Assessing the hygrothermal performance of innovative wall and window systems

Maref, W.; Rousseau, M. Z.; Manning, M. M.; Lei, W.; Abdulghani, K.; Nunes, S. C.

In-House IRC Seminar [Proceedings], pp. 1-26, 2006-10-11

NRC·CNRC Institute for Research in Construction
CNRC·NRC Institut de recherche en construction
http://irc.nrc-cnrc.gc.ca

Assessing the hygrothermal performance of innovative wall and window systems

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

IRC-ORAL-745

October 11, 2006

National Research Council Canada
Conseil national de recherches Canada
Canada

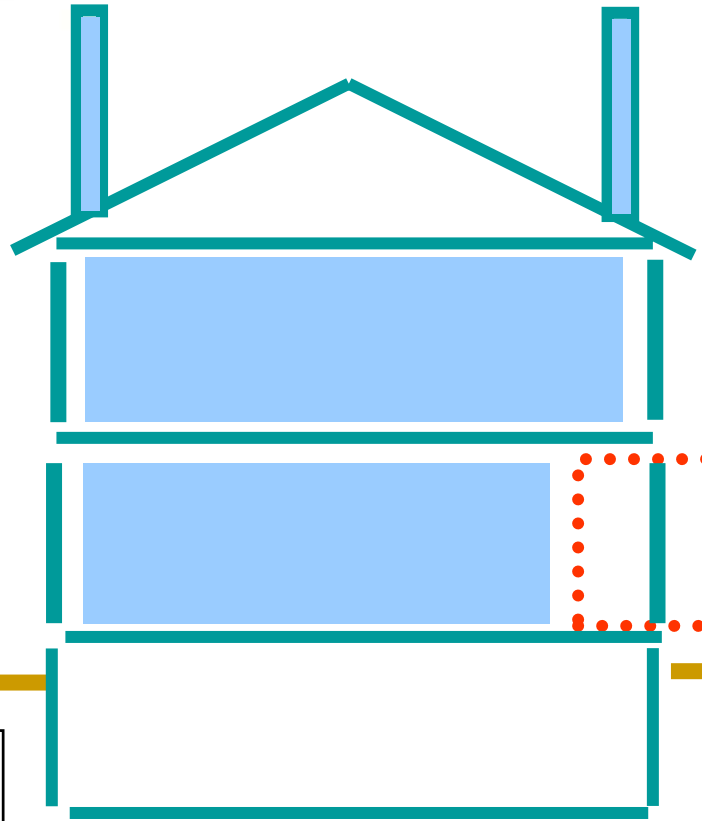
NRC-CNRC
Institute for Research in Construction

Outline

- Background
- Hygrothermal Performance of BES
  - Modeling
  - Field Experiments
  - Laboratory experiments
- Concluding Remarks and Future Work

NRC-CNRC
Institute for Research in Construction

Research House No. 3



HEATING AND VENTILATION FACILITY - IE

FY06/07 & 07/08 *: Study & compare traditional & innovative HV strategies*

FEWF- BES

Field monitoring

Practice Review

Lab Exp.

Numerical Modelling

FY06/07 & 07/08: Study & compare traditional & innovative BE strategies

NRC·CNRC
Institute for Research in Construction

Official Opening September 26, 2006

NRC·CNRC
Institute for Research in Construction

FEWF Team

 K. Abdulghani	 W. Lei	 M. Manning	 W. Maref
 M. Nicholls	 S. Nunes	 M. Rousseau	 R. Berzins

NRC·CNRC
Institute for Research in Construction

Ventilation Team

 J. Reardon	Coop Students	 B. Ouazia
 D. Booth	 G. Nong	 I. MacDonald

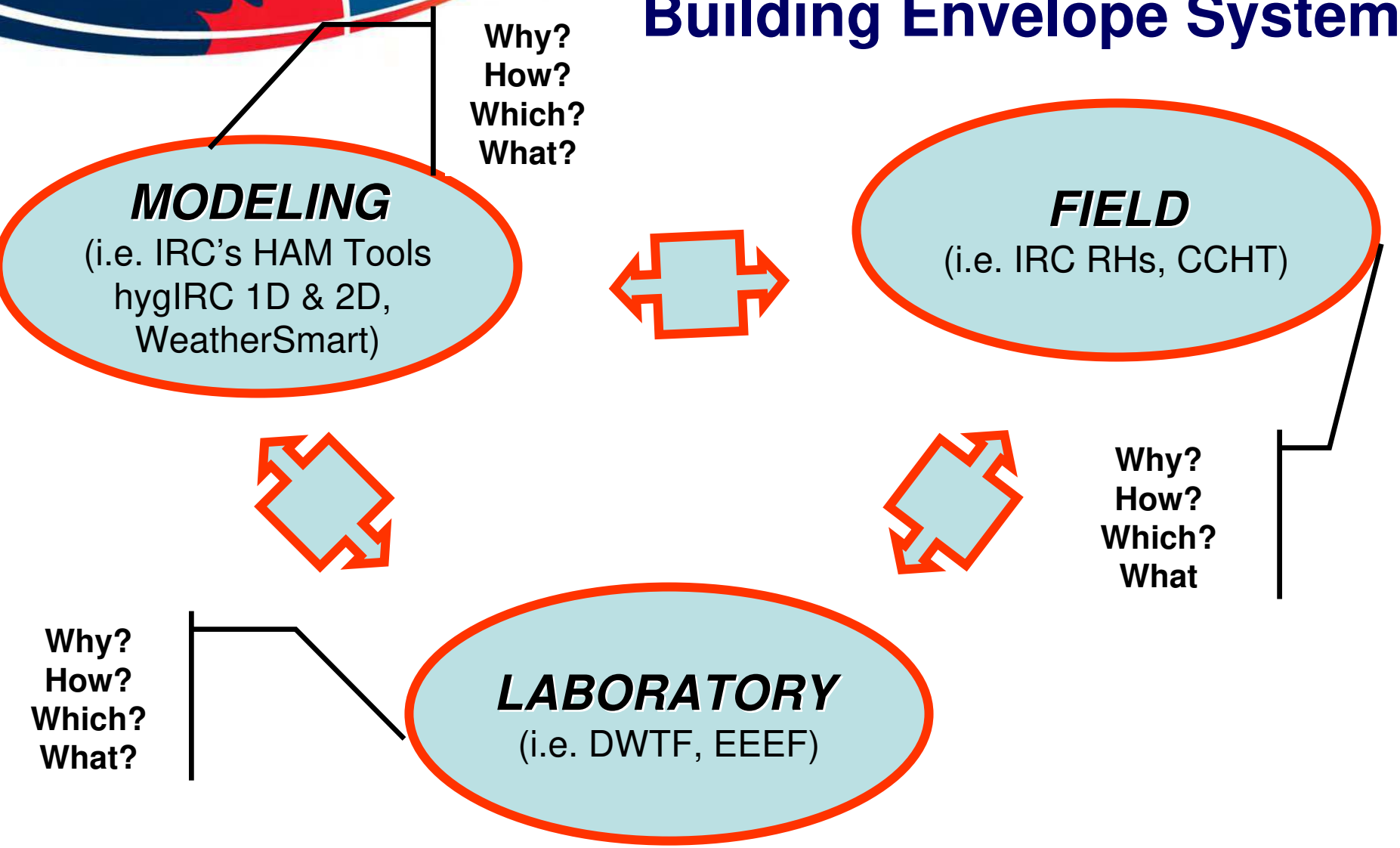
NRC-CNRC
Institute for Research in Construction

Outline

- Background
- Hygrothermal Performance of BES
  - Modeling
  - Field Experiments
  - Laboratory experiments
- Concluding Remarks and Future Work

NRC·CNRC
Institute for Research in Construction

Hygrothermal Performance of Building Envelope Systems



NRC-CNRC
Institute for Research in Construction

Outline

- Background
- Hygrothermal Performance of BES
  - Modeling
  - Field Experiments
  - Laboratory experiments
- Concluding Remarks and Future Work

NRC-CNRC
Institute for Research in Construction

Modeling

- Why to do modeling?
- How to model?
- Which model to use?
- What do you expect from modeling?

NRC·CNRC
Institute for Research in Construction

Modeling: IRC's HAM Tools

- *hyg*IRC 1-D V. 1.1 is a user-friendly, one-dimensional version of NRC-IRC's *hyg*IRC, a state-of-the-art hygrothermal model.
  - 1-D hygIRC can be used for
    - parametric analysis: changing weather (locations), materials, for example

    For more information please visit hygIRC Website:

    http://irc.nrc-cnrc.gc.ca/bes/software/hygIRC/index_e.html

- *hyg*IRC 2D is the Advanced hygrothermal models
  - Best handled by hygIRC 2-D
    - air leakage
    - water leaks
    - gravity effects

- *WeatherSmart*

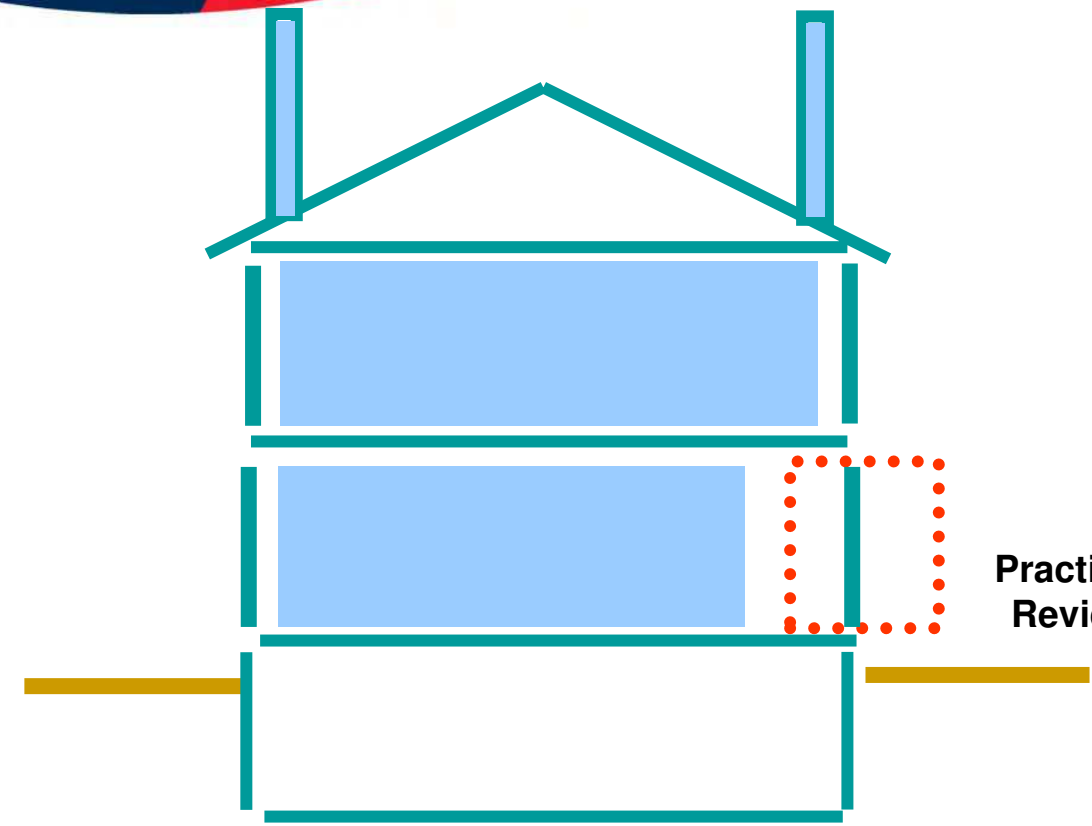
NRC·CNRC
Institute for Research in Construction

Outline

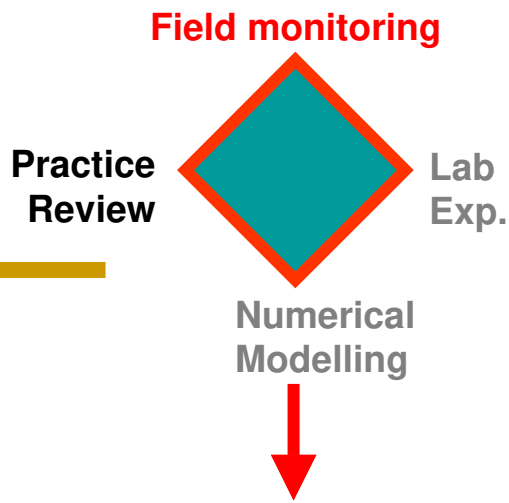
- Background
- Hygrothermal Performance of BES
  - Modeling
  - Field Experiments
  - Laboratory experiments
- Concluding Remarks and Future Work

NRC-CNRC
Institute for Research in Construction

Research House No. 3



FEWF- BES



FY06/07 & 07/08: Study & compare traditional & innovative BE strategies

NRC-CNRC
Institute for Research in Construction

Field Experiments

- Why to do field experiment?
- How to do experiment?
- Which physical phenomena to investigate,..?
- What do you expect from experiments?

NRC·CNRC
Institute for Research in Construction

IRC Field Exposure of Walls 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

NRC-CNRC
Institute for Research in Construction

IRC Field Exposure of Walls Facility (FEWF)

- **Experimental Approach**
  - **Year 1 (2006-2007)** Commission the facility by monitoring three identical test specimens of traditional construction (2x6) through Fall, Winter and Spring.
  - **Year 2 (2006-2007)** Investigate the performance of two to three wall specimens of different innovative designs based on industrial collaboration/partnership.
  - **Year 3 and beyond** Expand the program in collaboration with Indoor Environment to examine whole house performance issues.

South facade

North facade

West facade

Inst
ed w

sing

desi
the

specimens

NRC-CNRC
Institute for Research in Construction

Outline

- Background
- Hygrothermal Performance of BES
  - Modeling
  - Field Experiments
    - **Construction of the test bay**
    - **Construction of the walls**
    - **Wall Assembly (Inside)**
    - **Wall Assembly (Outside)**
    - **Instrumentation**
  - Laboratory experiments
- Concluding Remarks and Future Work

NRC·CNRC
Institute for Research in Construction

IRC Field Exposure of Walls Facility (FEWF)

NRC·CNRC
Institute for Research in Construction

IRC Field Exposure of Walls Facility (FEWF)

NRC·CNRC
Institute for Research in Construction

IRC Field Exposure of Walls Facility (FEWF)

NRC·CNRC
Institute for Research in Construction

IRC Field Exposure of Walls Facility (FEWF)

NRC·CNRC
Institute for Research in Construction

IRC Field Exposure of Walls Facility (FEWF)

NRC·CNRC
Institute for Research in Construction

IRC Field Exposure of Walls Facility (FEWF)

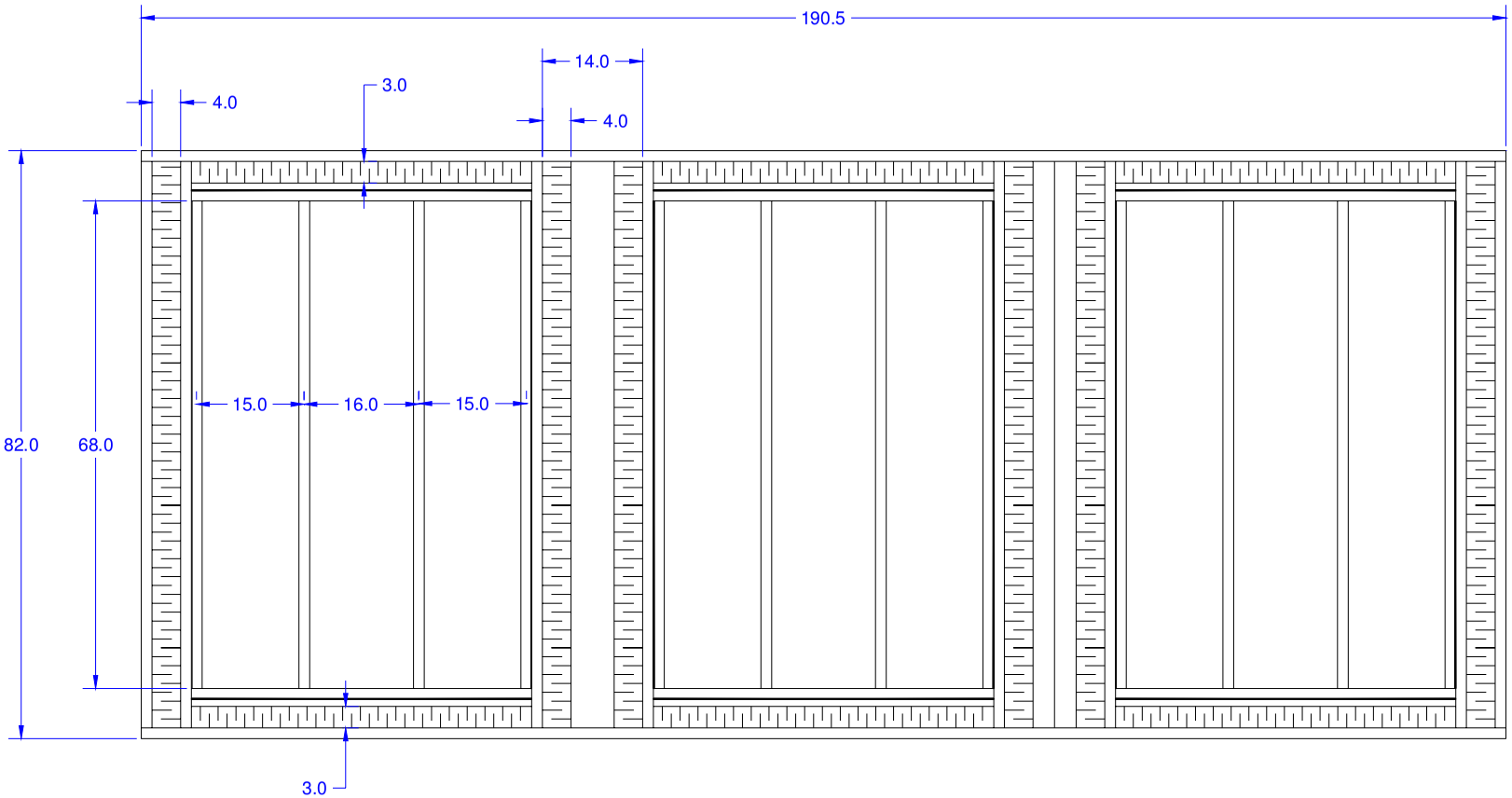
NRC-CNRC
Institute for Research in Construction

Outline

- Background
- Hygrothermal Performance of BES
  - Modeling
  - Field Experiments
    - **Construction of the test bay**
    - **Construction of the walls**
    - **Wall Assembly (Inside)**
    - **Wall Assembly (Outside)**
    - **Instrumentation**
  - Laboratory experiments
- Conclusion

NRC·CNRC
Institute for Research in Construction

IRC Field Exposure of Walls Facility (FEWF)



NRC·CNRC
Institute for Research in Construction

IRC Field Exposure of Walls Facility (FEWF)

NRC·CNRC
Institute for Research in Construction

IRC Field Exposure of Walls Facility (FEWF)

NRC-CNRC
Institute for Research in Construction

Outline

- Background
- Hygrothermal Performance of BES
  - Modeling
  - Field Experiments
    - **Construction of the test bay**
    - **Construction of the walls**
    - **Wall Assembly (Inside)**
    - **Wall Assembly (Outside)**
    - **Instrumentation**
  - Laboratory experiments
- Concluding Remarks and Future Work


LEPAGE
BULLDOG GRIP
BLACK
Vapour barrier


Installation d'exposition in-situ des murs de l'IRC (IEIM)
IRC Field Exposure of Wall Facility (FEWF)

NRC-CNRC
Institute for Research in Construction

Outline

- Background
- Hygrothermal Performance of BES
  - Modeling
  - Field Experiments
    - **Construction of the test bay**
    - **Construction of the walls**
    - **Wall Assembly (Inside)**
    - **Wall Assembly (Outside)**
    - **Instrumentation**
  - Laboratory experiments
- Concluding Remarks and Future Work


W3
W2


M-24TH3

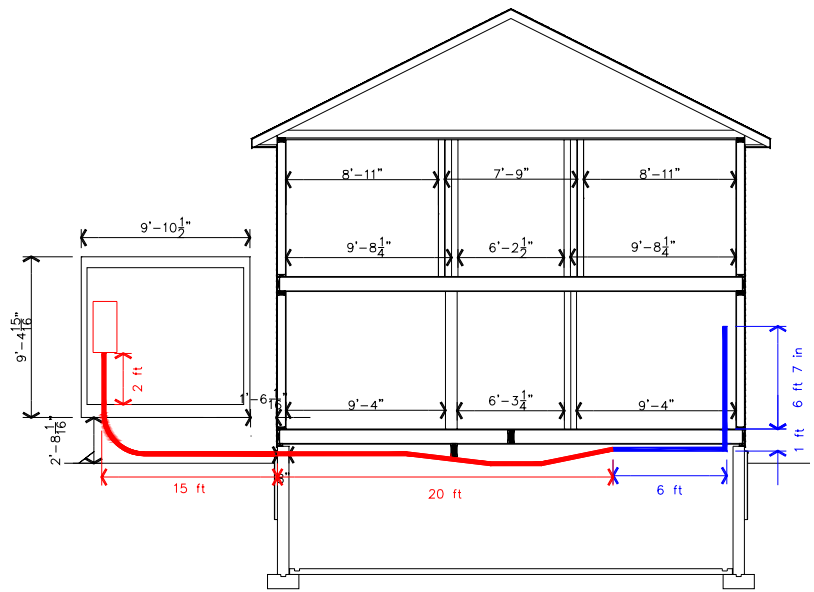
NRC-CNRC
Institute for Research in Construction

Outline

- Background
- Hygrothermal Performance of BES
  - Modeling
  - Field Experiments
    - **Construction of the test bay**
    - **Construction of the walls**
    - **Wall Assembly (Inside)**
    - **Wall Assembly (Outside)**
    - **Instrumentation**
  - Laboratory experiments
- Concluding Remarks and Future Work

NRC·CNRC
Institute for Research in Construction

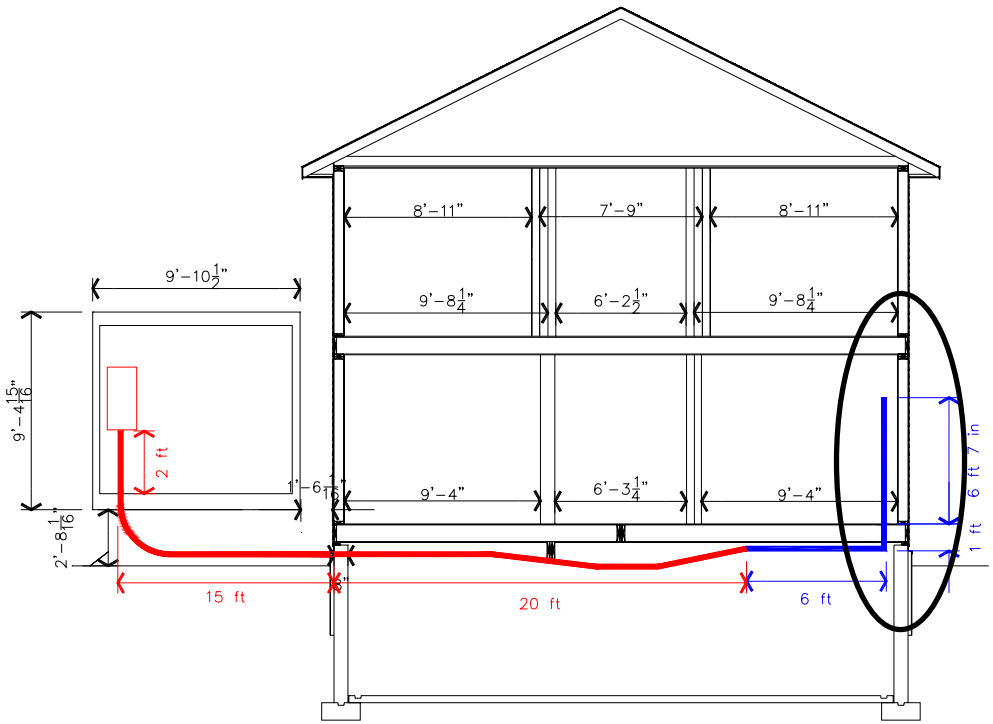
FEWF Instrumentation



- First Floor
- Basement
  - Wall to Junction Boxes
- Trailer

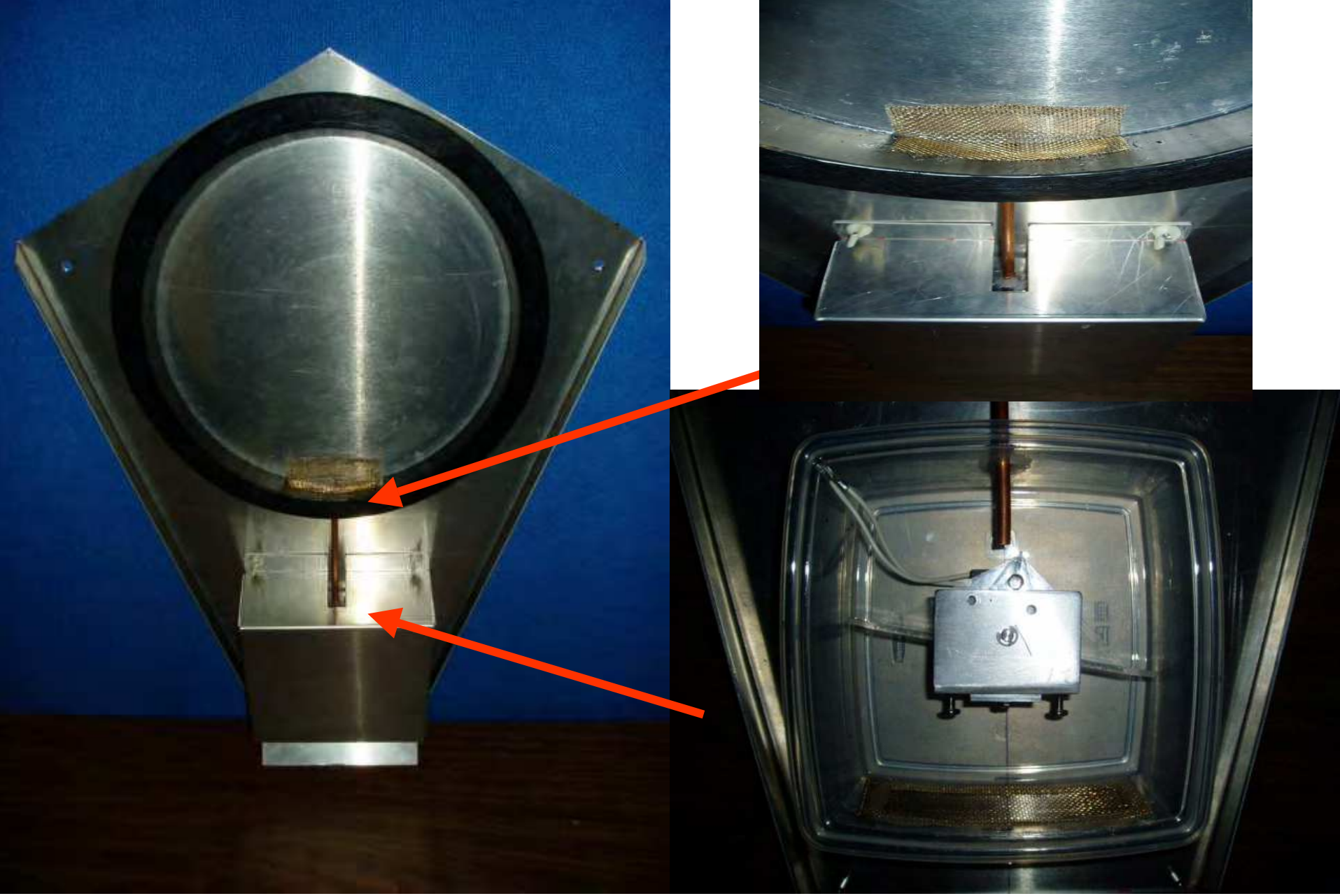
NRC·CNRC
Institute for Research in Construction

FEWF Instrumentation



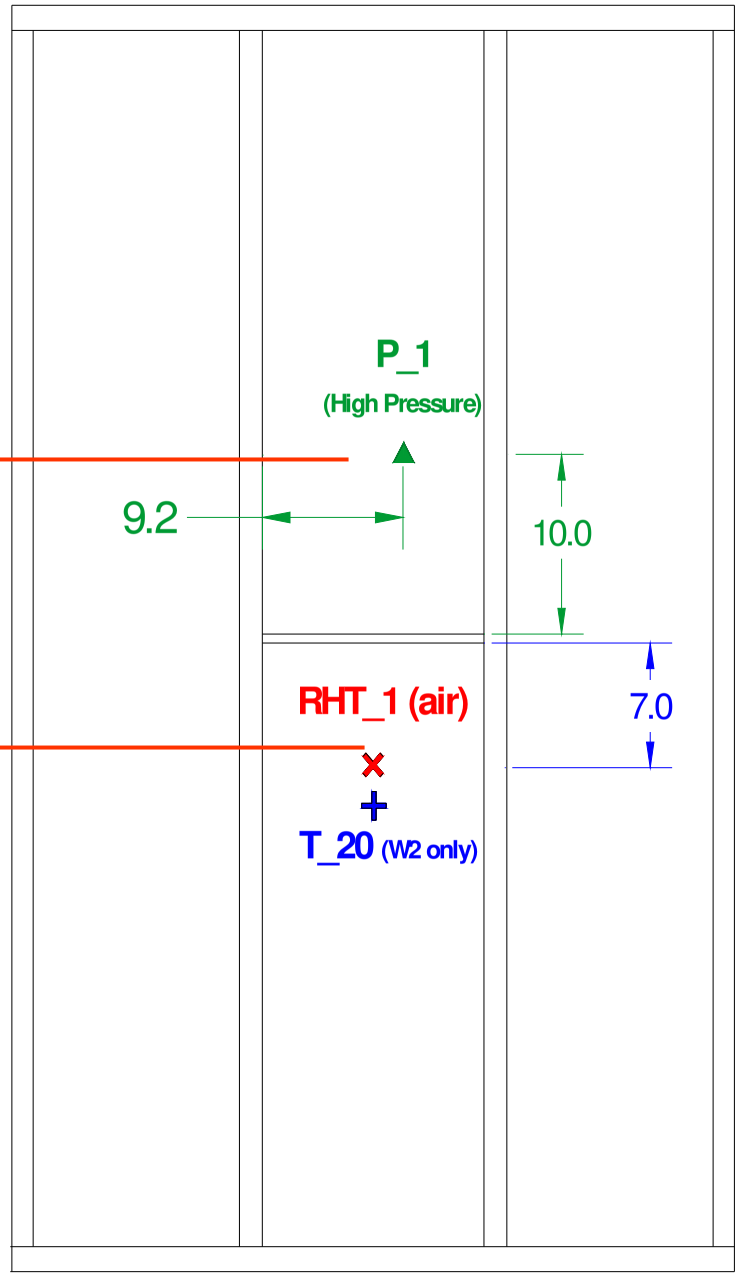
- First Floor
- Basement
  - Wall to Junction Boxes
- Trailer


M-24TH3



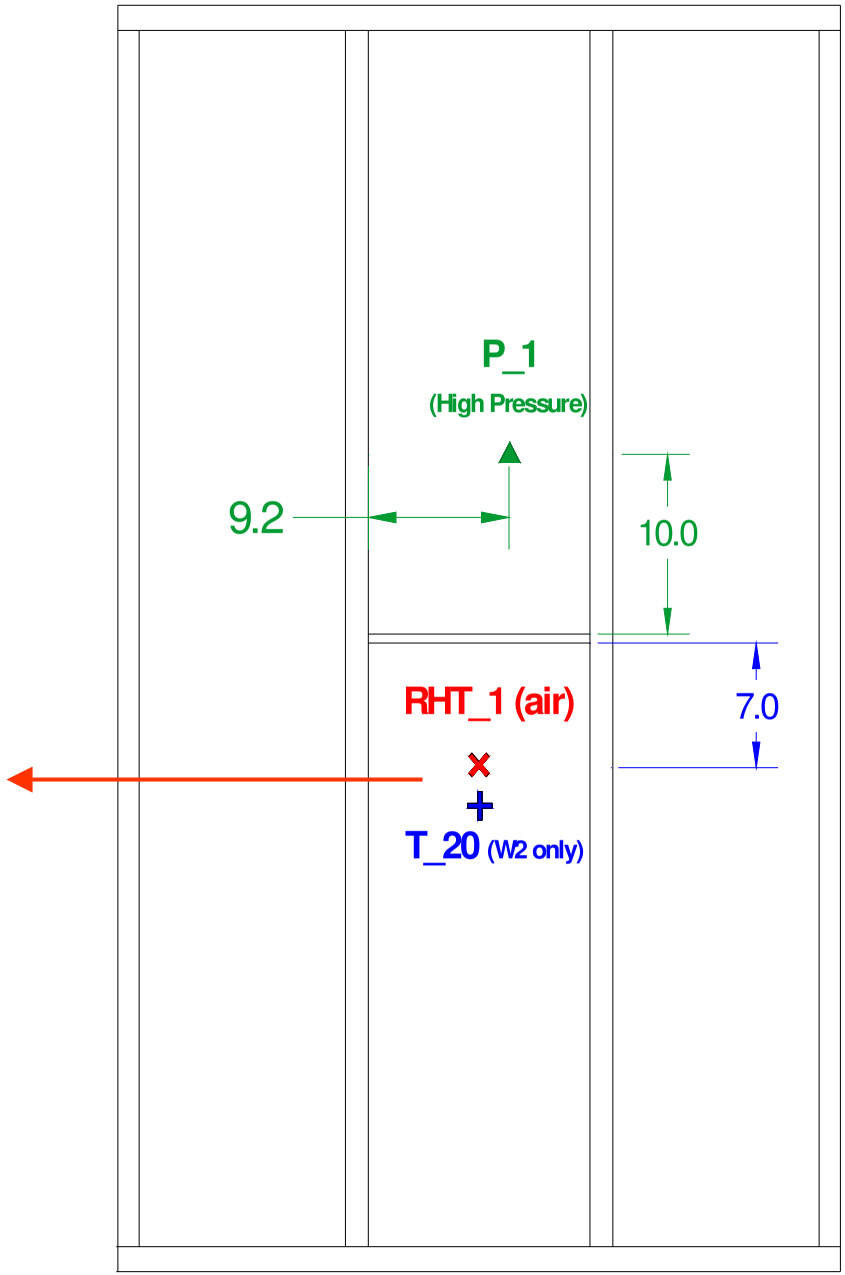
Rain Gauge

LAYER 1 - Exterior Face of Vinyl Siding

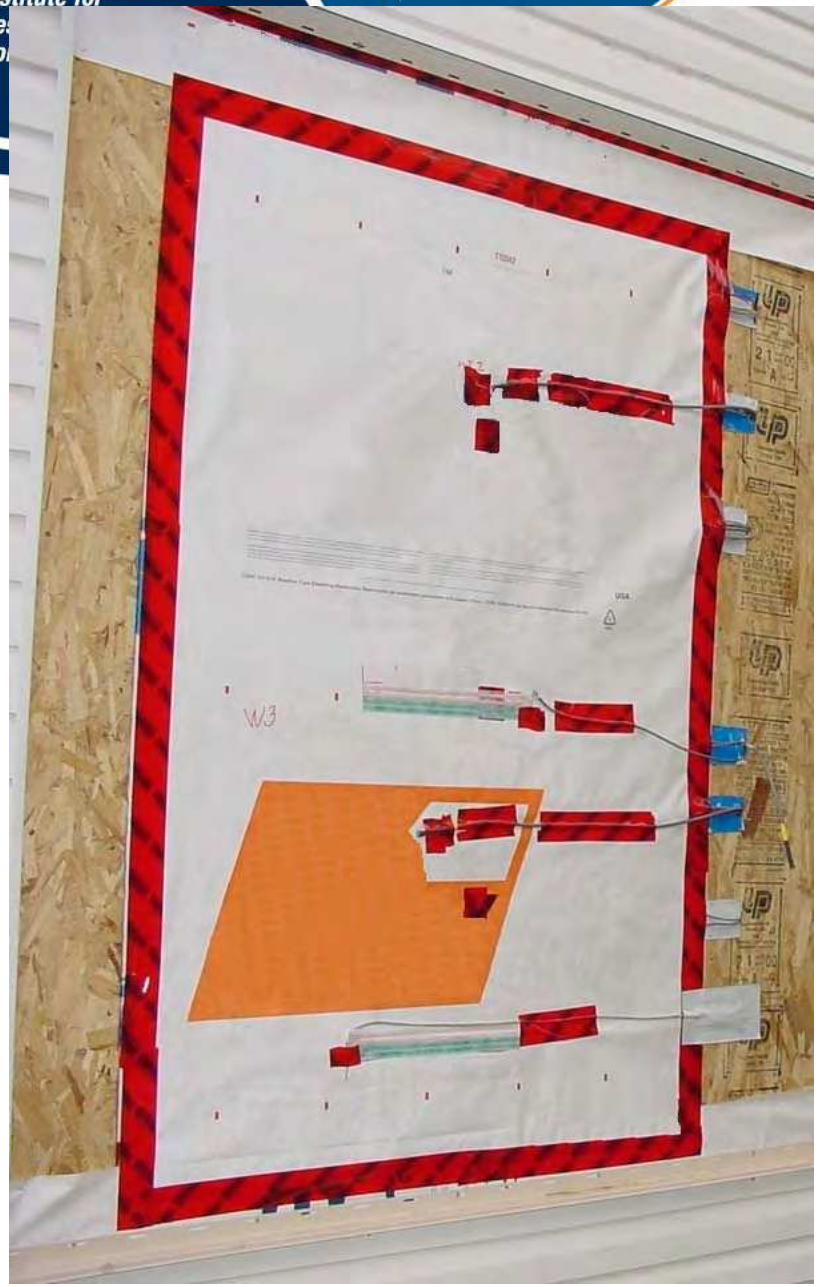


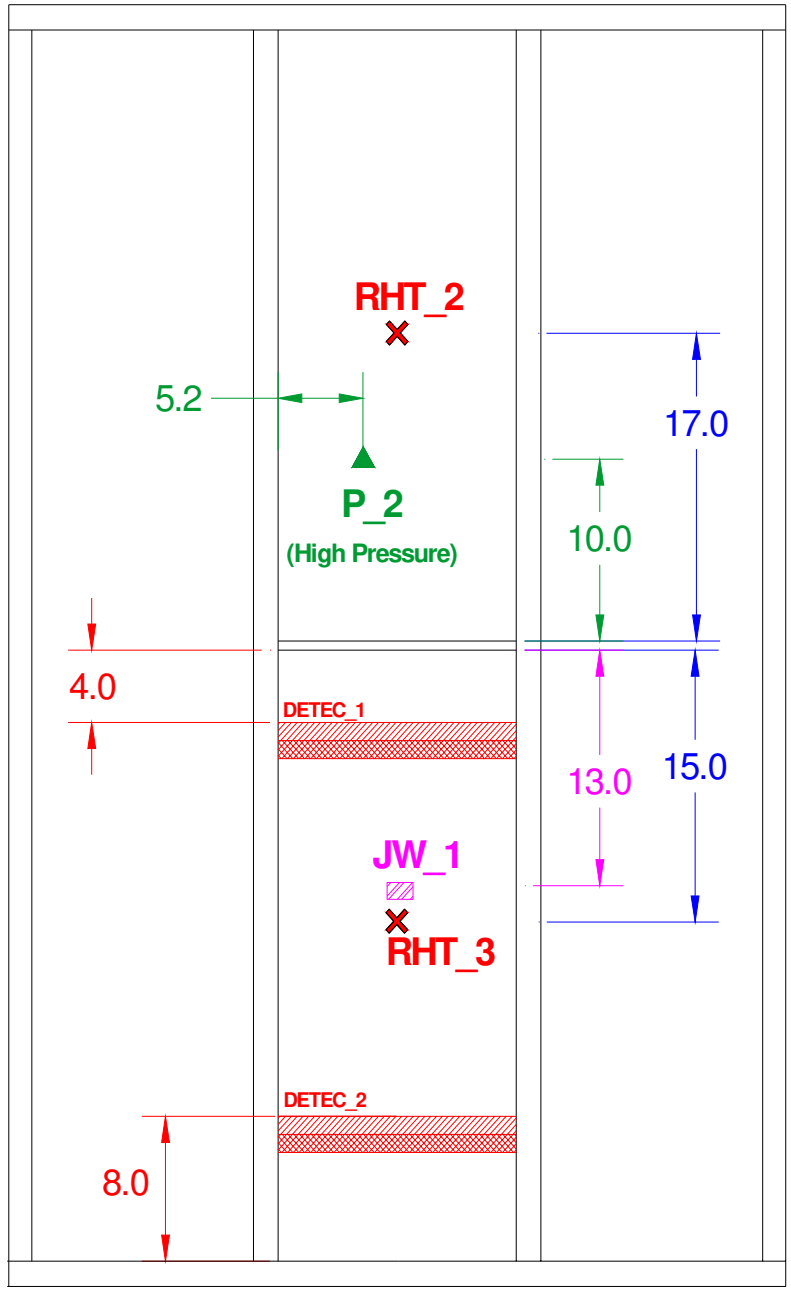
NRC·CNRC
Institute for Research in Construction

LAYER 1 - Exterior Face of Vinyl Siding

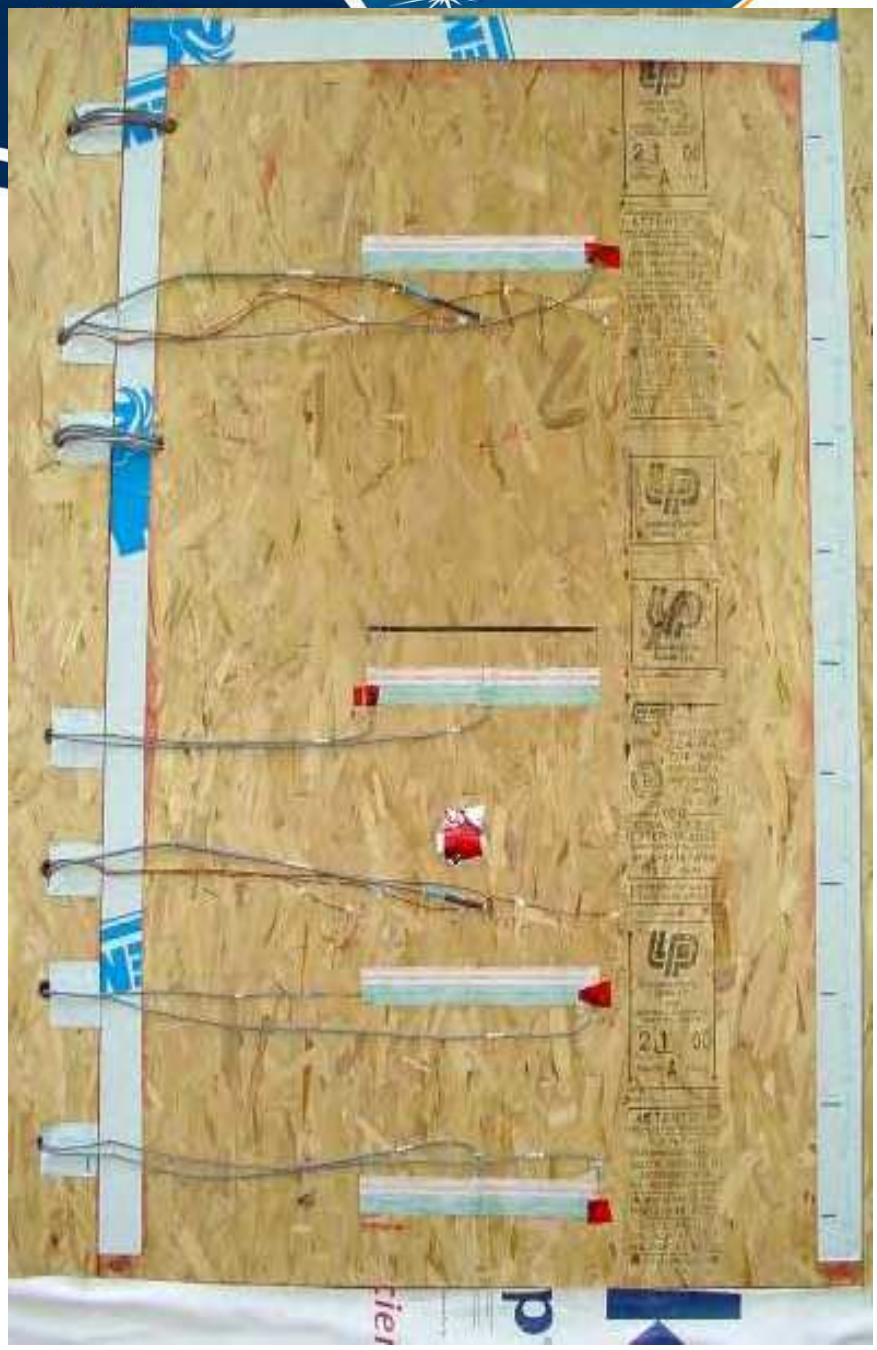


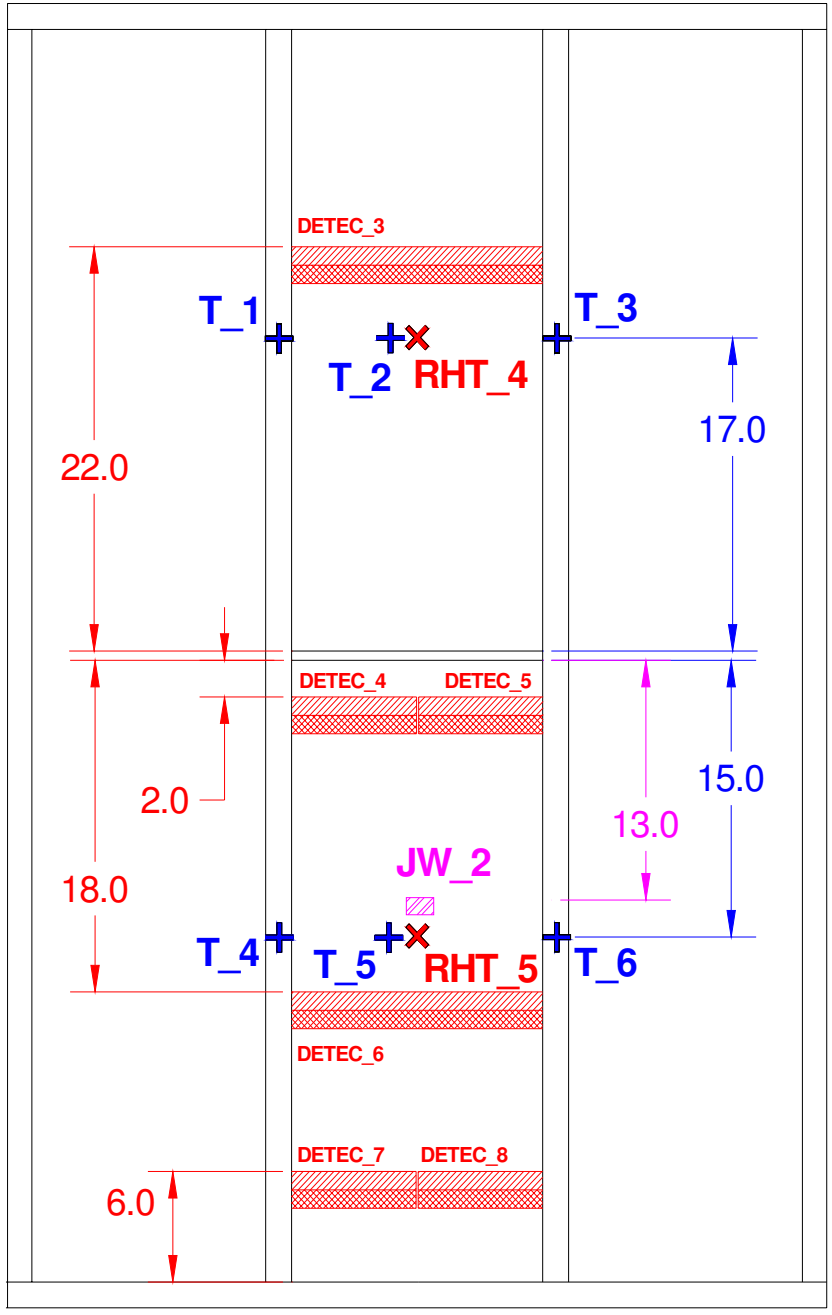
LAYER 2 - Exterior Face of Sheathing Membrane



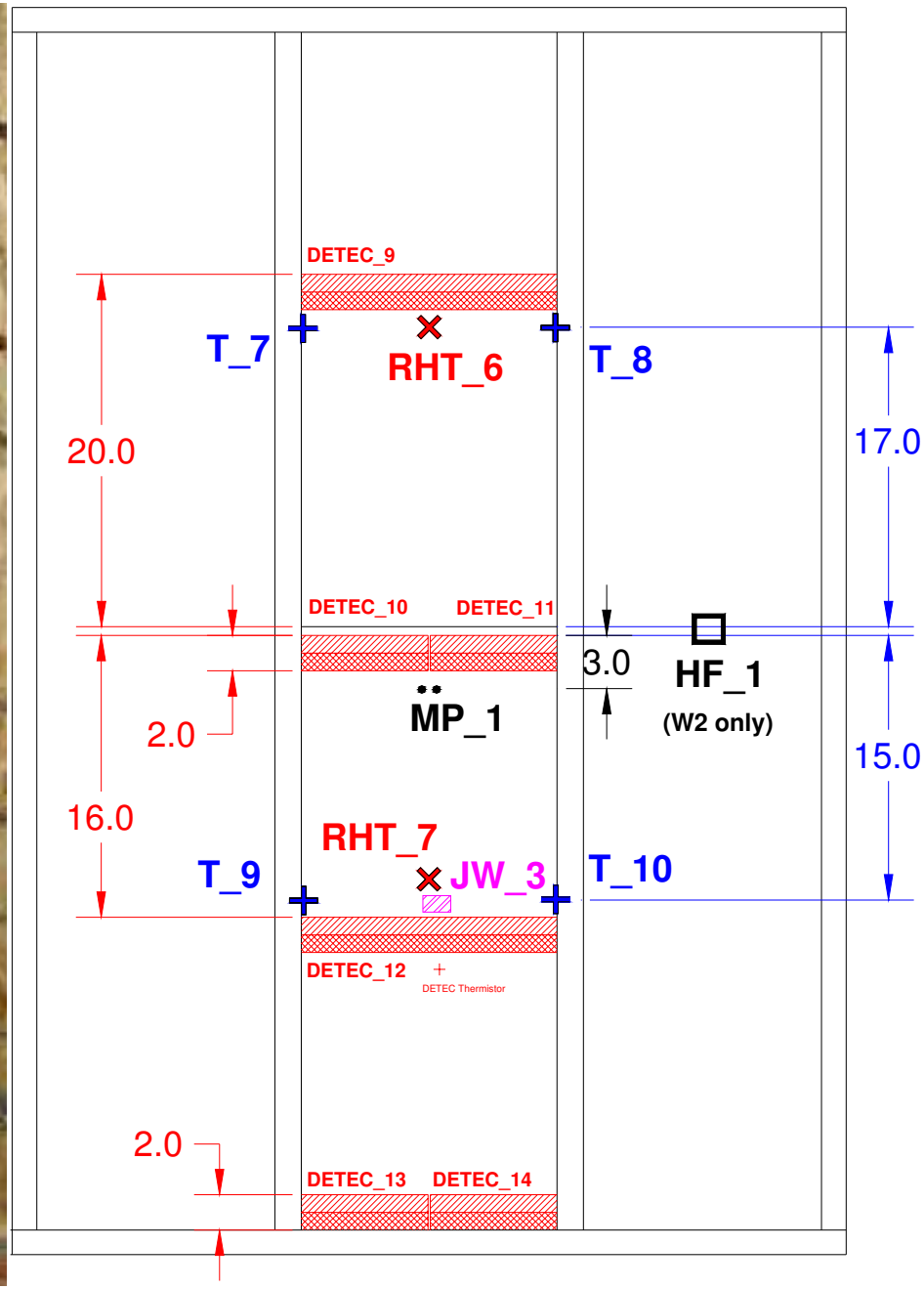


LAYER 3 - Exterior Face of OSB

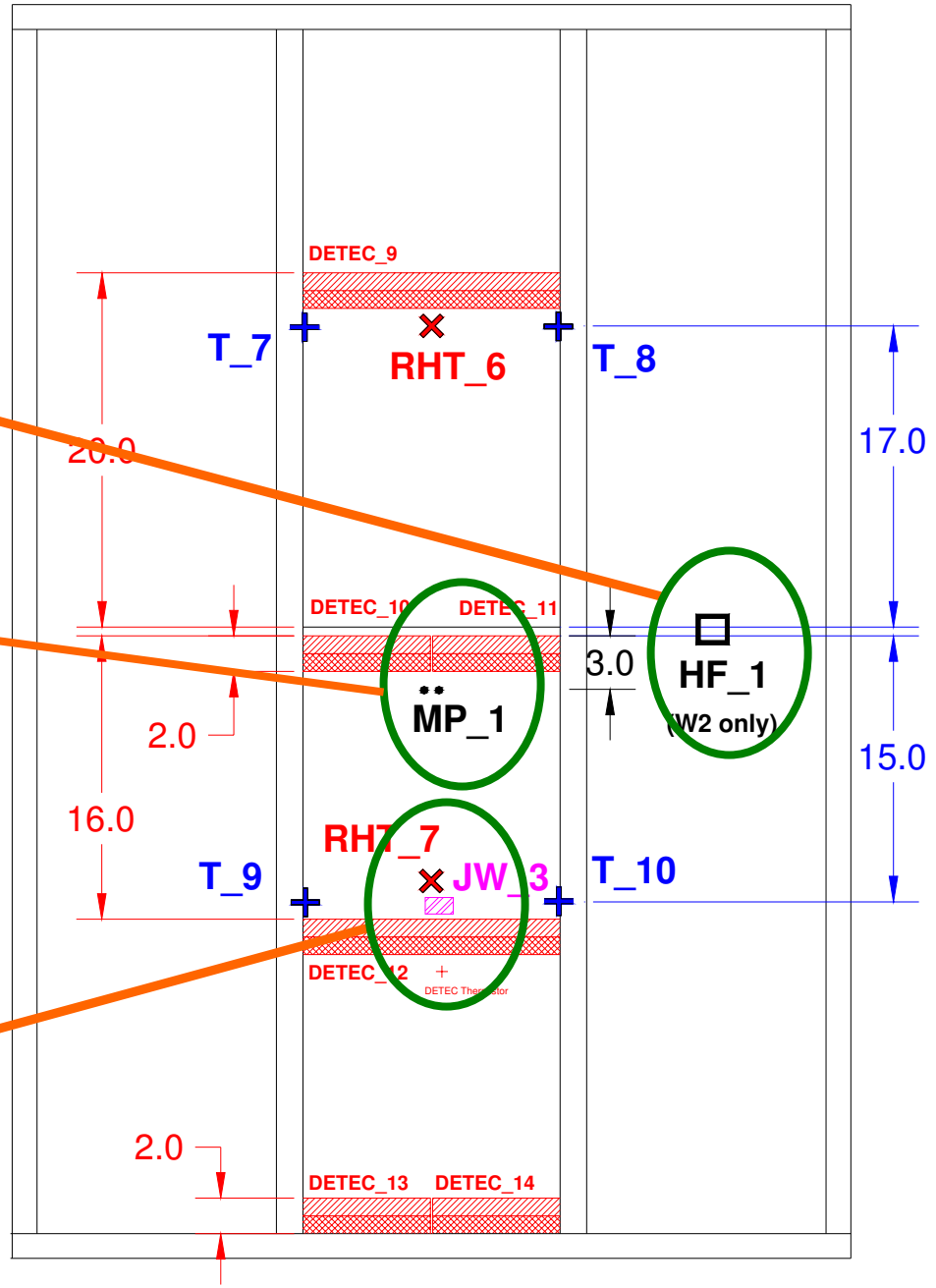




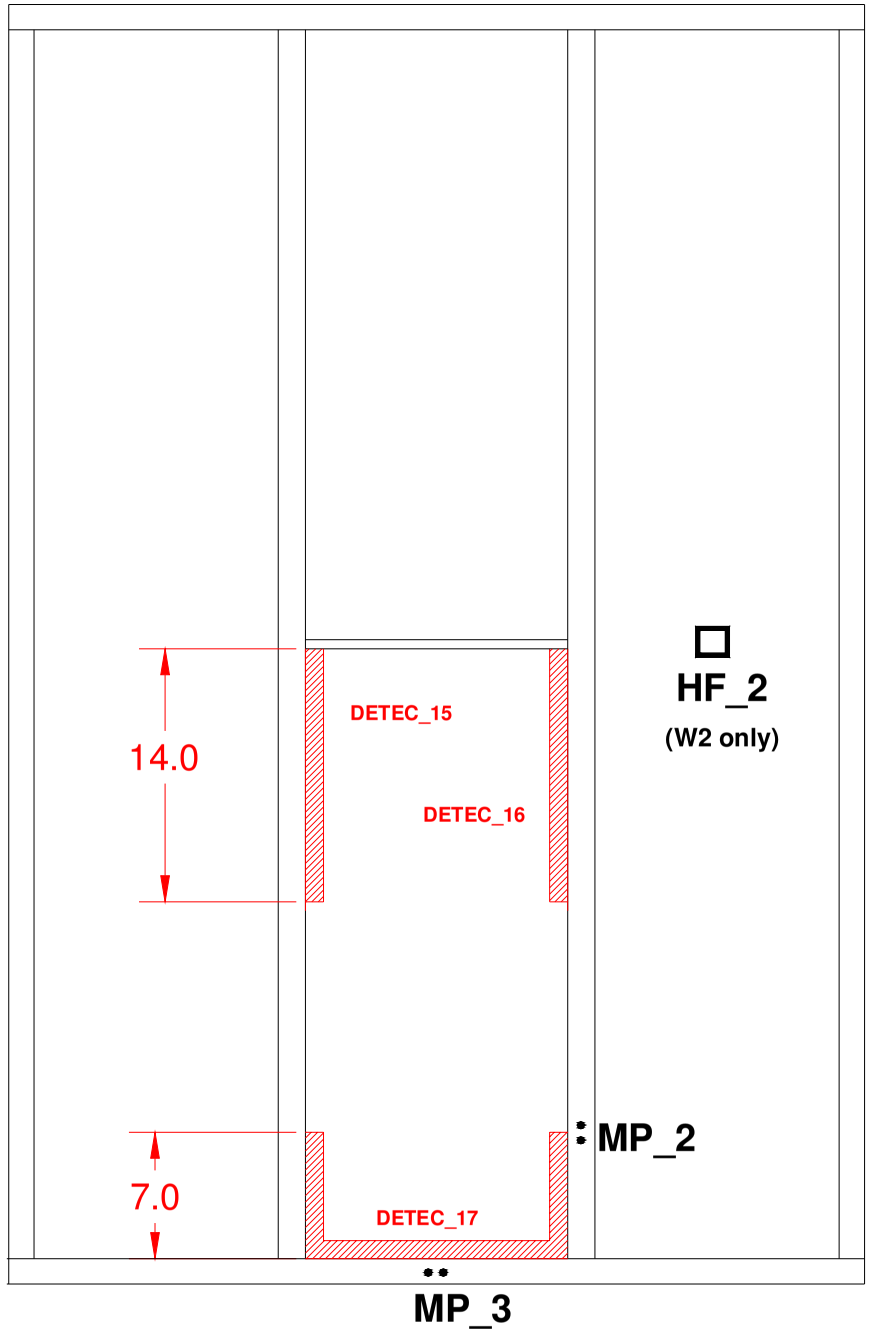
LAYER 4 - Interior Face of OSB



LAYER 4 - Interior Face of OSB

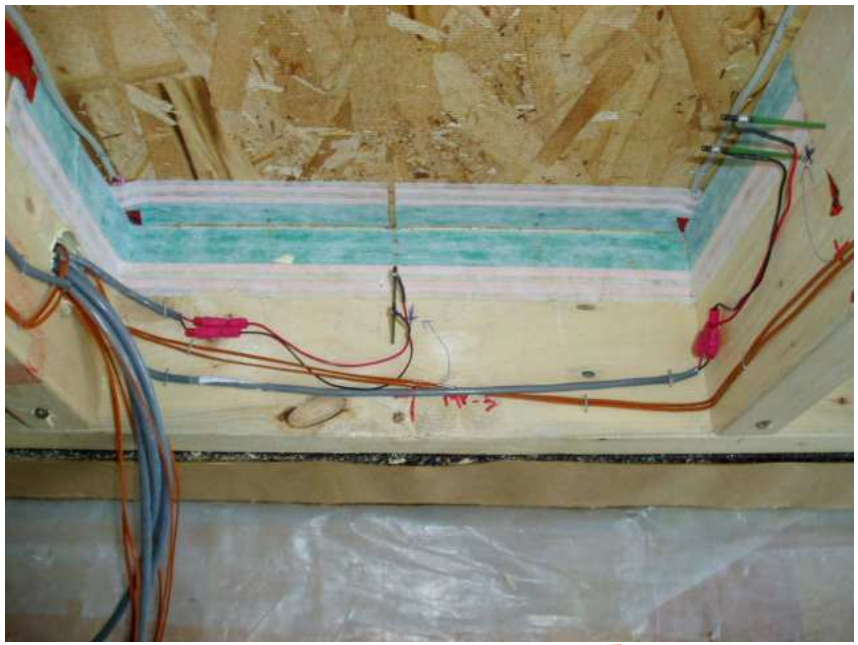


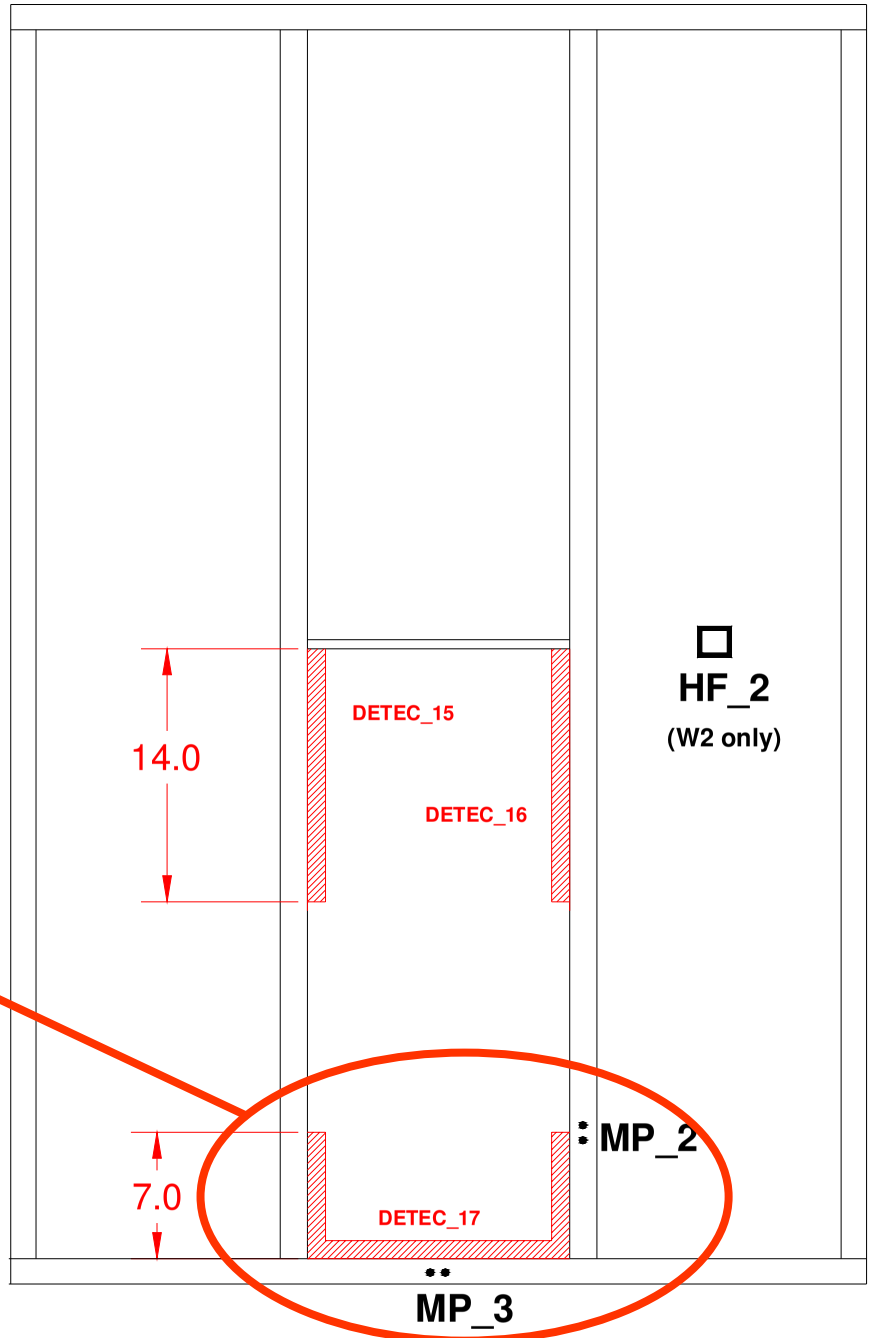
LAYER 5 - Stud Cavity



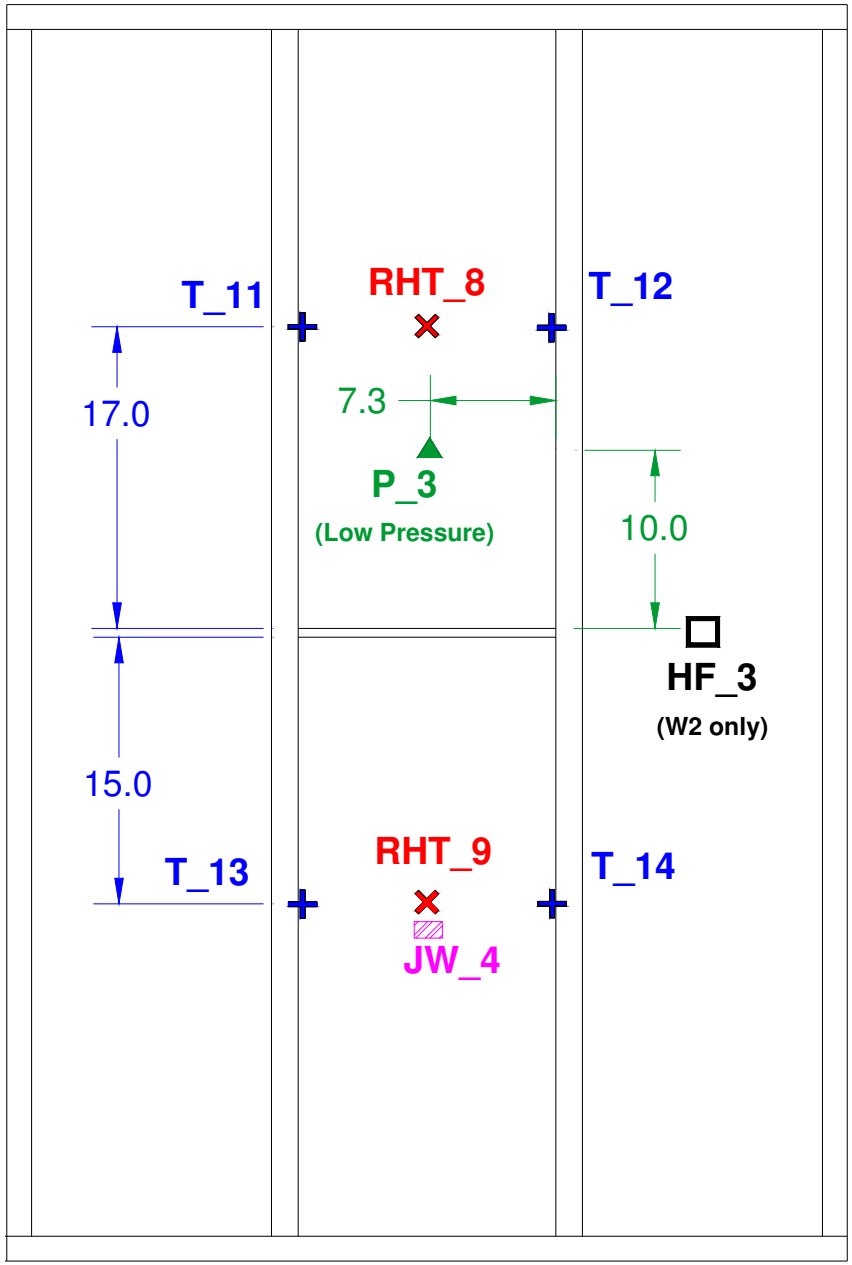
NRC·CNRC
Institute for Research in Construction

LAYER 5 - Stud Cavity

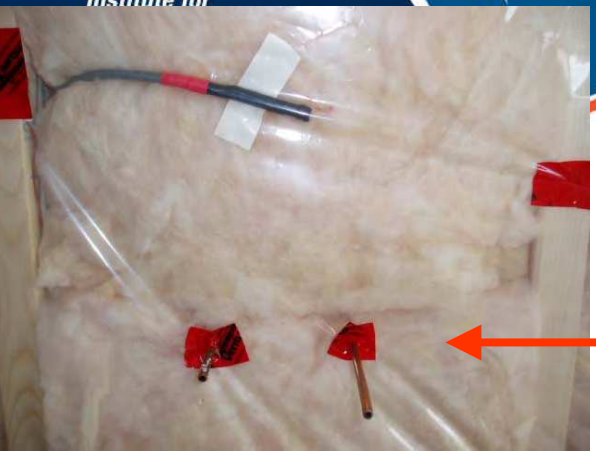


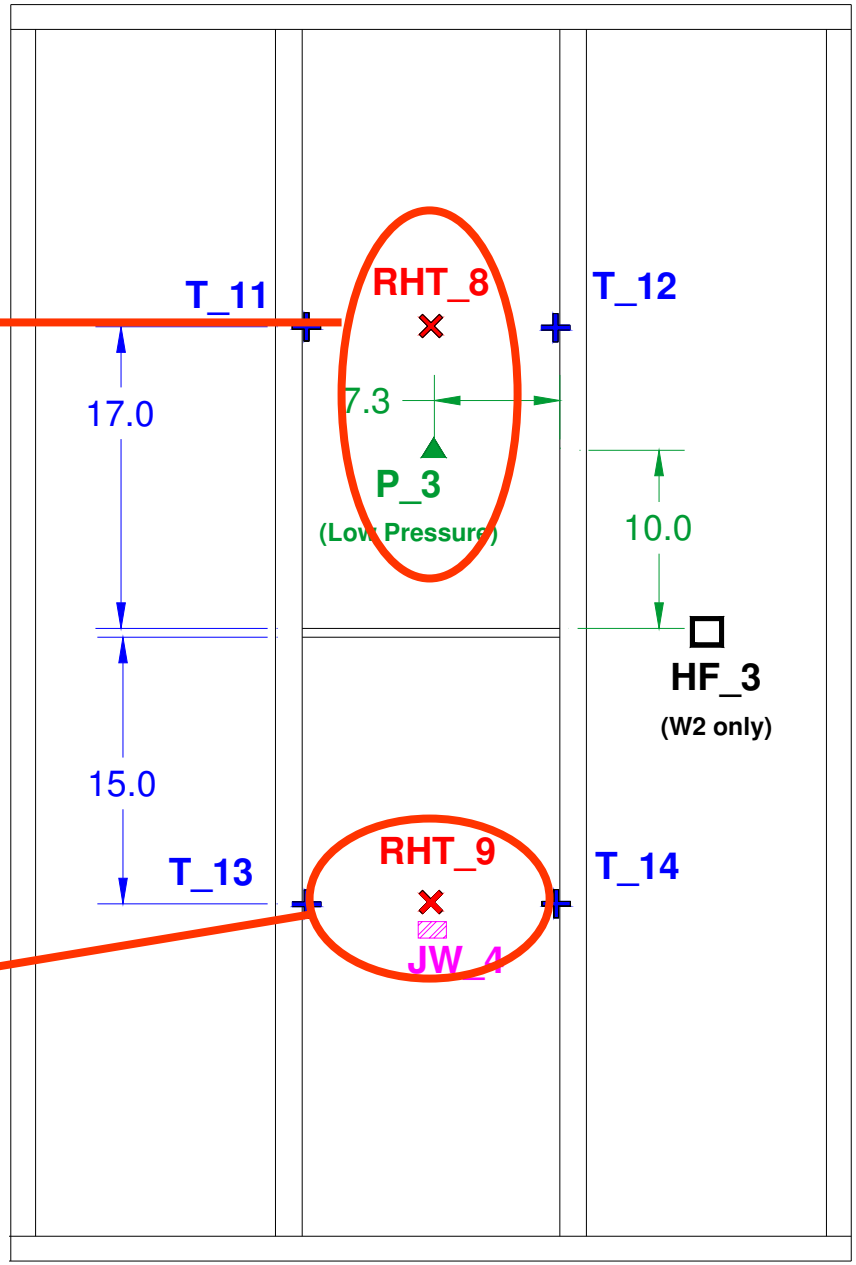


LAYER 6 - Interior Face of Insulation & Stud Cavity (Exterior side of Vapour Barrier)

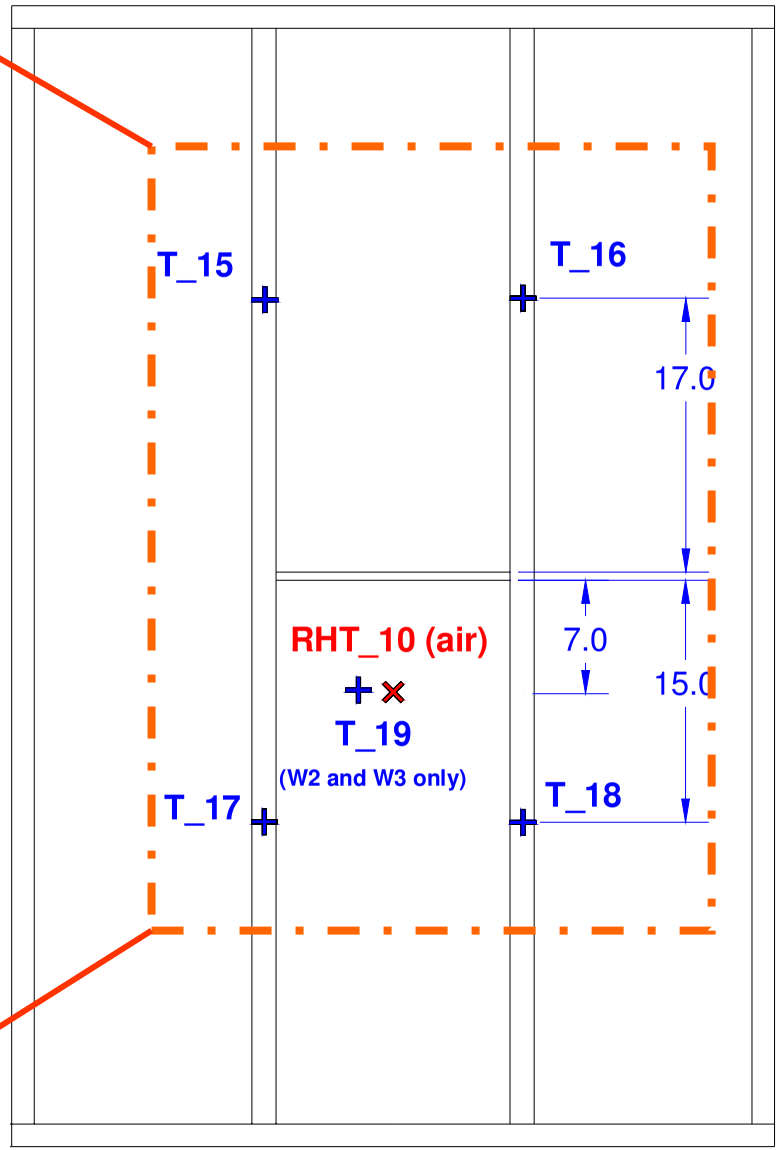


LAYER 6 - Interior Face of Insulation & Stud Cavity (Exterior side of Vapour Barrier)



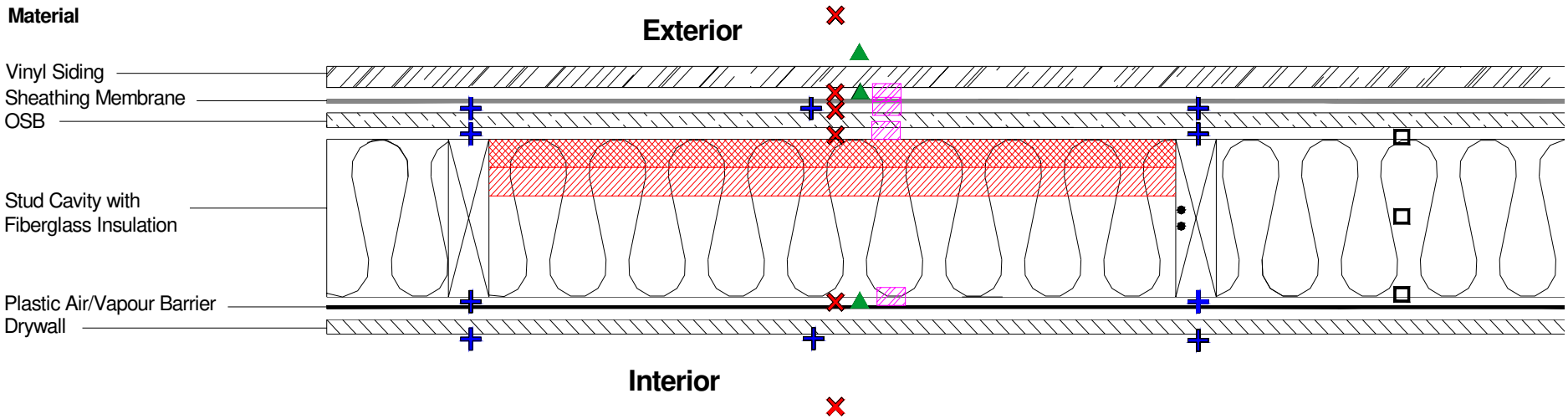


LAYER 7 - Interior Face of Drywall



NRC·CNRC
Institute for Research in Construction

IRC Field Exposure of Wall Facility (FEWF)

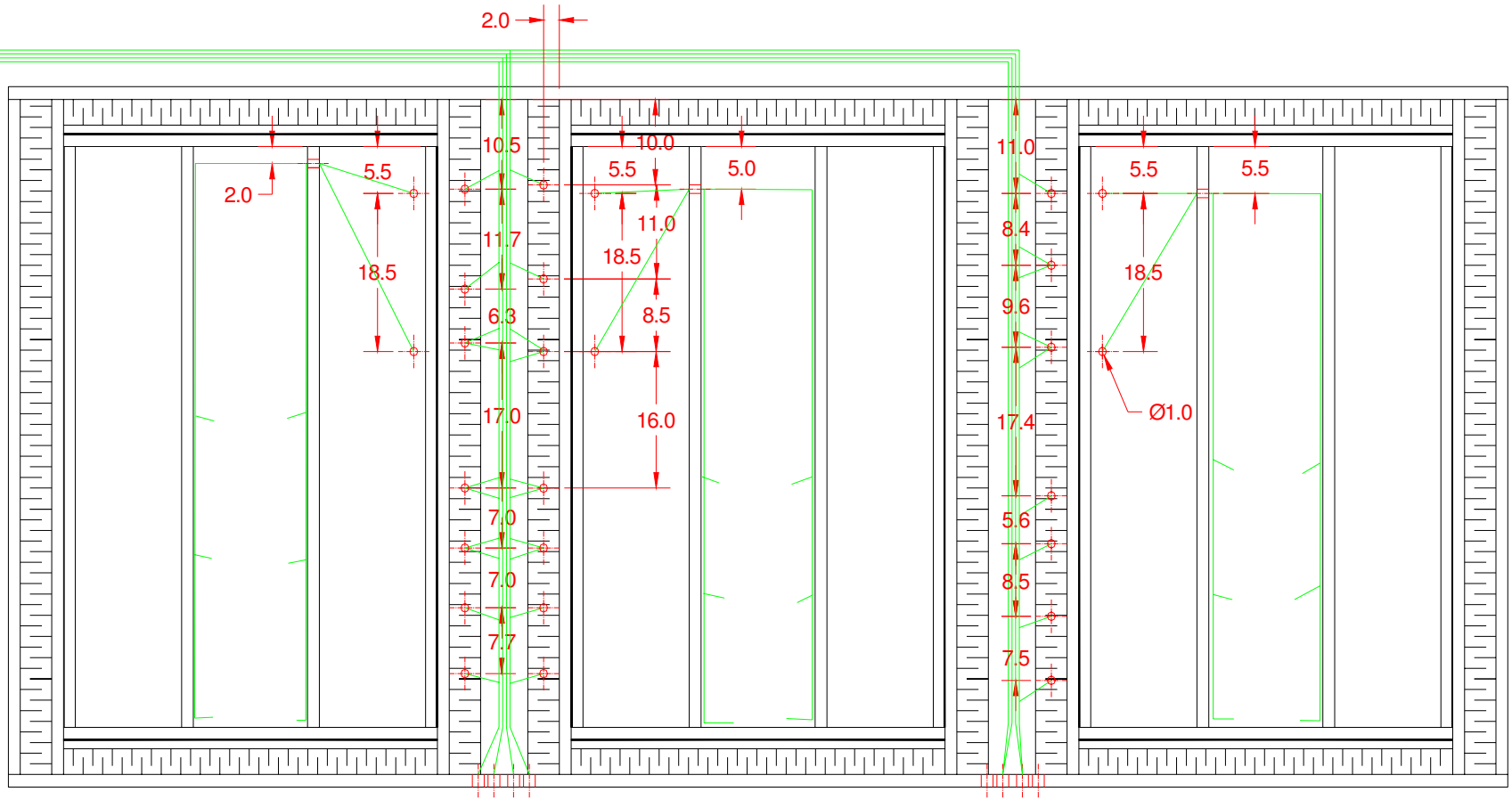


Instrumentation - Plan View

- RH and T sensors
- T sensors
- Air Pressure sensor
- Moisture Pins
- Jeld-Wen Wireless RH&T Sensors
- Heat Flux Transducer (for W2 only)
- DETEC

Around 17000ft of cable

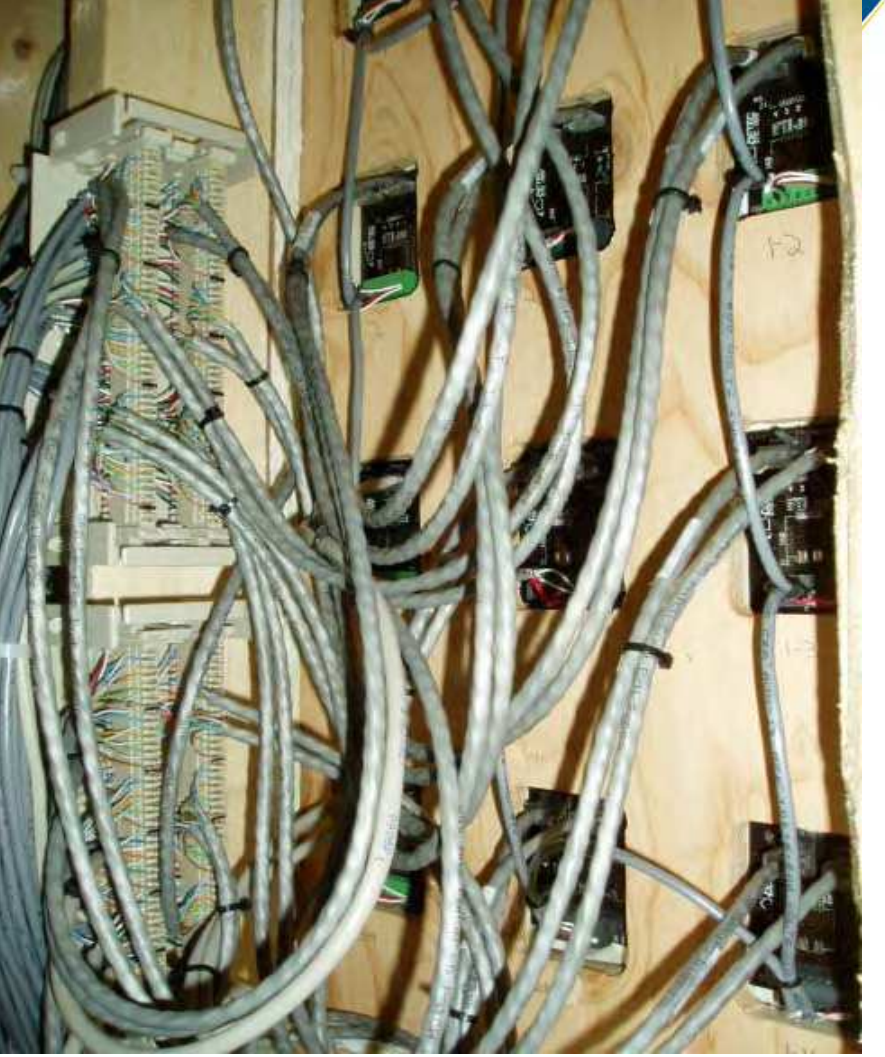
NRC·CNRC
Institute for Research in Construction



View from interior of specimen. All dimensions in inches.


Installation d'exposition in-situ des murs de l'IRC (IEIM)
IRC Field Exposure of Wall Facility (FEWF)


Installation d'exposition in-situ des murs de l'IRC (IEIM)
IRC Field Exposure of Wall Facility (FEWF)



Board Layout -Rear

Board Layout - Front

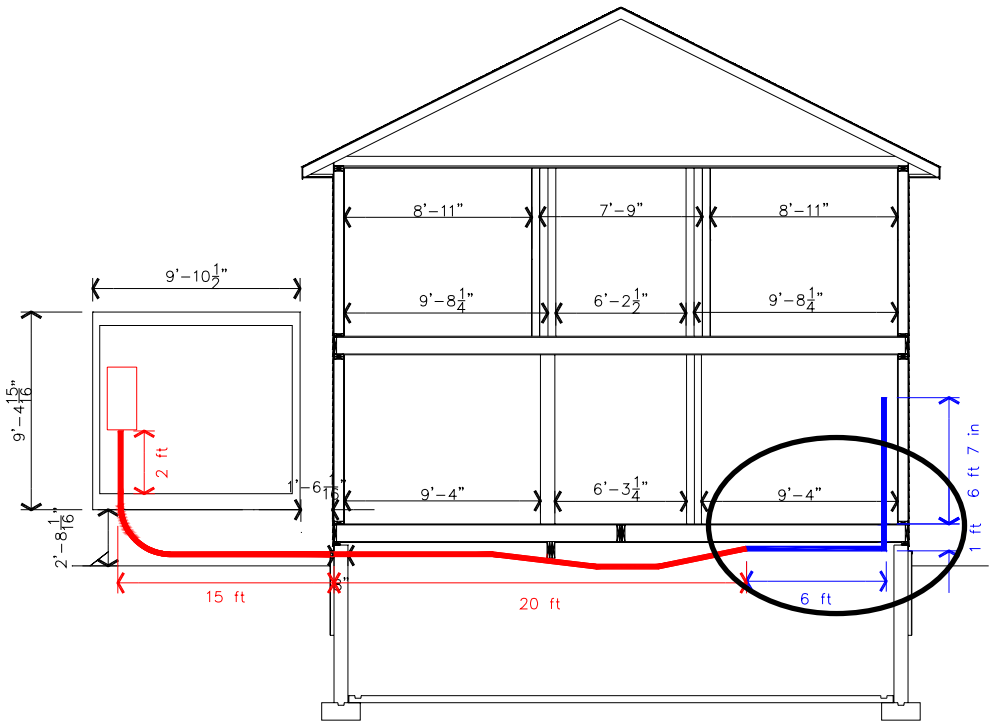
9 RMUs (Remote Monitoring Unit)
9 x 8 zones inputs = (72 zones)


Installation d'exposition in-situ des murs de l'IRC (IEIM)
IRC Field Exposure of Wall Facility (FEWF)

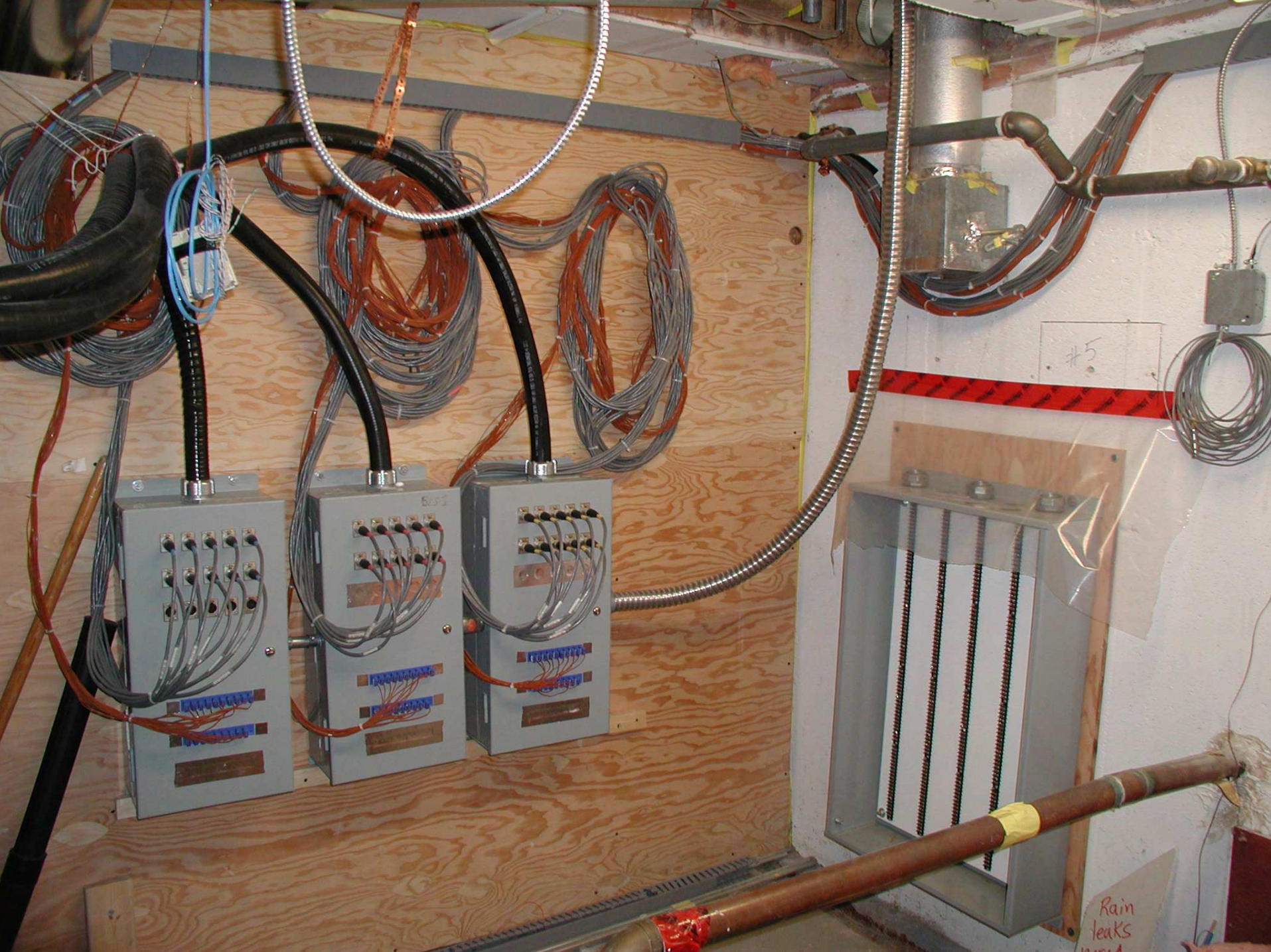
9 Differential Pressure Transducers:
3 DP of 0.25” WC
6 DP of 2.5” WC

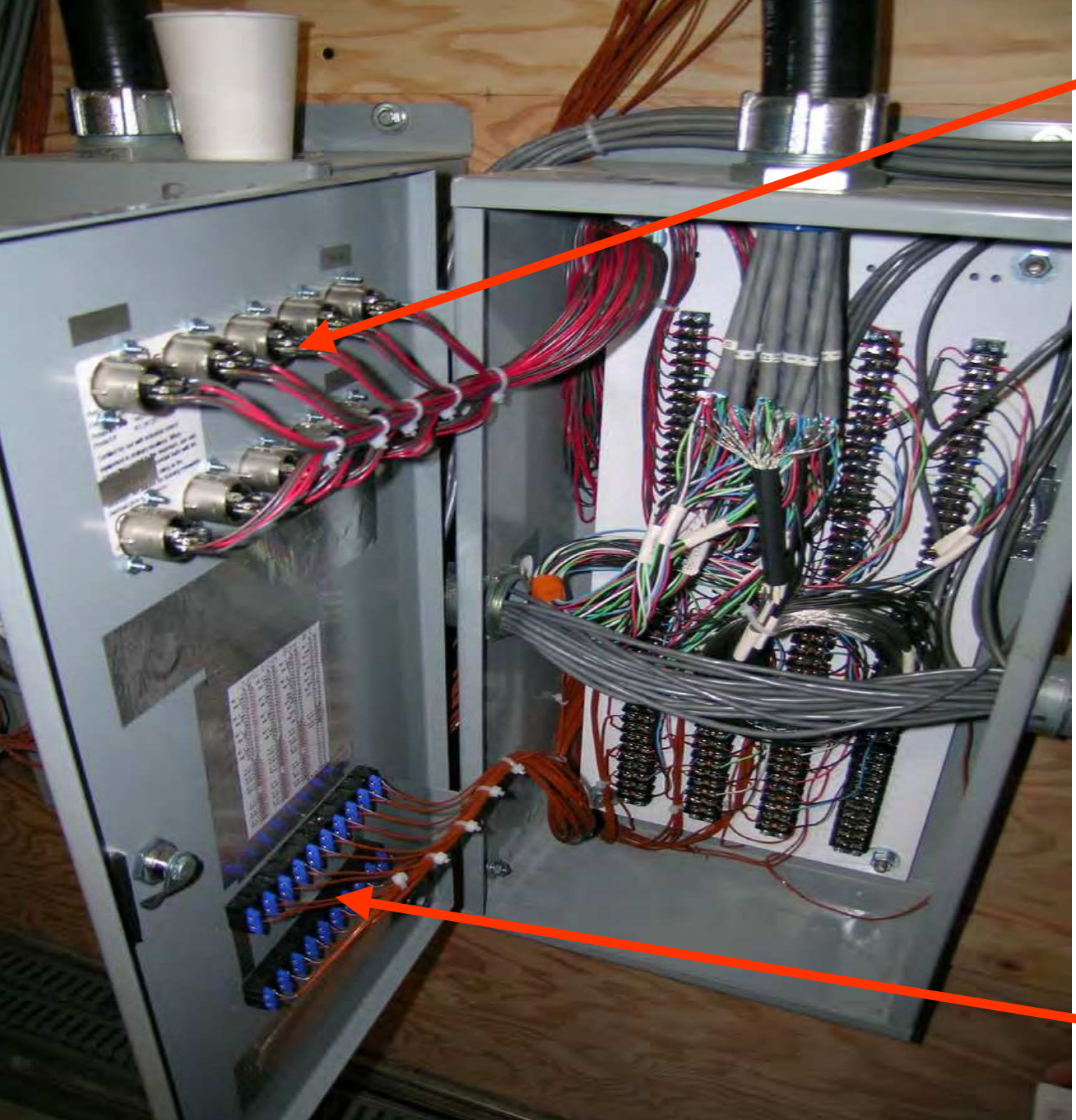
NRC·CNRC
Institute for Research in Construction

FEWF Instrumentation: Cable Wiring



- First Floor
- Basement
  - Wall to Junction Boxes
- Trailer


#5
Rain
leaks



10 RHT Sensors

3 DP Transducers

3 MP Sensors

Junction Box Wall 2

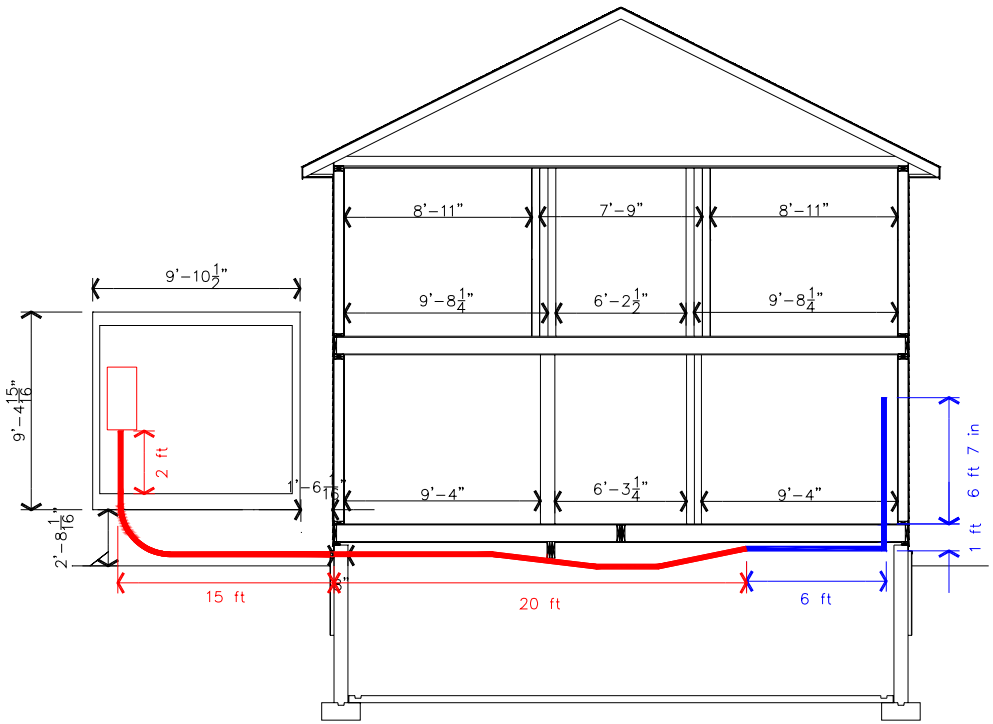
3 HFT

1 RTD as Ref

20 Thermocouples

NRC·CNRC
Institute for Research in Construction

FEWF Instrumentation: Cable Wiring



- First Floor
- Basement
  - Wall to Junction Boxes
- Trailer

NRC·CNRC
Institute for Research in Construction

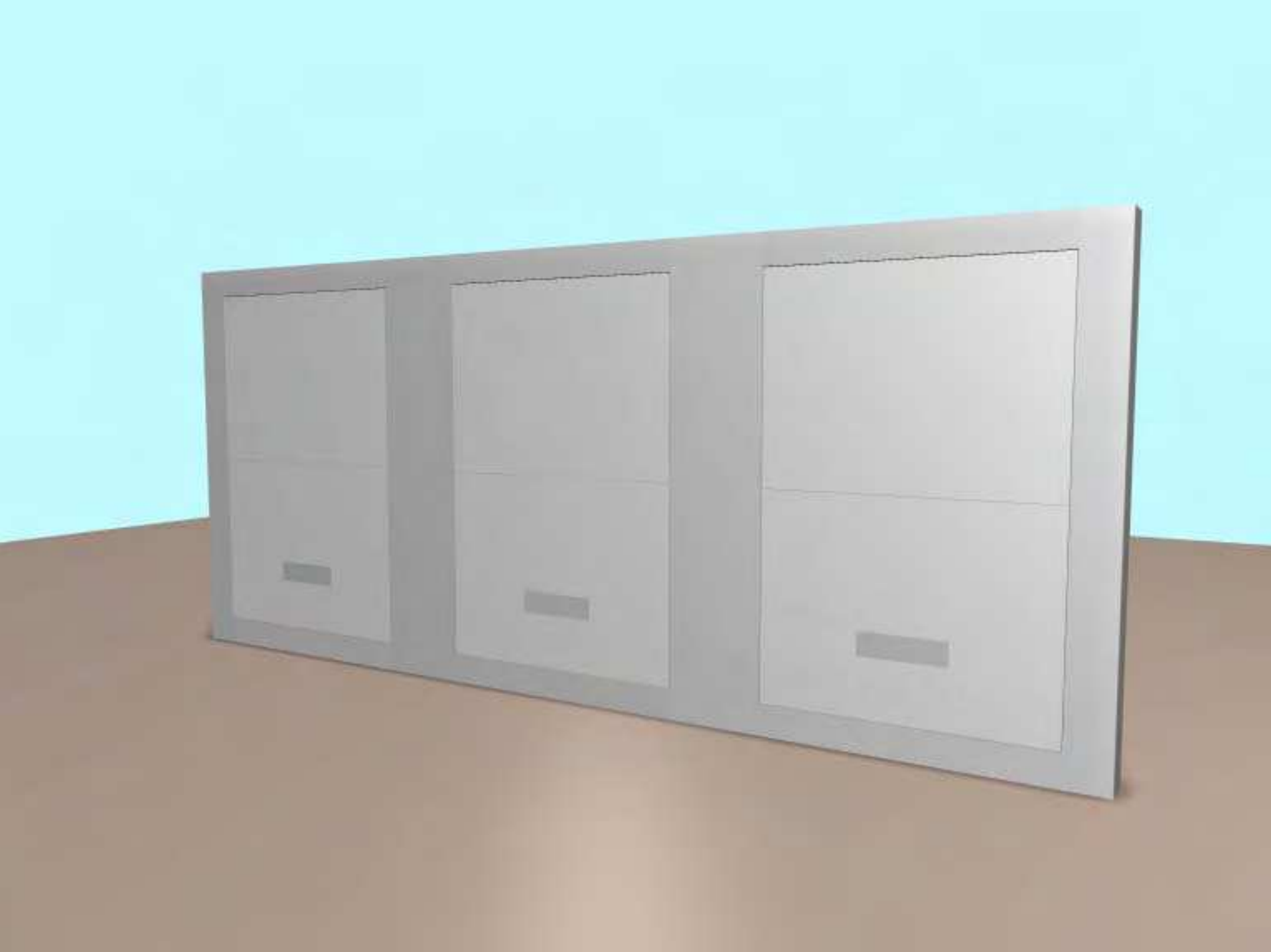
Experimental Approach

- **The experiments will be in three phases:**
  - **Phase 1:** Commission the facility by monitoring three identical test specimens of traditional construction (2x6) through Fall, and part of the Winter under naturally occurring conditions.
  - **Phase 2:** Challenging the wall during the Winter
    - 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 45% and induce 10 Pa positive pressure while air leak path is present in two specimens, for 2 weeks (?)
  - **Phase 3:** Return to naturally occurring conditions to monitor drying. Disassemble the indoor chamber

NRC·CNRC
Institute for Research in Construction

Experimental Approach

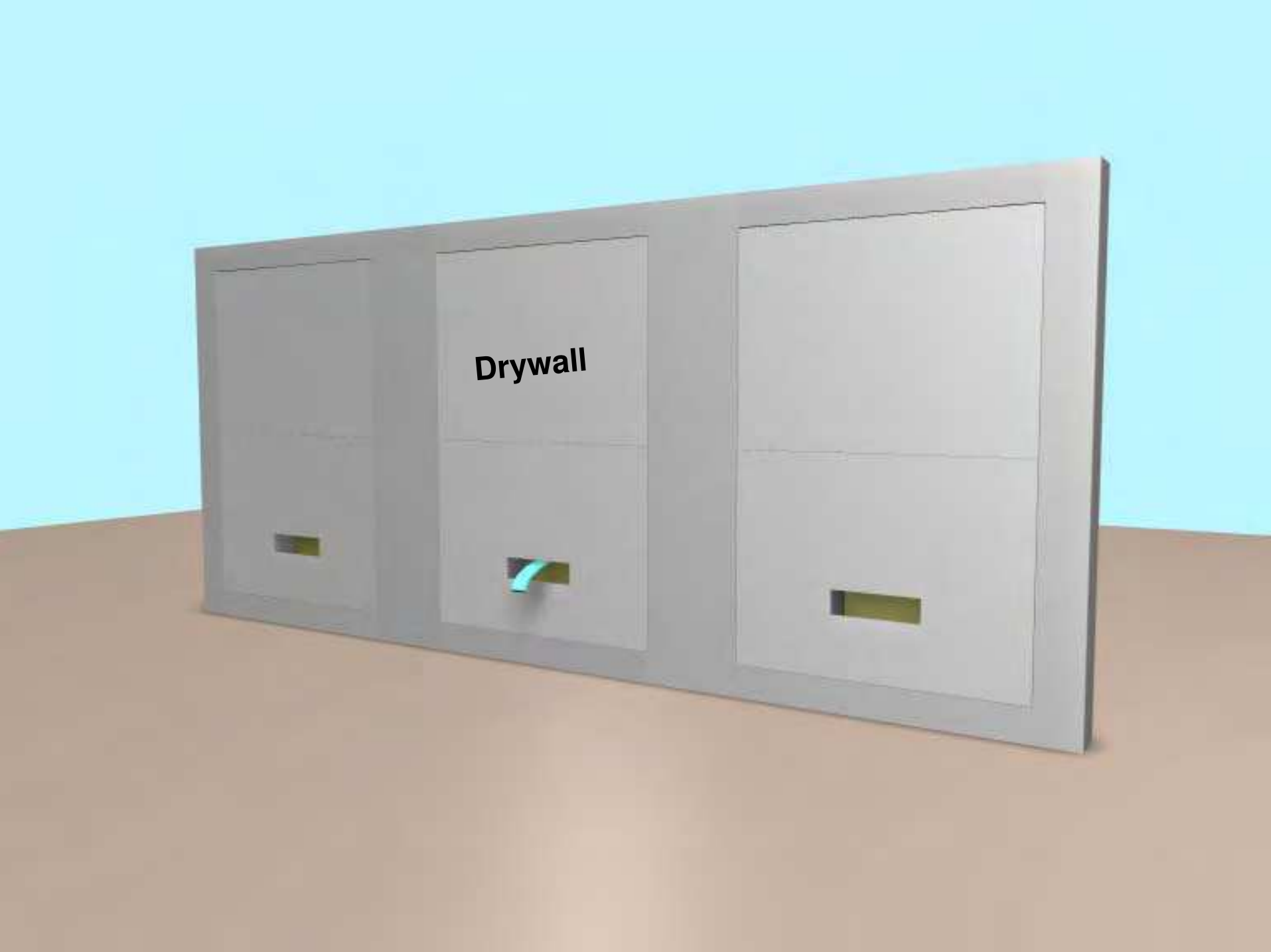
- **The experiments will be in three phases:**
  - **Phase 1:** Commission the facility by monitoring three identical test specimens of traditional construction (2x6) through Fall, and part of the Winter under naturally occurring conditions.
  - **Phase 2:** Challenging the wall during the Winter
    - 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 45% and induce 10 Pa positive pressure while air leak path is present in two specimens, for 2 weeks (?)
  - **Phase 3:** Return to naturally occurring conditions to monitor drying. Disassemble the indoor chamber

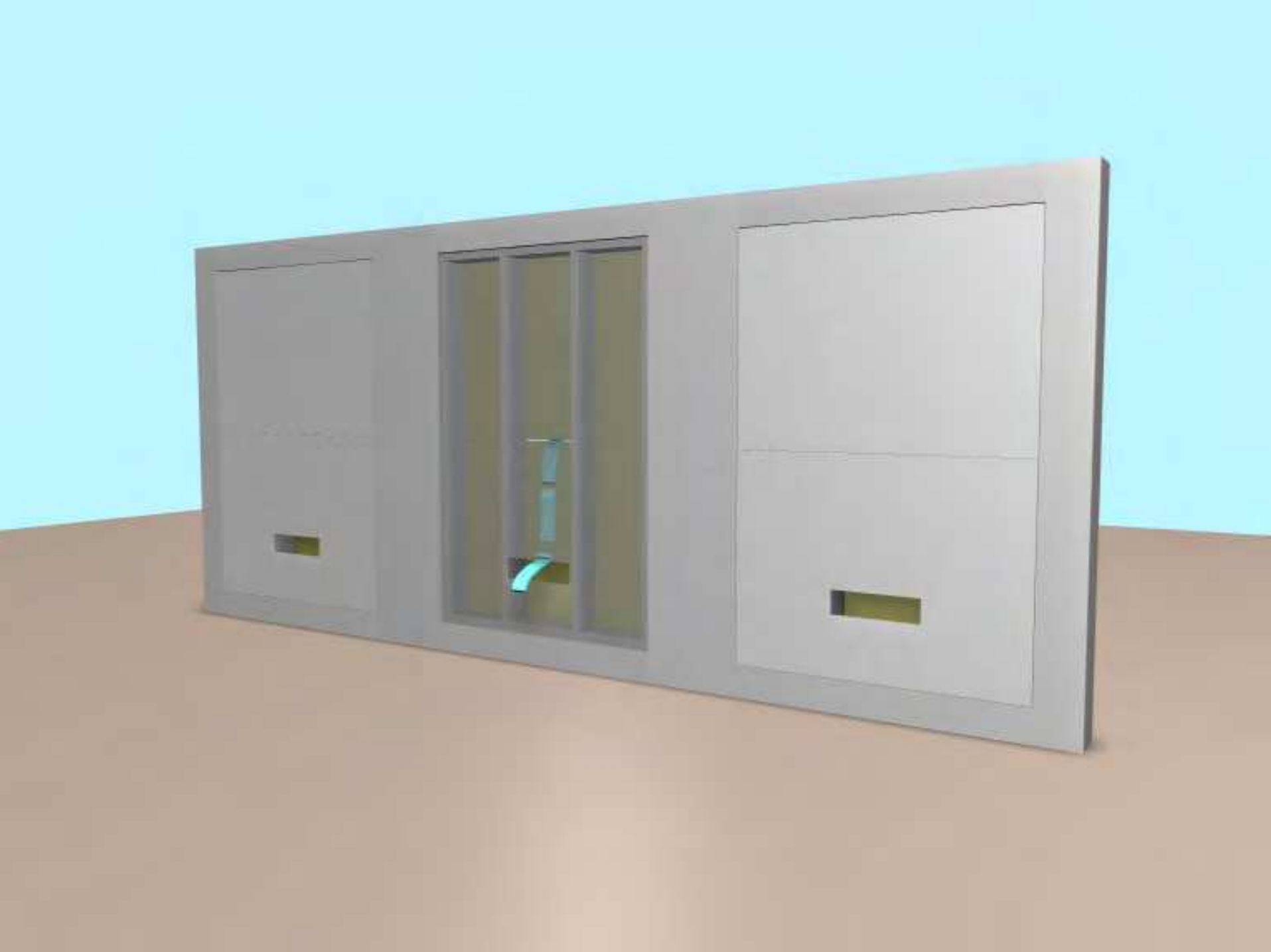


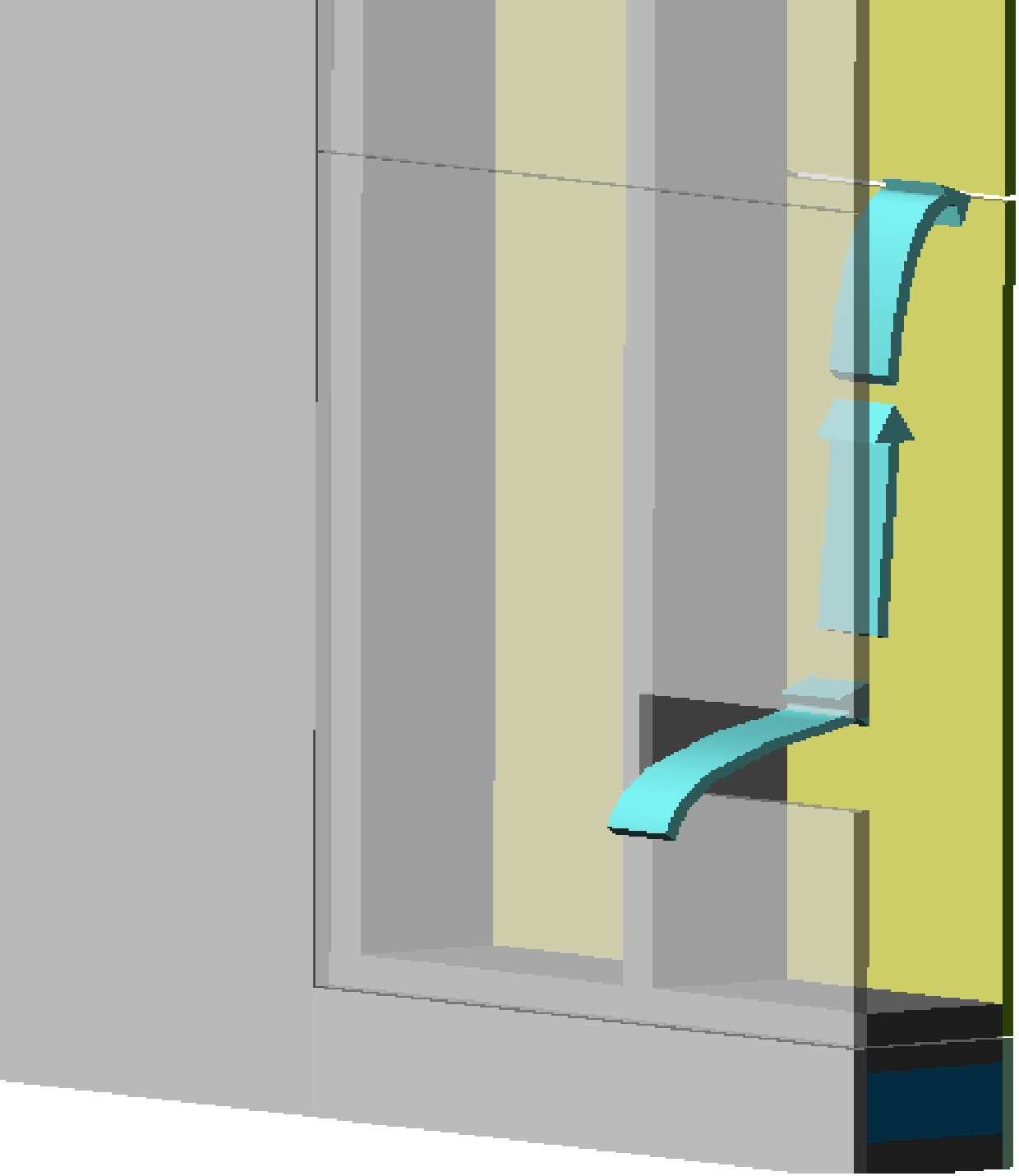
NRC·CNRC
Institute for Research in Construction

Experimental Approach

- **The experiments will be in three phases:**
  - **Phase 1:** Commission the facility by monitoring three identical test specimens of traditional construction (2x6) through Fall, and part of the Winter under naturally occurring conditions.
  - **Phase 2:** Challenging the wall during the Winter
    - 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 45% and induce 10 Pa positive pressure while air leak path is present in two specimens, for 2 weeks (?)
  - **Phase 3:** Return to naturally occurring conditions to monitor drying. Disassemble the indoor chamber


Drywall





Air leakage path: a 6 mm crack in the polyethylene air barrier element as well as in the OSB panel

NRC·CNRC
Institute for Research in Construction

View from the outside

NRC·CNRC
Institute for Research in Construction

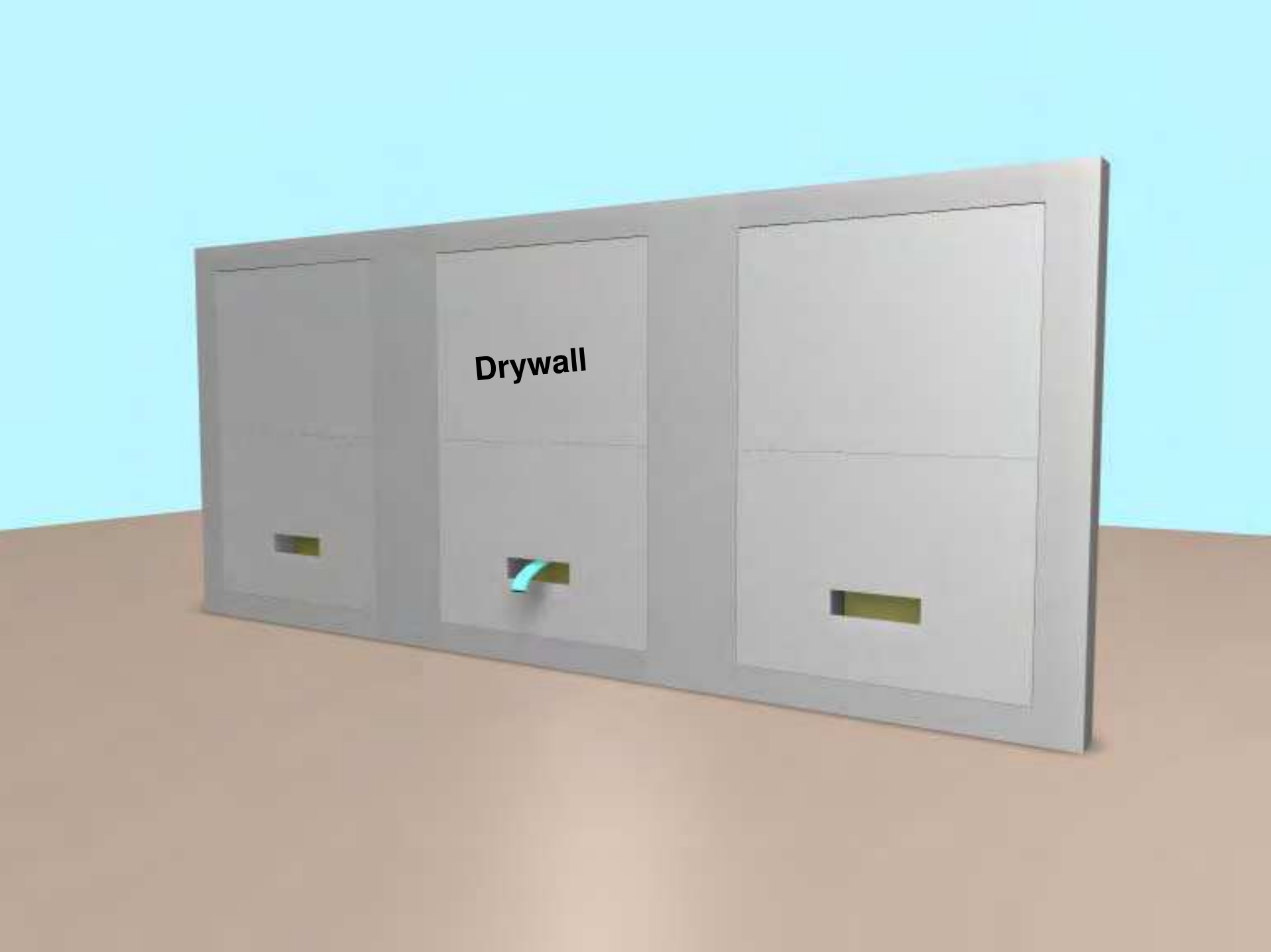
View from the outside

Air Leakage Path

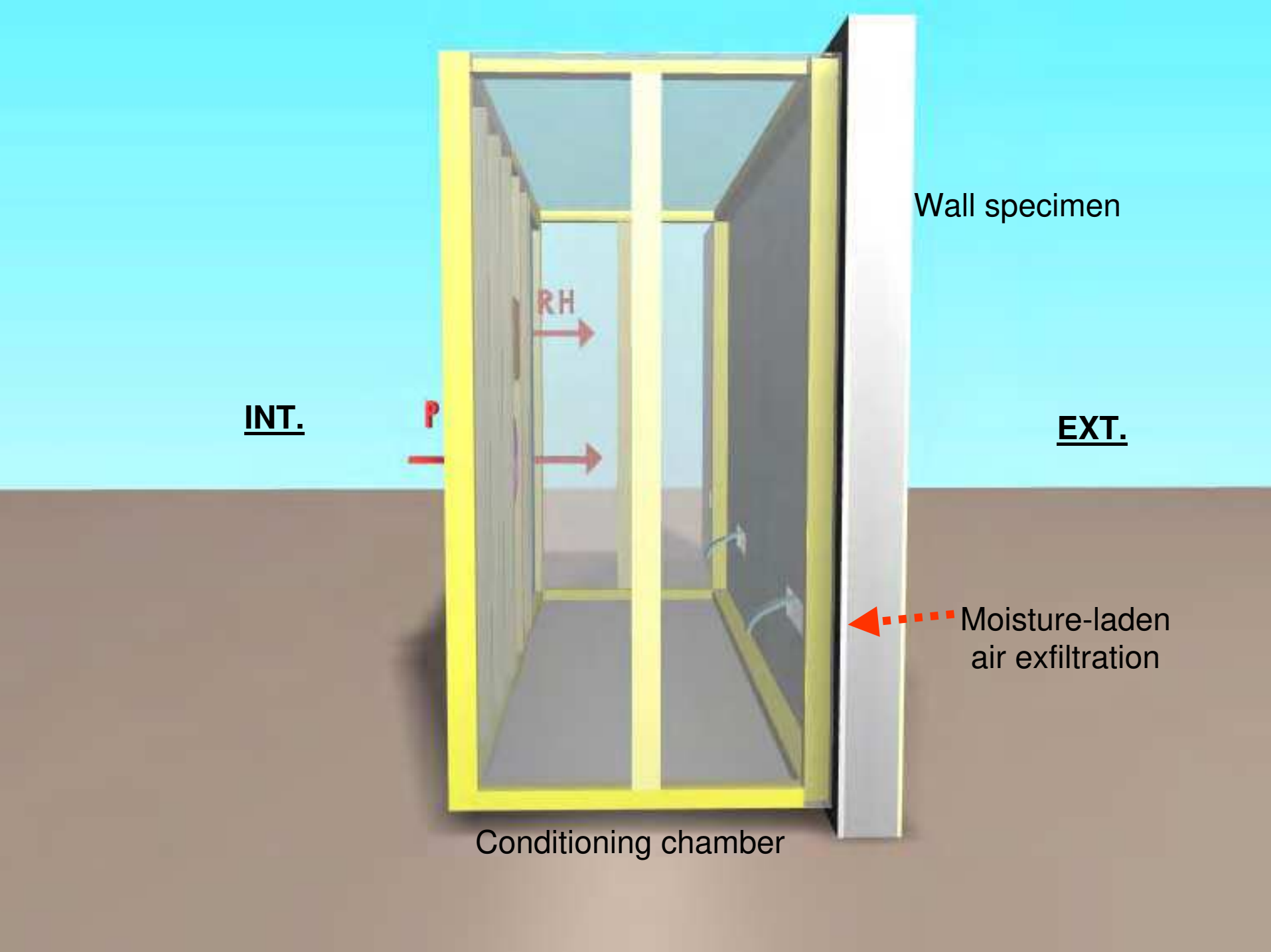
NRC·CNRC
Institute for Research in Construction

Experimental Approach

- **The experiments will be in three phases:**
  - **Phase 1:** Commission the facility by monitoring three identical test specimens of traditional construction (2x6) through Fall, and part of the Winter under naturally occurring conditions.
  - **Phase 2:** Challenging the wall during the Winter
    - 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 45% and induce 10 Pa positive pressure while air leak path is present in two specimens, for 2 weeks (?)
  - **Phase 3:** Return to naturally occurring conditions to monitor drying. Disassemble the indoor chamber


Drywall

Conditioning Chamber on the Room Side


Wall specimen
RH
P
INT.
EXT.
Moisture-laden
air exfiltration
Conditioning chamber

NRC·CNRC
Institute for Research in Construction

Experimental Approach

- **The experiments will be in three phases:**
  - **Phase 1:** Commission the facility by monitoring three identical test specimens of traditional construction (2x6) through Fall, and part of the Winter under naturally occurring conditions.
  - **Phase 2:** Challenging the wall during the Winter
    - 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 45% and induce 10 Pa positive pressure while air leak path is present in two specimens, for 2 weeks (?)
  - **Phase 3:** Return to naturally occurring conditions to monitor drying. Disassemble the indoor chamber

NRC-CNRC
Institute for Research in Construction

Outline

- Background
- Hygrothermal Performance of BES
  - Modeling
  - Field Experiments
  - Laboratory experiments
- Concluding Remarks and Future Work

NRC-CNRC
Institute for Research in Construction

Laboratory Experiments

- Why to do lab experiments?
- How to do experiment?
- Which physical phenomena to investigate,..?
- What do you expect from experiments?

NRC·CNRC
Institute for Research in Construction

Experiments — Apparatus - EEEF

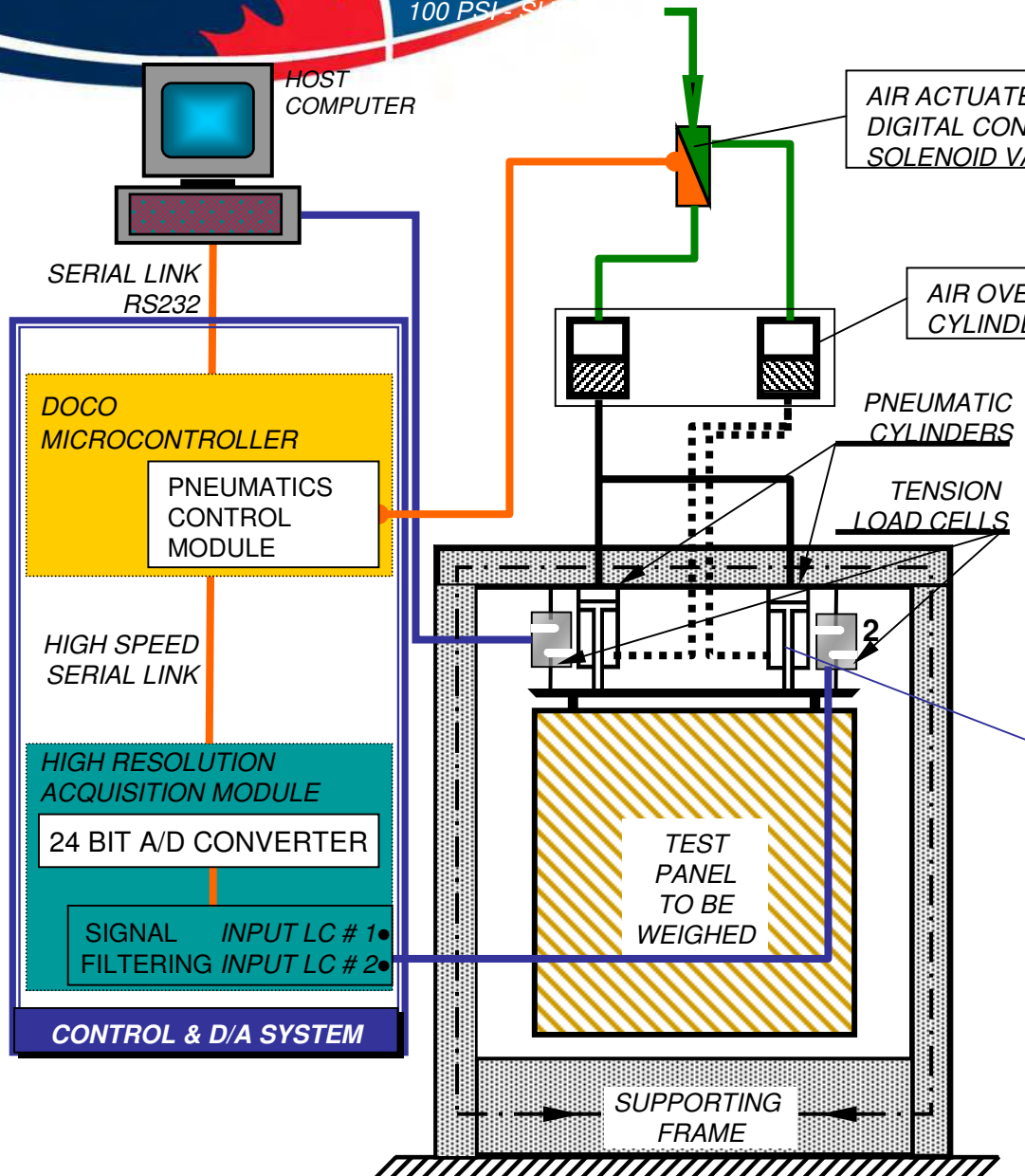
Environmental Exposure Envelope Facility

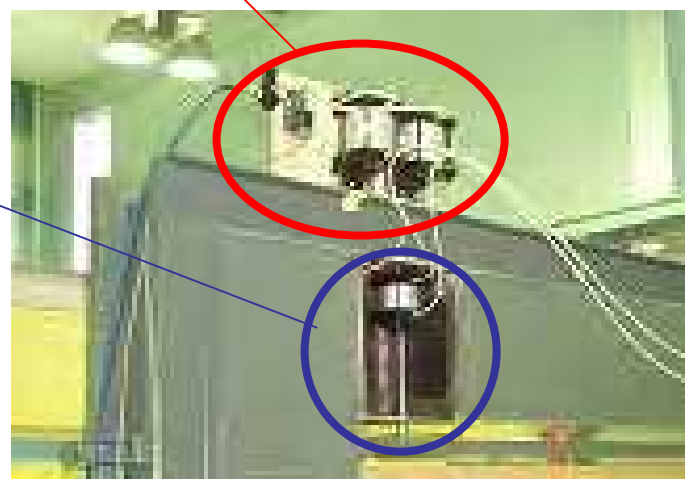
Specimens and weighing apparatus are placed in EEEF

EEEF maintains T and RH profile over course of experiment

NRC·CNRC
Institute for Research in Construction

Experiments — Weighing System





NRC·CNRC
Institute for Research in Construction

Experiments — Apparatus - EEEF

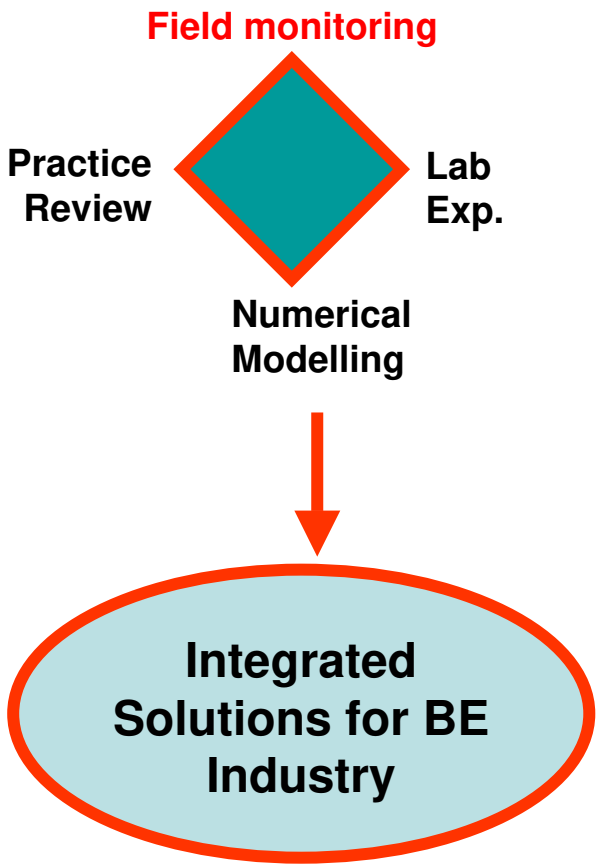
NRC·CNRC
Institute for Research in Construction

- Background
- Hygrothermal Performance of BES
- Modeling
- Field Experiments
- Laboratory experiments
- Concluding Remarks and Future Work

NRC·CNRC
Institute for Research in Construction

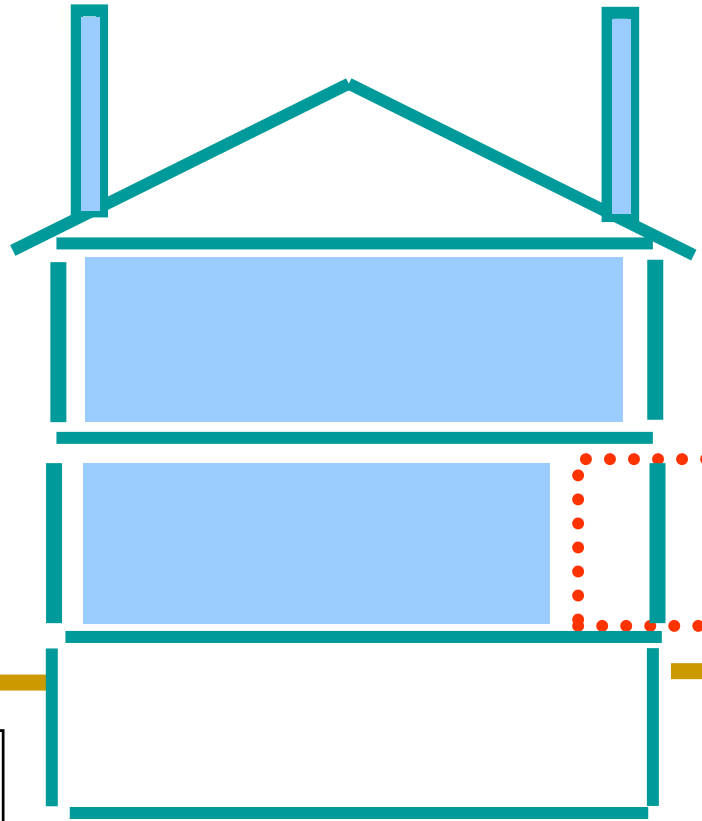
Concluding remarks

- FEWF is state-of-the-art field monitoring facility
- EEEF has demonstrated the capabilities of IRC's facilities to carry out a series of experimental works to mimic the exterior conditions effect on the moisture transport.
- Lab and/or Field Experiments help to benchmark models. Benchmarked models save time and money for doing parametric studies comparing to field and lab experiments
- Models, lab and field experiments complement each other



NRC-CNRC
Institute for Research in Construction

Research House No. 3: Future Work



HEATING AND VENTILATION FACILITY - IE

FY06/07 & 07/08 *: Study & compare traditional & innovative HV strategies*

FEWF- BES

Field monitoring

Practice Review

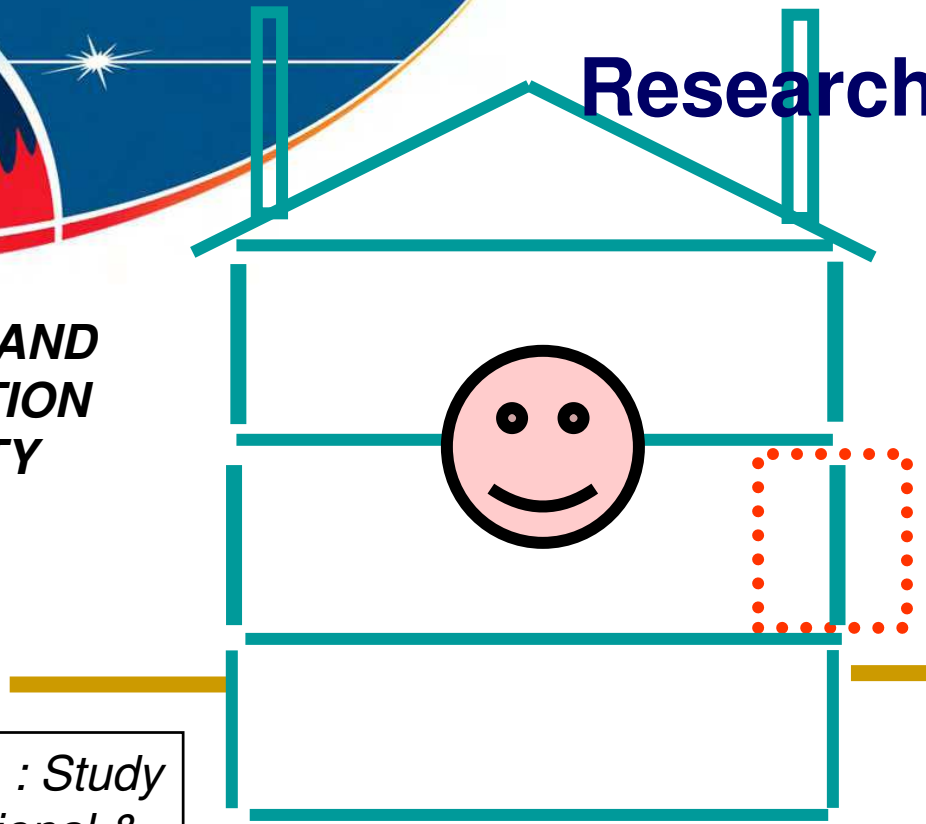
Lab Exp.

Numerical Modelling

FY06/07 & 07/08: Study & compare traditional & innovative BE strategies

NRC·CNRC
Institute for Research in Construction

Research House No. 3: Future Work



HEATING AND VENTILATION FACILITY

FY06/07 & 07/08 *: Study & compare traditional & innovative HV strategies*

FEWF

Field monitoring

Practice Review

Lab Exp.

Numerical Modelling

FY06/07 & 07/08: Study & compare traditional & innovative BE strategies

B IE S

FY08/09: Cross- program project on interaction between BE and VIAQ

Girls just want to have fun

Iain tries to help James to connect sensitive sensors

NRC·CNRC

From **Discovery** to **Innovation…**

Thank you