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Characterization of the hygrothermal performance of wall systems

Maref, W.; Manning, M. M.; Rousseau, M. Z.; Lei, W.

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Characterization of the hygrothermal performance of wall systems

IRC-ORAL-854

Maref, W.; Manning, M.; Rousseau, M.; Lei, W.

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NRC-CNRC

From **Discovery**
to **Innovation...**

Characterization of the Hygrothermal Performance of Wall Systems

W. Meref, M. Manning , M. Rousseau & W. Lei

*ASHRAE Seminar 29- Moisture Management Concerns in Commercial
and Residential Buildings, New York, USA, January 21, 2008*



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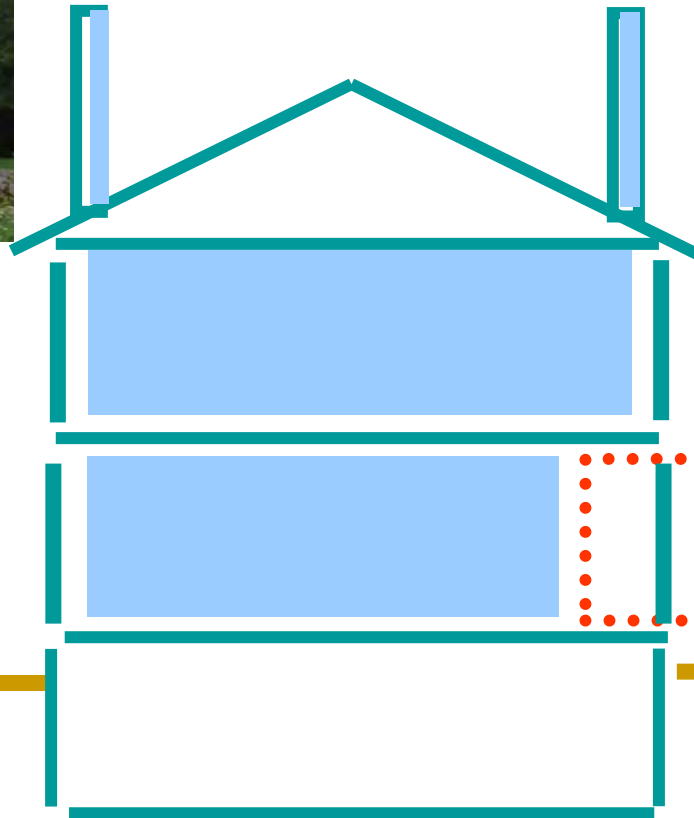
Team

			
K. Abdulghani	W. Lei	M. Manning	W. Maref
			
M. Nicholls	T. Aubin	M. Rousseau	R. Berzins

Outline

- Background
- Field Exposure of Wall Facility (FEWF)-BES
- Results and Discussion
- Summary
- Future Work

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

Field Exposure of Wall Facility (FEWF)

- **Experimental Approach**

- **Year 1 (2006-2007)** Commissioned the facility by monitoring three identical test specimens of traditional construction (2x6) through Fall, Winter and Spring.
- **Year 2 (2007-2008)** Examine the effect of exterior insulation retrofit on the hygrothermal response of wood-frame walls. This project is jointly funded with CMHC and NRCan
- **Year 3 and beyond** Expand the program in collaboration with Indoor Environment to examine whole house performance issues.



Inst
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South facade

North facade



Test
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West facade

Field Exposure of Walls Facility (FEWF)

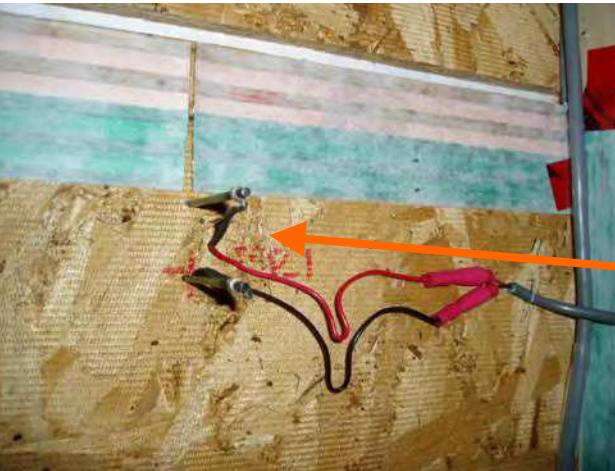




LAYER 4 - Interior Face of OSB



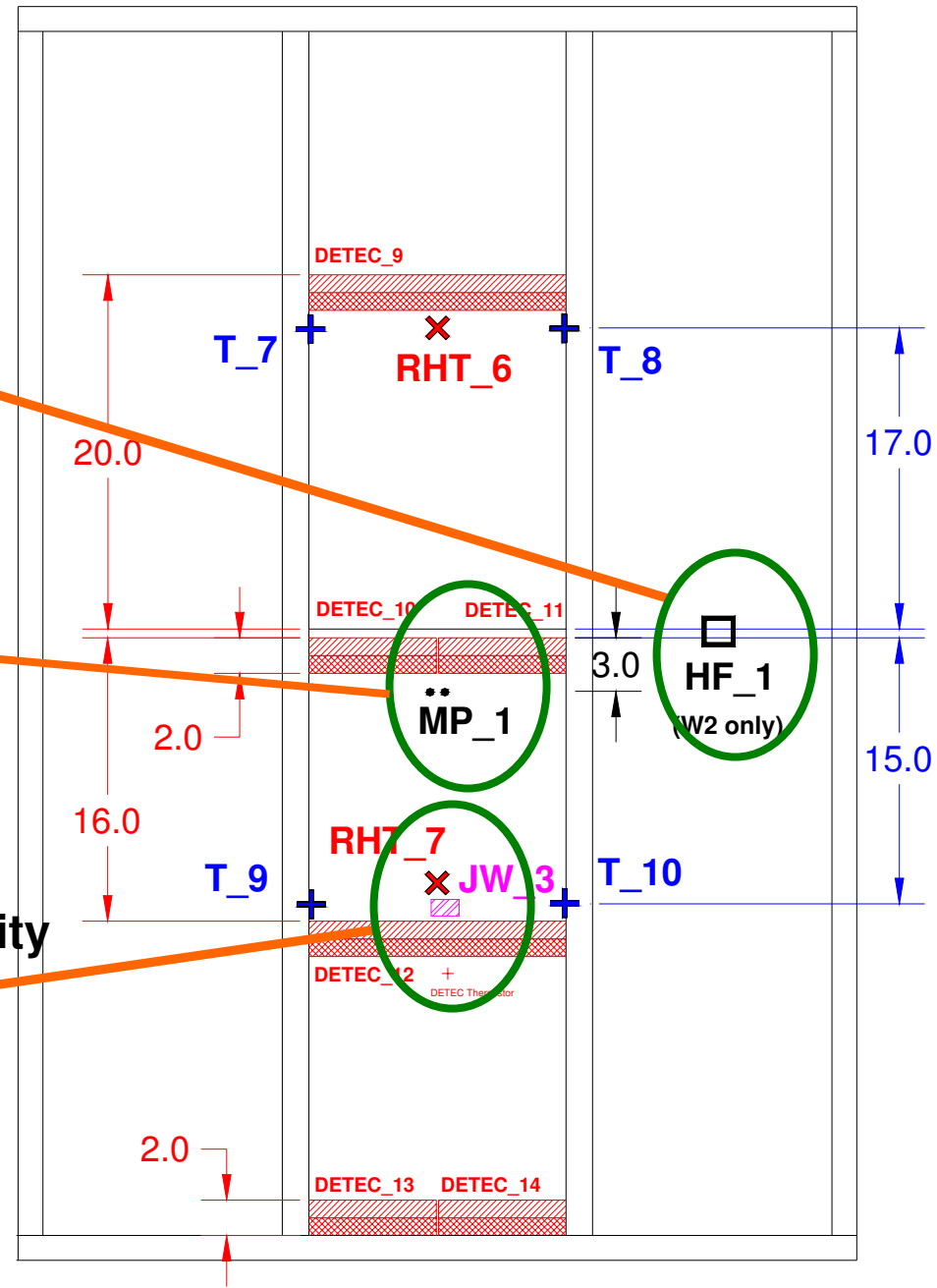
Heat Flux



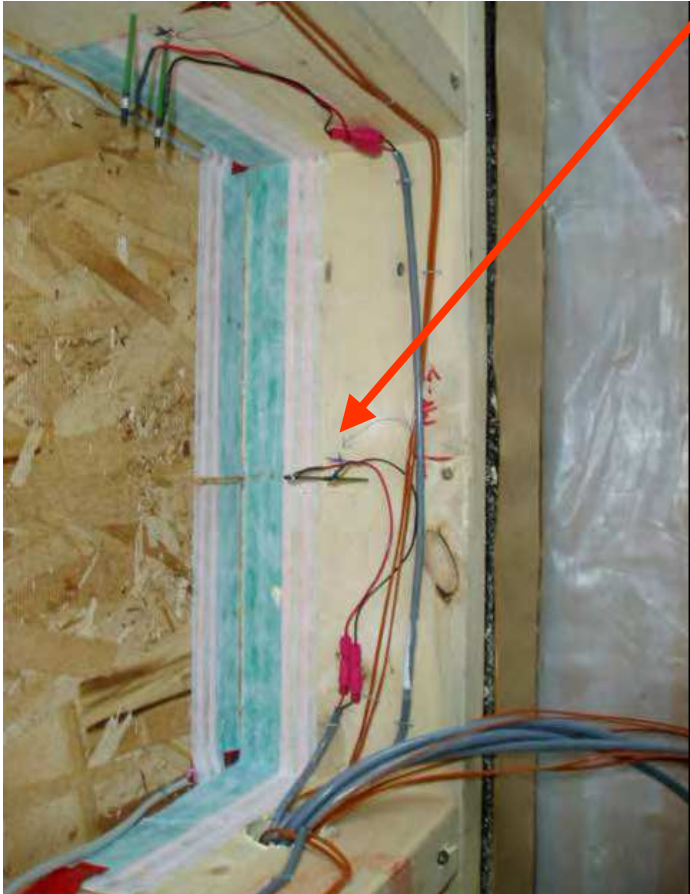
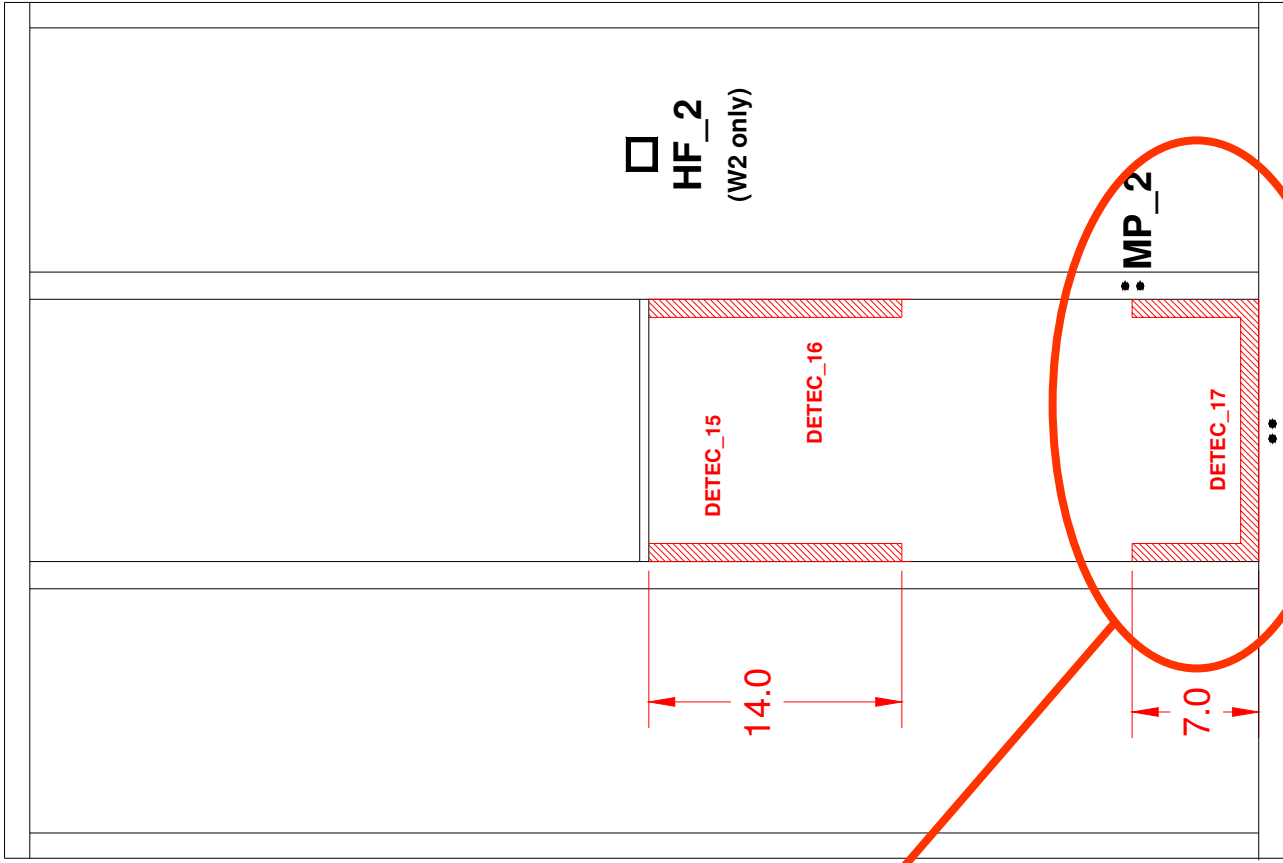
Moisture Pin



Wireless
Relative Humidity



LAYER 5 - Stud Cavity

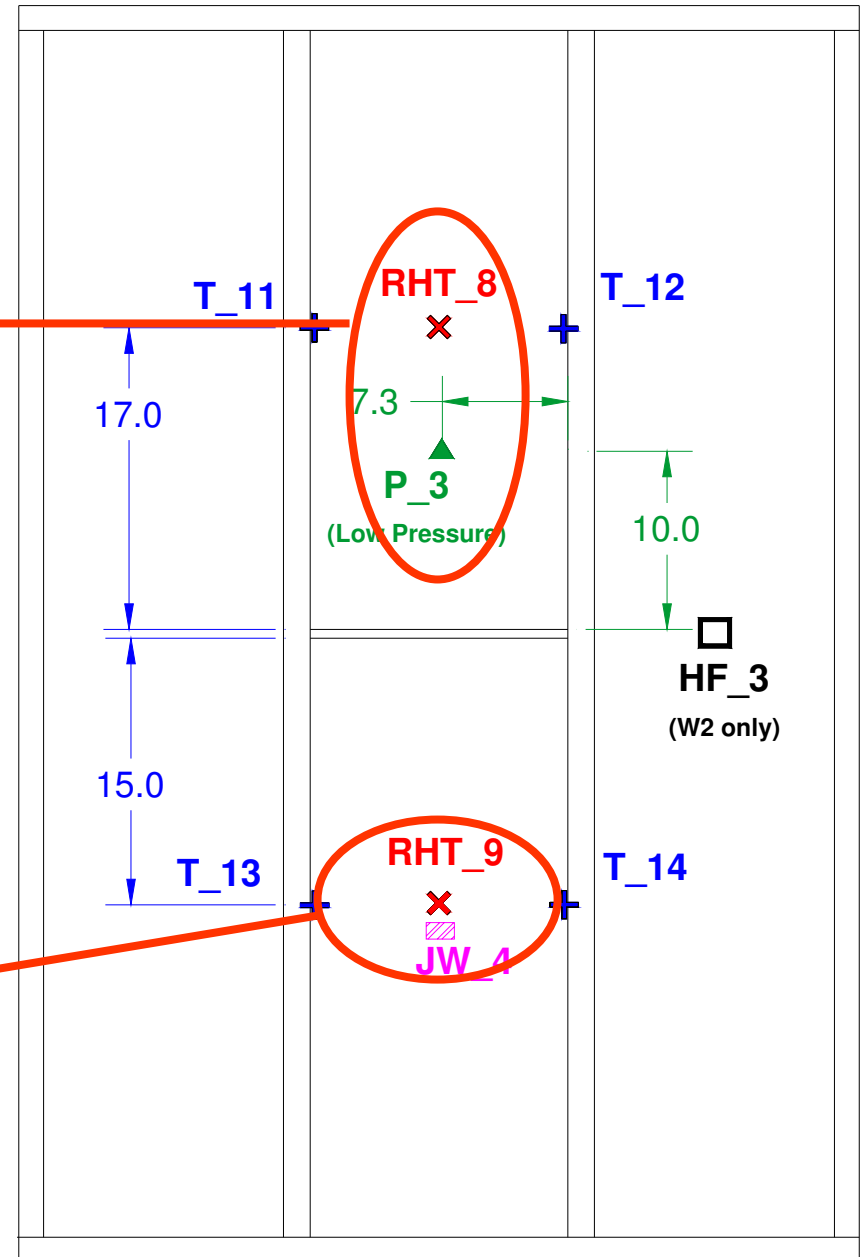


Moisture Pin

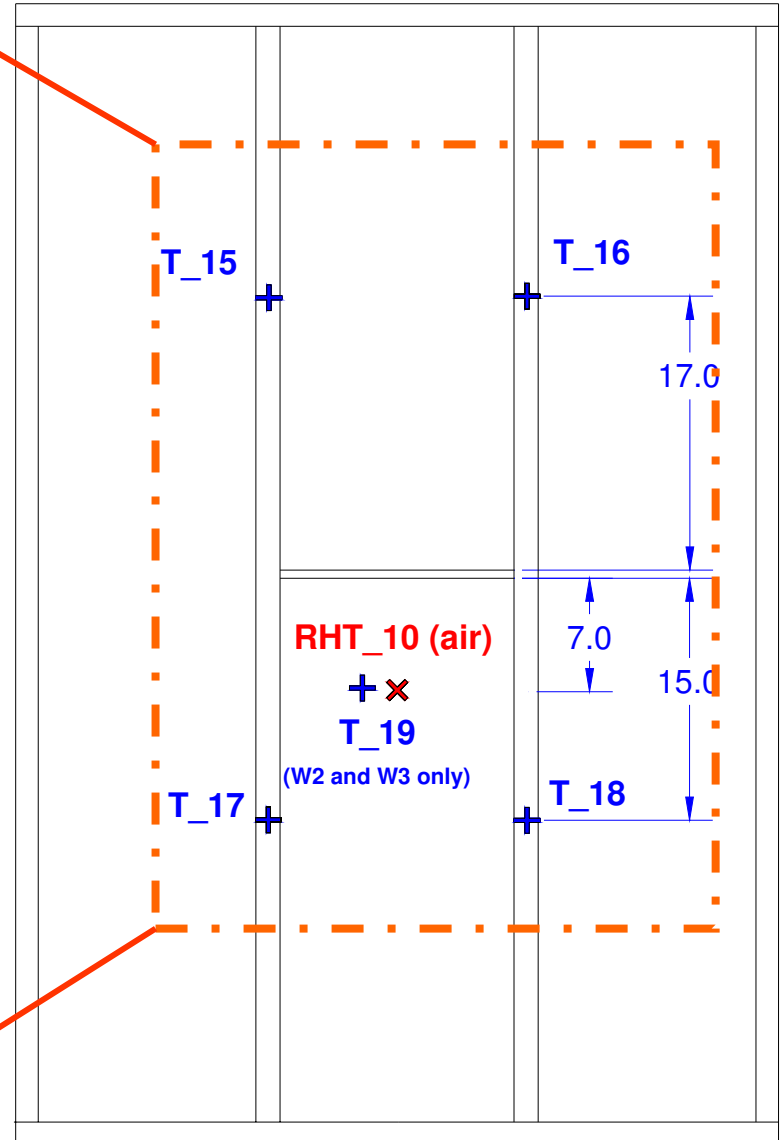


Delta Pressure

A photograph of a red and black striped object, possibly a tool or a piece of equipment, lying on a light-colored surface. A red arrow points to a small white label with the number '2' written on it.



LAYER 7 - Interior Face of Drywall



W1

W2

W3





M-24TH3

3

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)

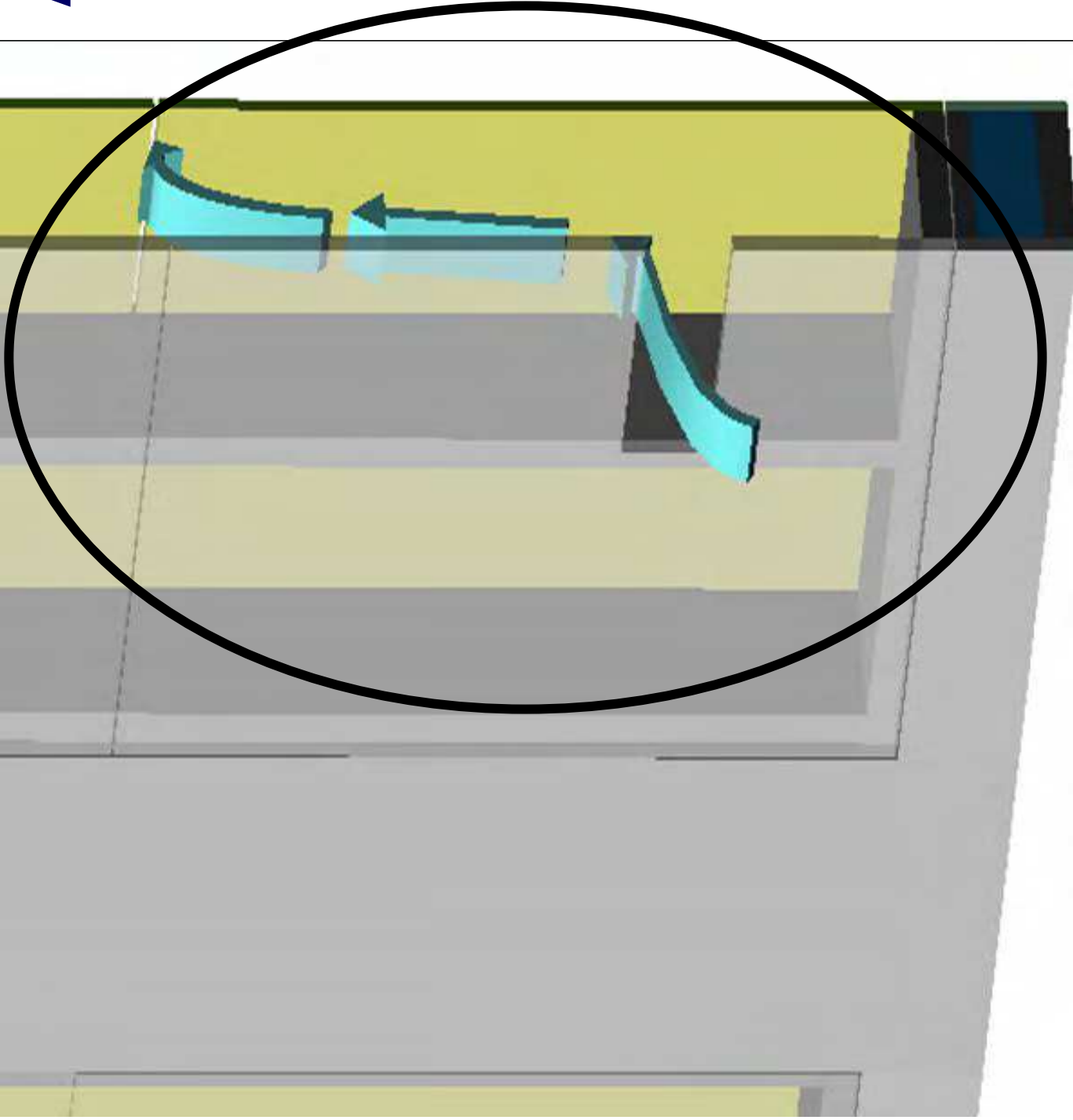


W3

W2

W1

Air Leakage Path



- 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

W3



W2



W1



Conditioning Chamber on the Room Side



INT.

P

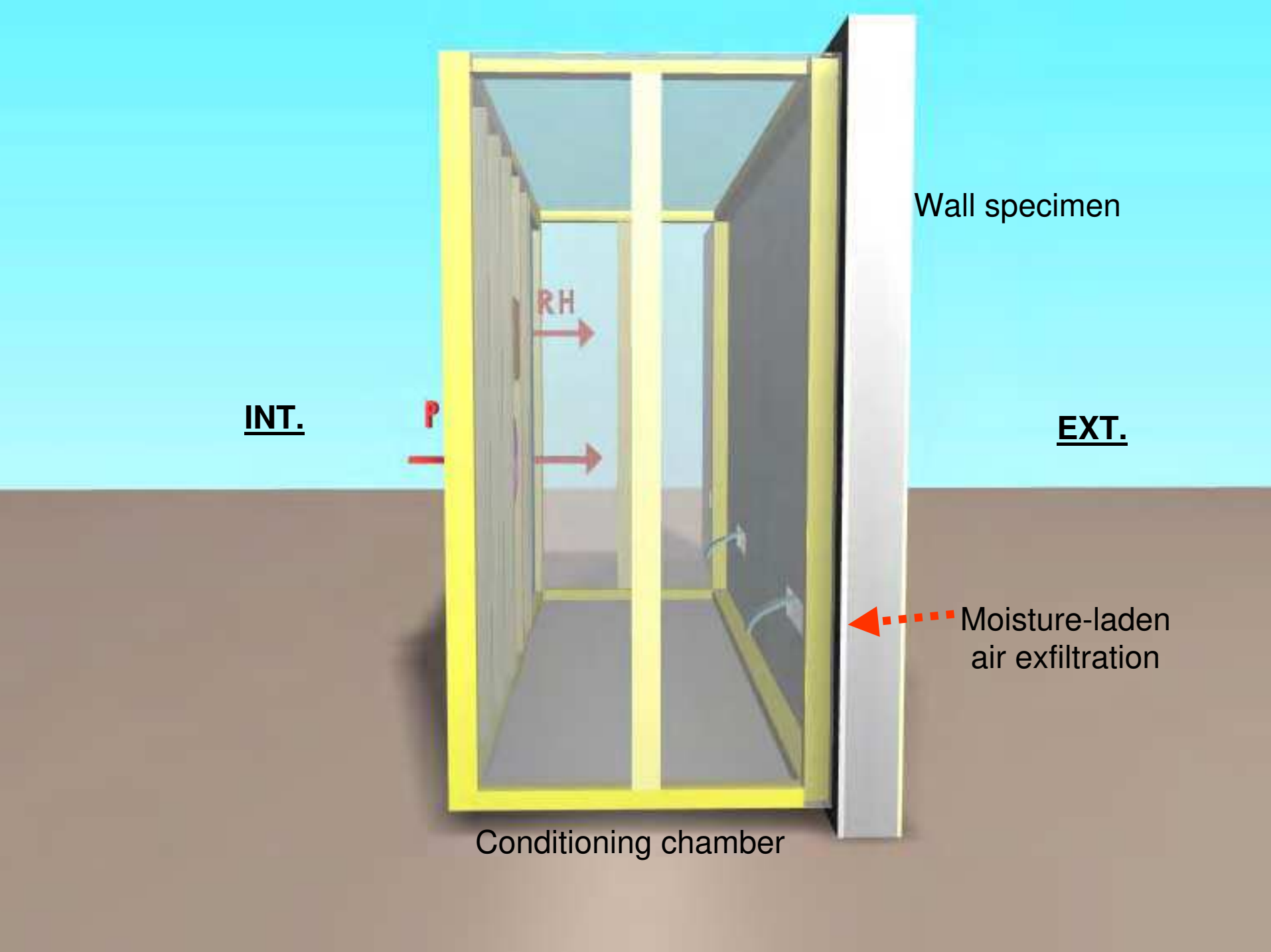
RH

EXT.

Wall specimen

Moisture-laden
air exfiltration

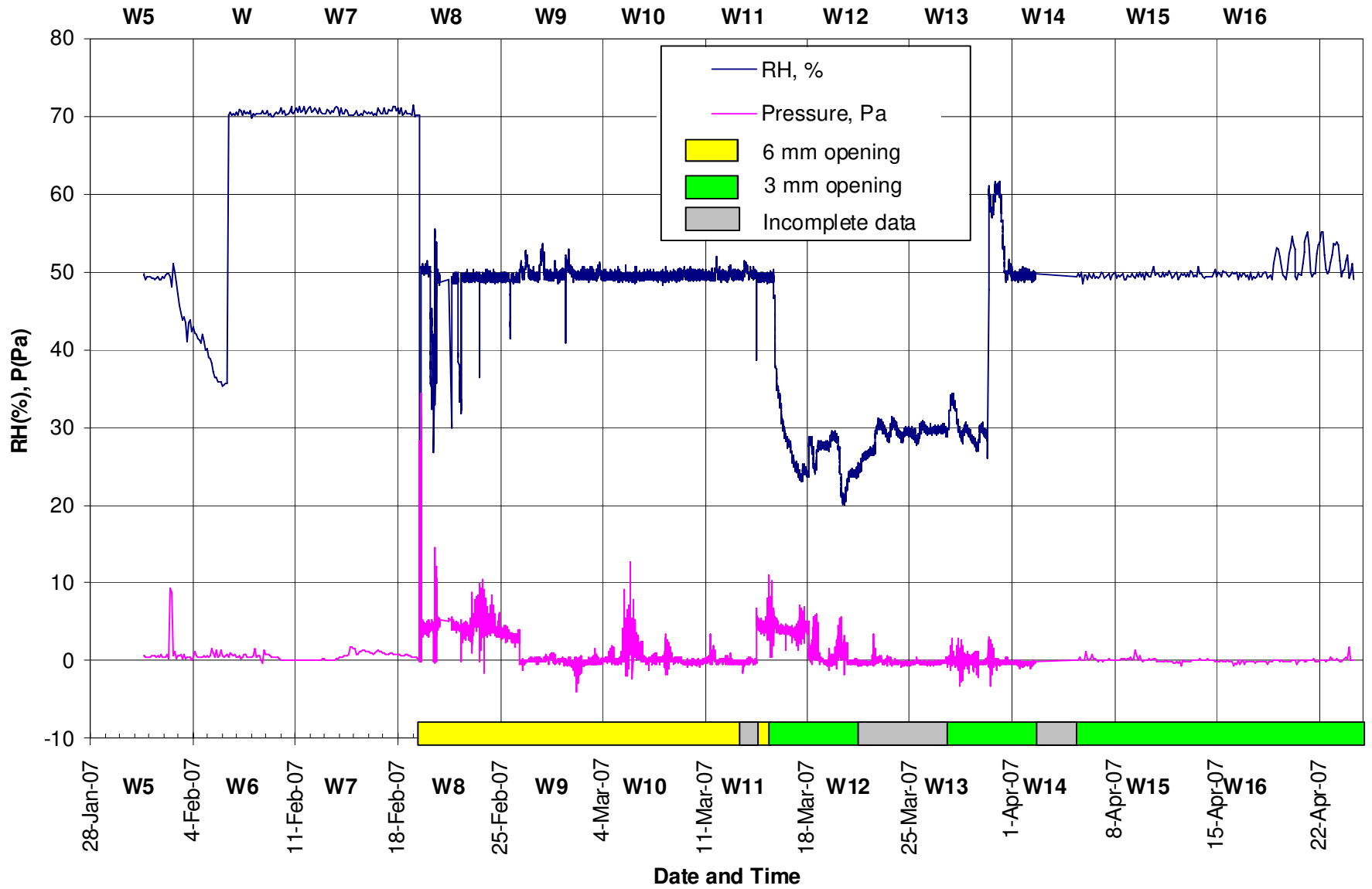
Conditioning chamber



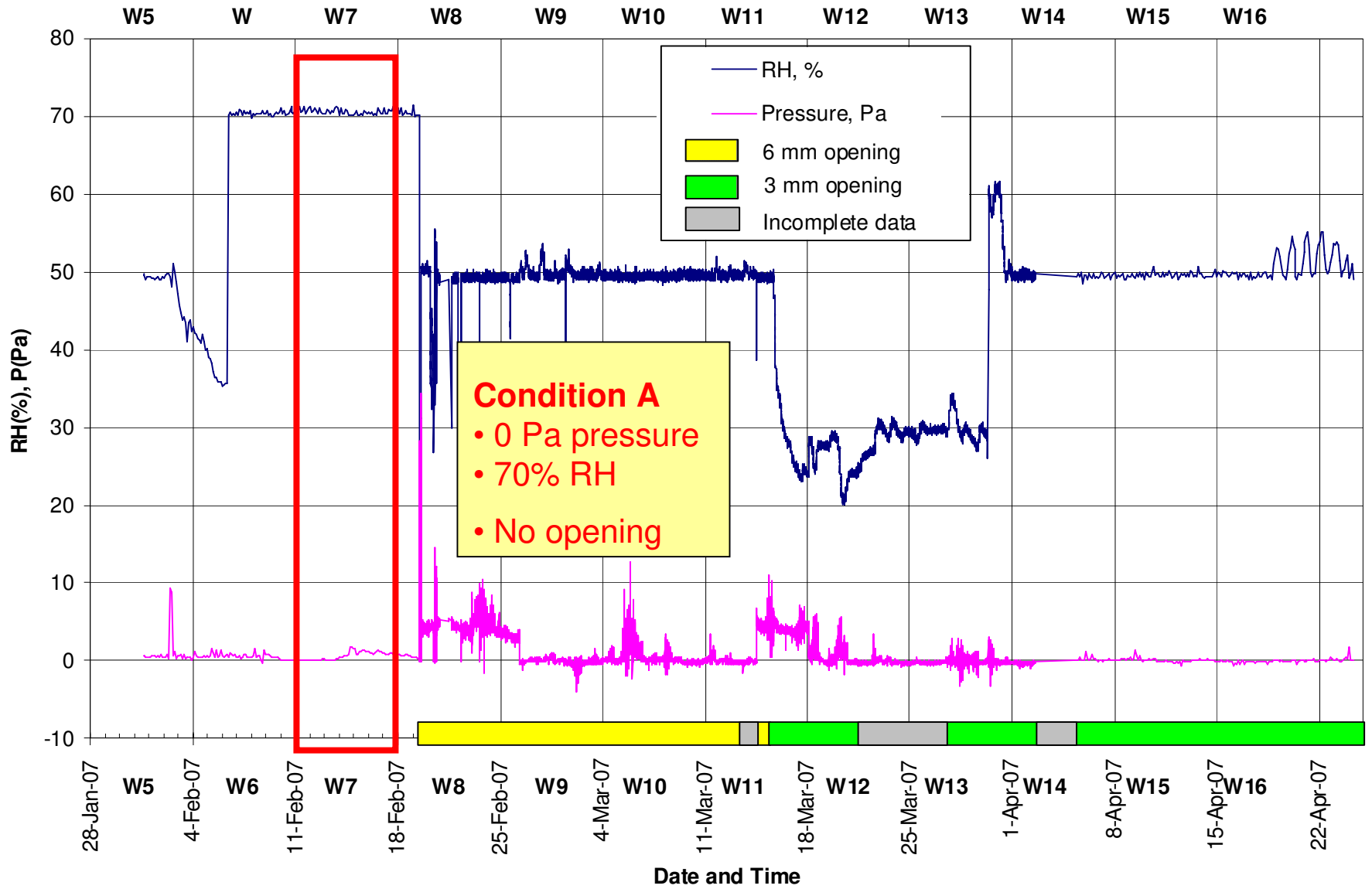
- Challenging the wall experimental begins:
 - Stage 1- Create air leakage path and monitor under naturally occurring int. and ext. conditions on two of three specimens (1 week)
 - Stage 2- Increase indoor RH to 70% and induce 5 Pa positive pressure while air leak is present in two specimens, for a certain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

Results

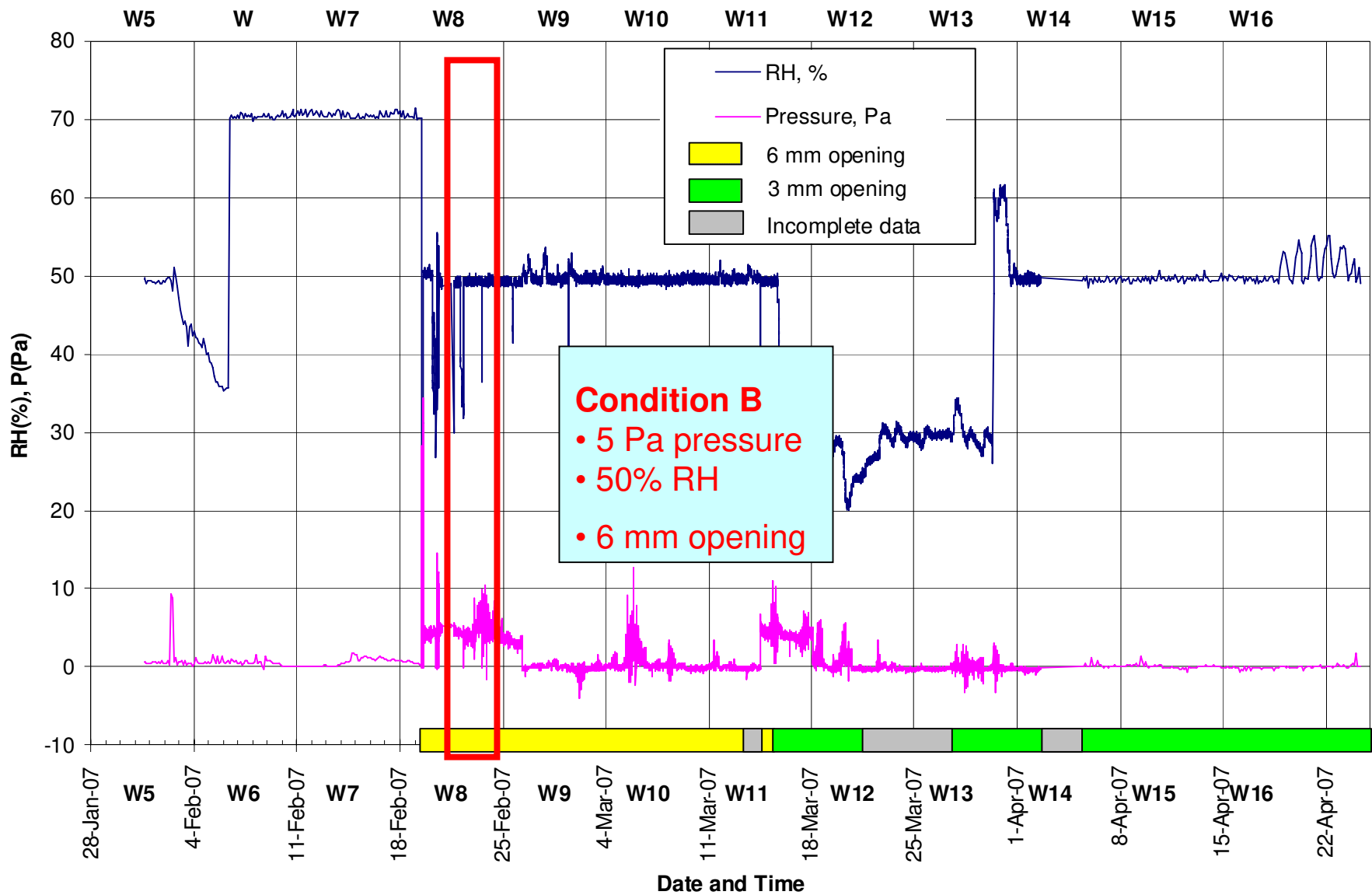
FEWF Chamber RH%, Pressure Vs Time



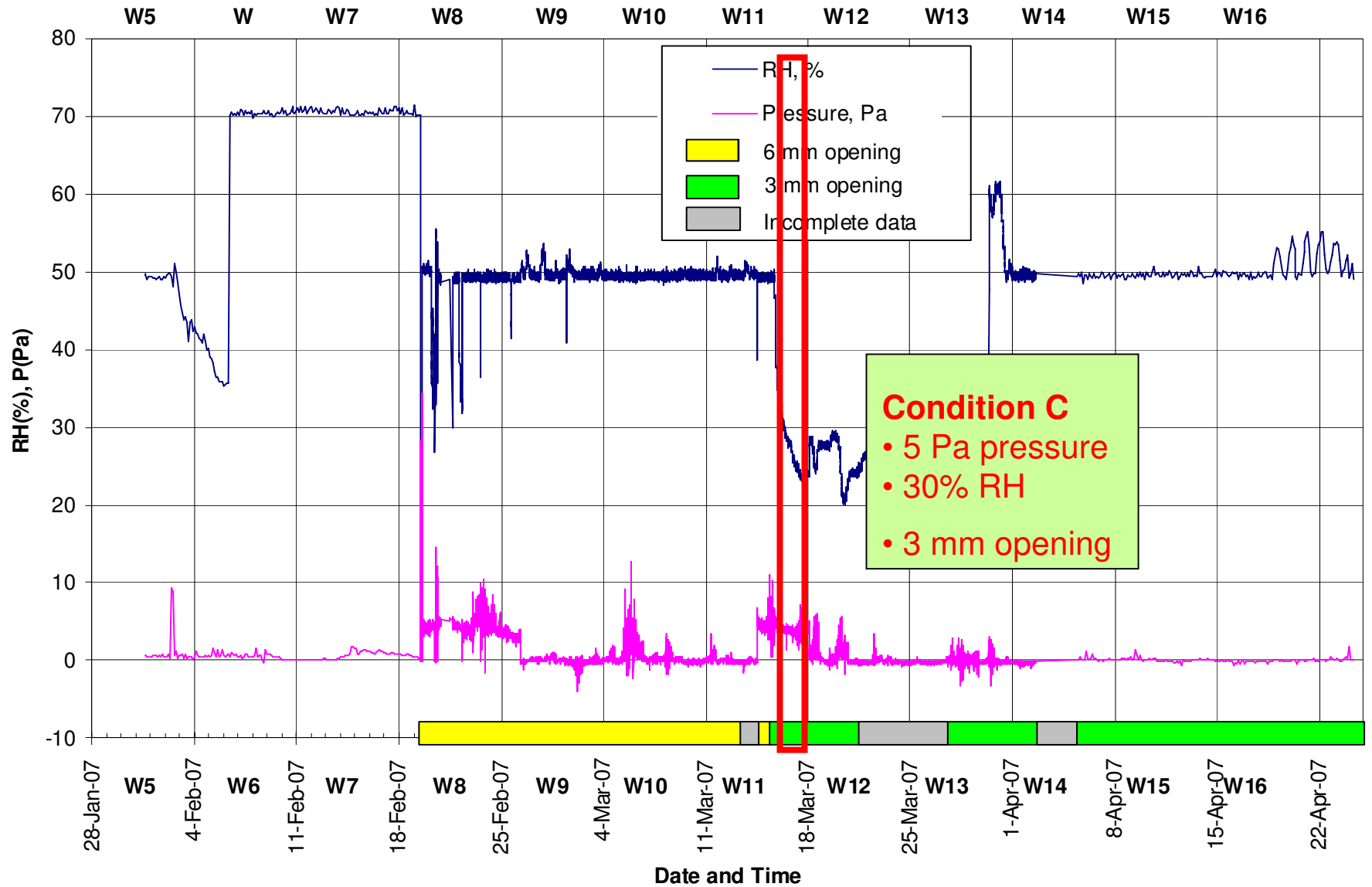
FEWF Chamber RH%, Pressure Vs Time



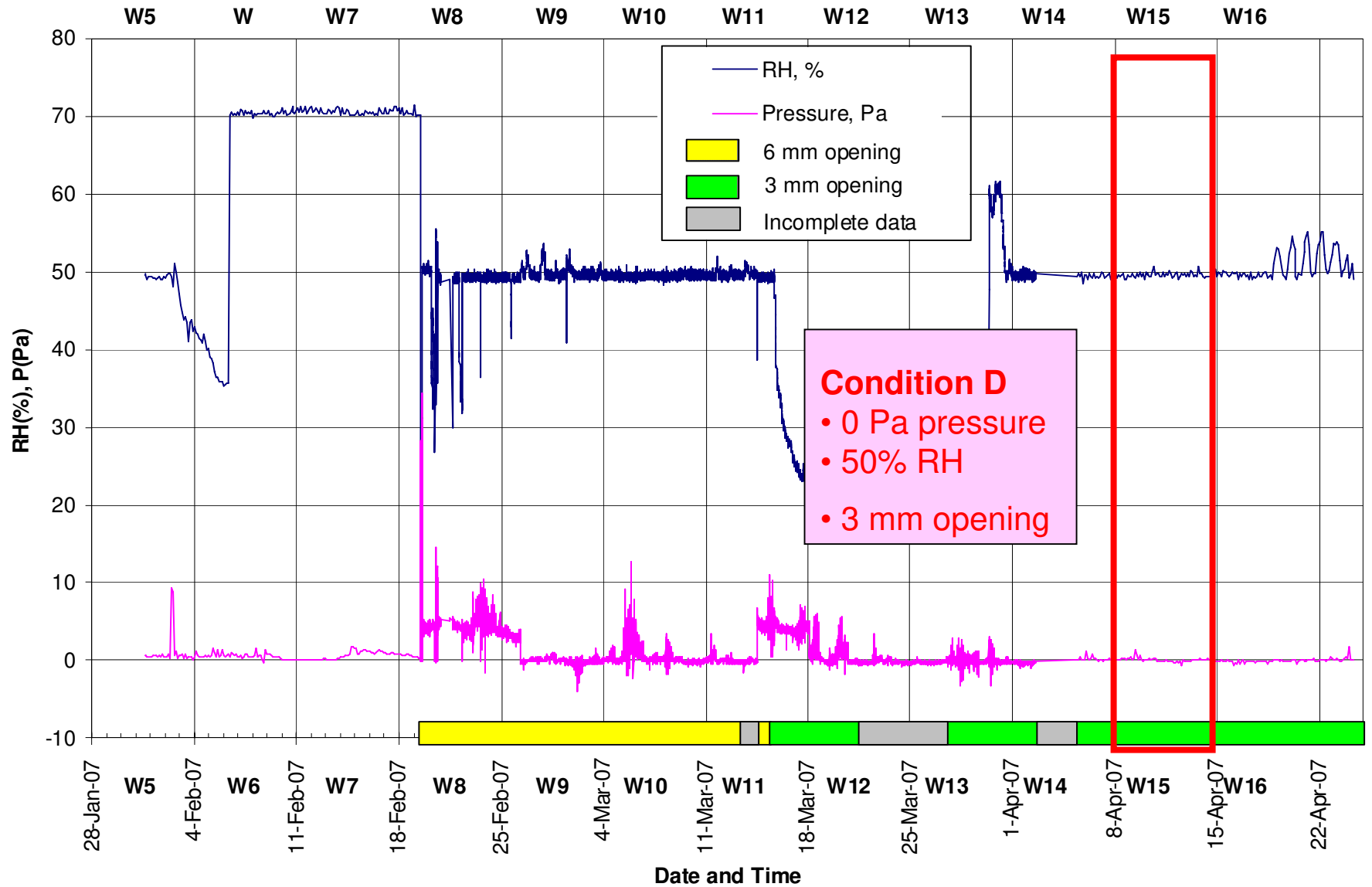
FEWF Chamber RH%, Pressure Vs Time



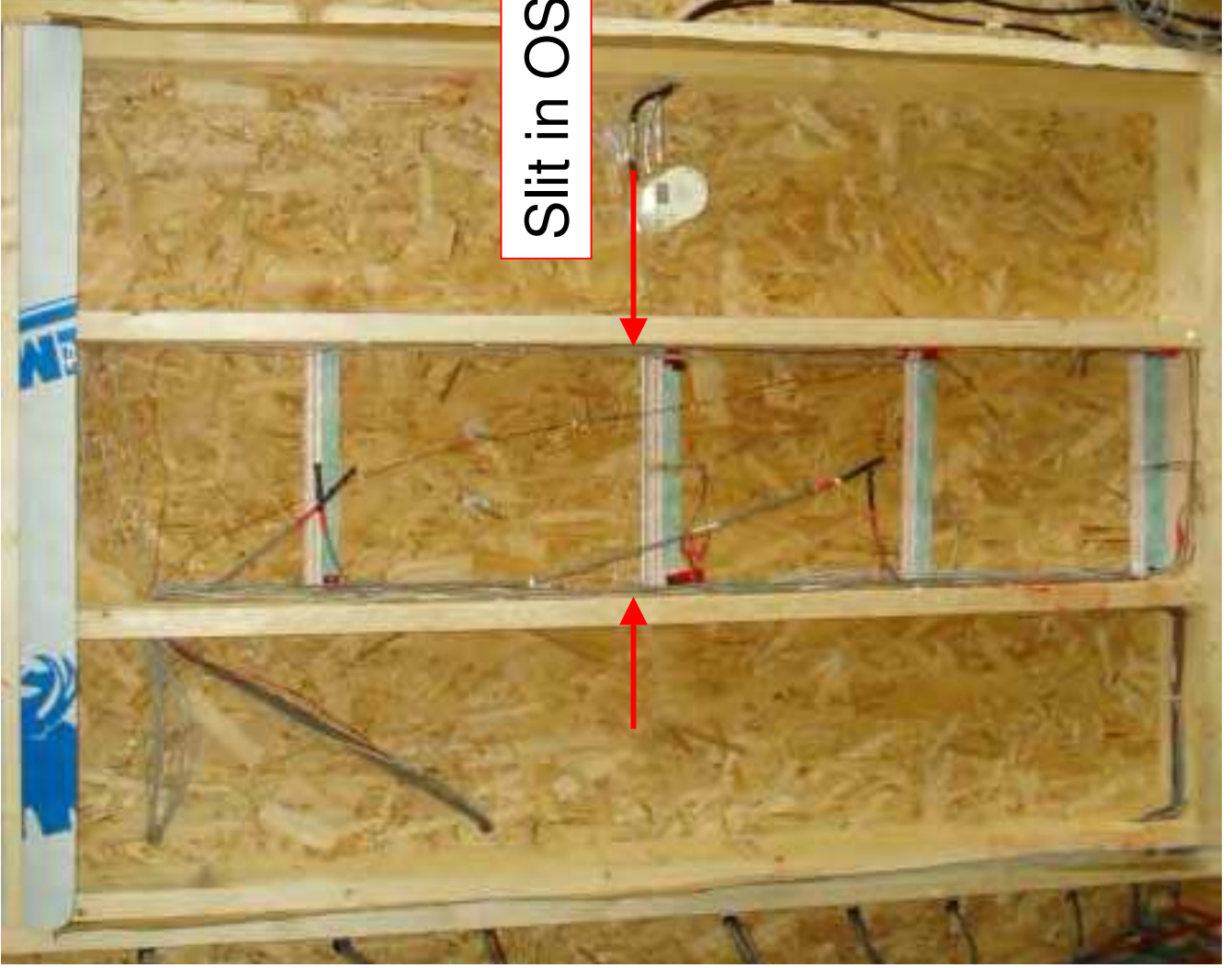
FEWF Chamber RH%, Pressure Vs Time



FEWF Chamber RH%, Pressure Vs Time



Slit in OSB





Slit in OSB

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

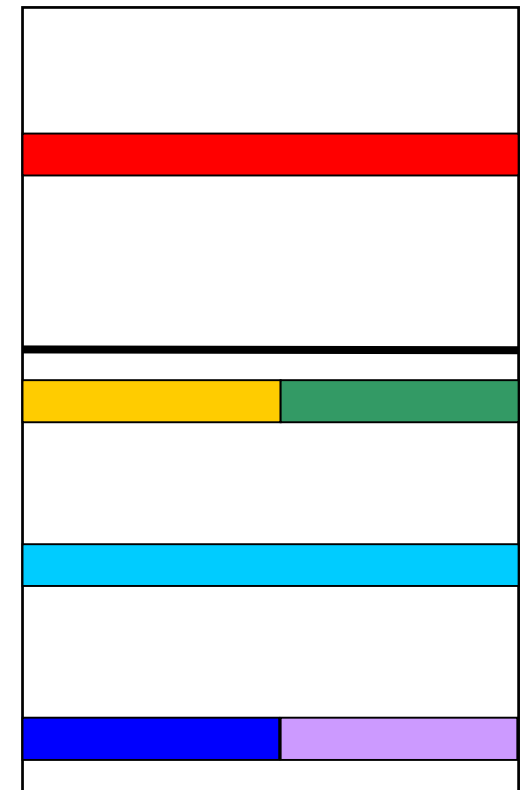
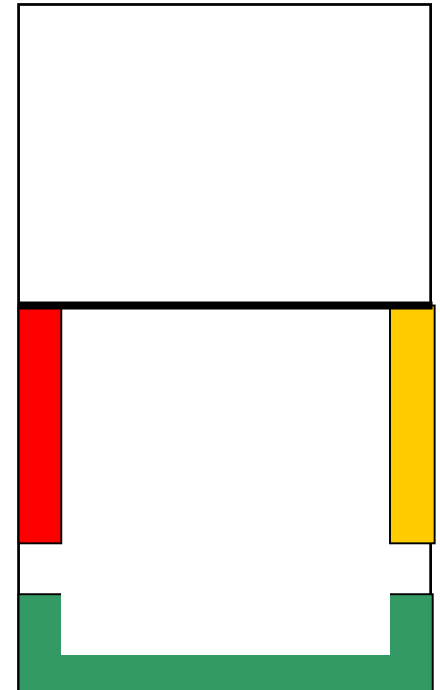
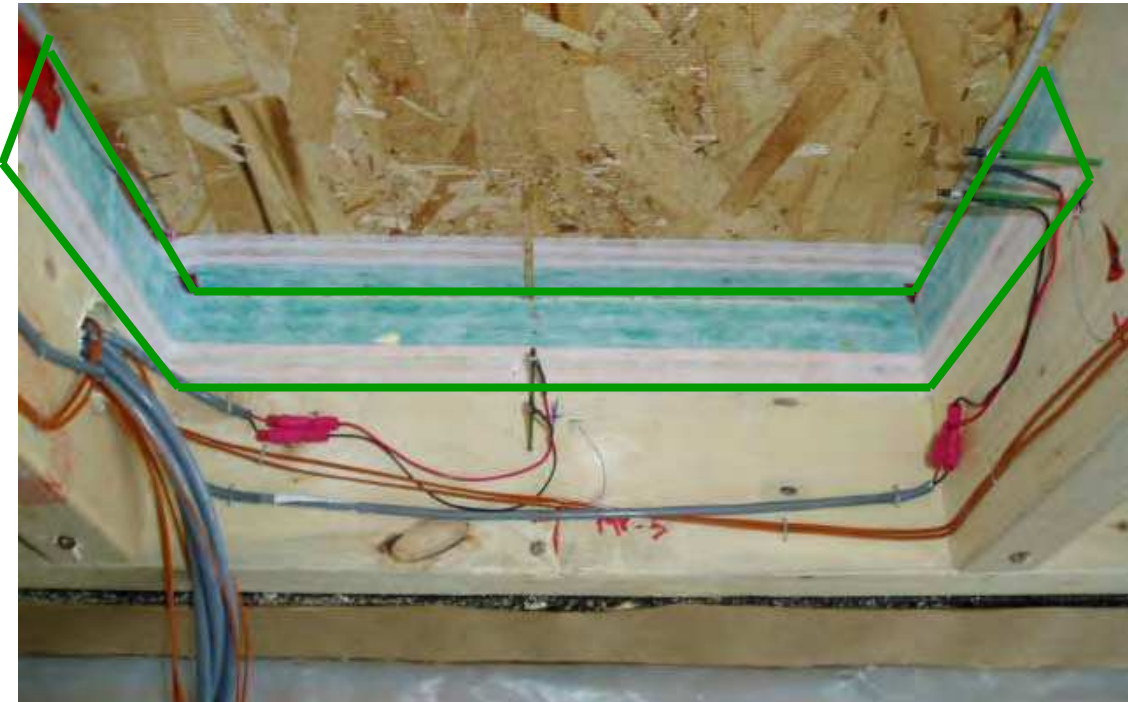
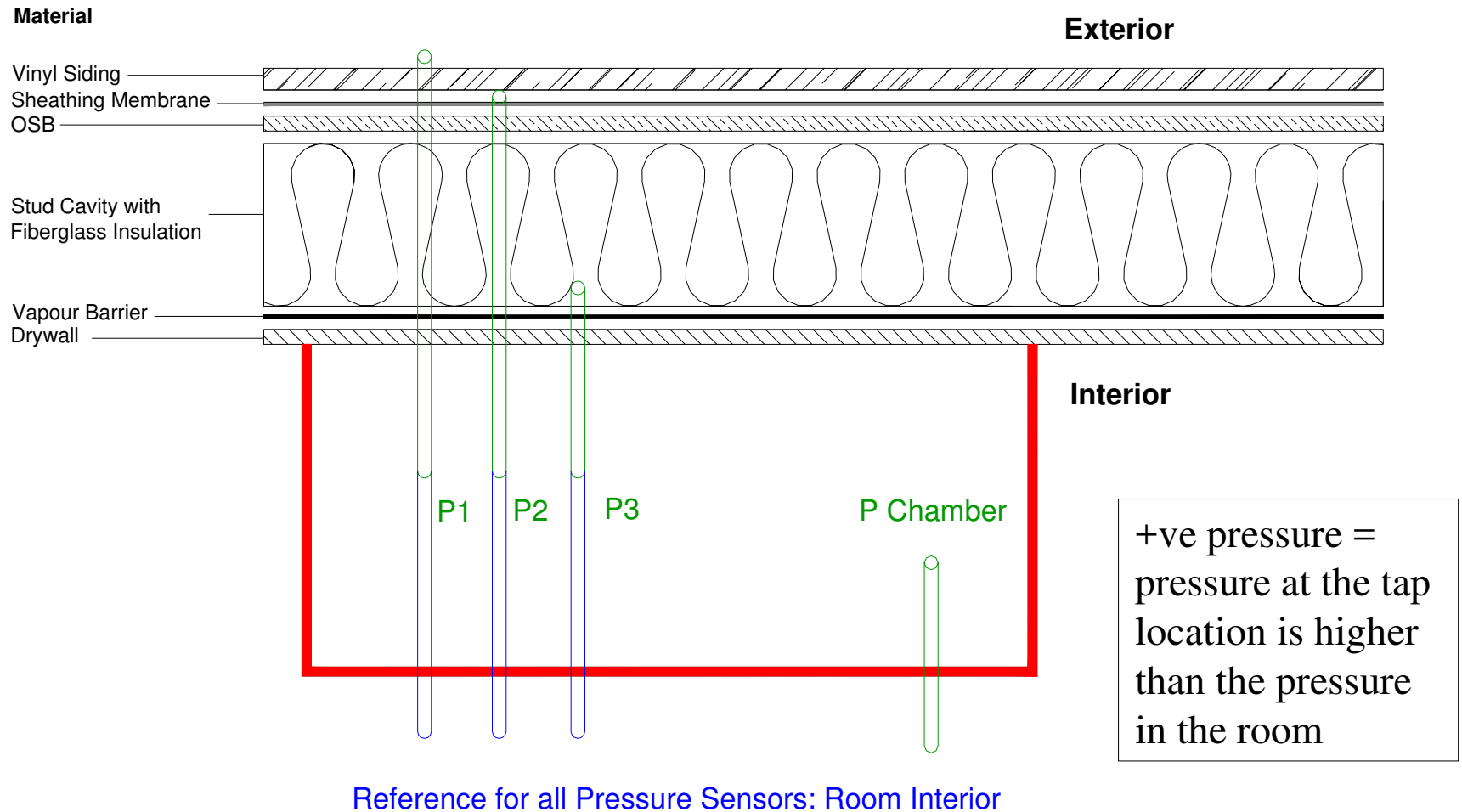


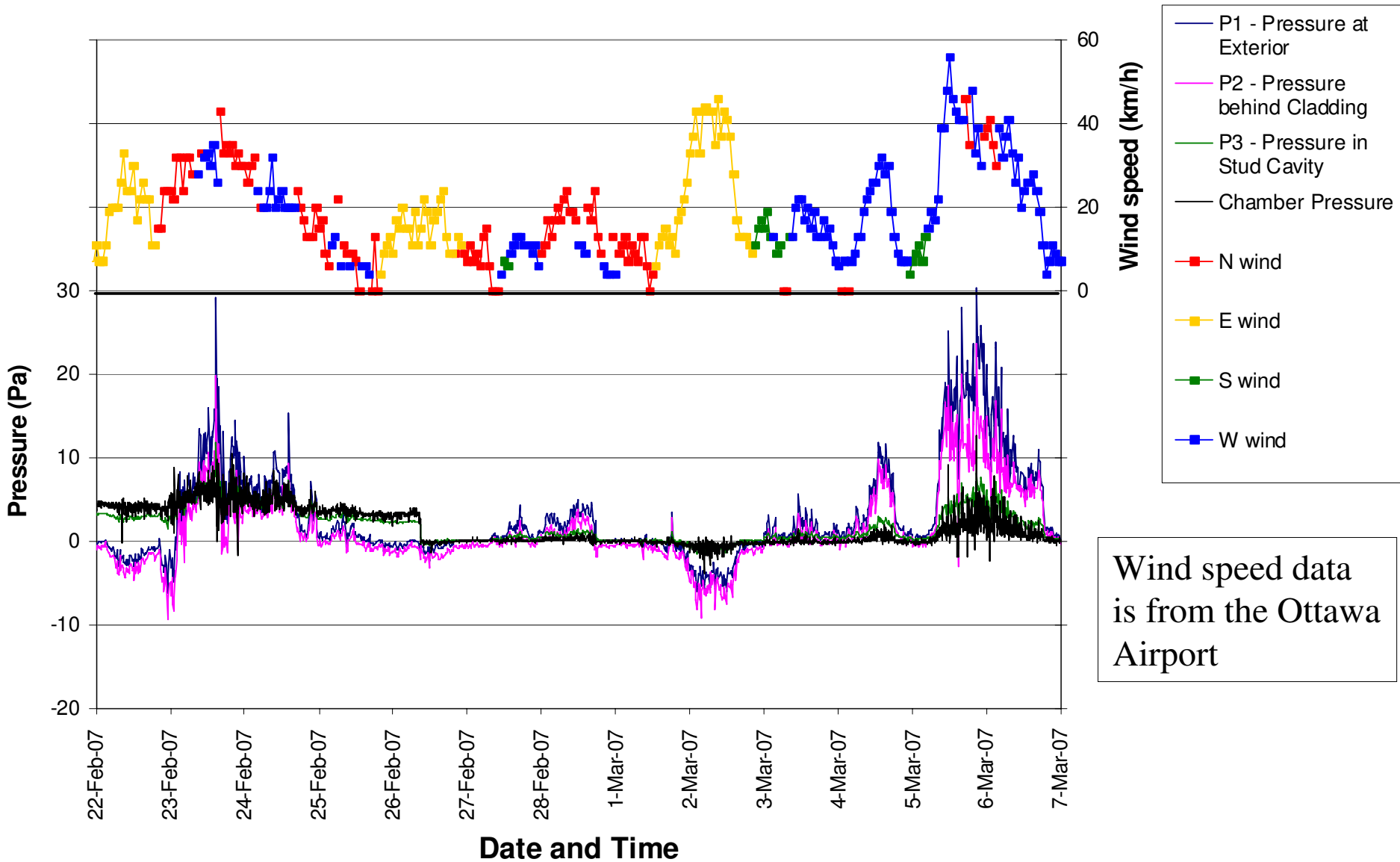
Diagram for Moisture
Detection Tape Locations
in the Stud Cavity



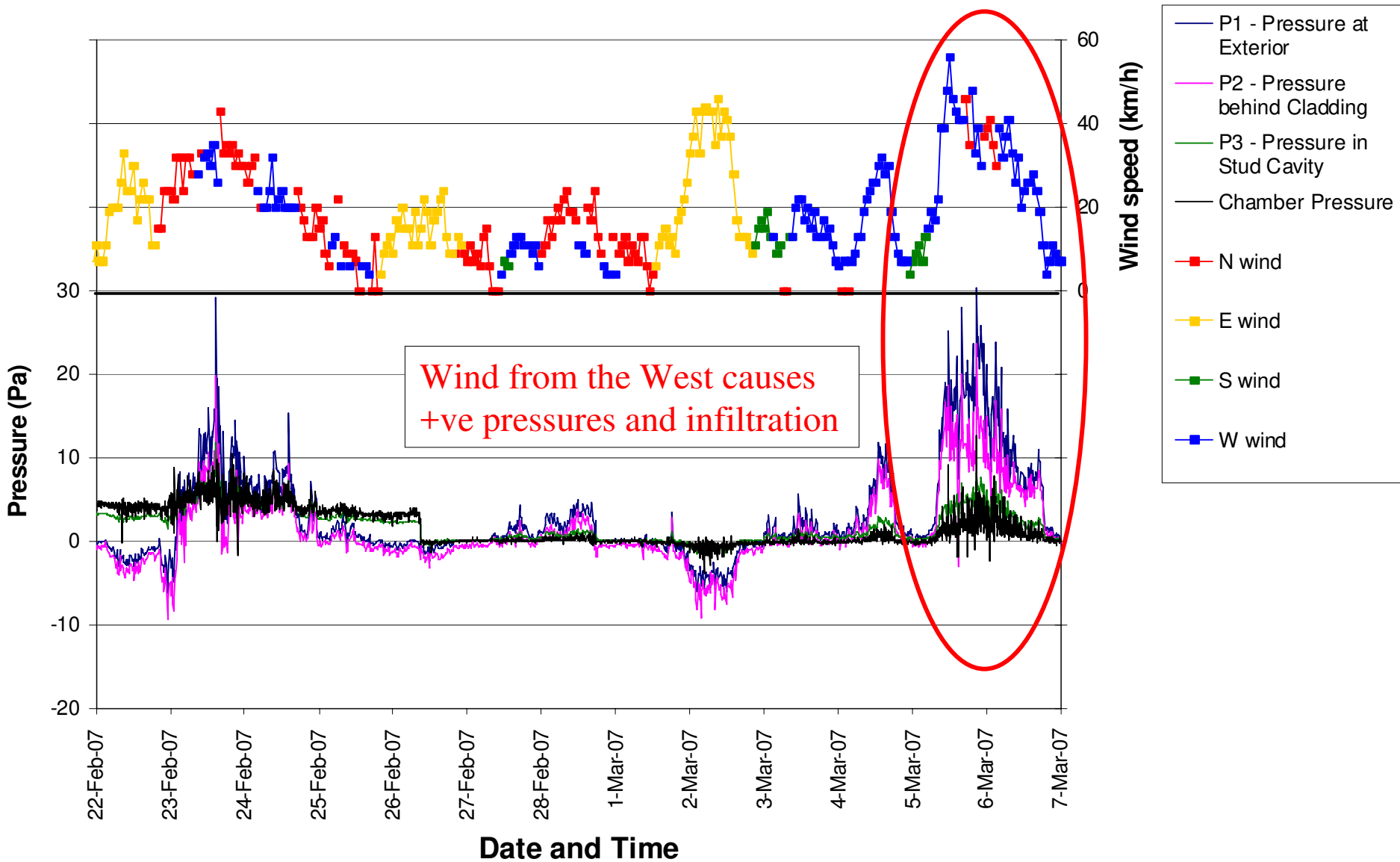
Pressure Tap Locations



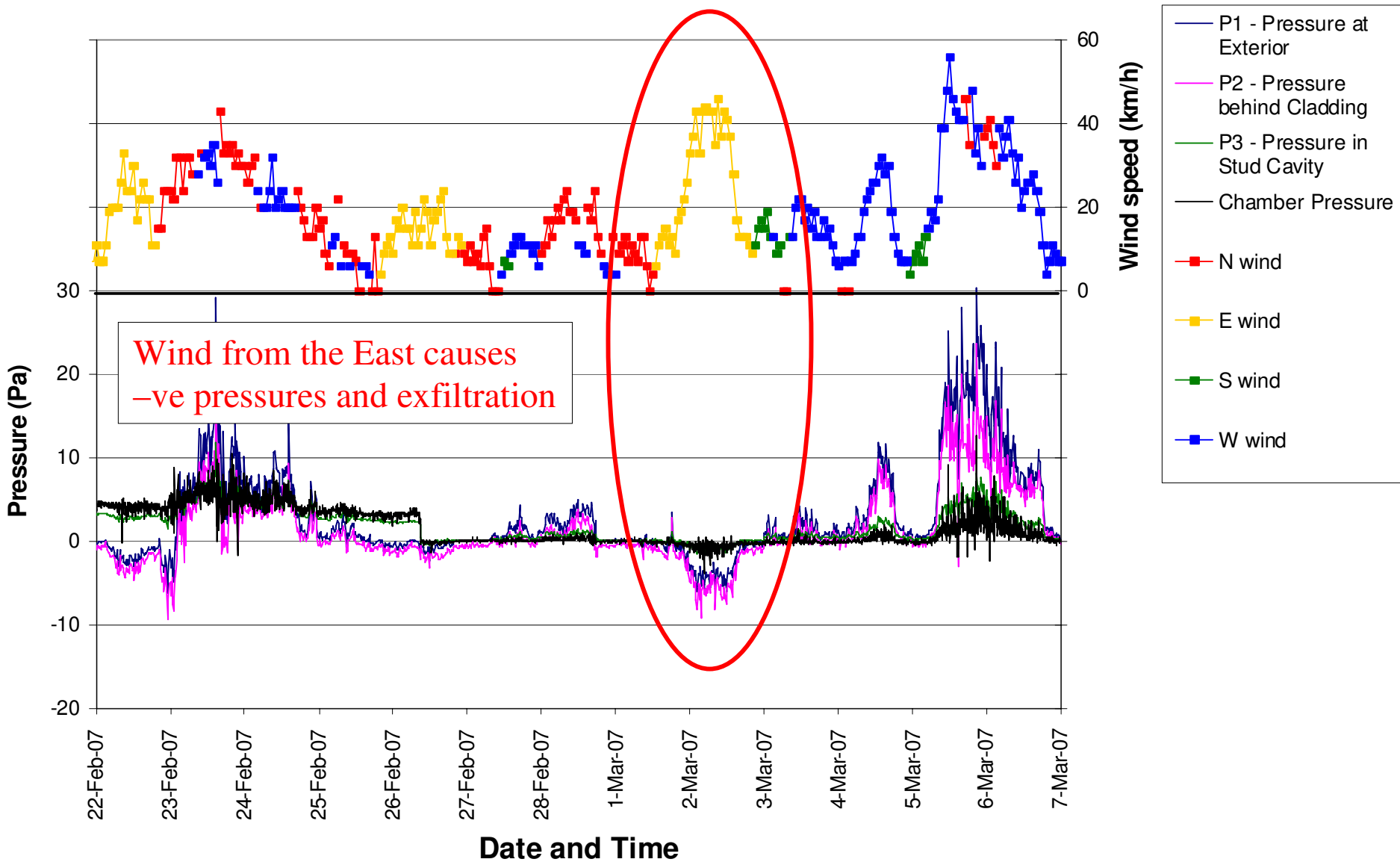
Pressure, Wind speed and direction



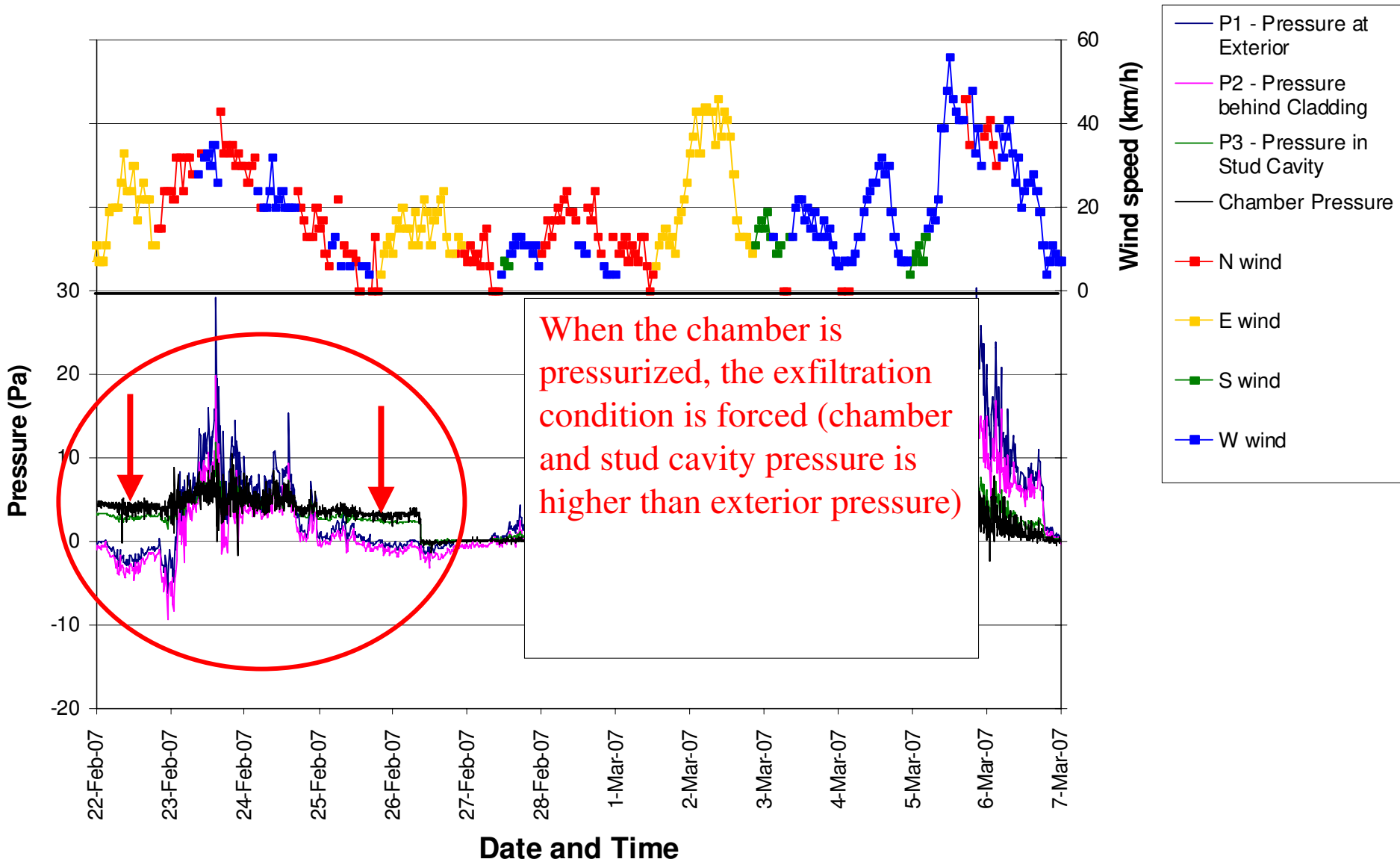
Pressure, Wind speed and direction



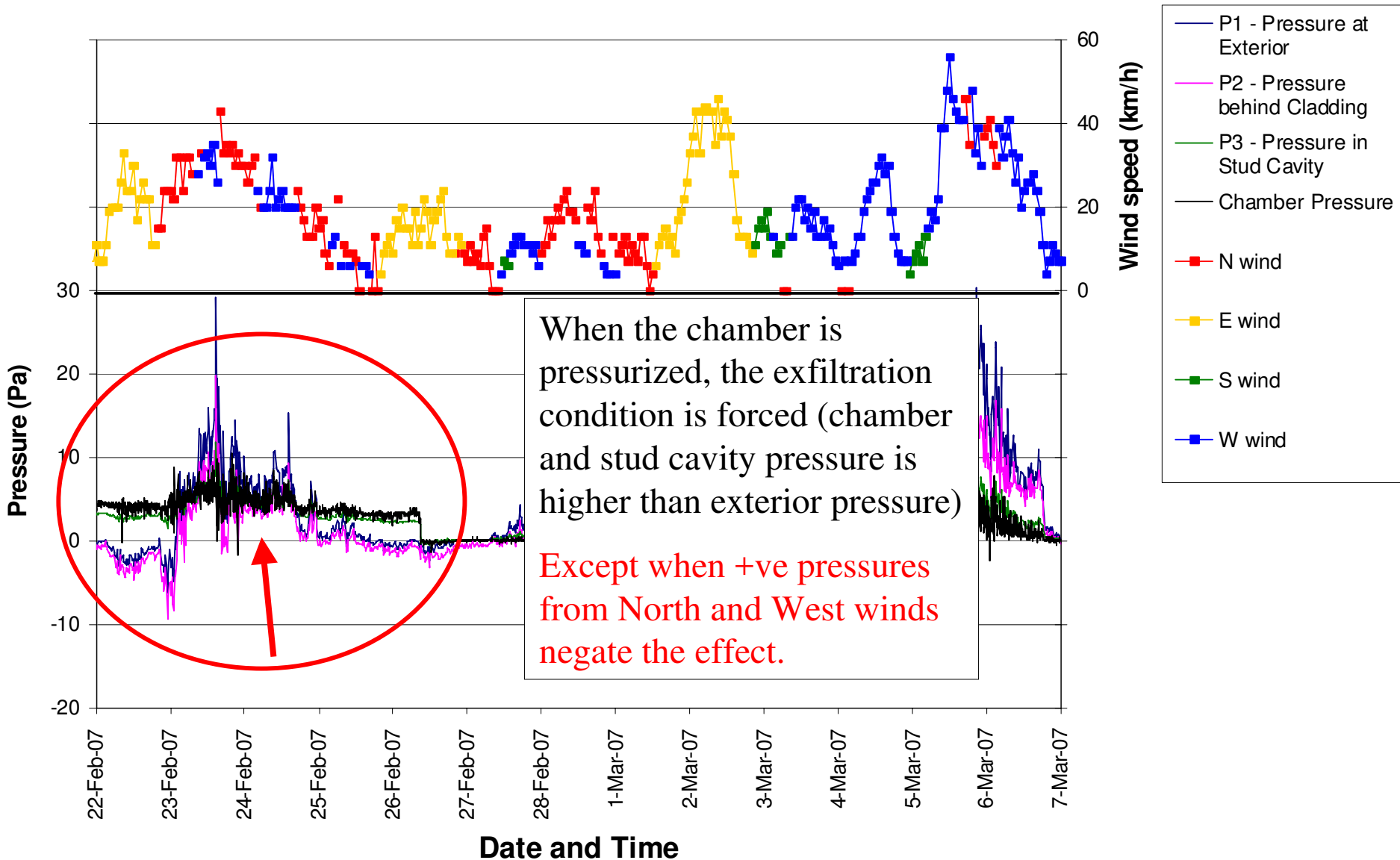
Pressure, Wind speed and direction



Pressure, Wind speed and direction



Pressure, Wind speed and direction

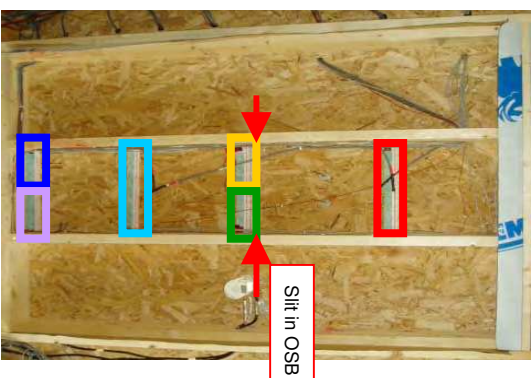
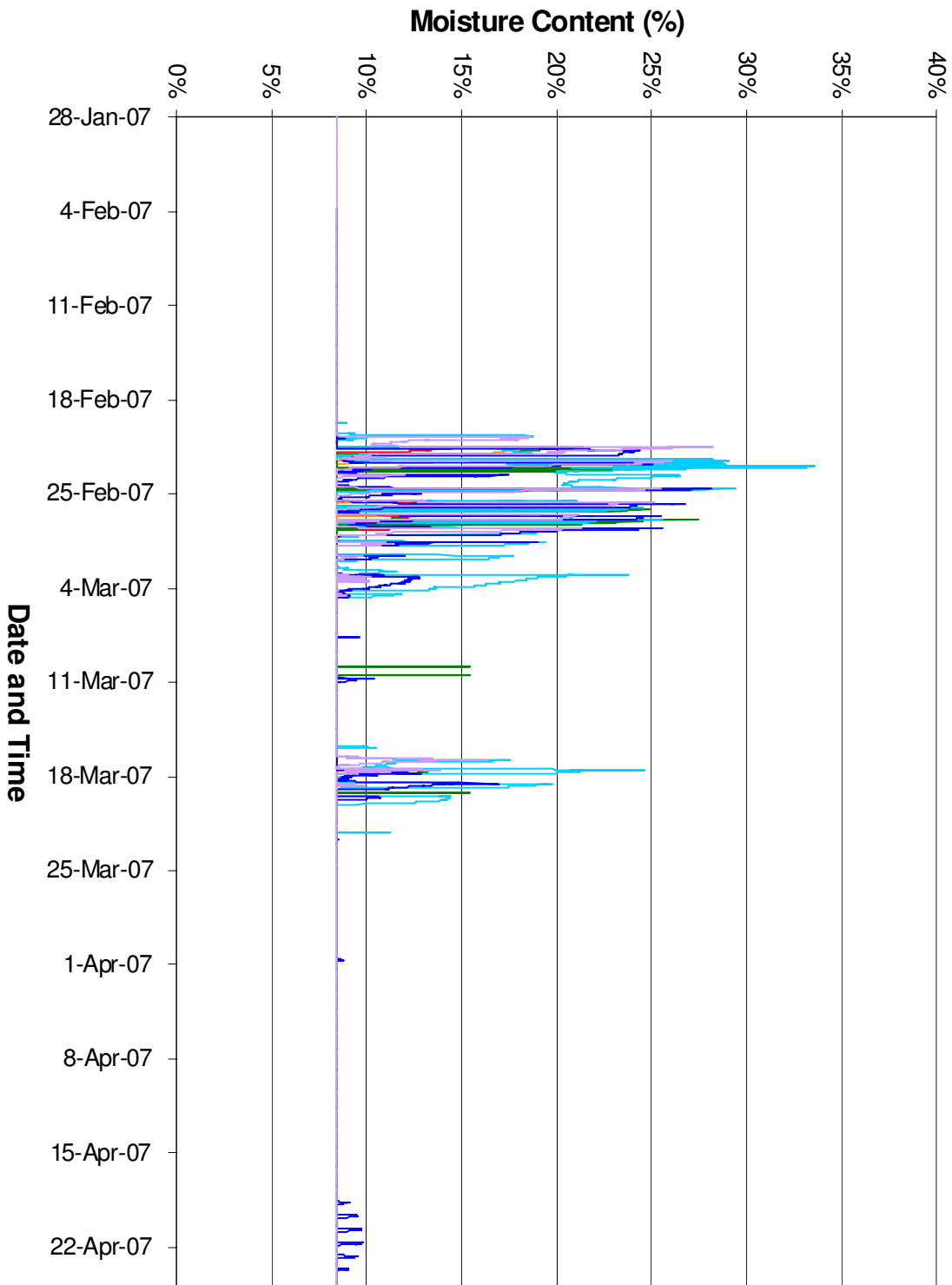


Conditions

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

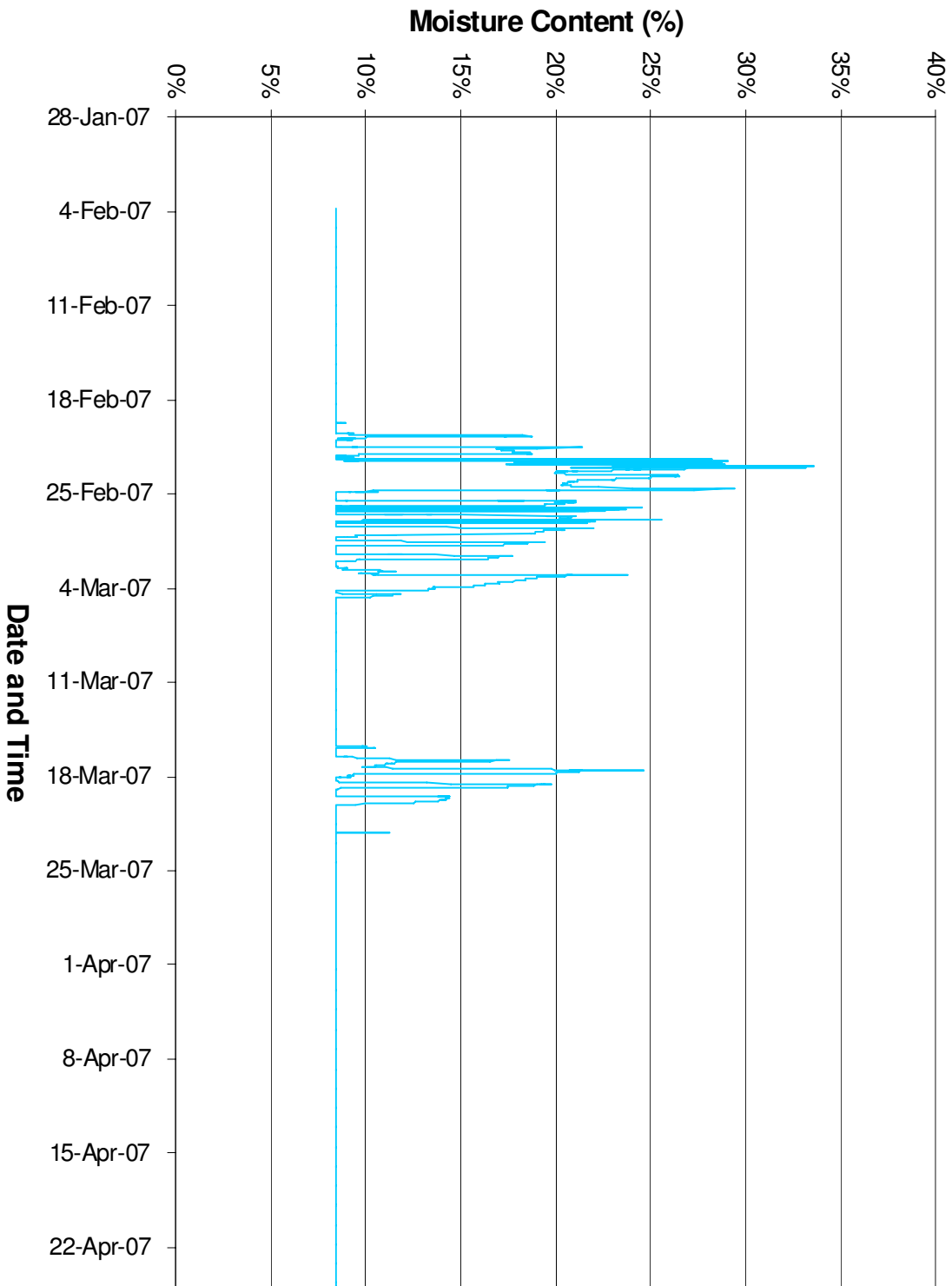
All data presented are averaged over the test period indicated above

Moisture Content - Wall 2 Interior OSB

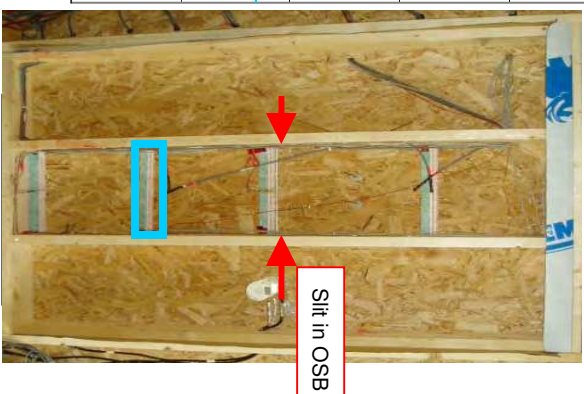


- 209MC
- 210MC
- 211MC
- 212MC
- 213MC
- 214MC

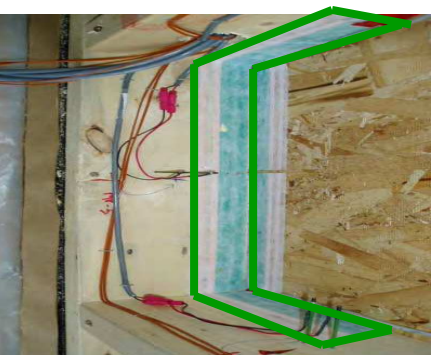
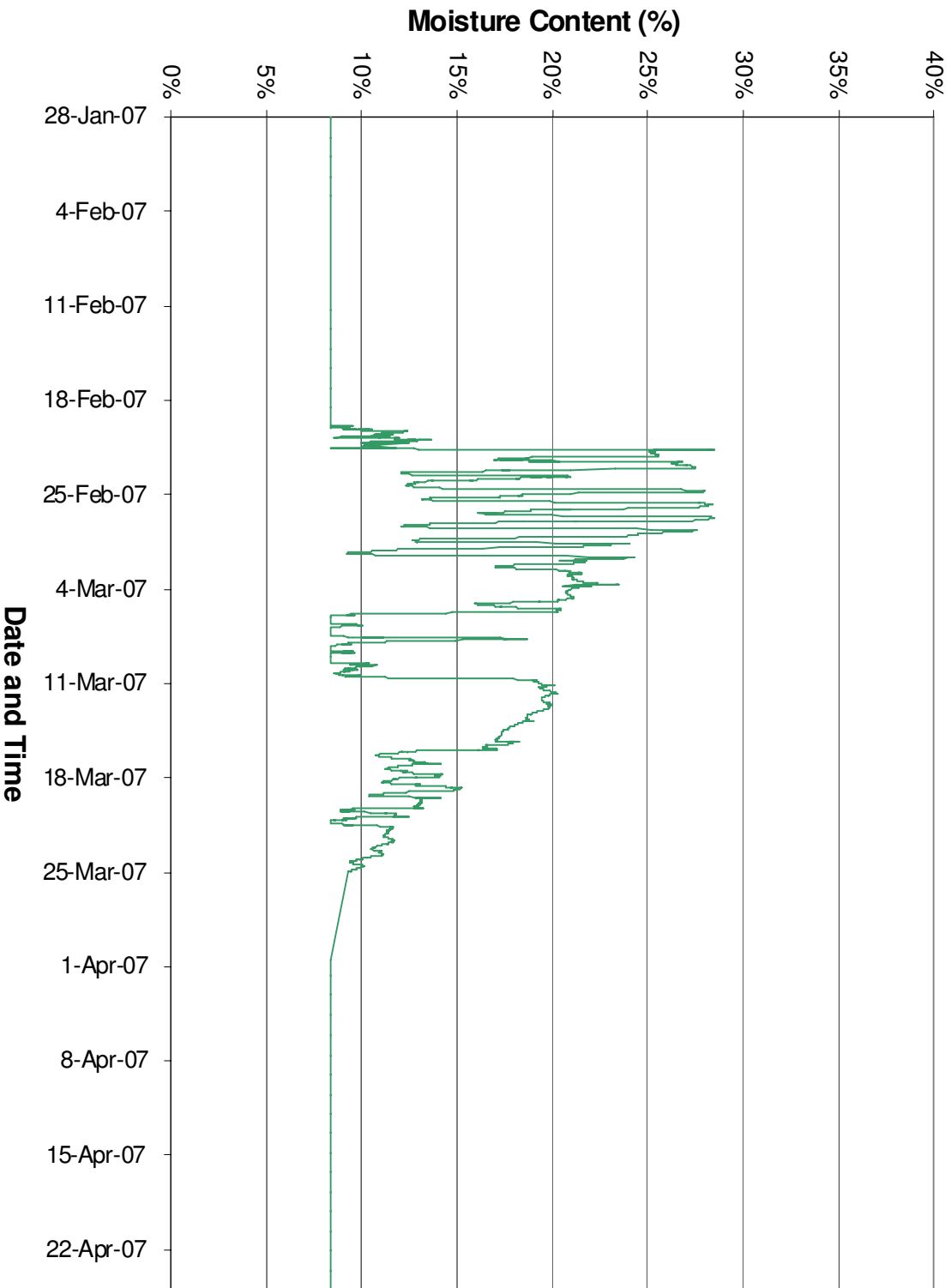
Moisture Content - Wall 2 Interior OSB



212MC



Moisture Content - Wall 2 Stud Cavity

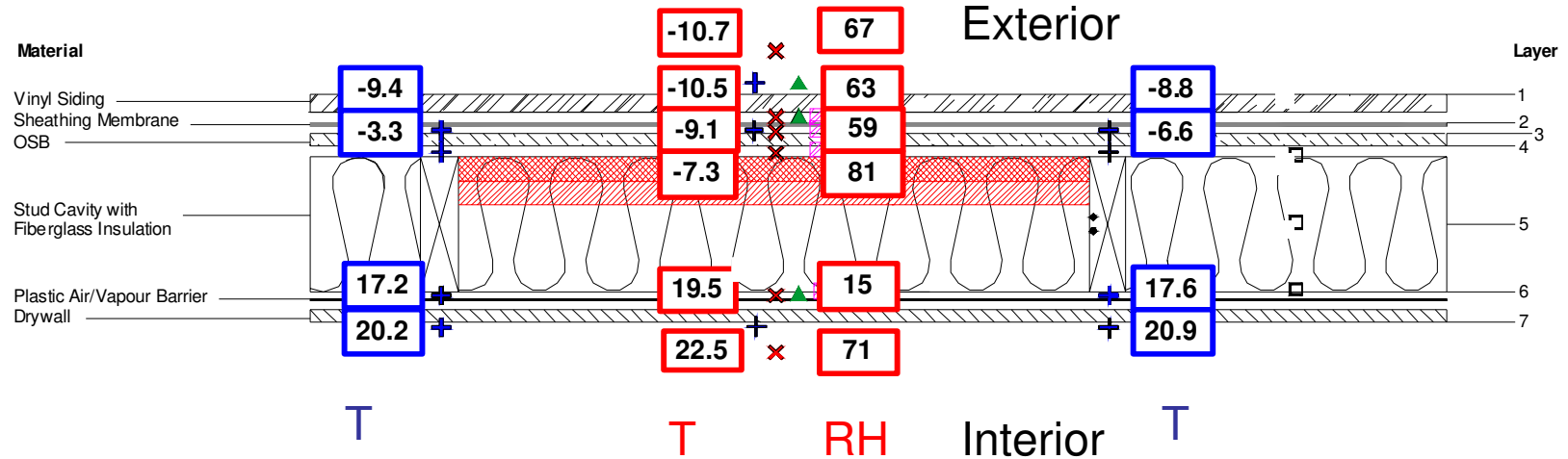


217MC

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

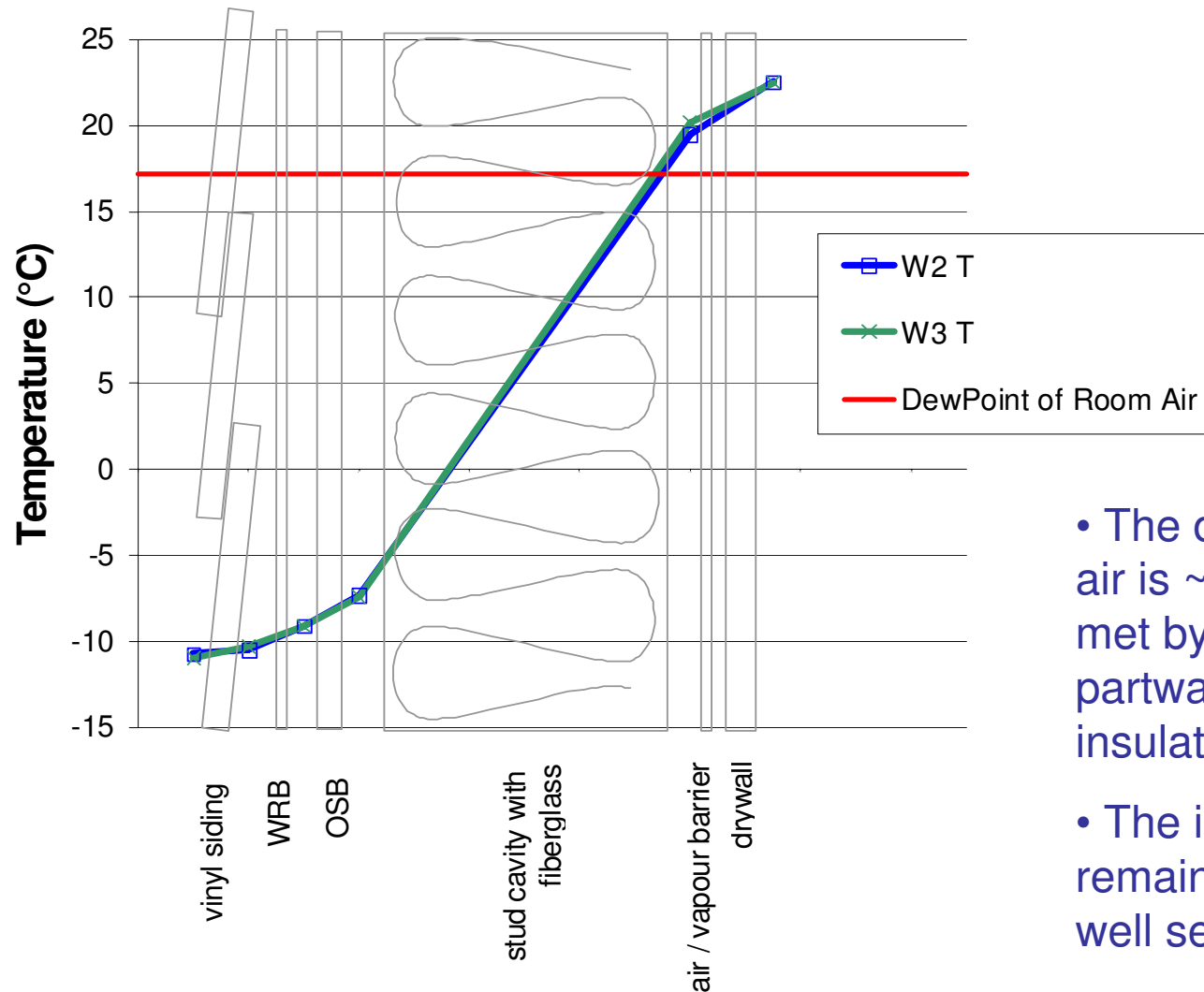
Wall 2 Horizontal Cross Section

Week 07 11-Feb-07



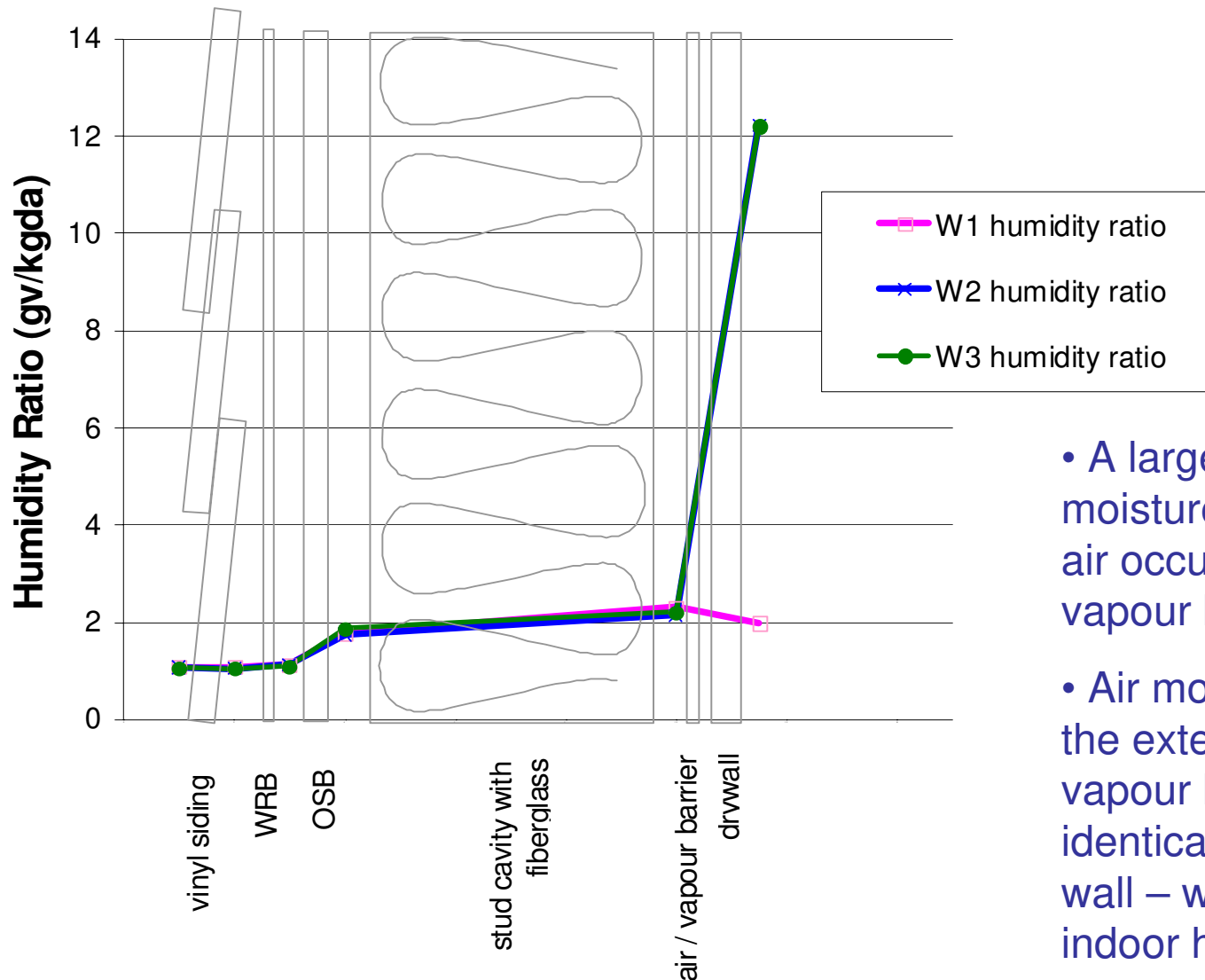
- Despite the high humidity on the interior of the room (71%), the humidity behind the air/vapour barrier is low, 15%
- The location with the highest RH is the interior of the OSB, at ~81% - still below dewpoint

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

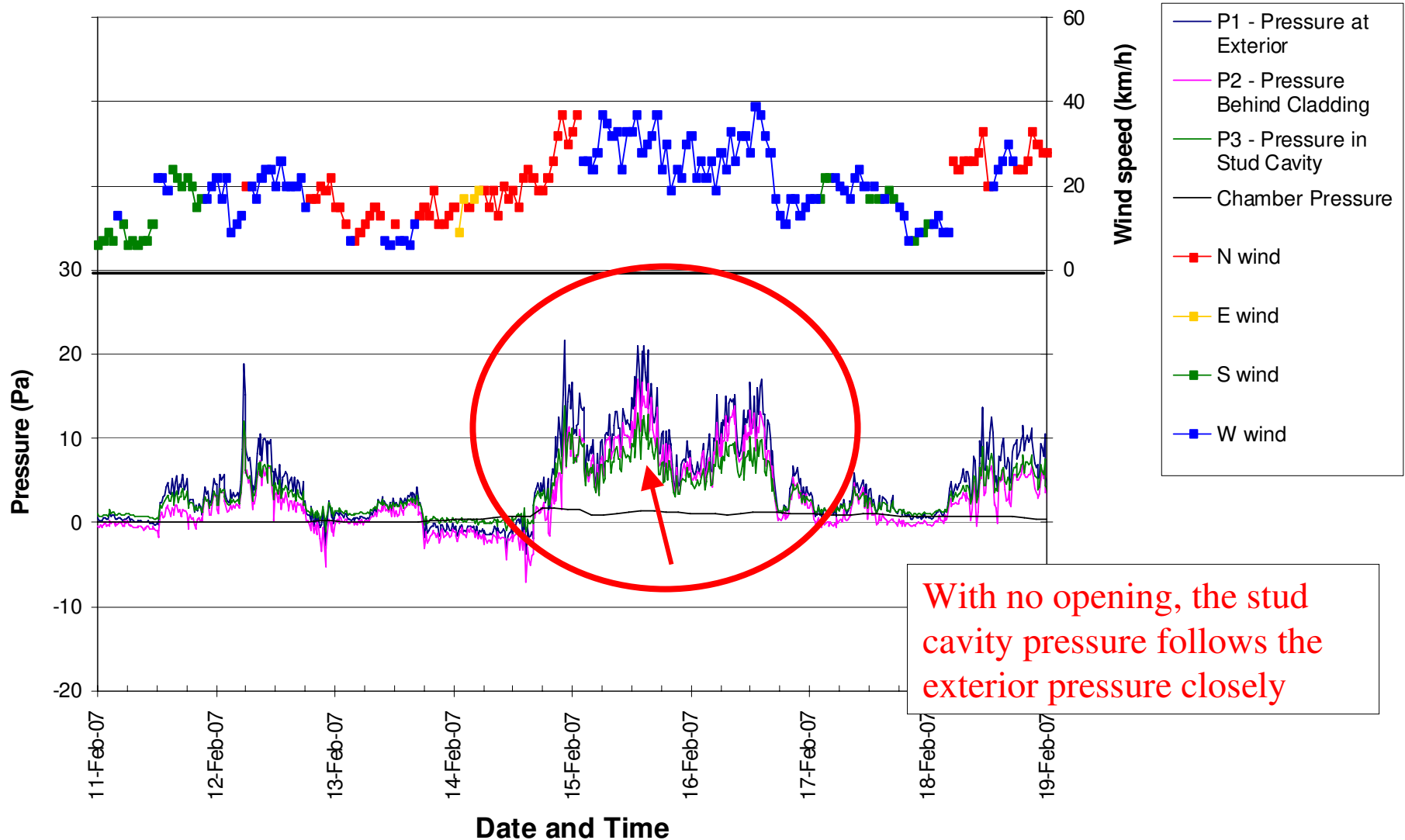
Condition A: 0 Pa, 70% RH, no opening



- 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

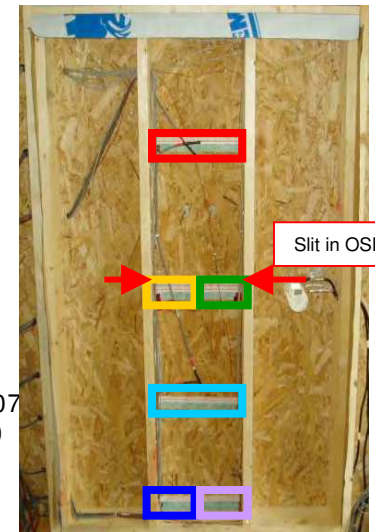
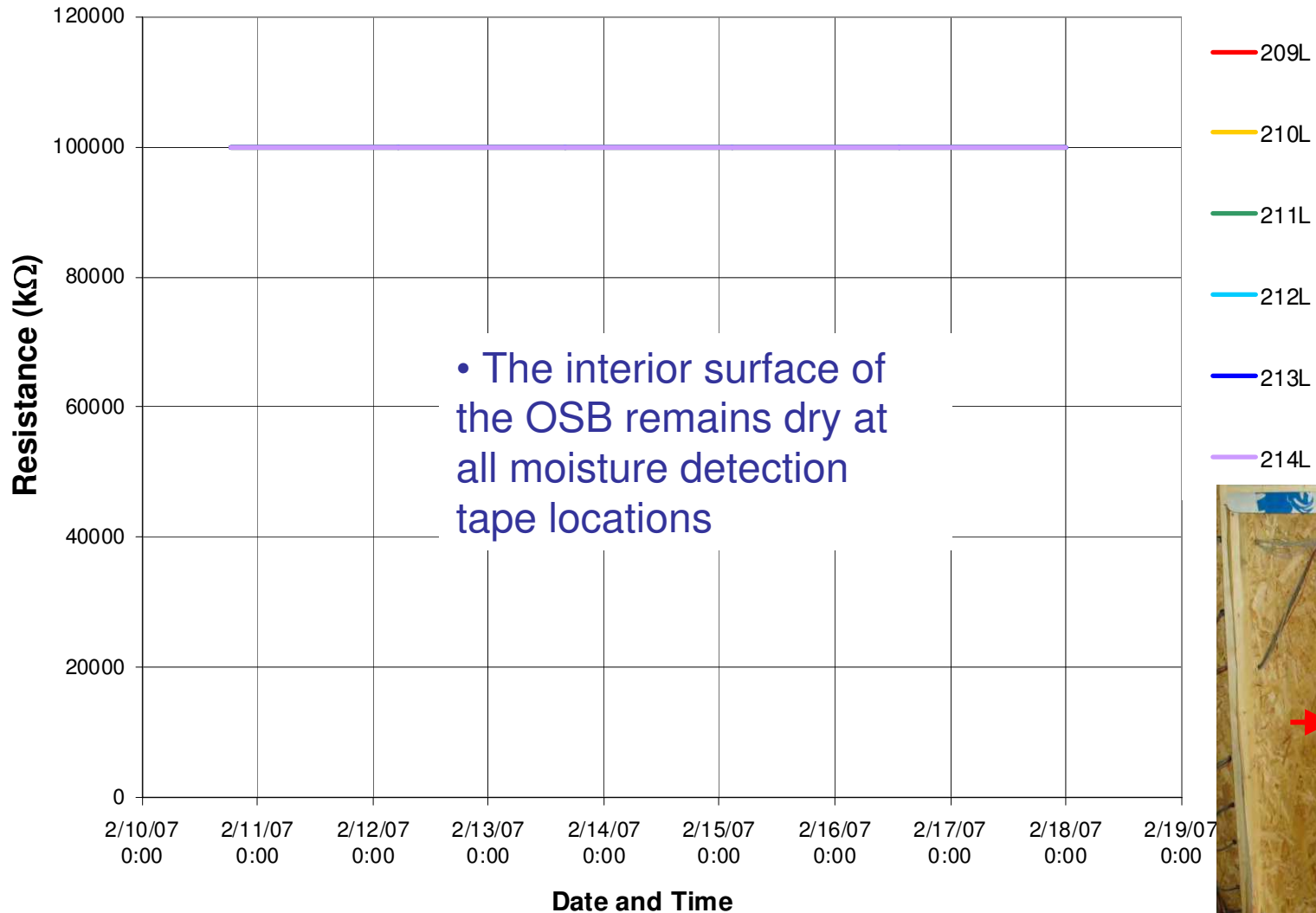
Pressure, Wind speed and direction



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

11-Feb-07

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

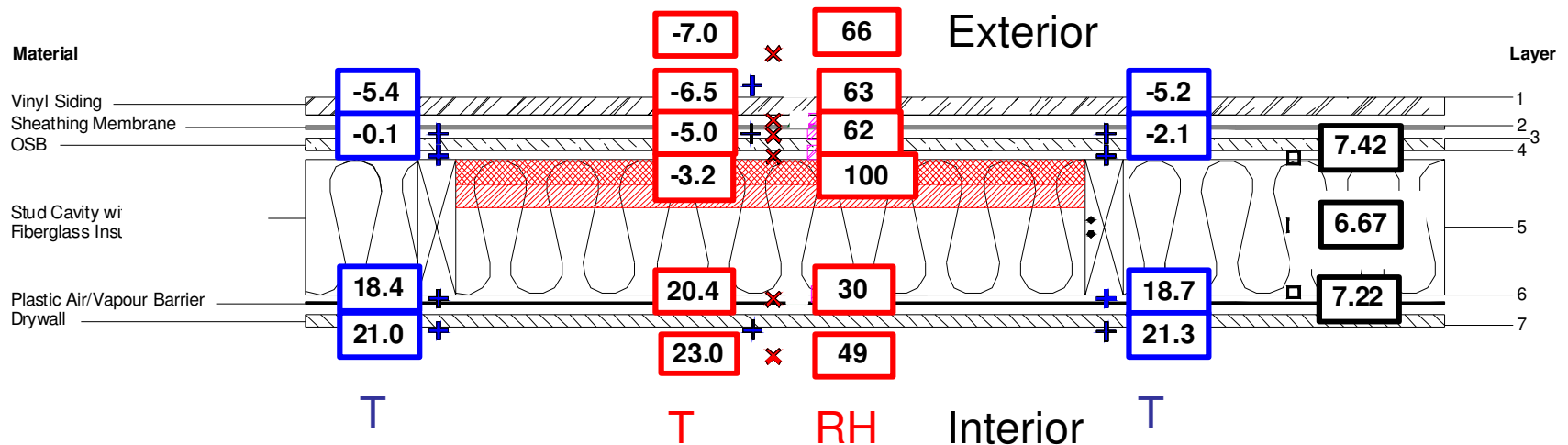


Condition B: 5 Pa, 50% RH, 6mm opening

Week 08

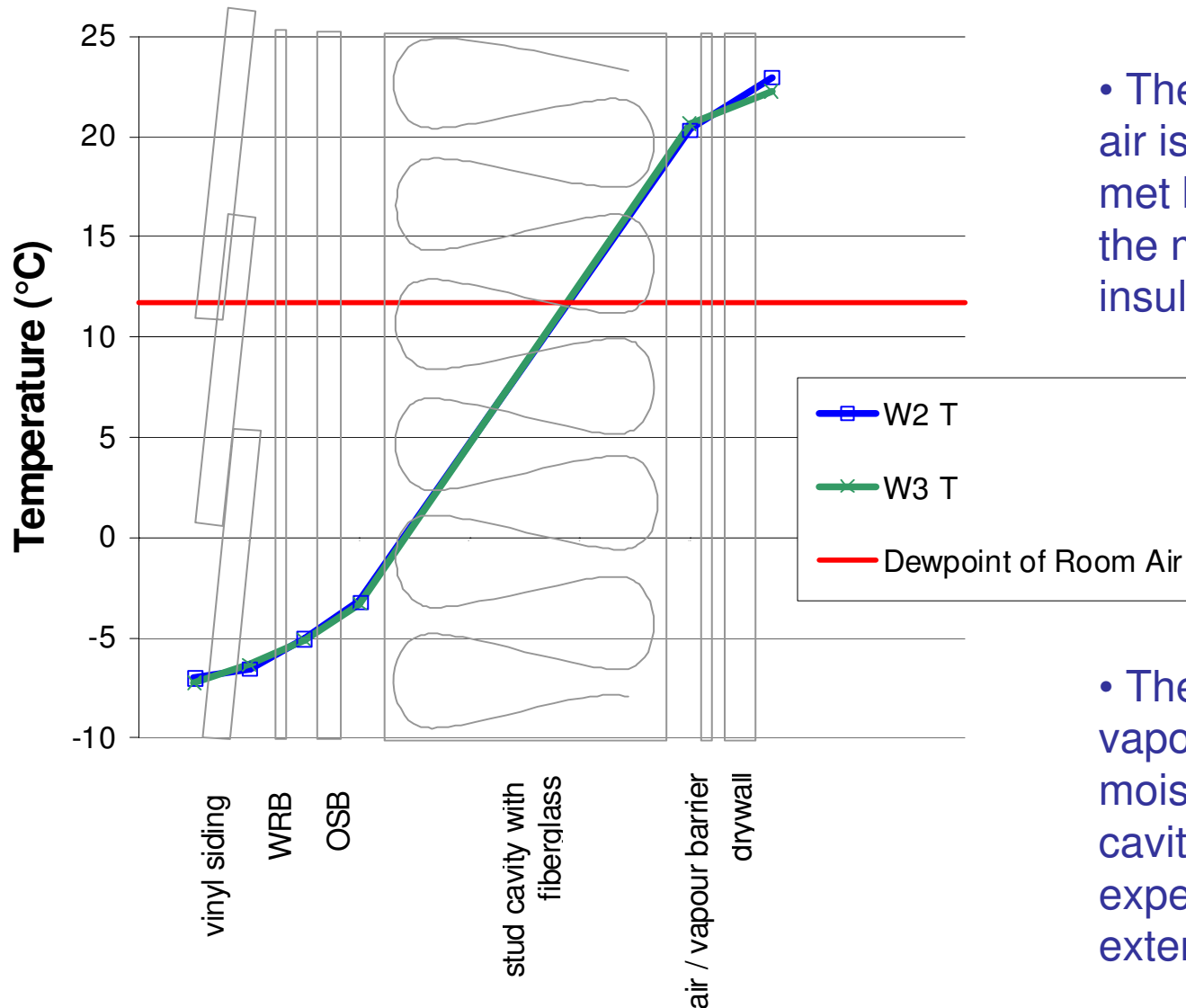
22-Feb-07

Wall 2 Horizontal Cross Section



- 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

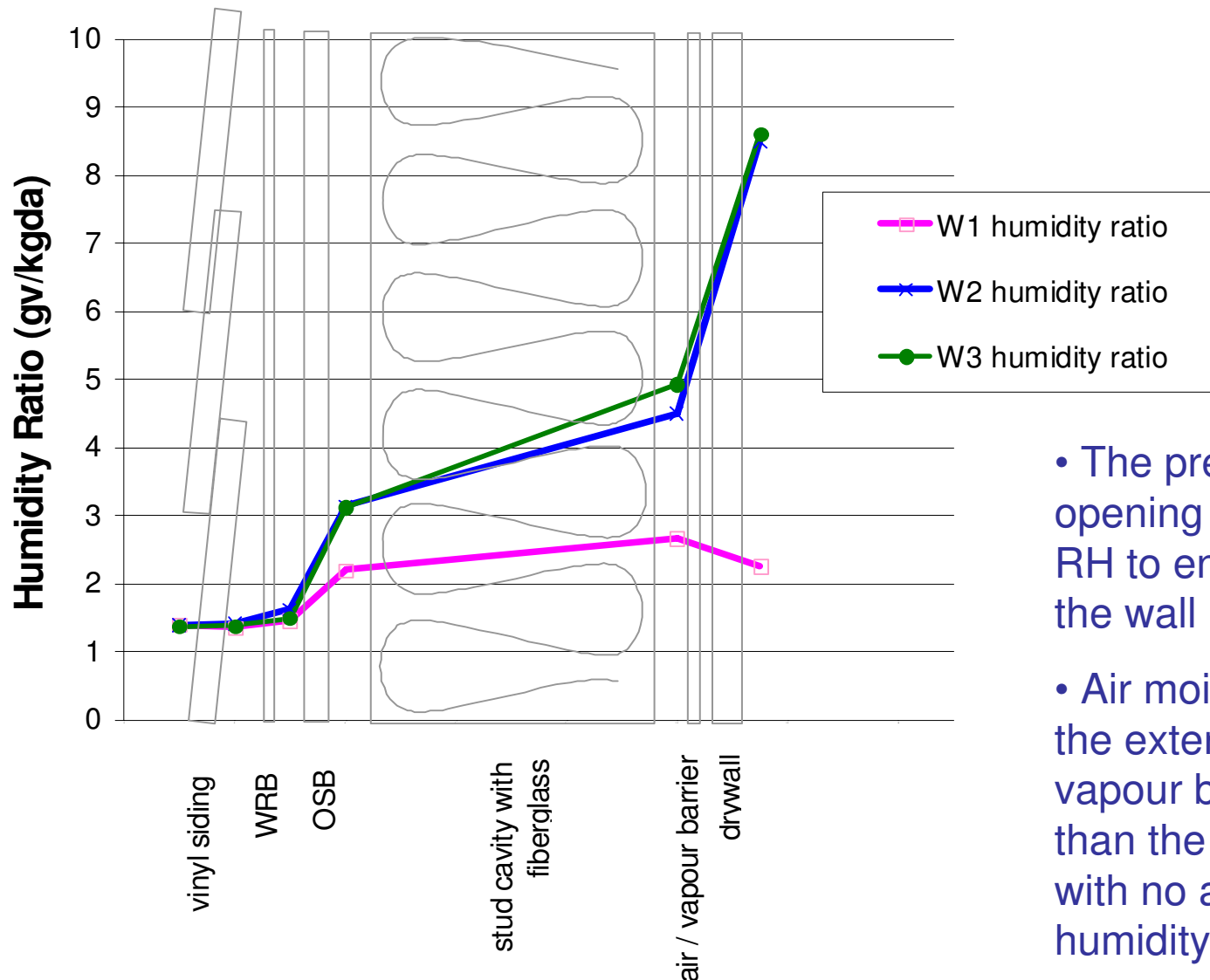
Condition B: 5 Pa, 50% RH, 6mm opening



- The dewpoint of room air is ~12°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

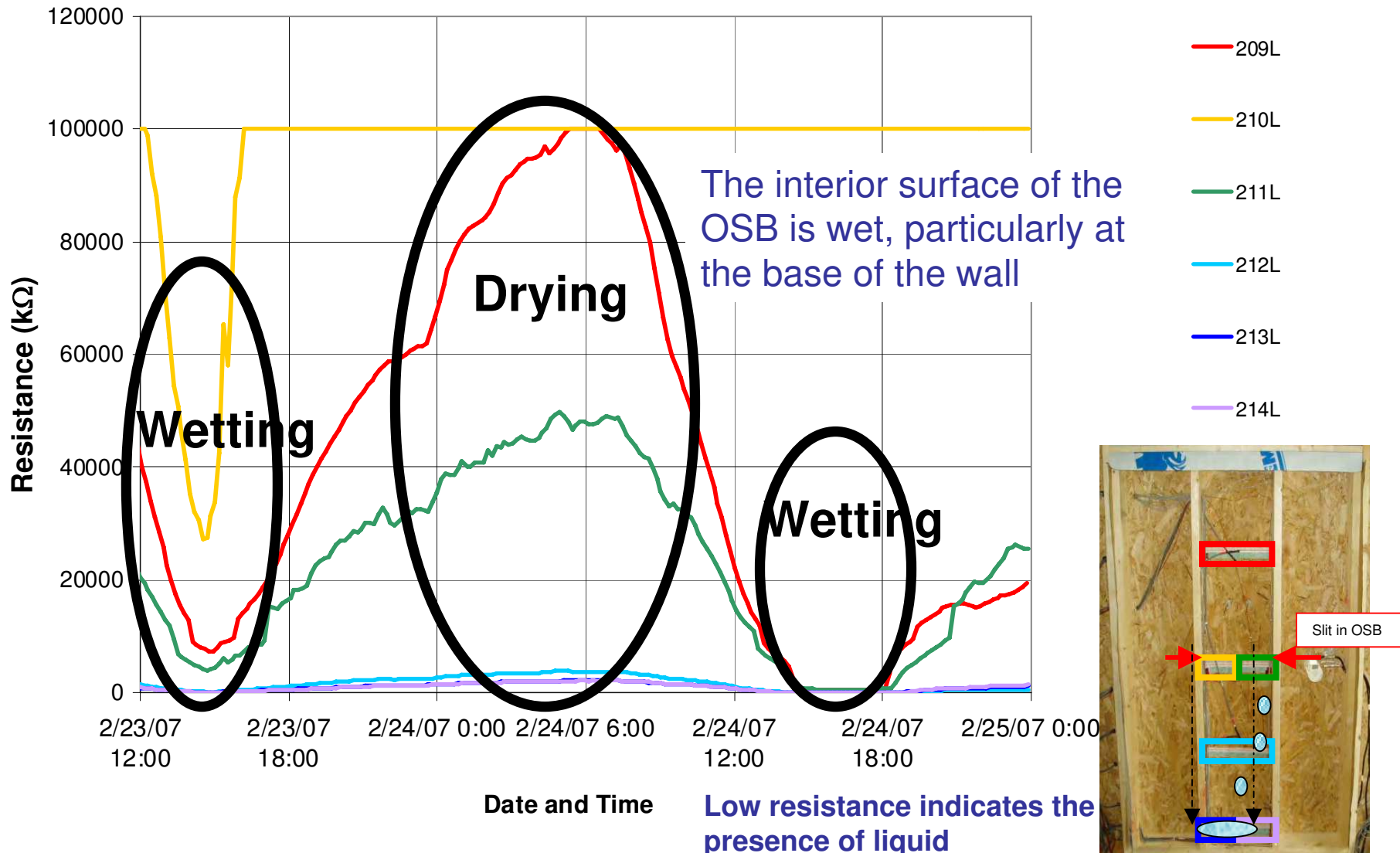
Condition B: 5 Pa, 50% RH, 6mm opening



- 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

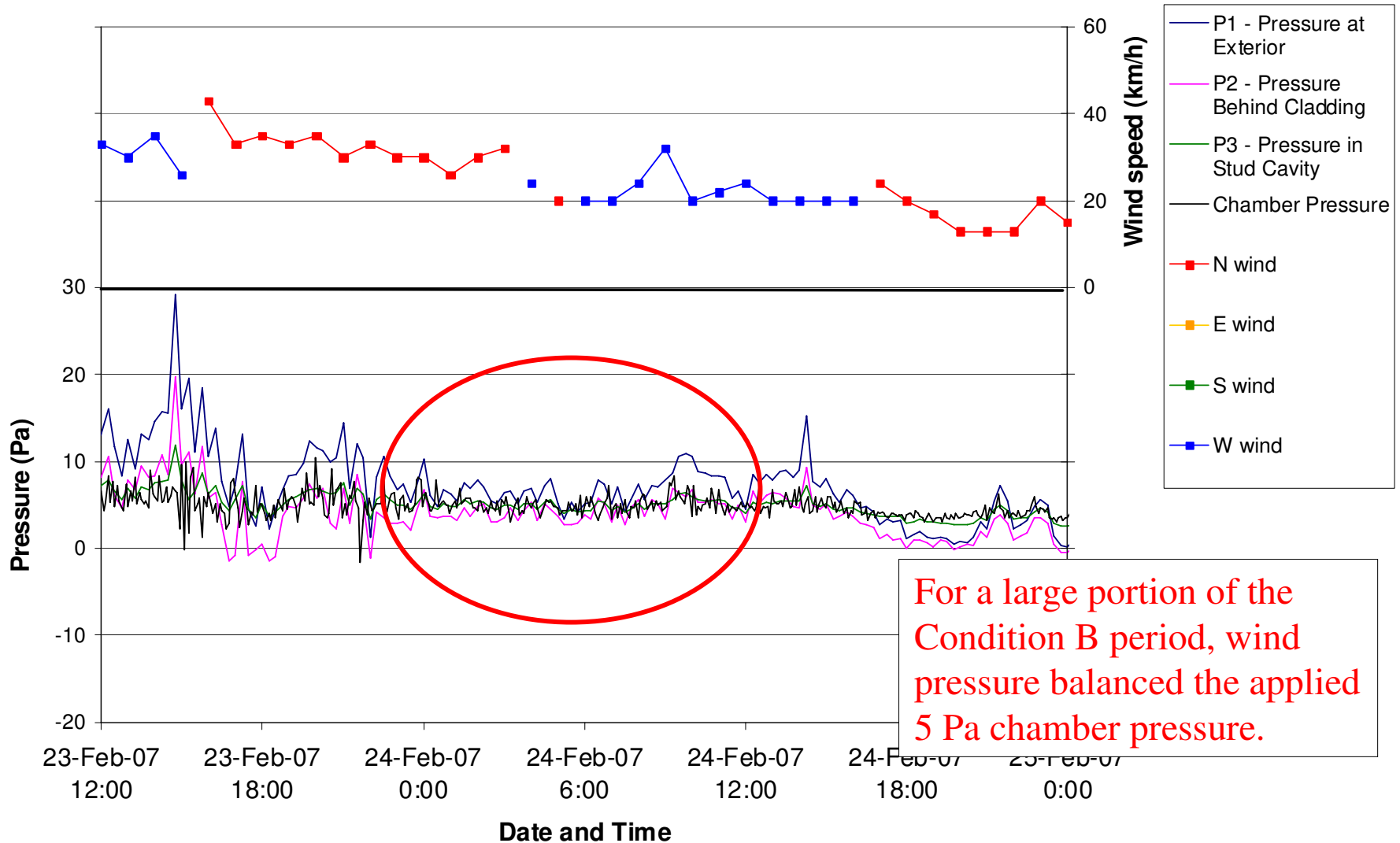
Condition B: 5 Pa, 50% RH, 6mm opening

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



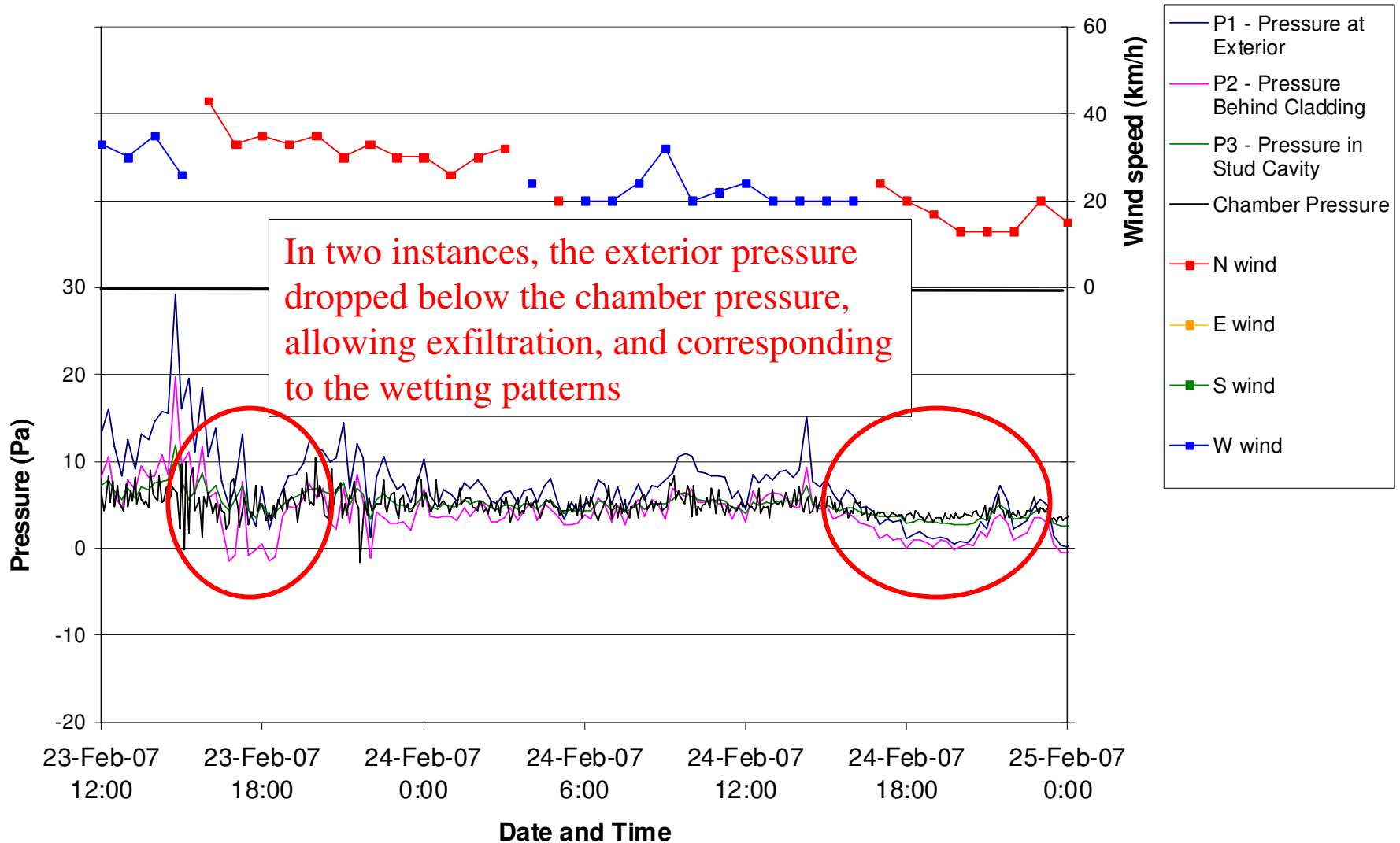
Condition B: 5 Pa, 50% RH, 6mm opening

Pressure, Wind speed and direction



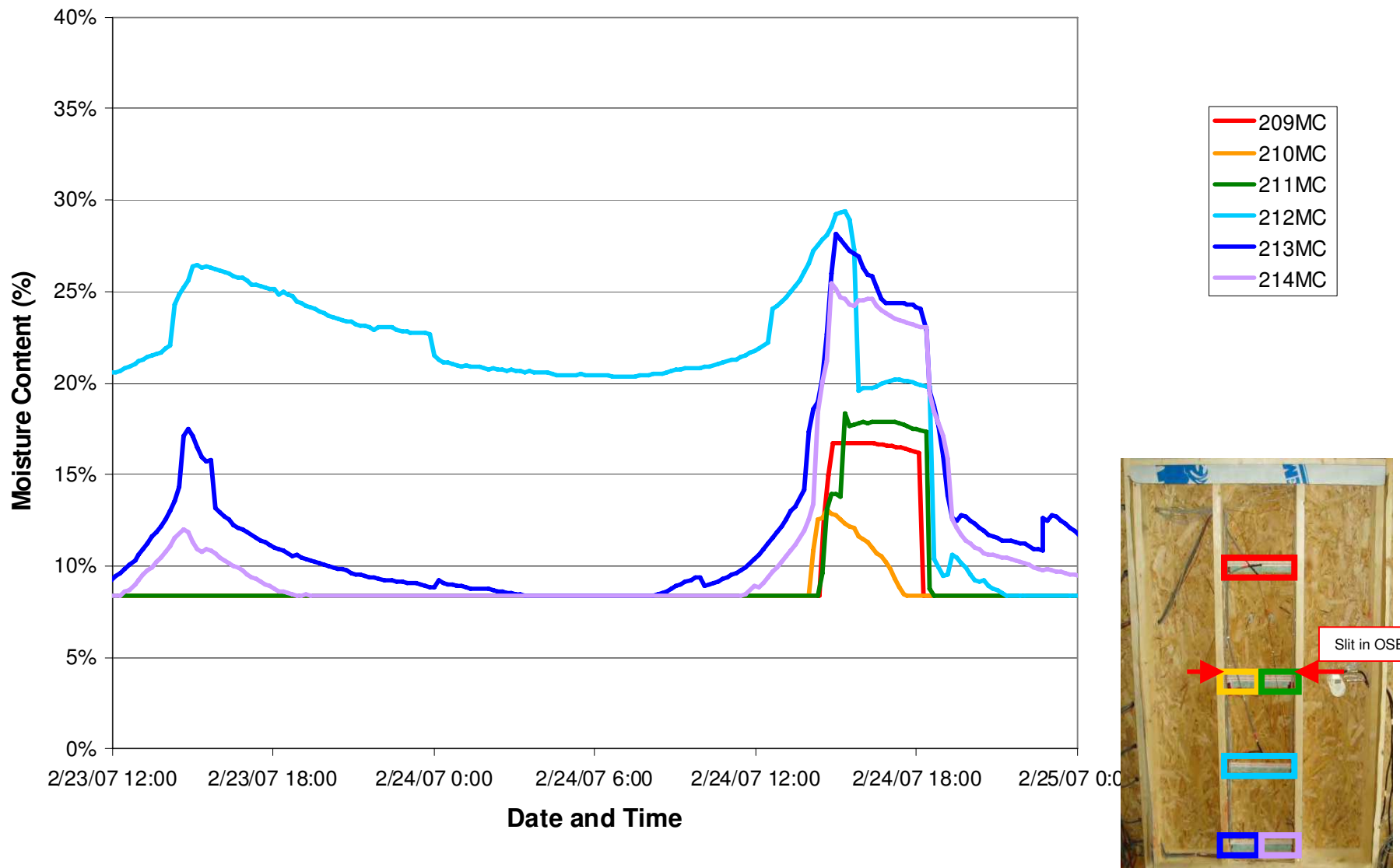
Condition B: 5 Pa, 50% RH, 6mm opening

Pressure, Wind speed and direction



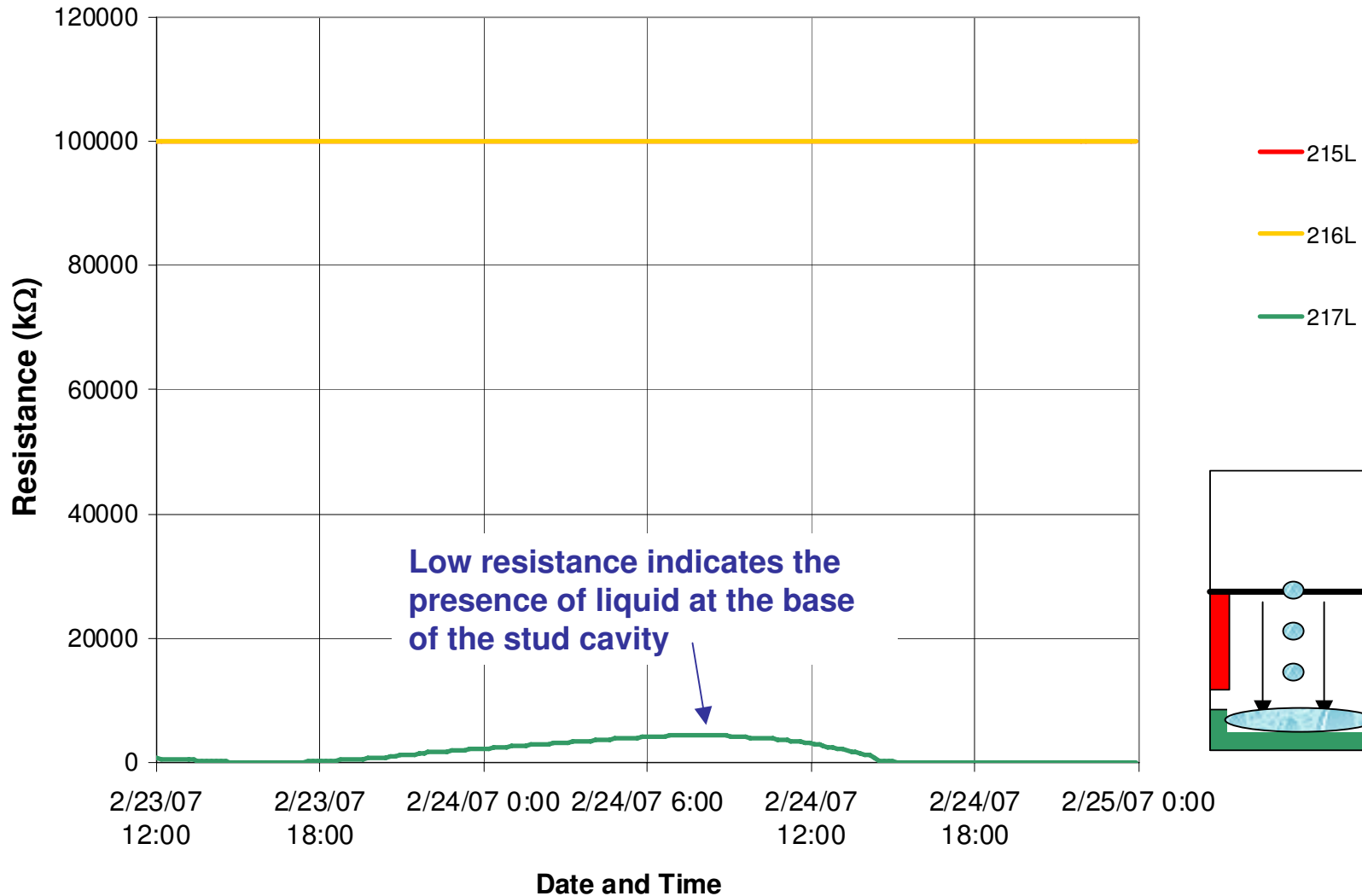
Condition B: 5 Pa, 50% RH, 6mm opening

Moisture Content - Wall 2 Interior OSB



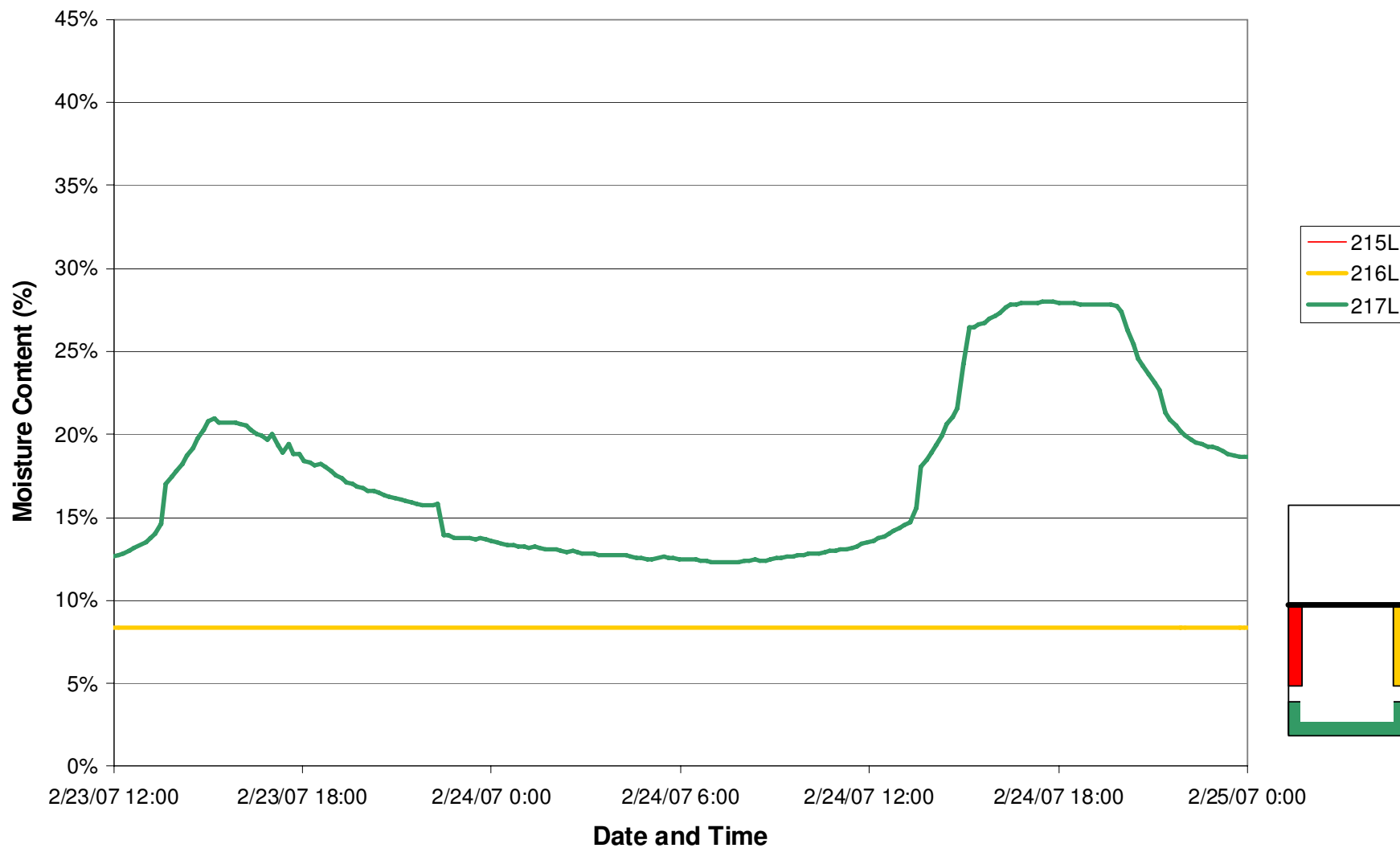
Condition B: 5 Pa, 50% RH, 6mm opening

FEWF Wall 2 - Stud - Layer 5 - Liquid



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

Moisture Content - Wall 2 Stud Cavity



Results



Before



After

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

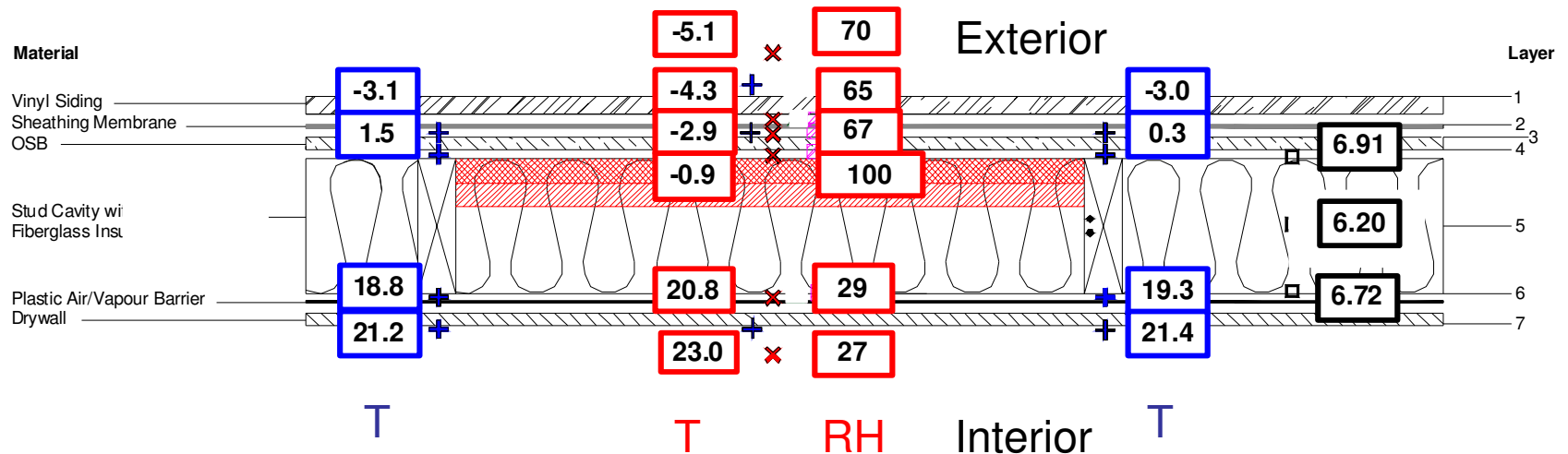


Condition C: 5 Pa, 30% RH, 3mm opening

Wall 2 Horizontal Cross Section

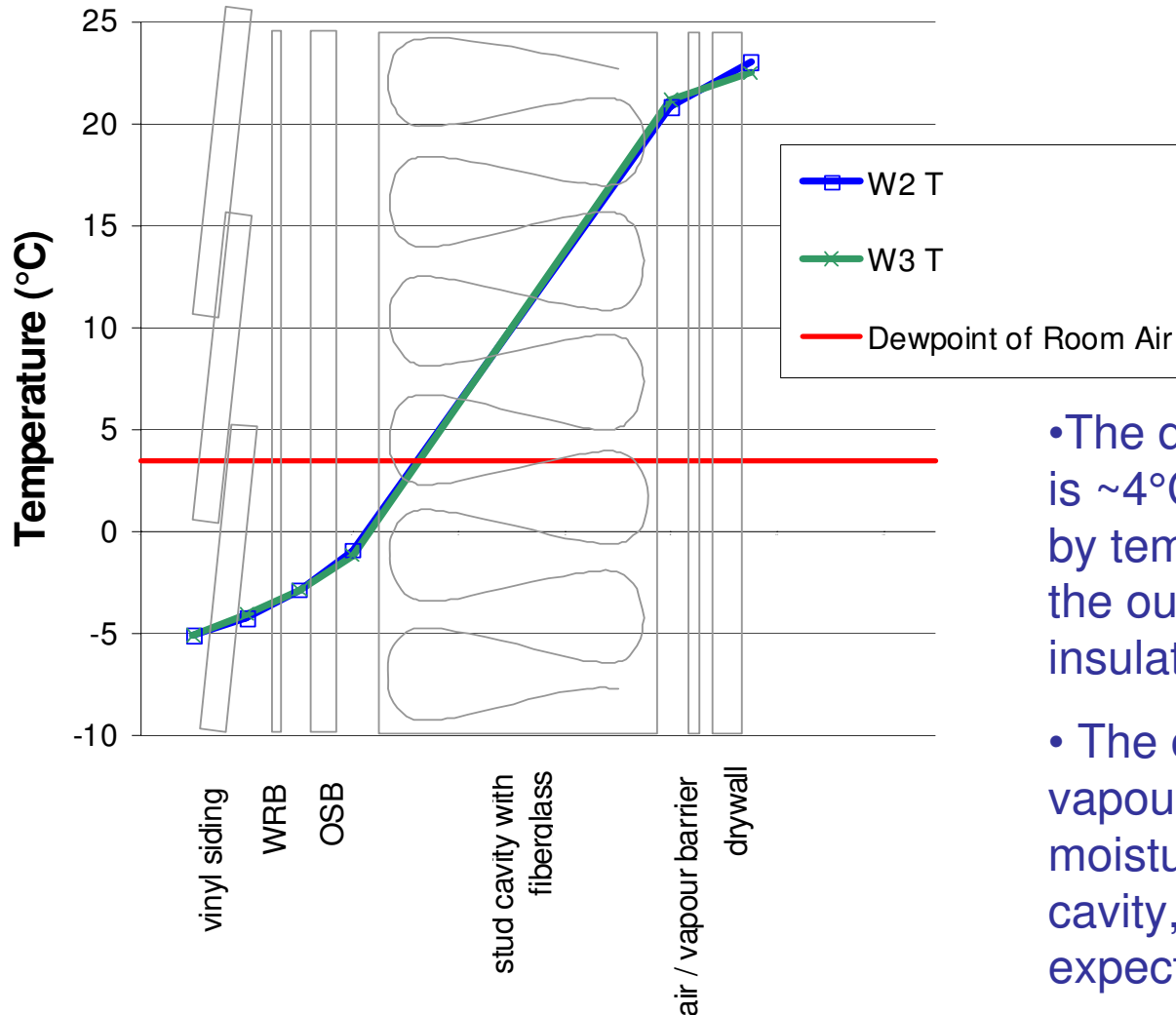
Week 11

16-Mar-07



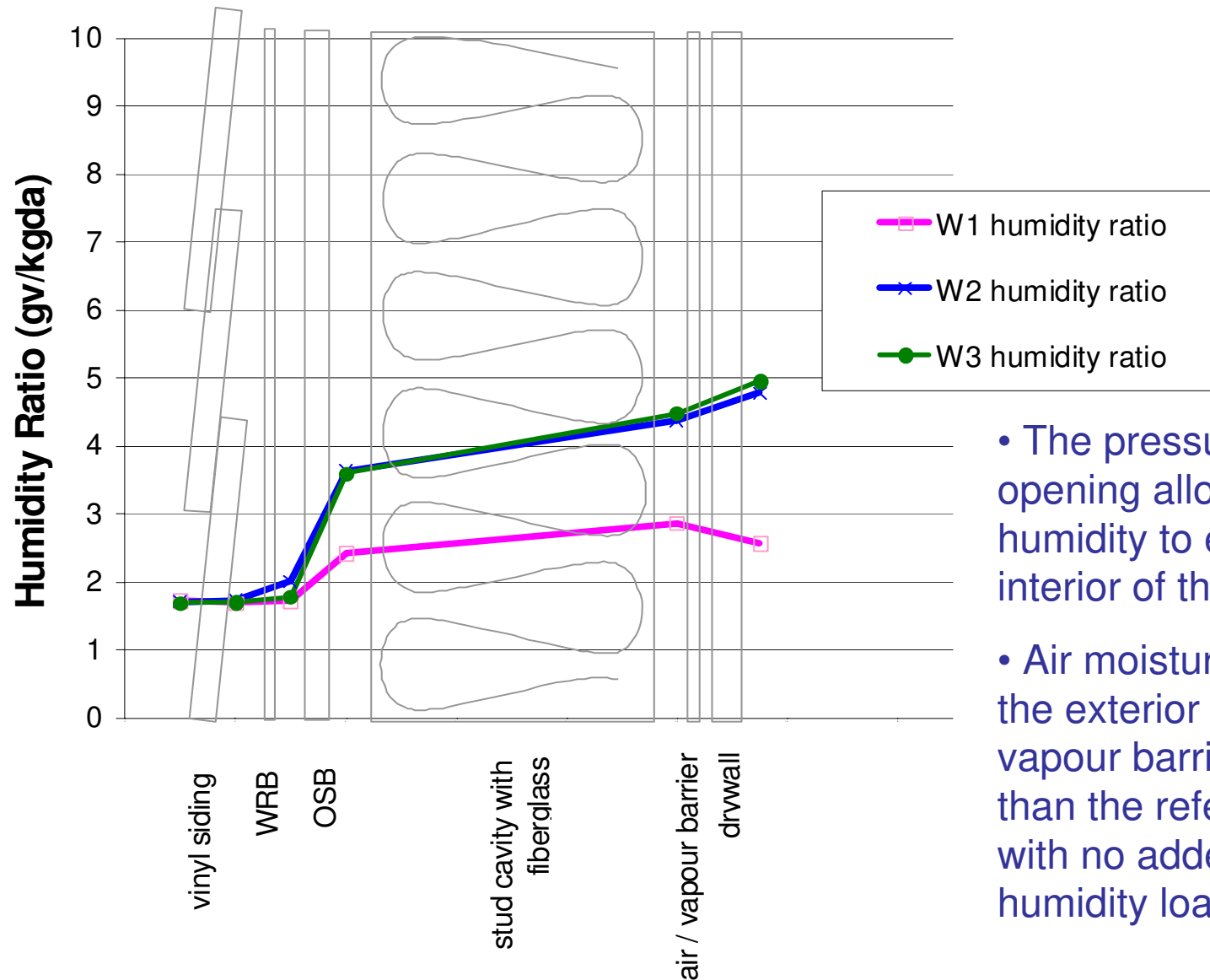
- The interior of the room is at 27% RH, the humidity behind the air/vapour barrier is 29% RH – indicating that moisture is being introduced through the opening
- The location with the highest RH is the interior of the OSB, at 100% - condensation would be expected

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



- The dewpoint of room air is $\sim 4^{\circ}\text{C}$, 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

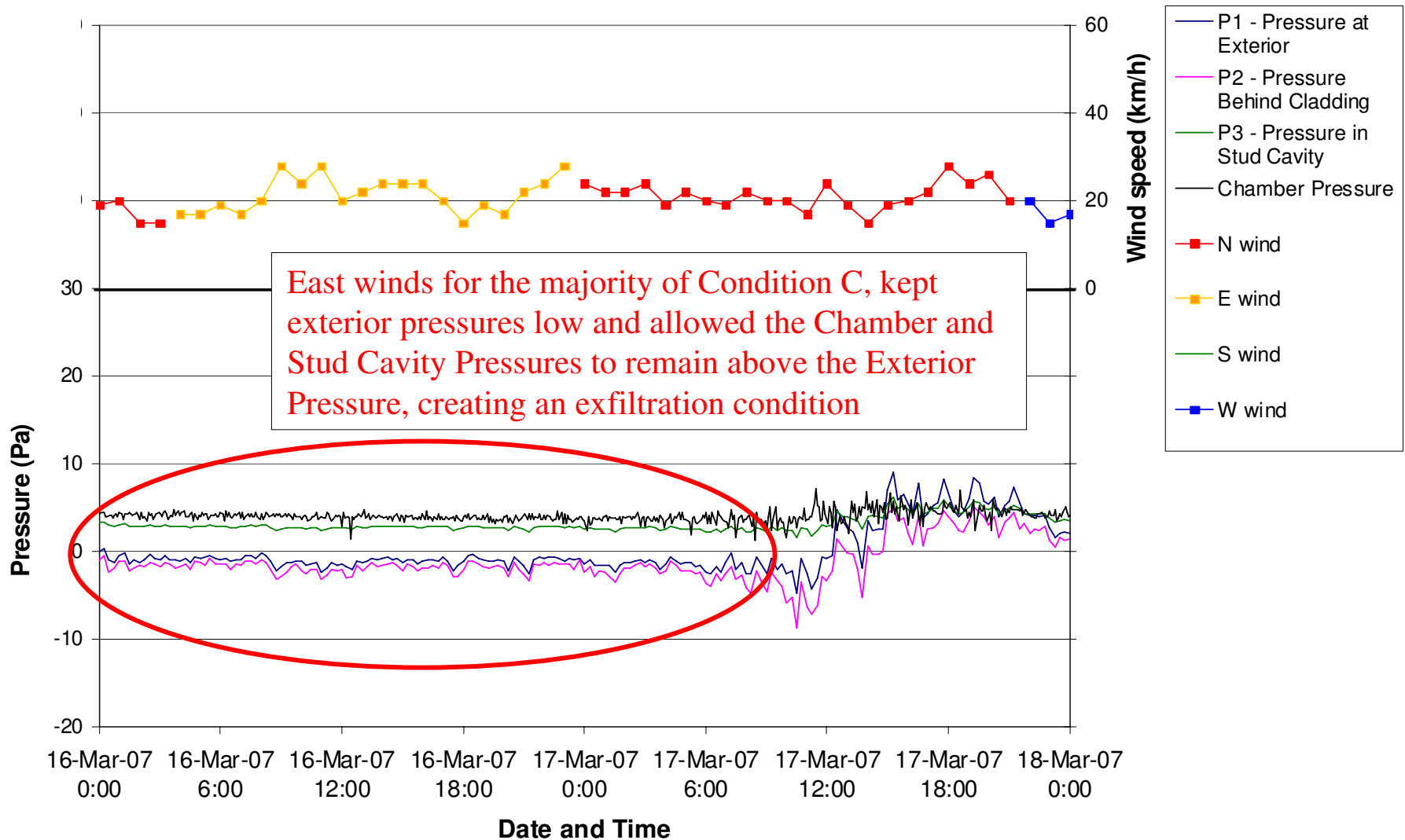
Condition C: 5 Pa, 30% RH, 3mm opening



- 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

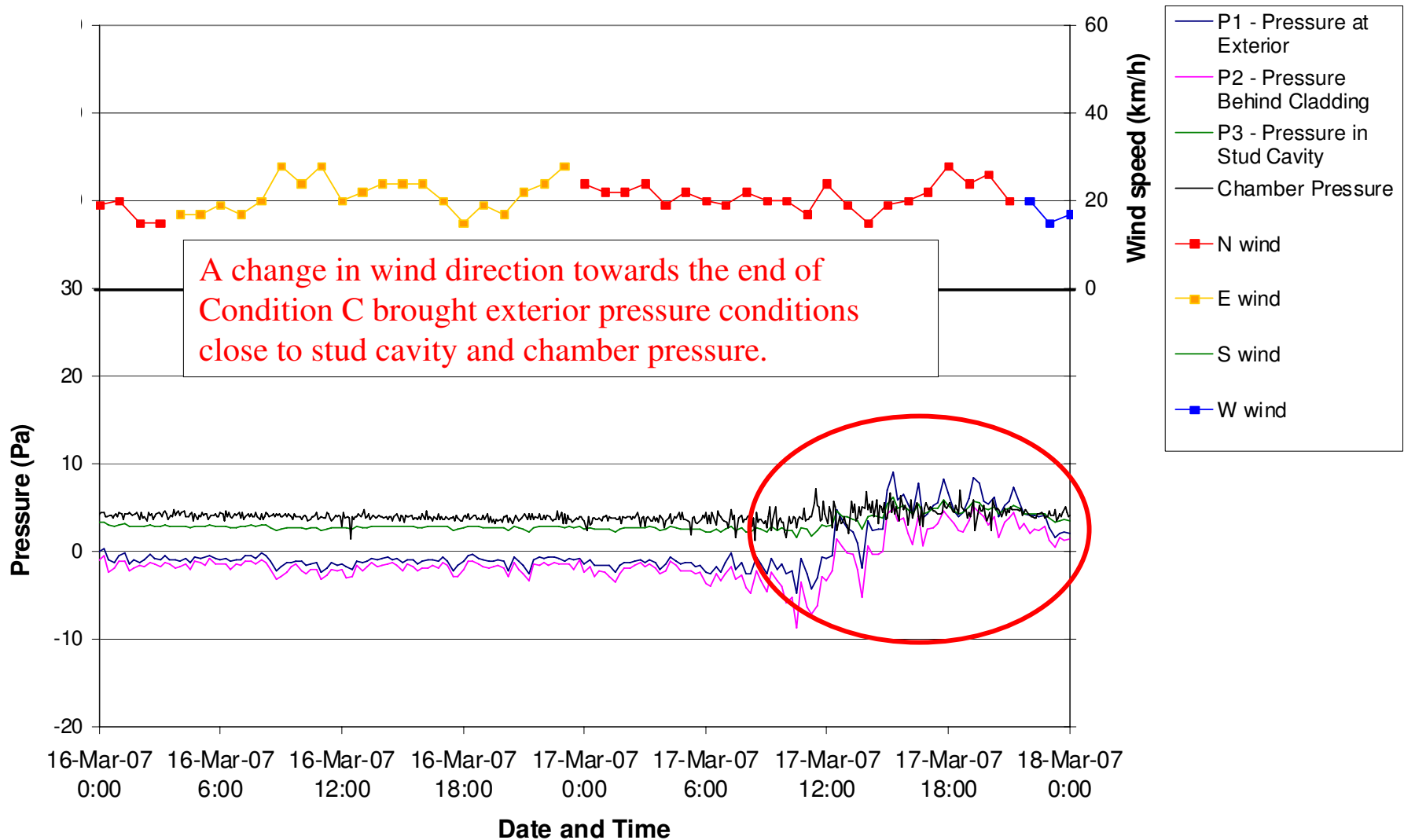
Condition C: 5 Pa, 30% RH, 3mm opening

Pressure, Wind speed and direction



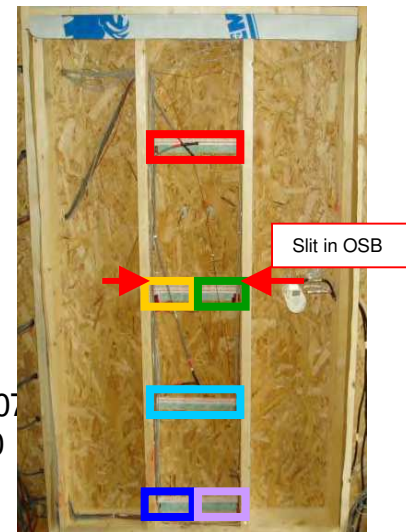
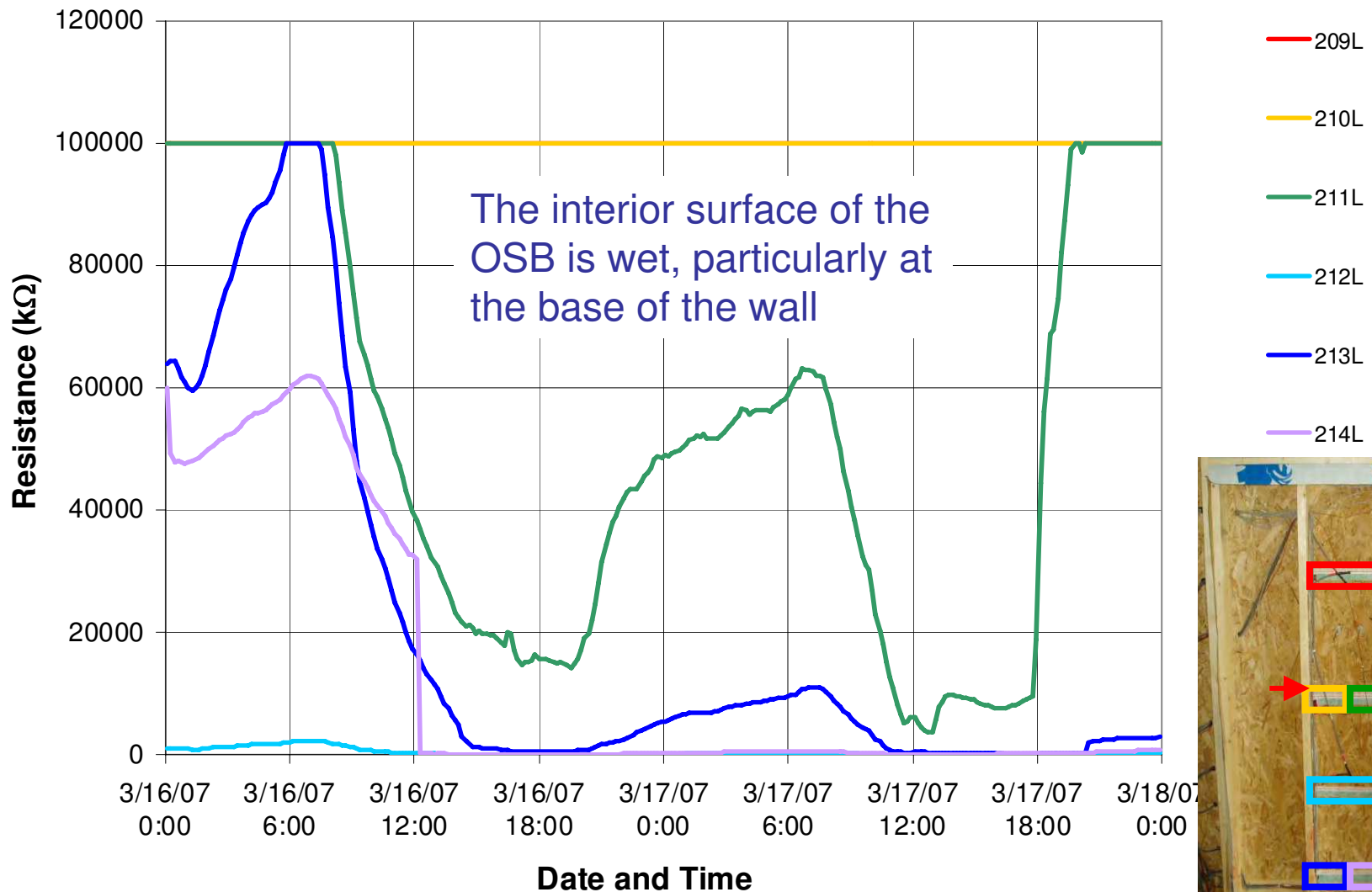
Condition C: 5 Pa, 30% RH, 3mm opening

Pressure, Wind speed and direction



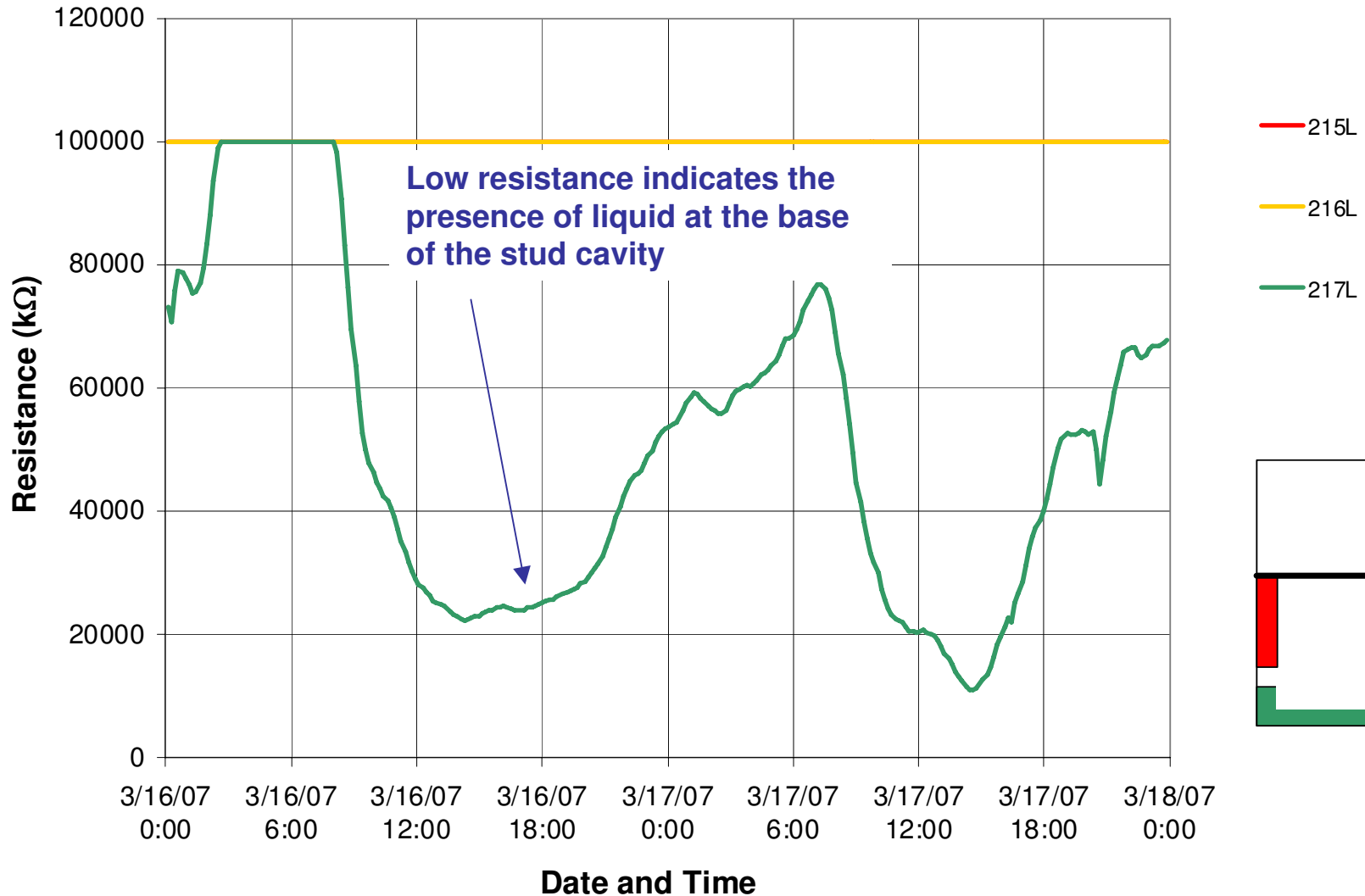
Condition C: 5 Pa, 30% RH, 3mm opening

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



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

FEWF Wall 2 - Stud - Layer 5 - Liquid

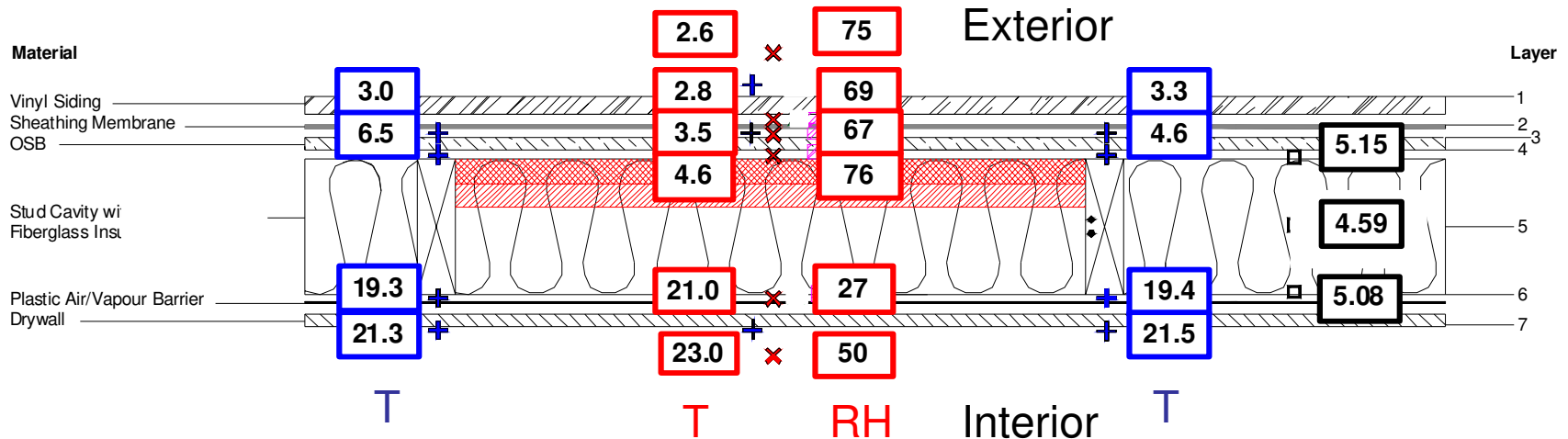


Condition D: 0 Pa, 50% RH, 3mm opening

Wall 2 Horizontal Cross Section

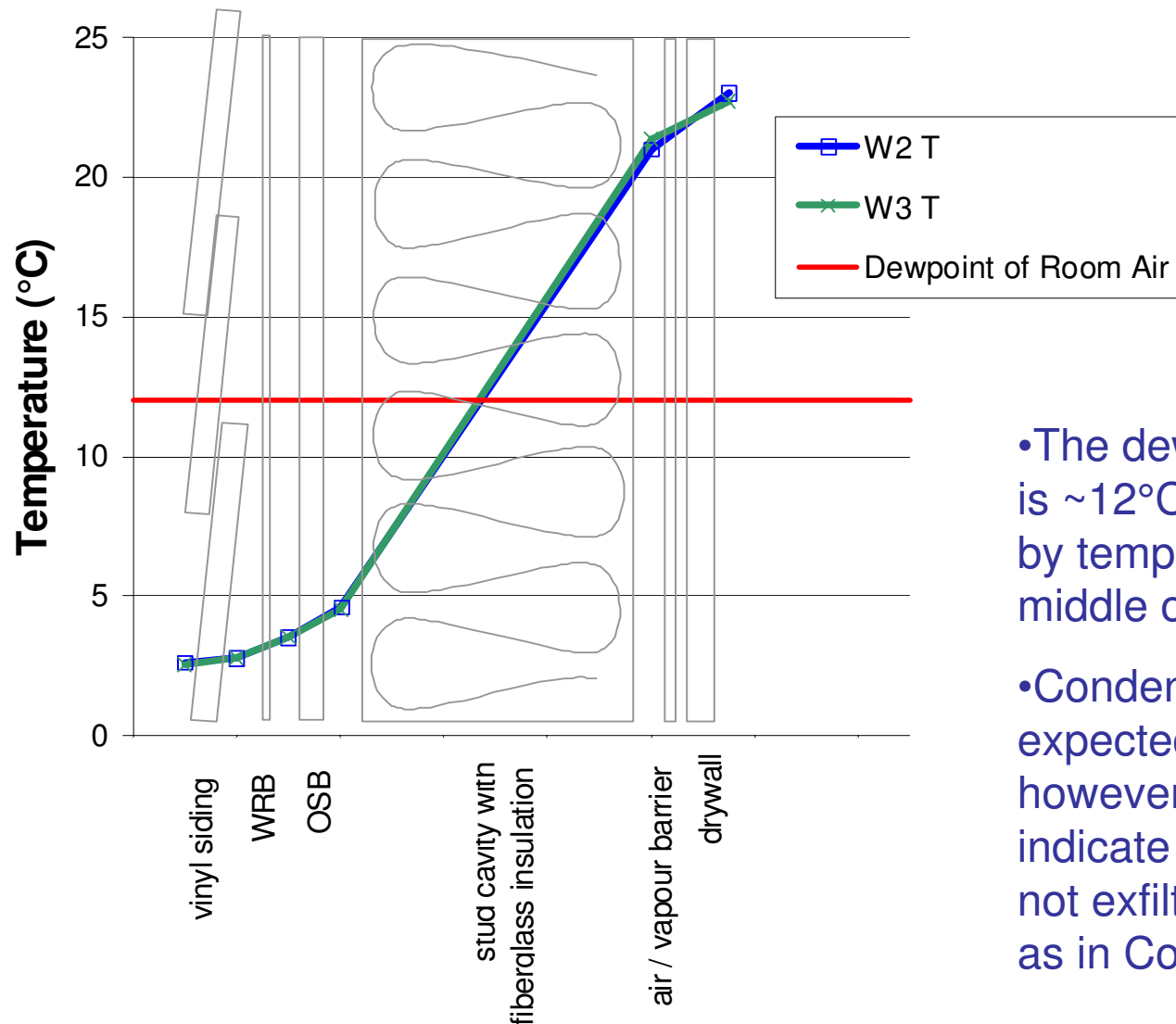
Week 15

08-Apr-07



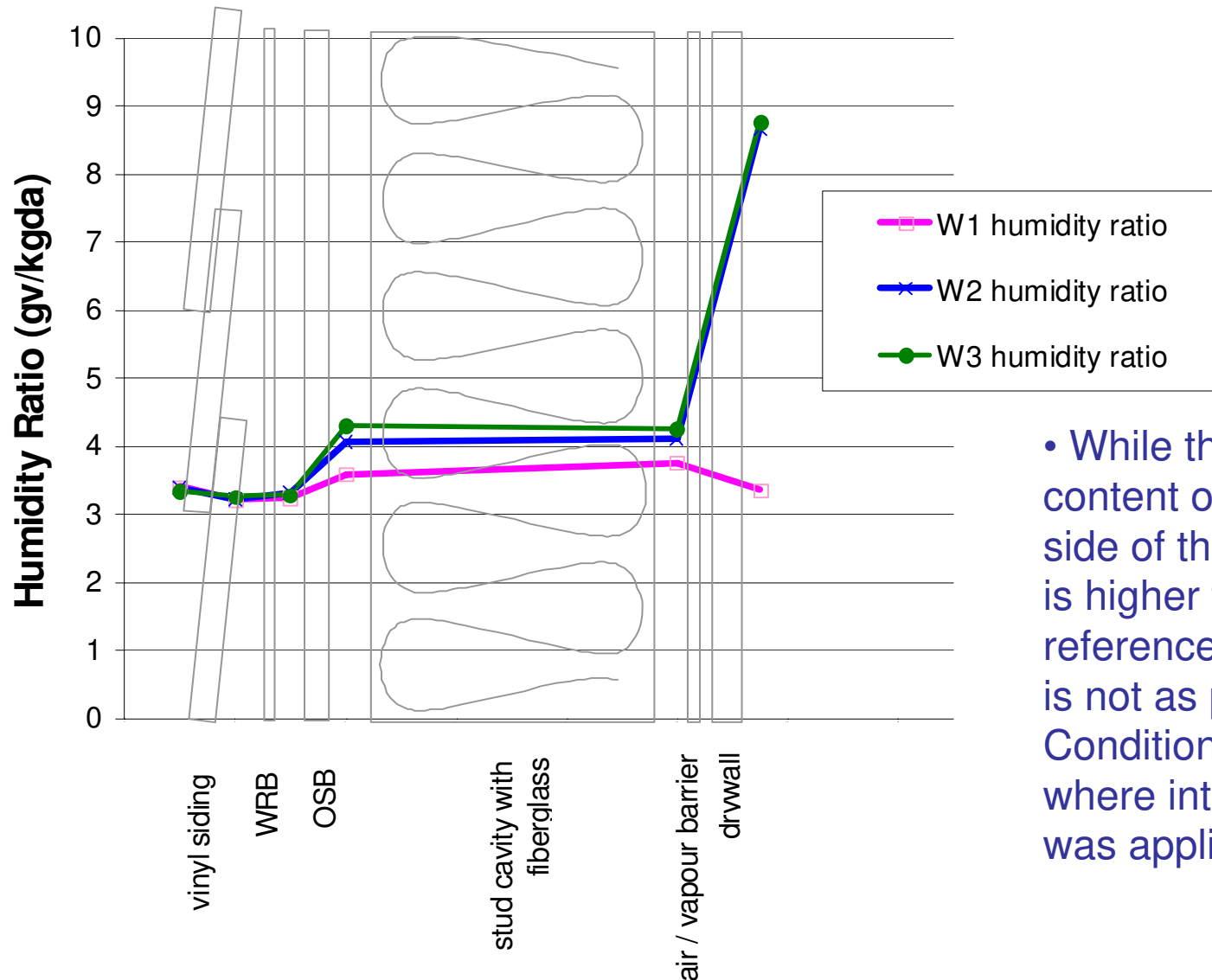
- The interior of the room is at 50% RH, the humidity behind the air/vapour barrier is 27% RH
- The location with the highest RH is the interior of the OSB, at 76% (likely due to the lack of a pressure driving force for exfiltration, and warmer exterior temperatures)

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

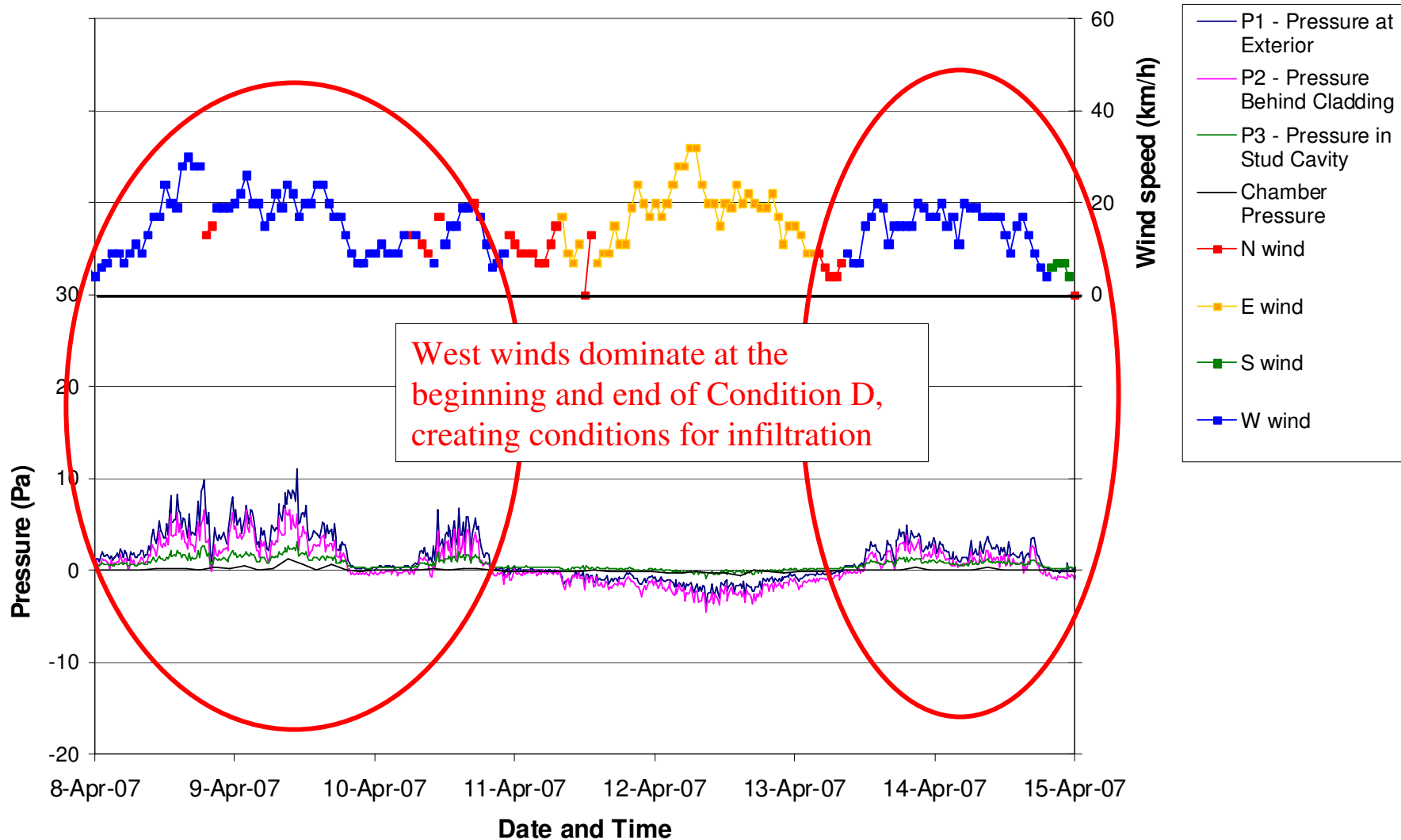
Condition D: 0 Pa, 50% RH, 3mm opening



- 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

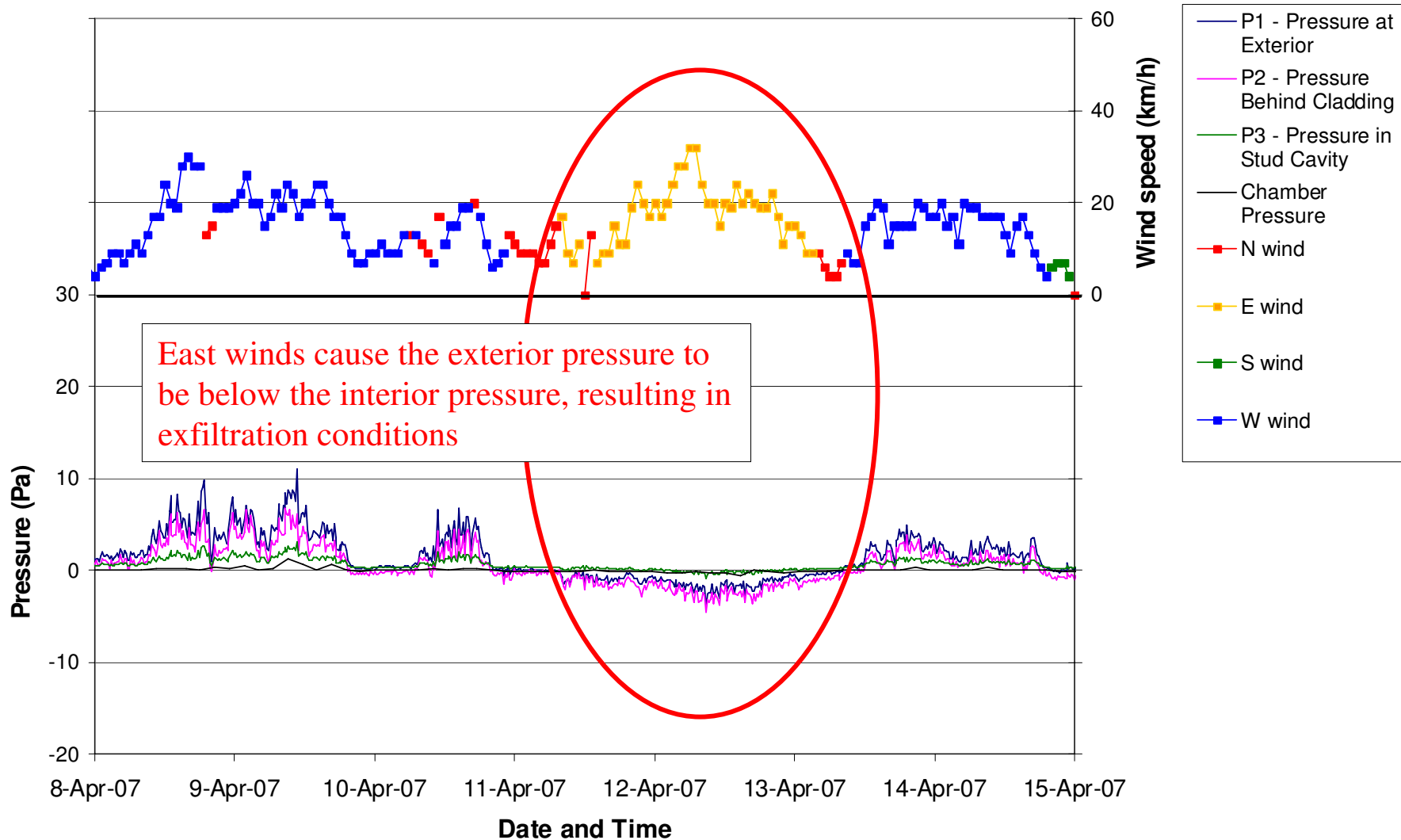
Condition D: 0 Pa, 50% RH, 3mm opening

Pressure, Wind speed and direction



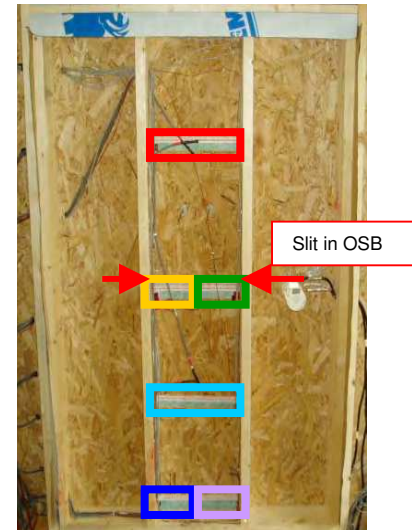
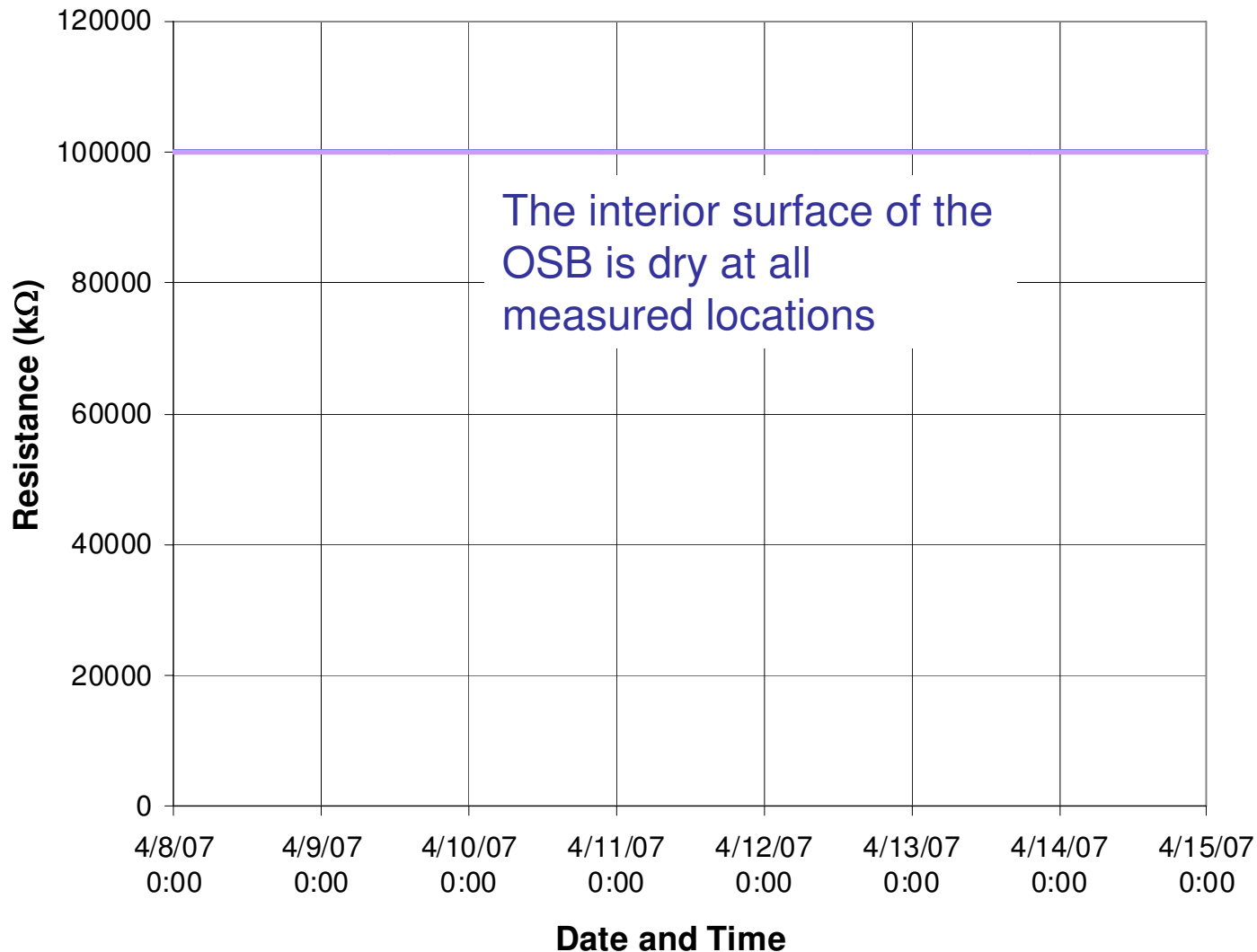
Condition D: 0 Pa, 50% RH, 3mm opening

Pressure, Wind speed and direction



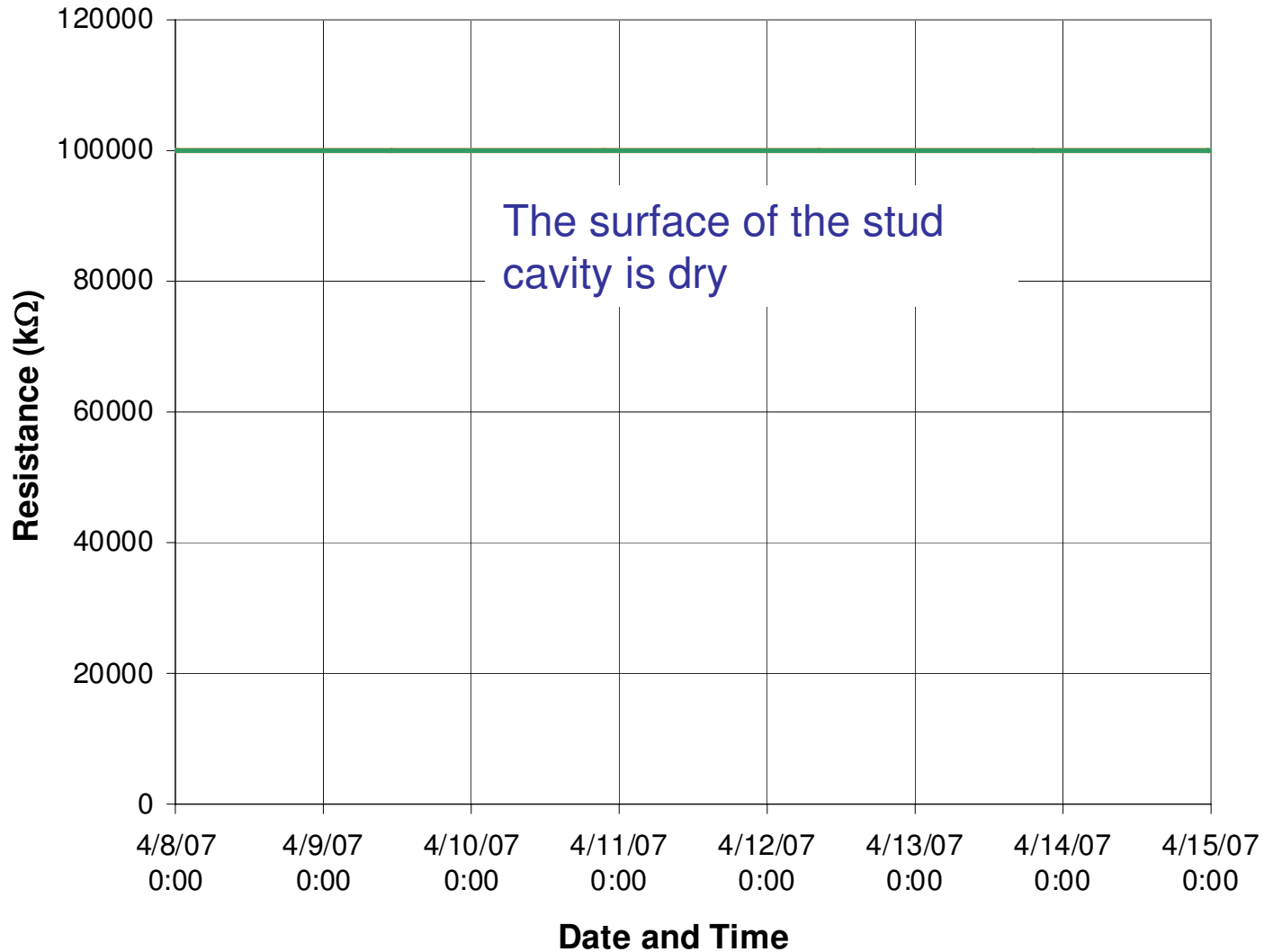
Condition D: 0 Pa, 50% RH, 3mm opening

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

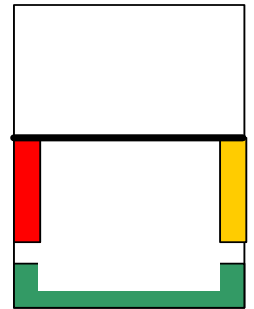


Condition D: 0 Pa, 50% RH, 3mm opening

FEWF Wall 2 - Stud - Layer 5 - Liquid



215L
216L
217L



SUMMARY

- We looked at risk of condensation due to exfiltration (wetting) combined with infiltration (drying)
- Looked at the importance of wind speed and directions and orientation of the envelope.
 - Wind from West causes +ve pressures and infiltration
 - Wind from East causes –ve pressures and exfiltration
 - When the chamber is pressurized the exfiltration cdt is forced (Chamber & Stud cavity pressure is higher than ext pressure) except when +ve from N & W winds negate the effect.
- If we have to look for long time period the exfiltration cdt, we have to pressurized the chamber more than 35 Pa.
- Experimental results will be used to benchmark the HAM *hygl*IRC 1D.

Plans for this Winter and Spring

- Context:
 - Focus on two energy retrofit scenarios for exterior walls
- The question to investigate:
 - What is the effect of the properties of thermal insulation installed on the exterior of an existing R20 wall on the wetting and drying potential of that assembly, particularly when air leakage is involved?

Adding thermal insulation on the exterior of an insulated stud cavity wall can ...

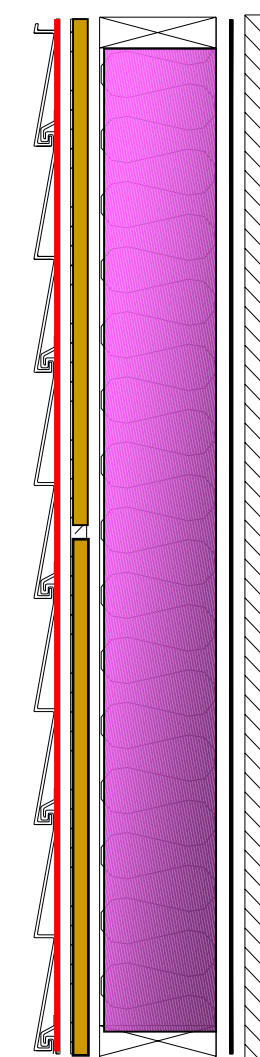
- Reduce thermal bridging at the framing 😊
- Raise the temperature of that cavity, during cold weather, resulting in lower potential for condensation in stud cavity 😊
- Reduce the drying potential to the exterior 😞
- Promote mould growth in a wet cavity as the cavity stays warmer over longer periods of the year 😞

What Happens Depends On:

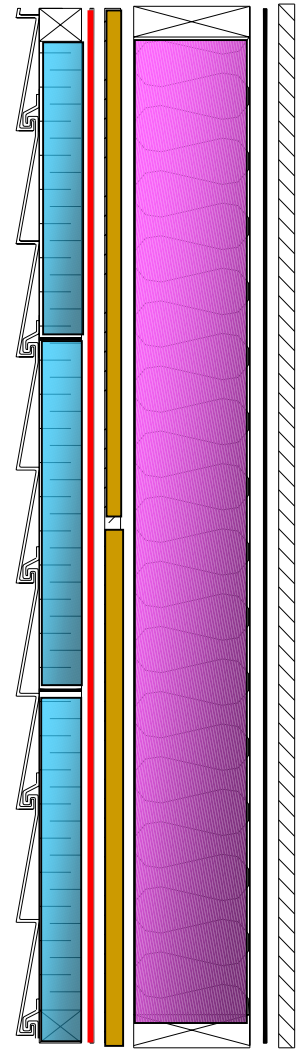
- Vapour permeance and air permeance of added insulation layer
- R value of the external layers in relation to the R value of the internal layers
- Methods of installation for the insulation and siding layers
- Air leakage rates & paths (deficiencies, gaps, cracks unsealed openings in the assembly)
- Indoor conditions of RH, T and P
- Outdoor climate
- Other factors! e.g. rain penetration bypassing the 1st and 2nd line of protection

The 3 Test Specimens – Vertical Section View

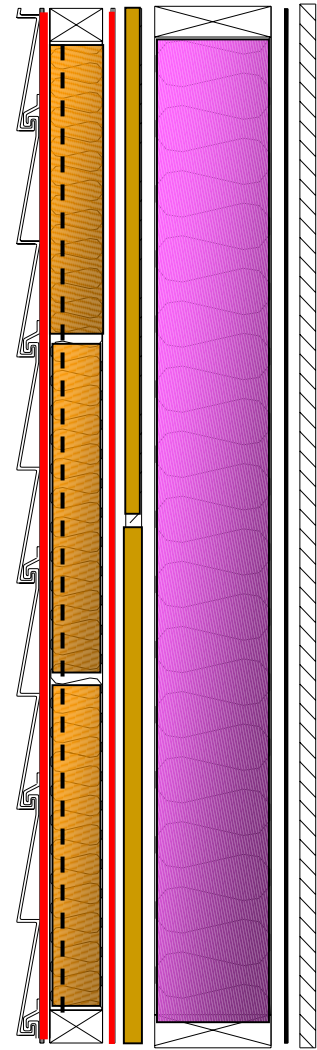
Exterior



**R20 2X6
typical
construction**



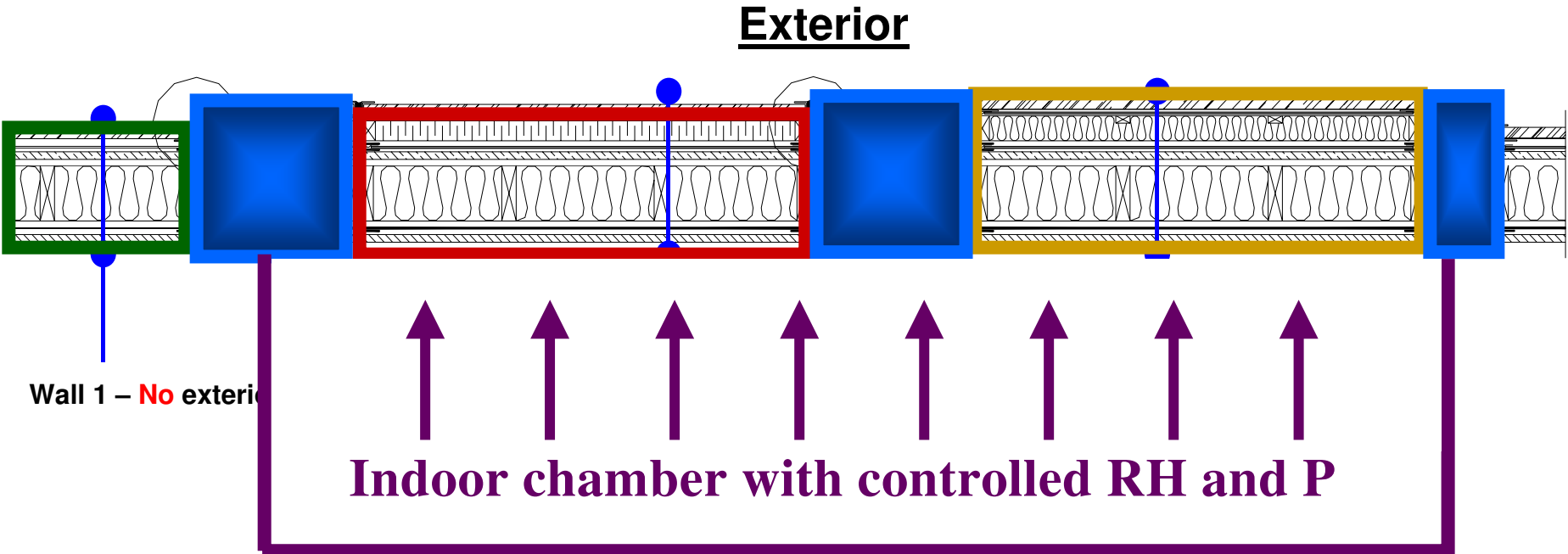
**Addition of a Low Air
and Vapour Permeance
Insulation**



**Addition of a High Air and
Vapour Permeance Insulation
& sheathing membrane**

Interior

Plan View of the Test Specimens in Test Bay



Steps for Specimen Construction





ТОЙНА ЖАНА



Lab-EEEF



Field-FEWF



HAM Model-hygIRC 1D

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http://irc.nrc-cnrc.gc.ca/bes/facilities/fieldex_e.html