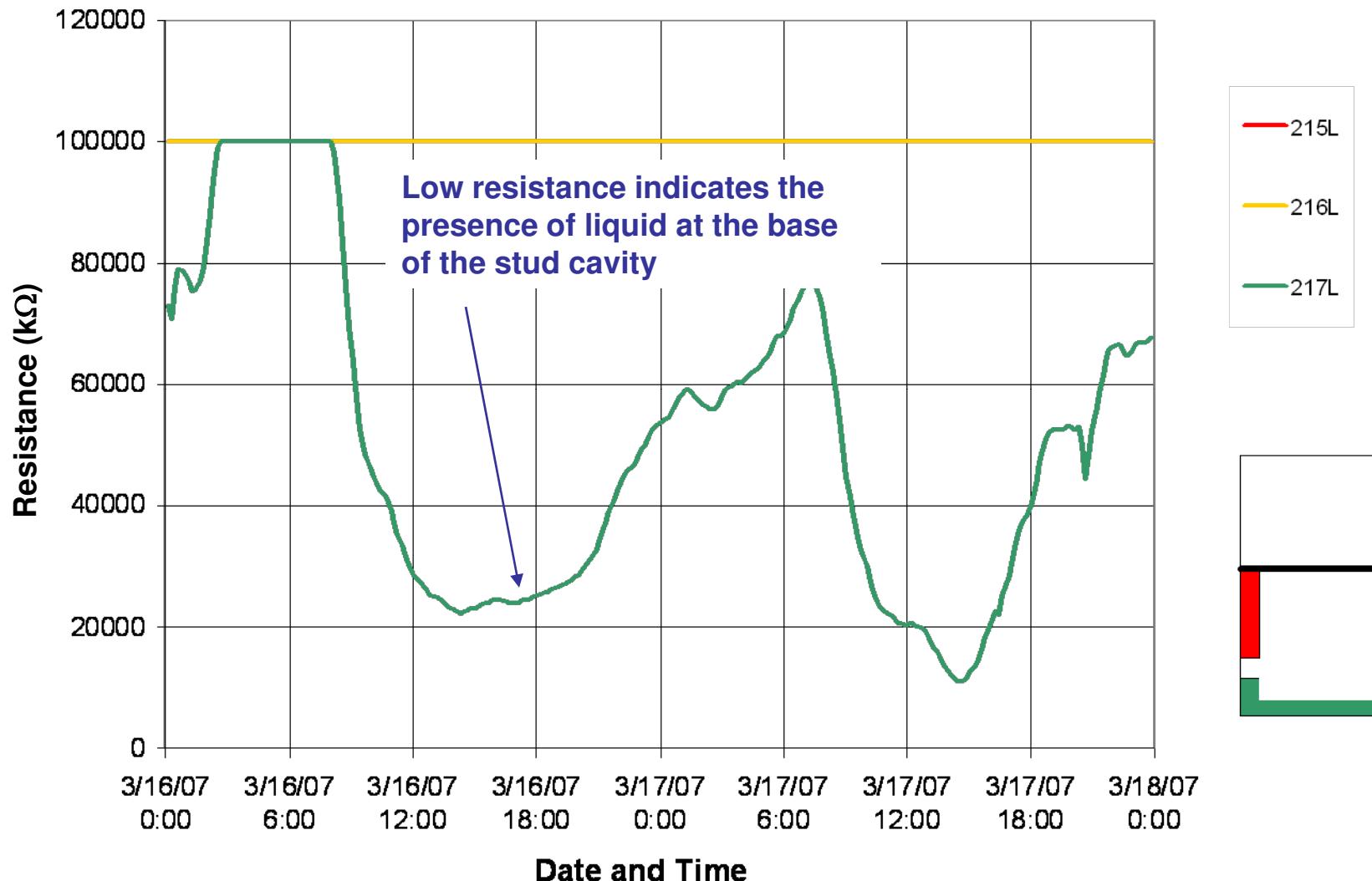
Condition C: 5 Pa, 30% RH, 3mm opening

FEWF Wall 2 - Interior of OSB - Layer 4 - Liquid



Condition C: 5 Pa, 30% RH, 3mm opening

FEWF Wall 2 - Stud - Layer 5 - Liquid

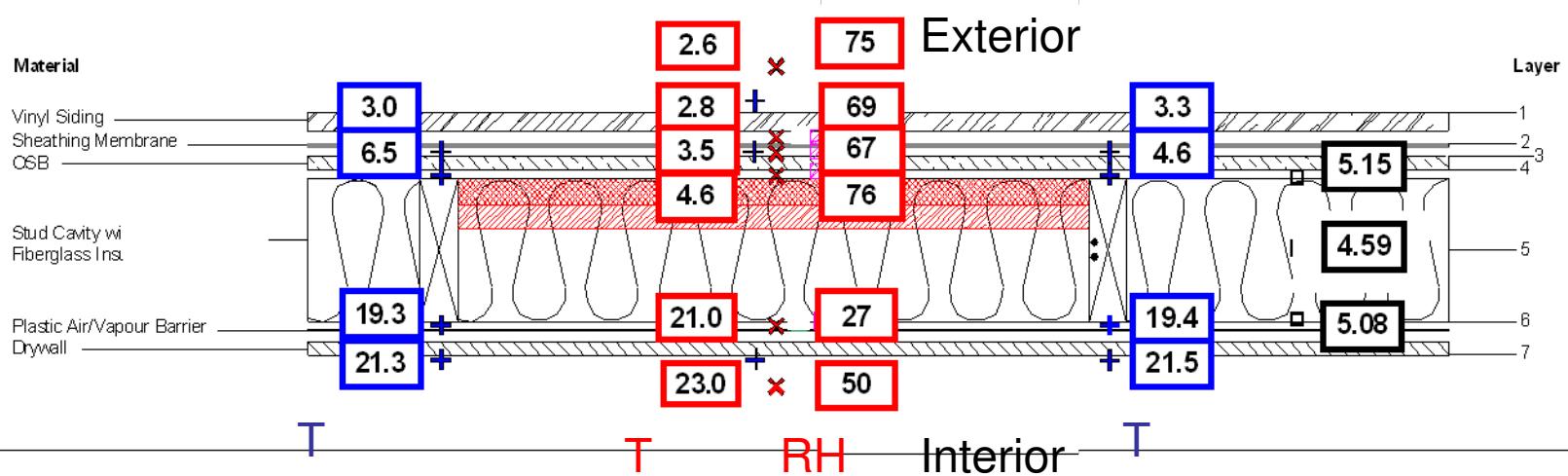


Condition D: 0 Pa, 50% RH, 3mm opening

Wall 2 Horizontal Cross Section

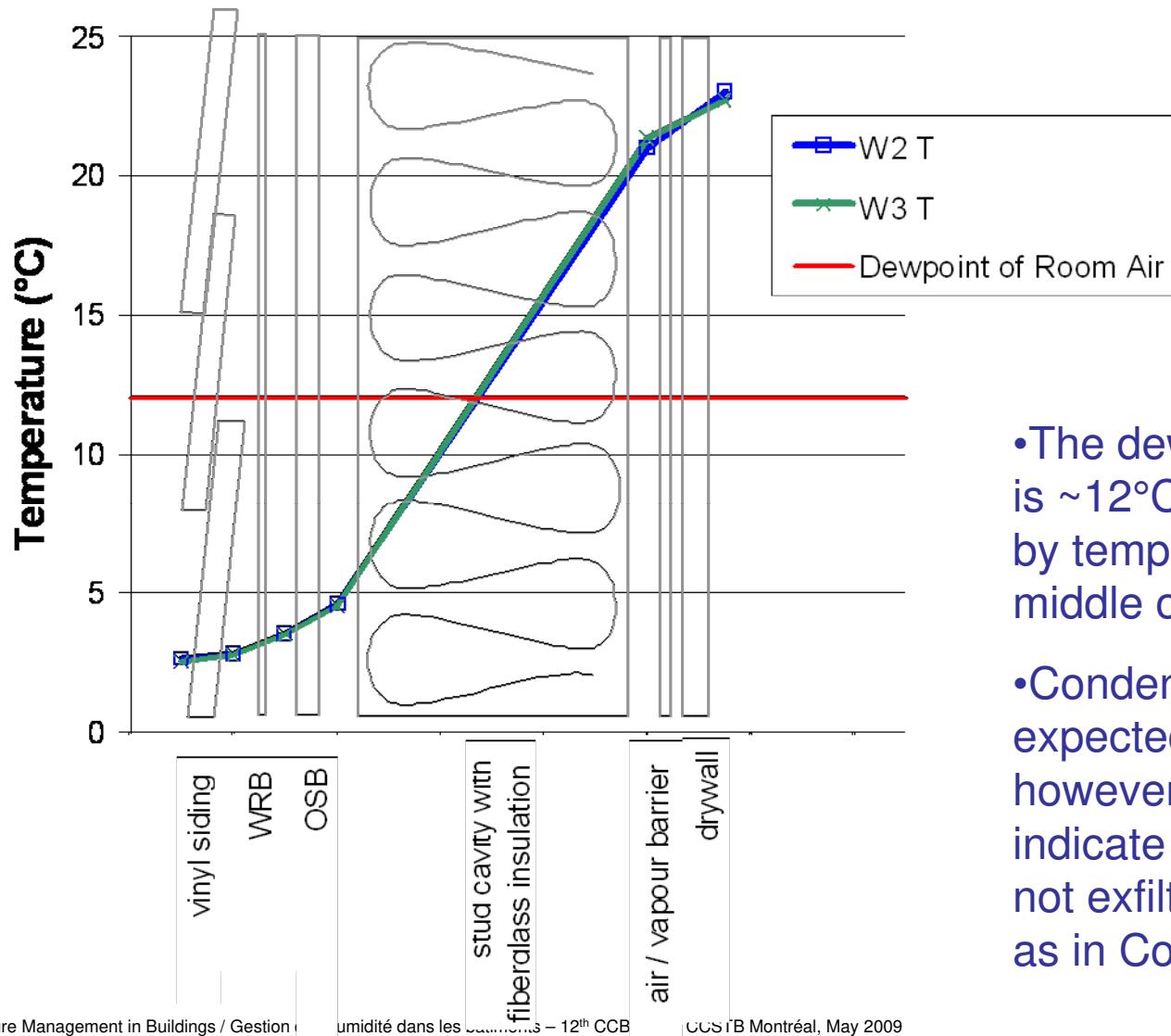
Week 15

08-Apr-07



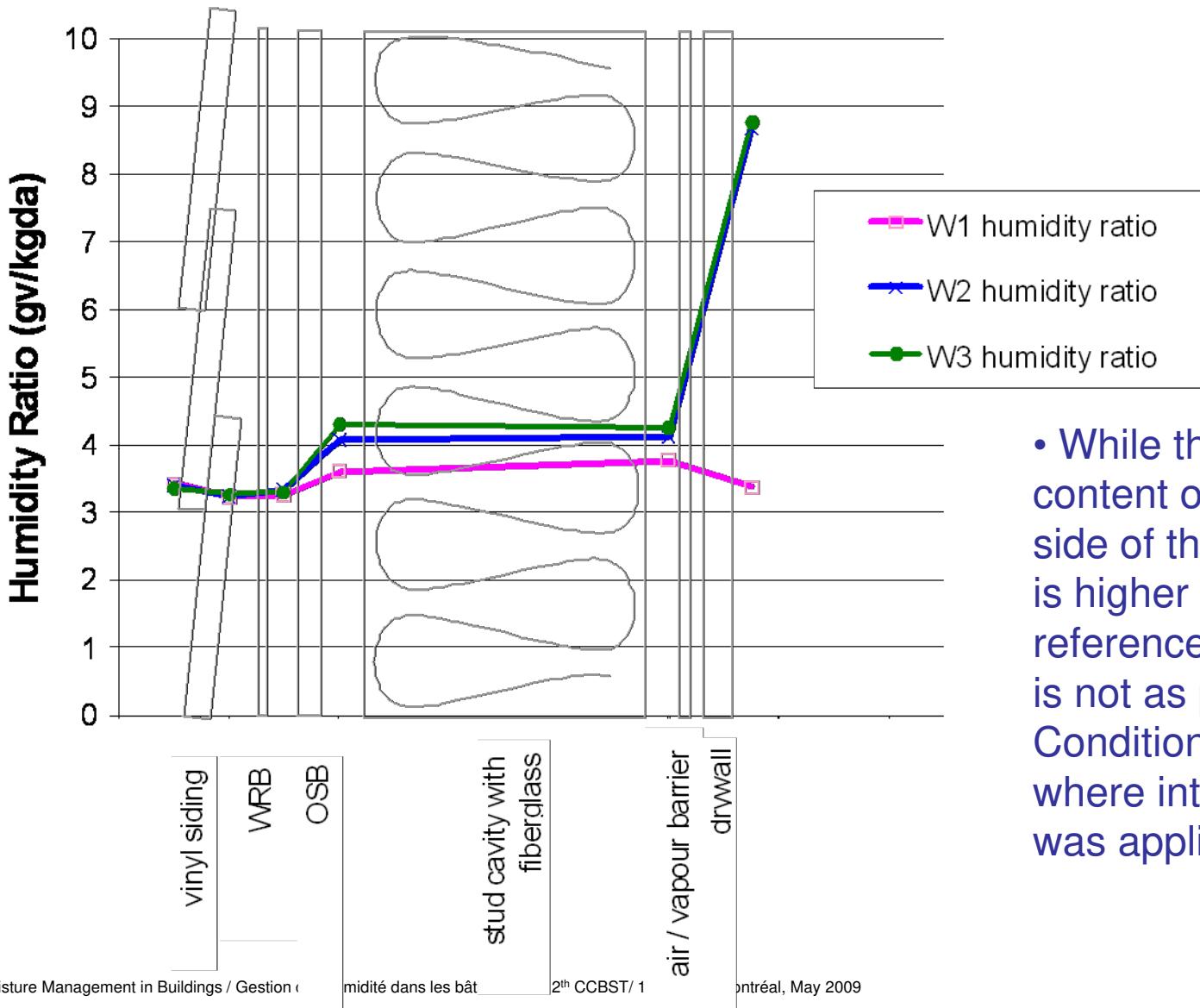
- The interior of the room is at 50% RH, the humidity behind the air/vapour barrier is 27% RH
- The location with the highest RH is the interior of the OSB, at 76% (likely due to the lack of a pressure driving force for exfiltration, and warmer exterior temperatures)

Condition D: 0 Pa, 50% RH, 3mm opening



- The dewpoint of room air is $\sim 12^{\circ}\text{C}$, a condition met by temperatures at the middle of the insulation
- Condensation is expected at the OSB, however, measurements indicate that room air is not exfiltrating as much as in Conditions B and C

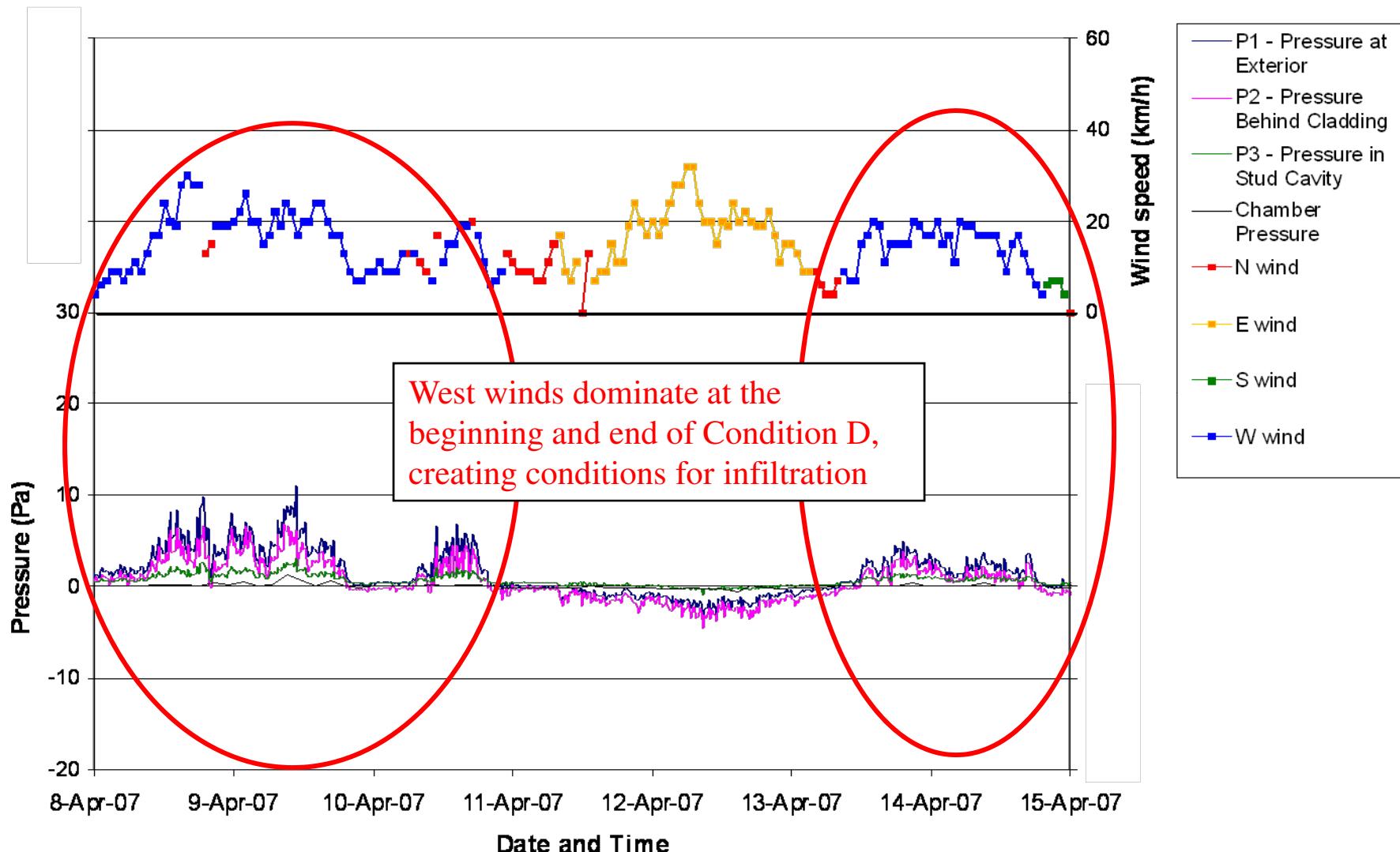
Condition D: 0 Pa, 50% RH, 3mm opening



- While the air moisture content on the exterior side of the vapour barrier is higher than the reference wall, the effect is not as pronounced as Conditions B and C – where interior pressure was applied

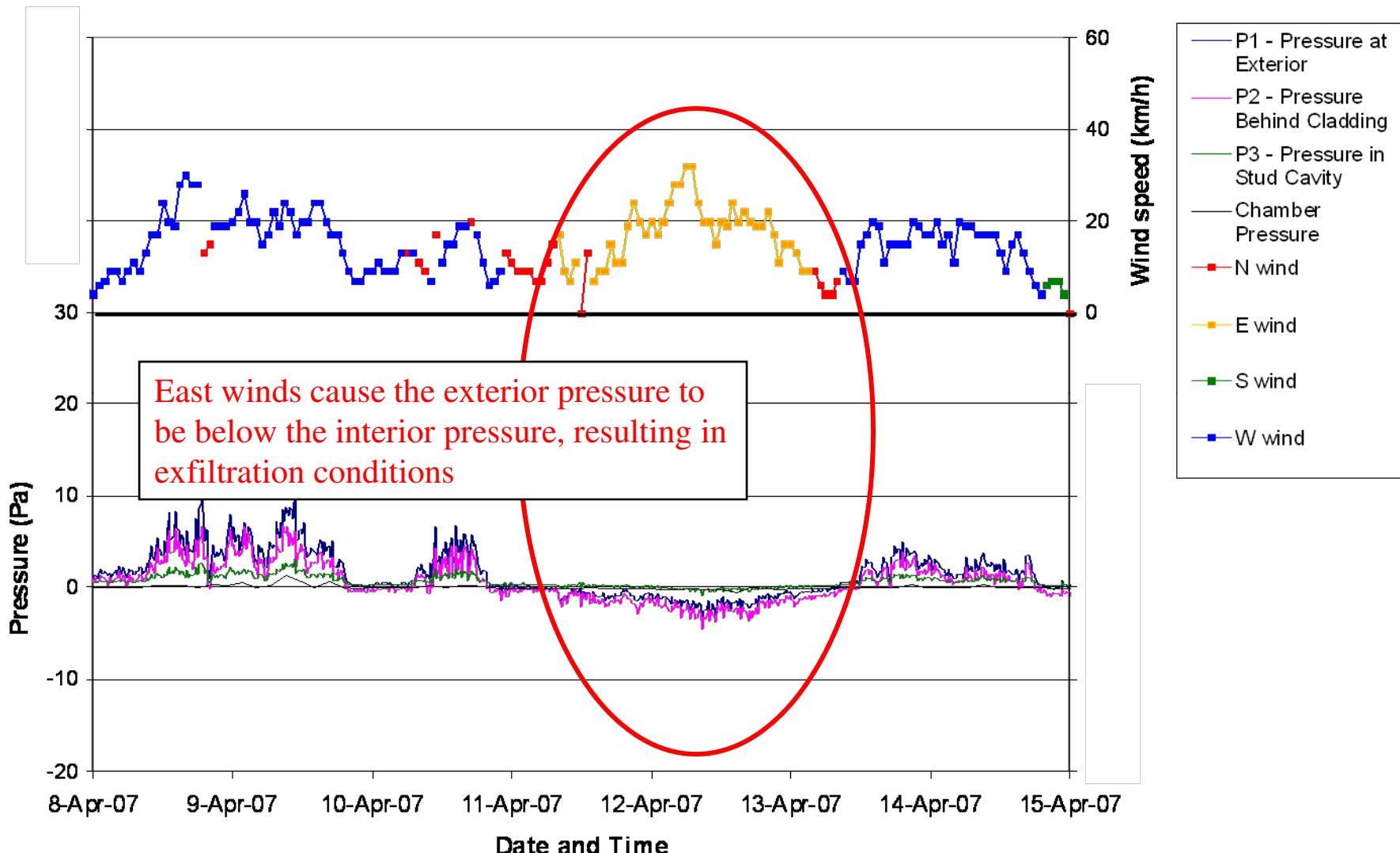
Condition D: 0 Pa, 50% RH, 3mm opening

Pressure, Wind speed and direction



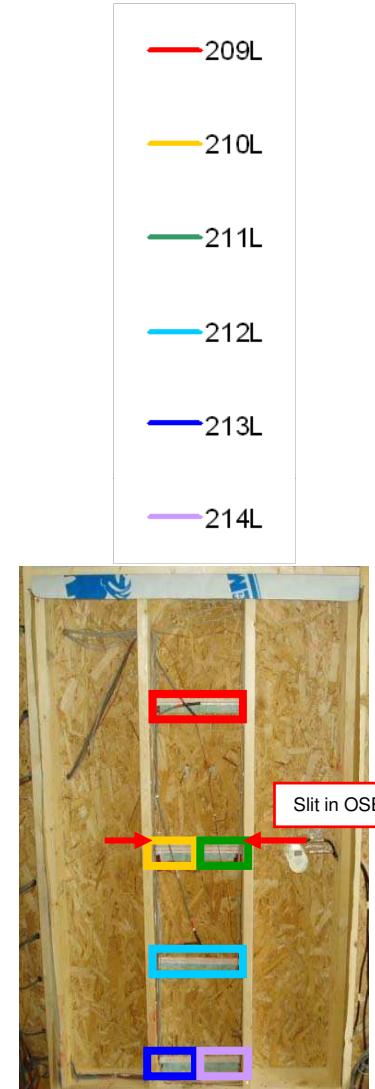
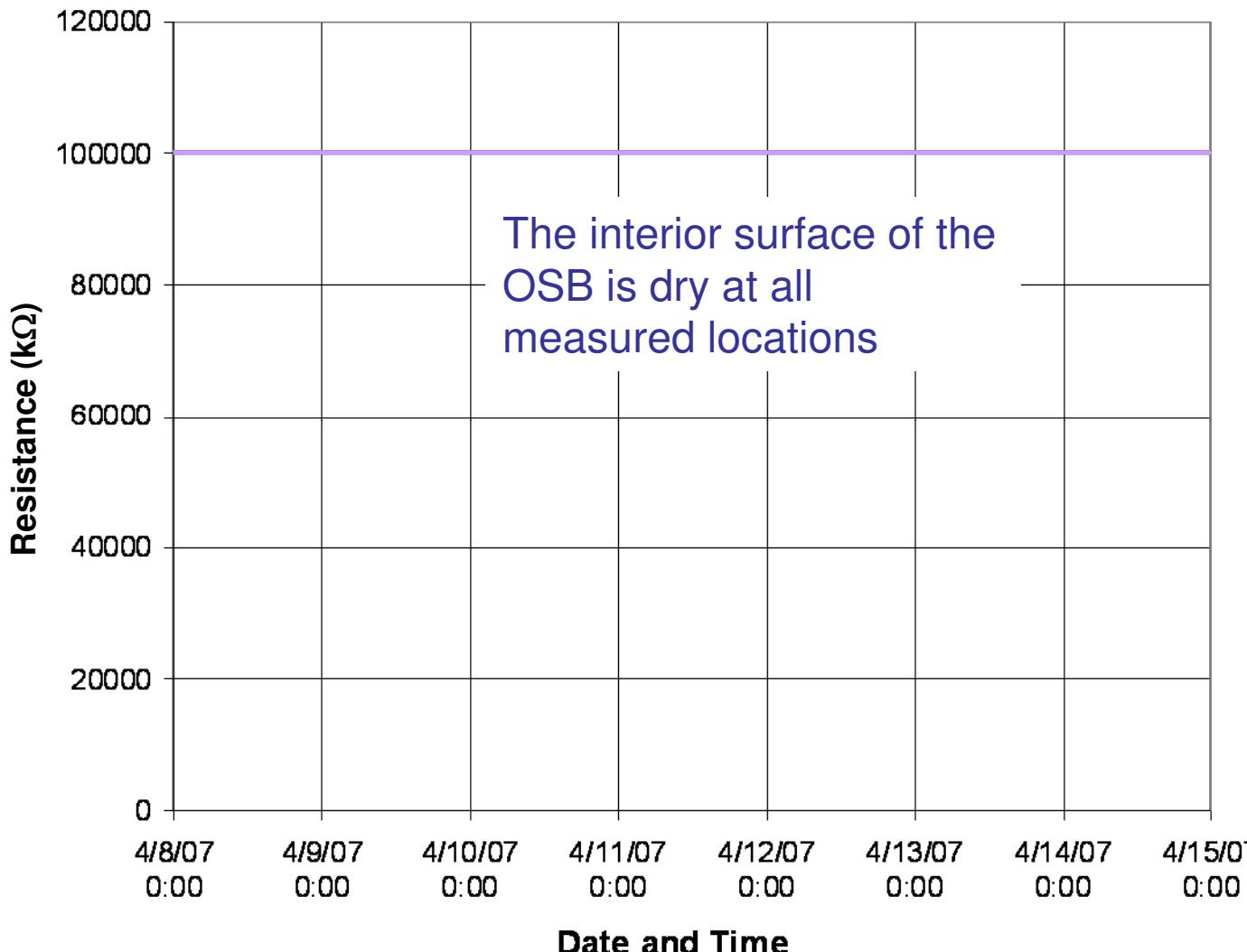
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Pressure, Wind speed and direction



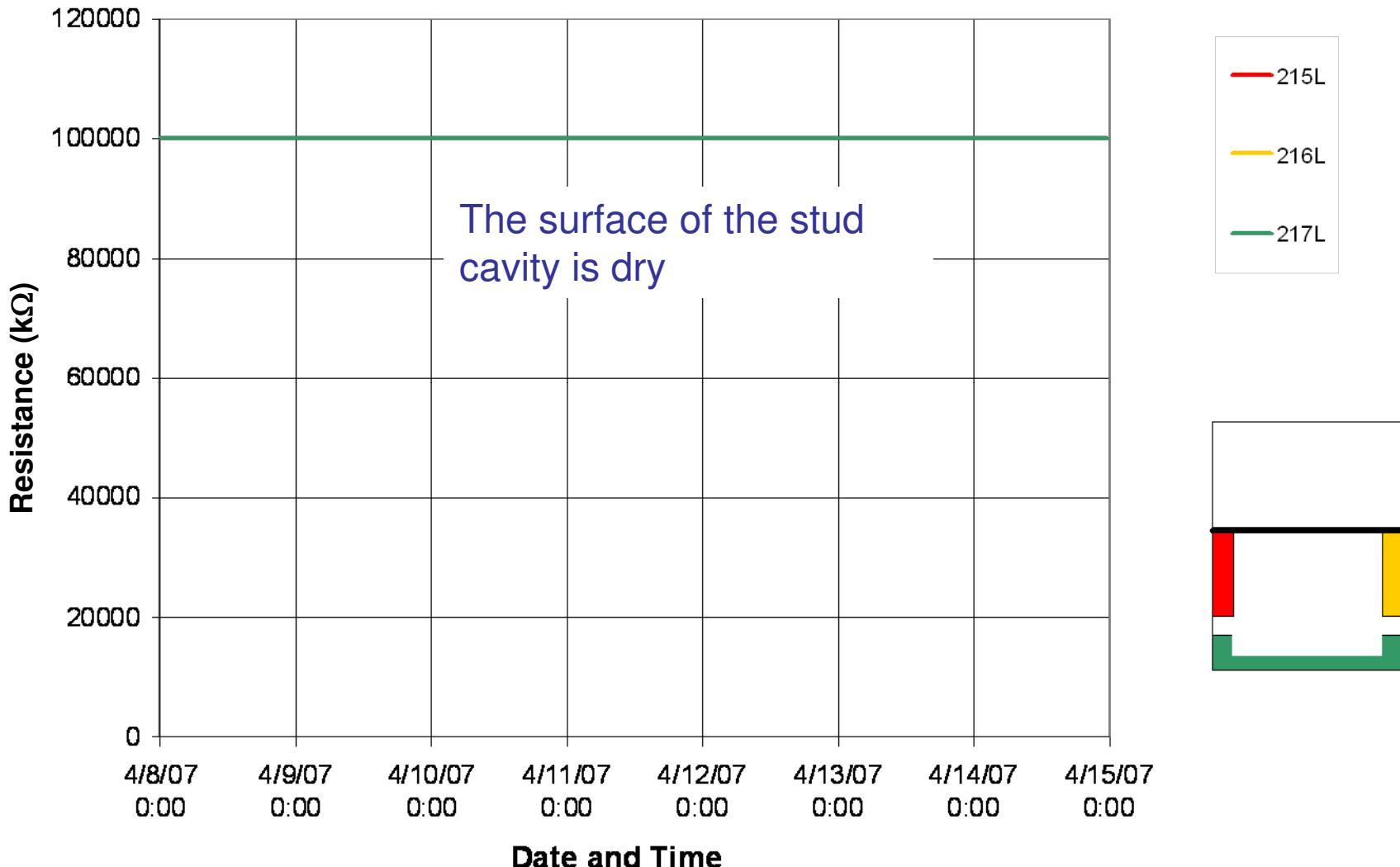
Condition D: 0 Pa, 50% RH, 3mm opening

FEWF Wall 2 - Interior of OSB - Layer 4 - Liquid



Condition D: 0 Pa, 50% RH, 3mm opening

FEWF Wall 2 - Stud - Layer 5 - Liquid



SUMMARY

- Successful characterization of hygrothermal performance.
- Water detection tape provided valuable data on wetting locations
- Strong relationship between wind conditions and air infiltration/exfiltration

SUMMARY (Cont'd)

- We looked at risk of condensation due to exfiltration (wetting) combined with infiltration (drying)
- Similar results for the three test specimens
- FEWF can be used for future exposure tests:
 - Part II- Exterior energy retrofit strategies
- FEWF Results can be used to benchmark hygrothermal tools *hygIRC*

Questions

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