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

Evaluating the effectiveness of window/wall interface details to manage rainwater

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For the

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National Research Council Canada

Conseil national de recherches Canada

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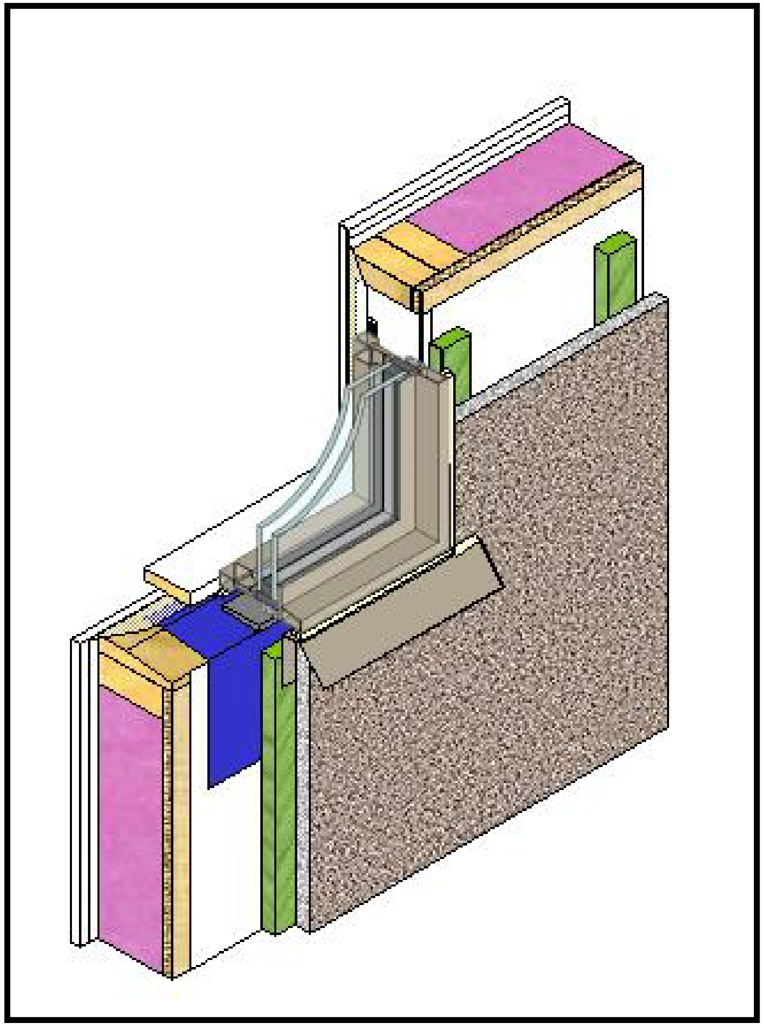
Overview



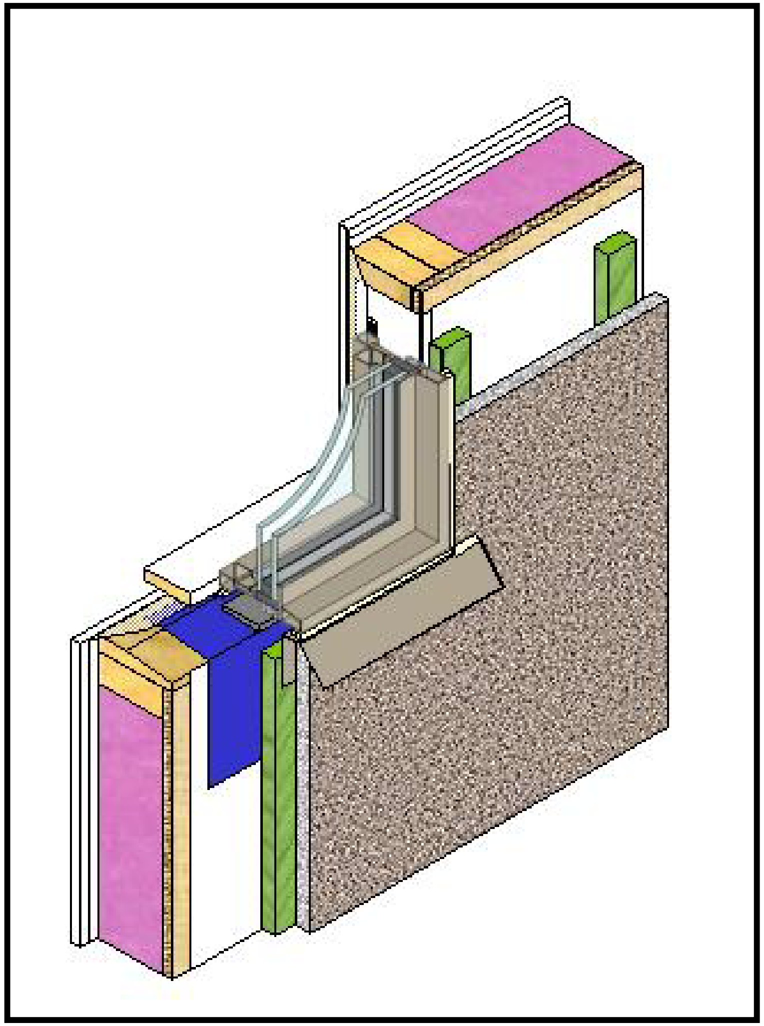
Past and recent studies

- ***Building envelope failures***
- ***Window performance***
  - ***NRC & others***
  - ***RDH 2002***

Window-Wall Interface Project

- ***Approach***
- ***Results***
- ***Summary of key findings***

Recent Surveys



Recent CMHC Surveys of Building Envelope Performance

- *1995 – Survey of Building Envelope Failures in the Coastal Climate of British Columbia*
- *1999 – Wall Moisture Problems in Alberta Dwellings*
- *2001 – Study of High-Rise Envelope Performance In The Coastal Climate of British Columbia*

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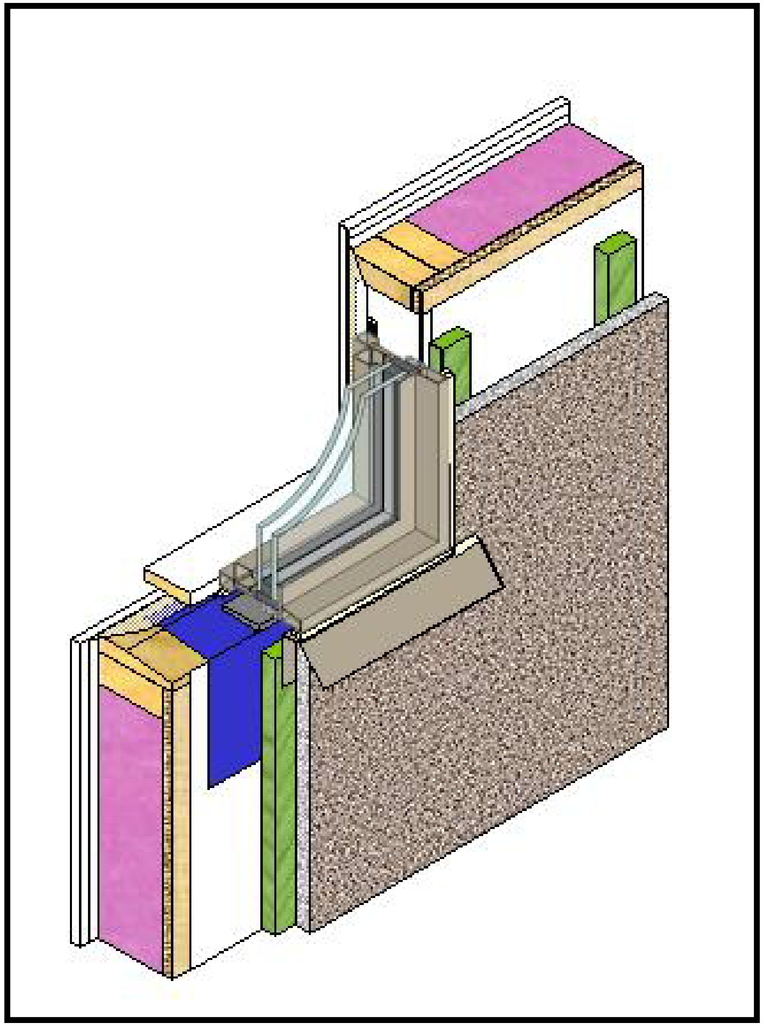
CMHC Surveys of Building Envelope Performance



Key findings -

- ***(at least) 25% of the moisture problems associated with water ingress into wall assemblies were directly attributed to penetration through the windows or the window-wall interface***

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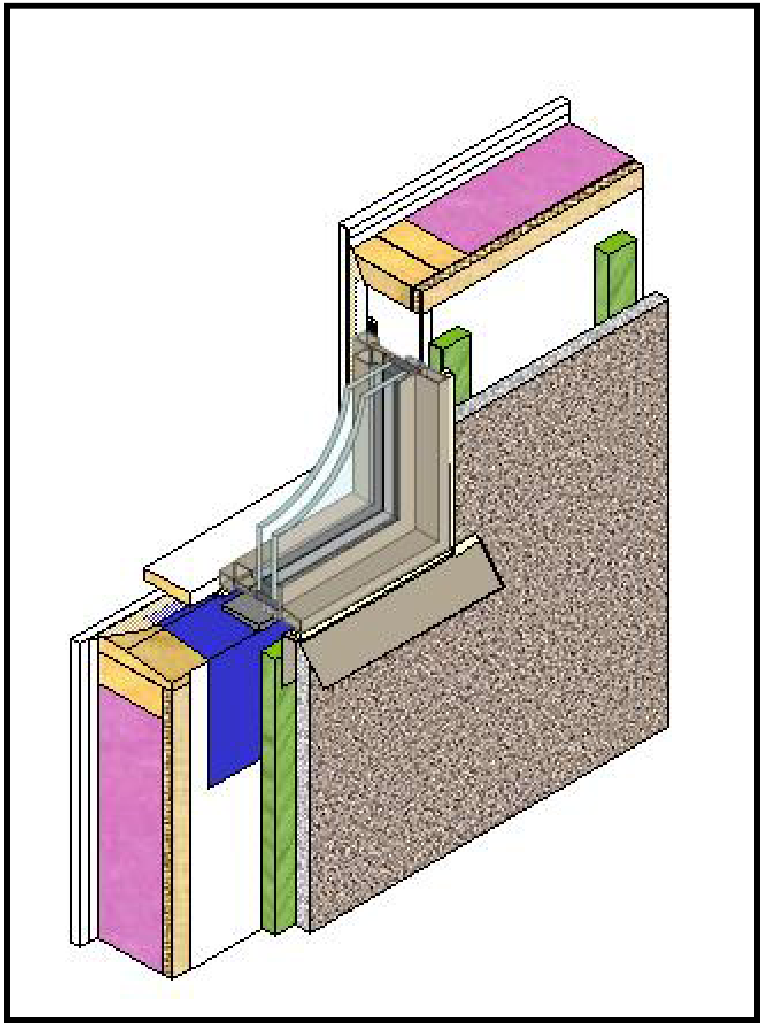
Recent Surveys

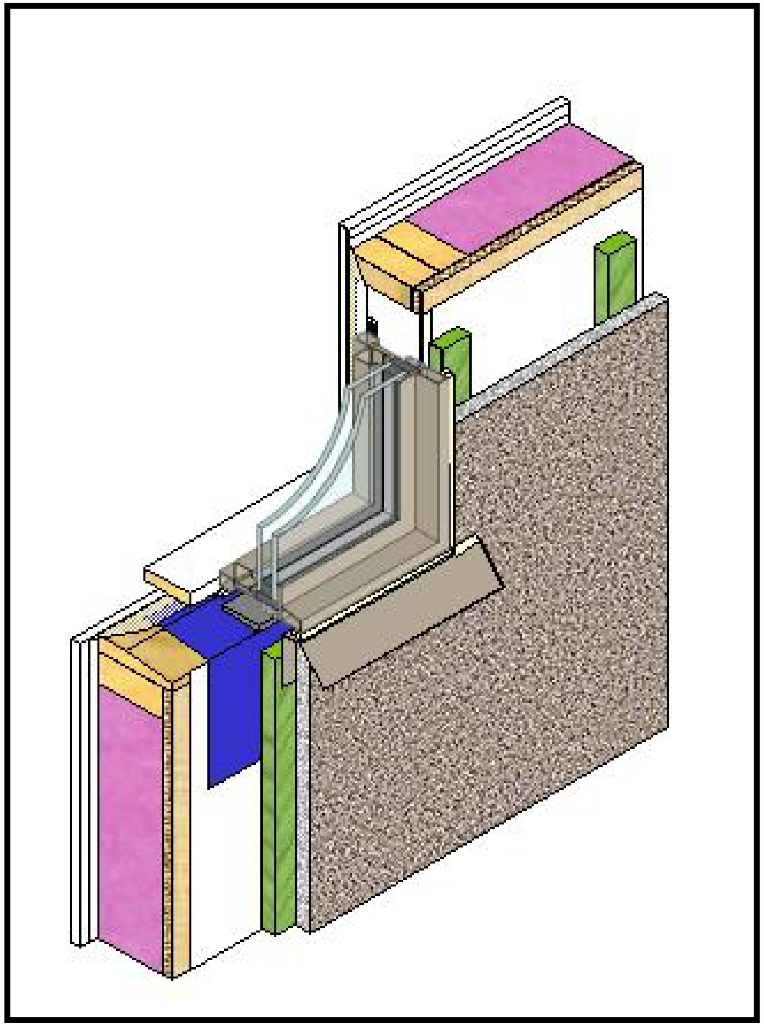


Minnesota problems –

"Stucco in Residential Construction“, A position paper by City of Woodbury (MN) Building Inspection Division, Update, February 9, 2005

- *Homes built in Woodbury since 1990 were experiencing major durability problems*
    - *To date, 276 of 670 stucco homes built in Woodbury in 1999 have failed (ca. 41%)*
- *Primary causes - Window leaks, lack of kickout flashing, improper deck flashing…above the wood framing.*

Surveys - Why Did Walls Fail?



- *Inappropriate balance between wetting and drying mechanisms*
  - *Exposure - walls got wet*
  - *Details - let water in*
  - *Sensitivity of assemblies - inability to drain or dry*

Windows and the Building Envelope

“Rain penetration is a major problem with glazing and must be controlled….”

Glazing Design - Canadian Building Digest #55 (CBD55) published in July 1964

“Many inquiries concerning rain penetration of exterior wall are received by the B.C. Regional Station…. and are focused on window installation practices.”

Rain Leakage of Residential Windows in the Lower Mainland of British Columbia – Building Practice Note No. 42 (BPN42)
Division of Building Research,
National Research Council of Canada
November 1984

“….reports on window performance problems in Atlantic Canada…..”

Building Research Note No. 210 (BRN No. 210) - 1984

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Recent studies focused on windows and window installation

- *BRANZ (NZ) studies (2002) - WANZ WIS Parameter Investigation*
- *CMHC sponsored study (2002) - Water Penetration Resistance of Windows*
- *GTI studies (2006) - Window Installation Methods Test Results*

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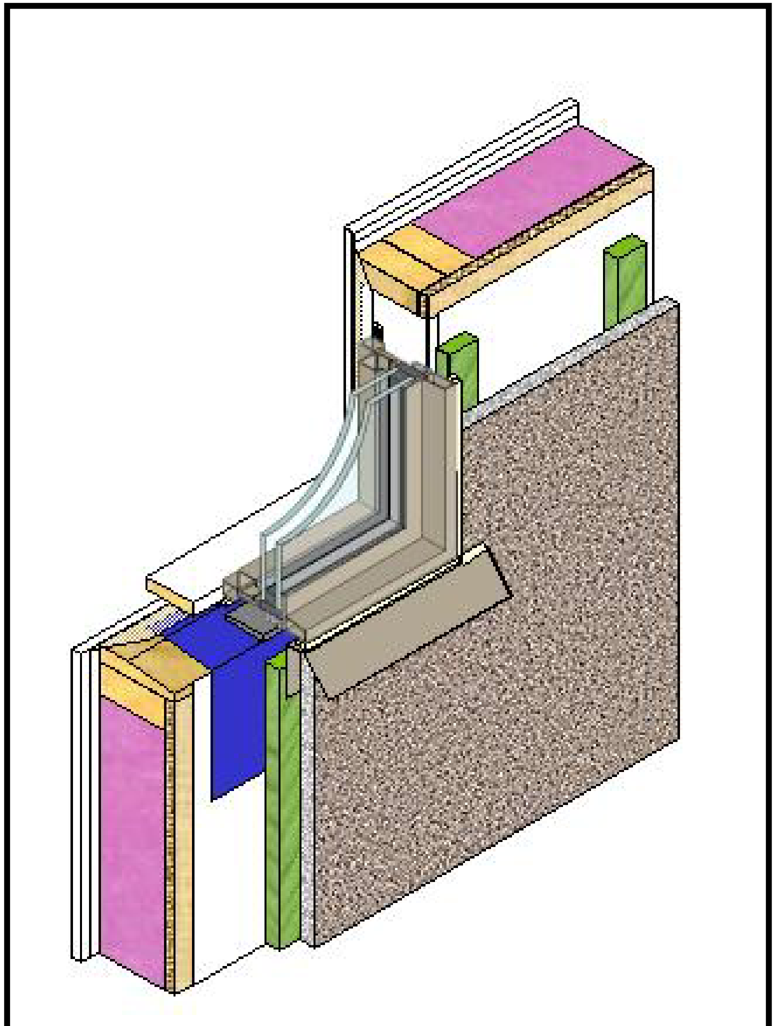
2002 Water Penetration Resistance of Windows



STUDY OF MANUFACTURING, BUILDING & INTERFACE DESIGN, INSTALLATION AND MAINTENANCE FACTORS

WINDOW TERMINOLOGY	SUMMARY OF STUDY	WINDOW INSTALLATION GUIDE

STUDY OF CODES, STANDARDS, TESTING AND CERTIFICATION

BC Housing

Homeowner Protection Office

RDH

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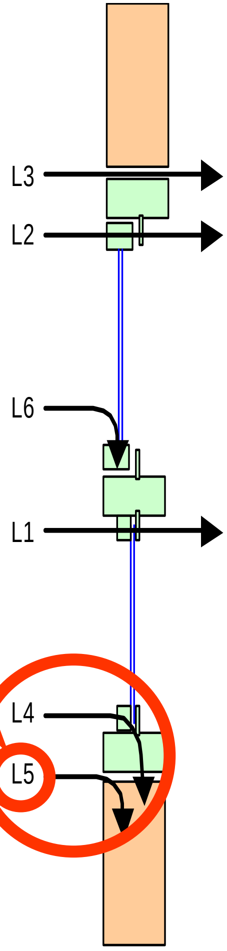
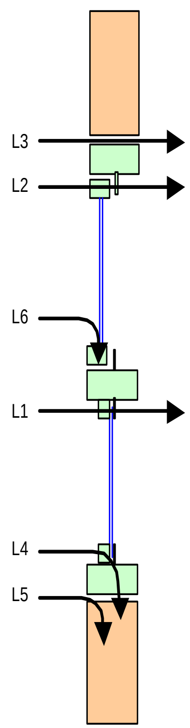
Partial Conclusions and Recommendations

- ***Most frequent leakage path ➔ L5***
  (L5 : Through window-wall interface to adjacent wall assembly)
- ***L4 and L5 are considered "high" risk for consequential damage***
  (L4 : through window to adjacent wall assembly)
- ***Minor variation exists between window types with respect to leakage paths***



Partial Conclusions and Recommendations

- **The CSA A440 B rating performance criteria does not address the current dominant leakage paths that are associated with installed windows**



Leakage Paths	Risk of Consequential Damage Rating	Applicability of A440 Testing to Leakage Path
L1 - Through fixed unit to interior	Moderate	Good
L2 - Around operable unit to interior	Moderate	Good
L3 - Through window to wall interface to interior	Moderate	Never
L4 - Through window assembly to adjacent wall assembly	High	Sometimes*
L5 - Through window to wall assembly interface to adjacent wall assembly	High	Never
L6 - Through window assembly to concealed compartments within window assembly	Minor	Good

Depends on where window frame is attached to test frame

Partial Conclusions and Recommendations

- ***<u>Manufacturers</u> have to focus on the design of the entire installed window. This includes …the interface with the perimeter building walls.***
- ***Windows need to be …installed with redundant assemblies.***
- e.g. ➔ ***The addition of sub sill drainage to interface design would improve water penetration performance of installed windows***
- ***<u>Designers</u> need "…to increase their focus on interface detailing, considering continuity of all of the critical barriers.."***
- ***<u>Installers</u> need to have greater understanding of the manufacturing and building design strategy.***
- ***The creation of a mandated or generally accepted certification protocol, would have a positive impact on quality control issues.***

Key Points

CMHC-NRC (with industry partners) initiate WWI project to evaluate water management performance of various window installation details

- ***Possibility to evaluate different interface details and their ability to manage rainwater entry – evaluate robustness of design***
- ***Development of a "standards" approach in a laboratory setting – precursor to a field certification protocol***
- ***Benchmark "performance" of proposed designs***

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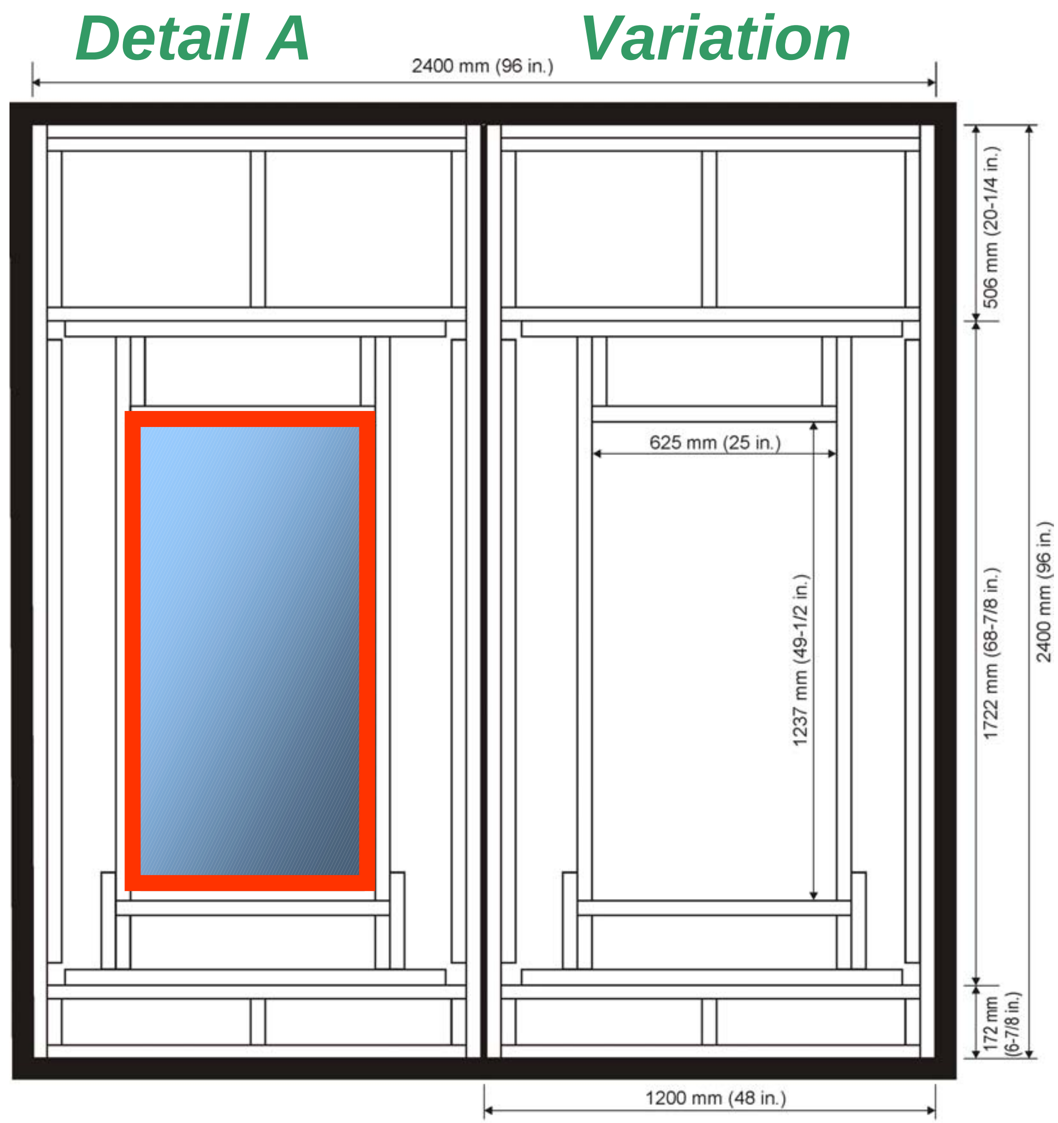
NRC/IRC Test Program

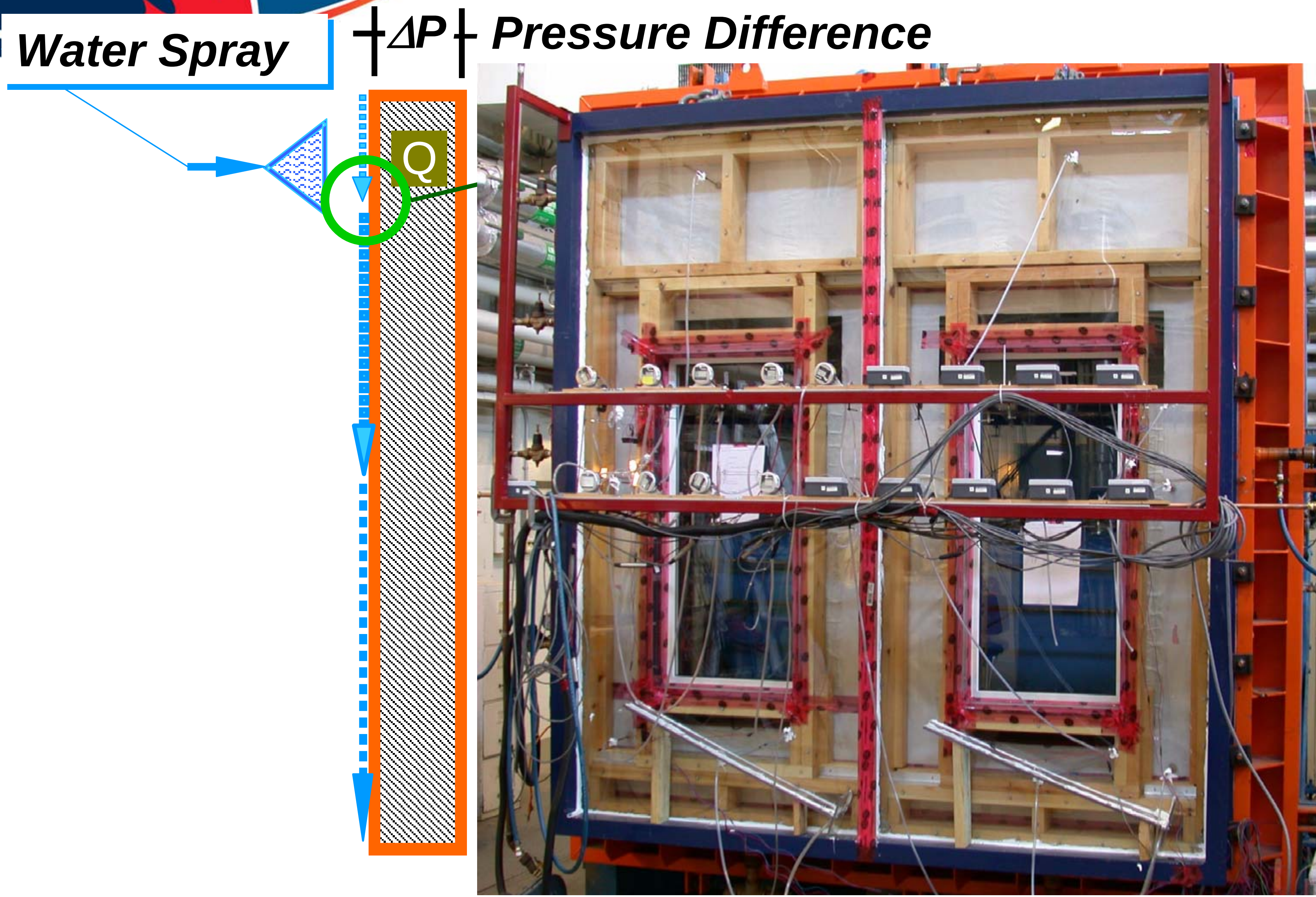
- ***Develop procedure to assess rainwater ingress***
- ***Evaluate specific window-wall interface details to determine how effective they manage rainwater intrusion***



Elevation view of the test frame

Test Specimen

Test Specimen



Test Program

Test conditions represent range of climate conditions in Canada

- *Test Pressures -*
  - *Ranges between 0 and 700 Pa (75, 150, 200, 300, 500, 700 Pa)*
- *Spray rates –*
  - *0.8, 1.6 and 3.4 L/min.-m^2*
- *Wall system air leakage variations*
  - *0.3 to 0.8 L/s-m^2 at 75 Pa*
- *Spray rate maintained for 15 min. intervals at each pressure level – for a given system leakage*

Variations selected

<table>
<tr><th>Specimen</th><th>Siding Installation</th><th>Window Frame</th></tr>
<tr><td>W1</td><td rowspan="2">With Clear Cavity Behind Siding</td><td>Non-finned (box)</td></tr>
<tr><td>W2</td><td>Flanged</td></tr>
<tr><td>W3
W4</td><td>Without Clear Cavity Behind Siding</td><td>Flanged</td></tr>
</table>

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Overview - Specimen Details

Specimen	W1	W2	W3	W4
OBJECTIVES ***To determine the effect of:***	***An extra seal at jambs and head of R.O. window junction,*** ***for –*** • ***Box frame fixed window, sloped subsill and rainscreen wall***	***Changes in protection of R.O. members, back dam at subsill,*** ***for –*** • ***Fixed flanged window installed in a concealed barrier wall***	***Two subsill drainage methods of flat sill with back dam*** ***for –*** • ***Combination flanged window installed in a rainscreen wall***	***Sealing WRB to window flange,*** ***for –*** • ***Combination window with brick mould installed in concealed barrier wall***

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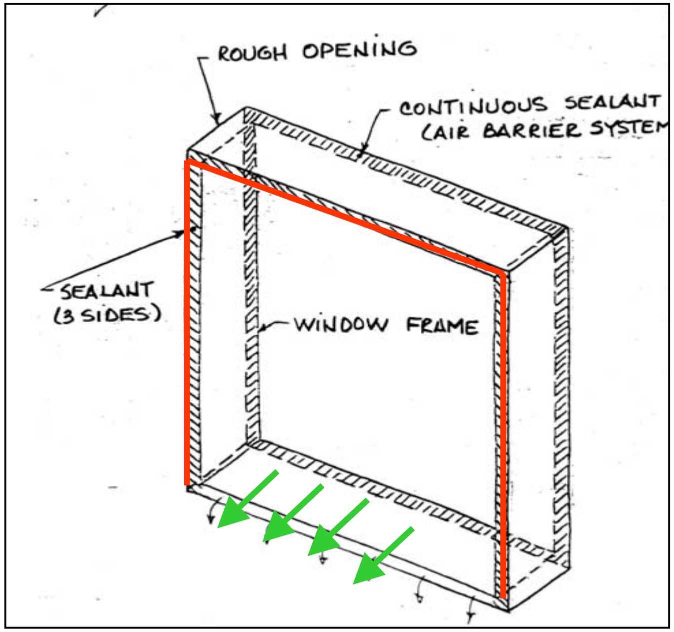
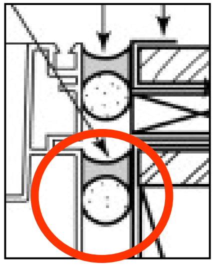
Specimen Details- W1

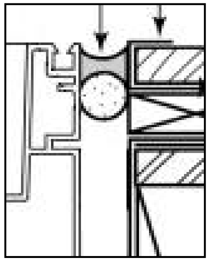


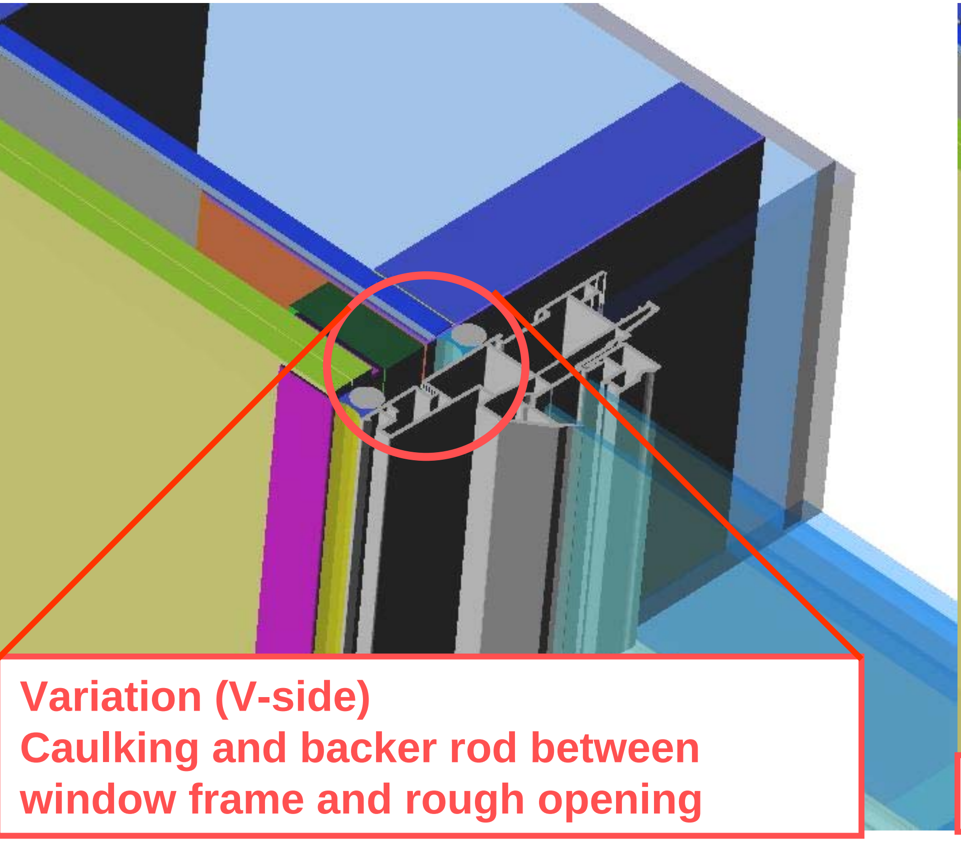
- *Clear cavity behind siding (19 mm wood furring strips used)*
- *Non-finned (box) window frame*
- *Variation - extra sealant and backer rod at the jambs and head*

Specimen Details- W1

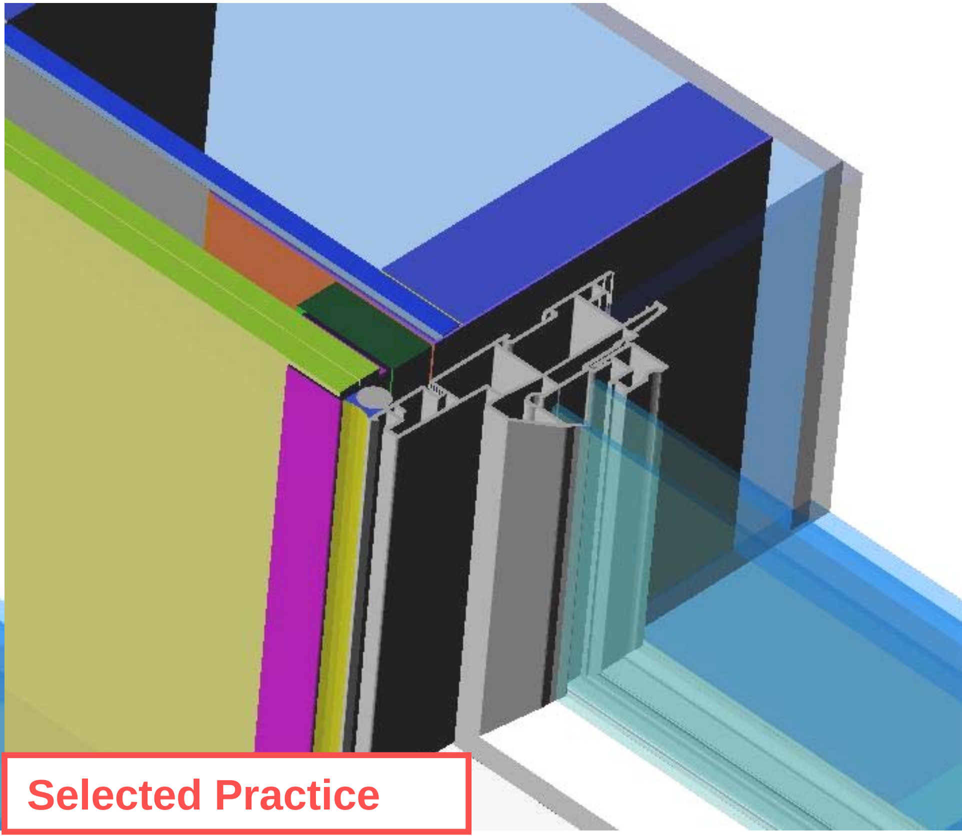
V-side B-side







Variation (V-side)
Caulking and backer rod between window frame and rough opening



Selected Practice

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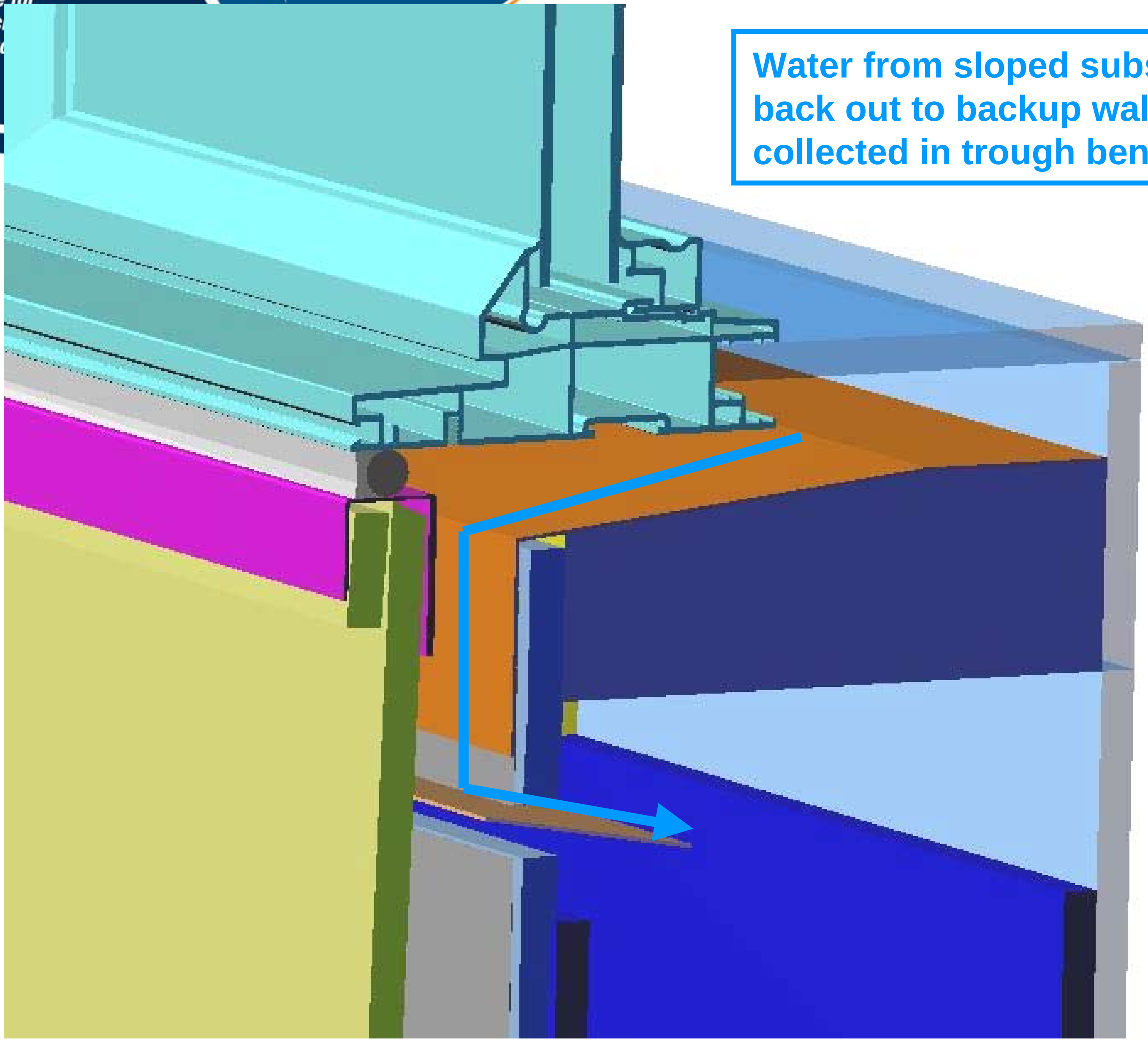
Water from sloped subsill is directed back out to backup wall and is collected in trough beneath sill



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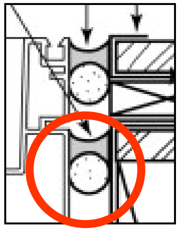
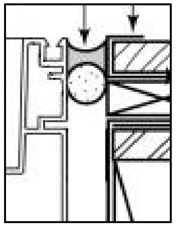
Wall 1 - Water entry summary

V-side



B-side



- **Water entry affected by water spray rate and tightness of assembly (air barrier system leakage)**
  - **Higher rates of water spray and higher system leakage resulted in greater rates of water entry to collection troughs**
- **Water entry through the <u>windows</u> occurred mainly at:**
  - **500 and 700 Pa chamber pressure.**
- **Restricted water entry for either "B" or "V" interfaces for assemblies having :**
  - **"NO deficiencies", and**
  - **Selected deficiencies, with exception of "Step 4" deficiency**
- **"Step 4" Deficiency -**
  (90 mm of caulking and backer rod removed from horz. joint)
- **Significant increases in water entry to reservoir on both sides**
  - **"V" side permitted about half the rate of water entry as compared to "B" side**

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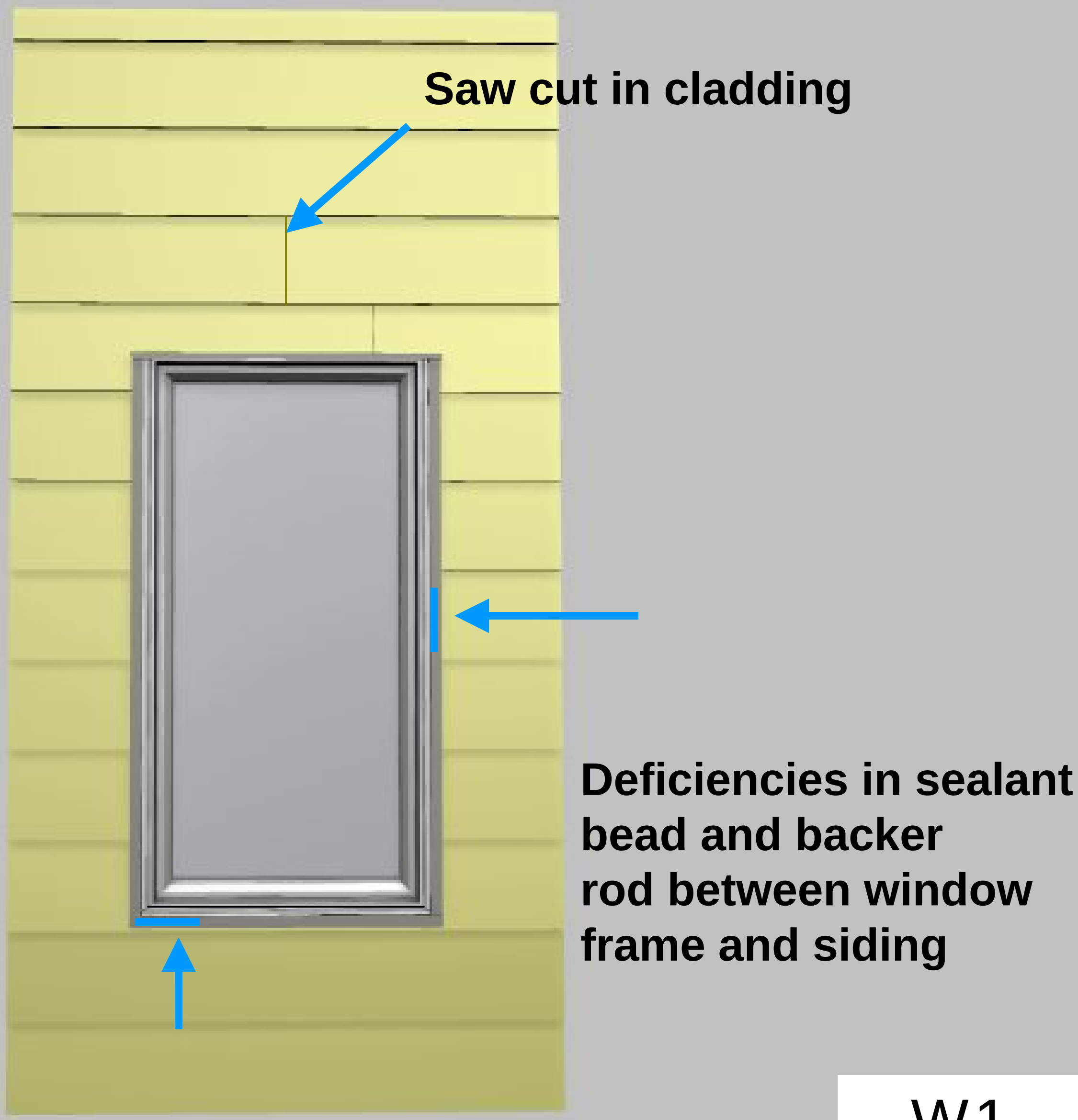
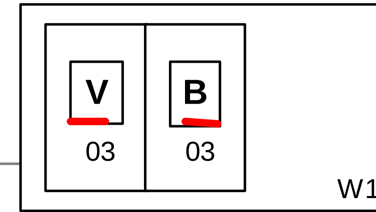
Location of Deficiencies



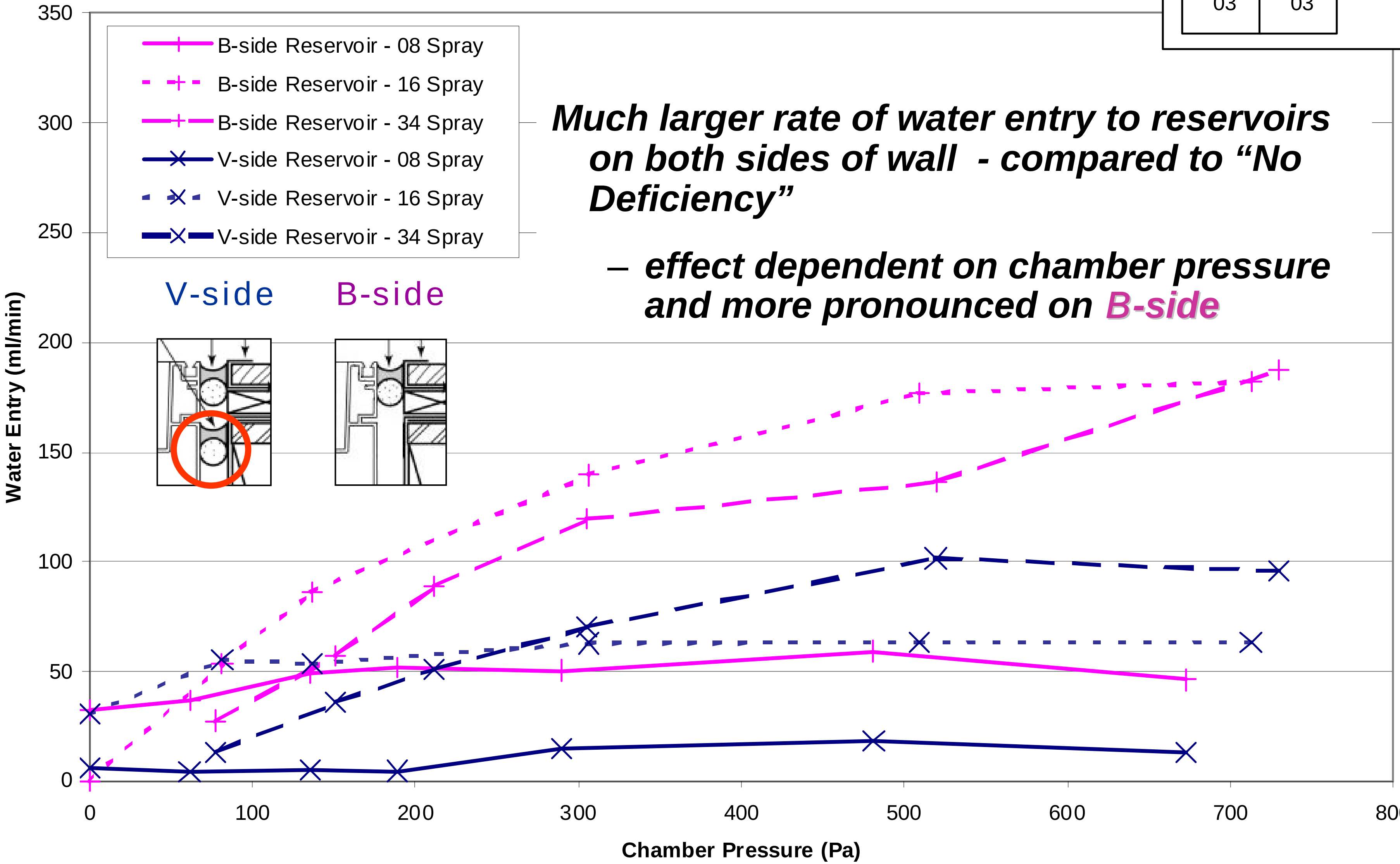
W1

Water Management + Deficiency

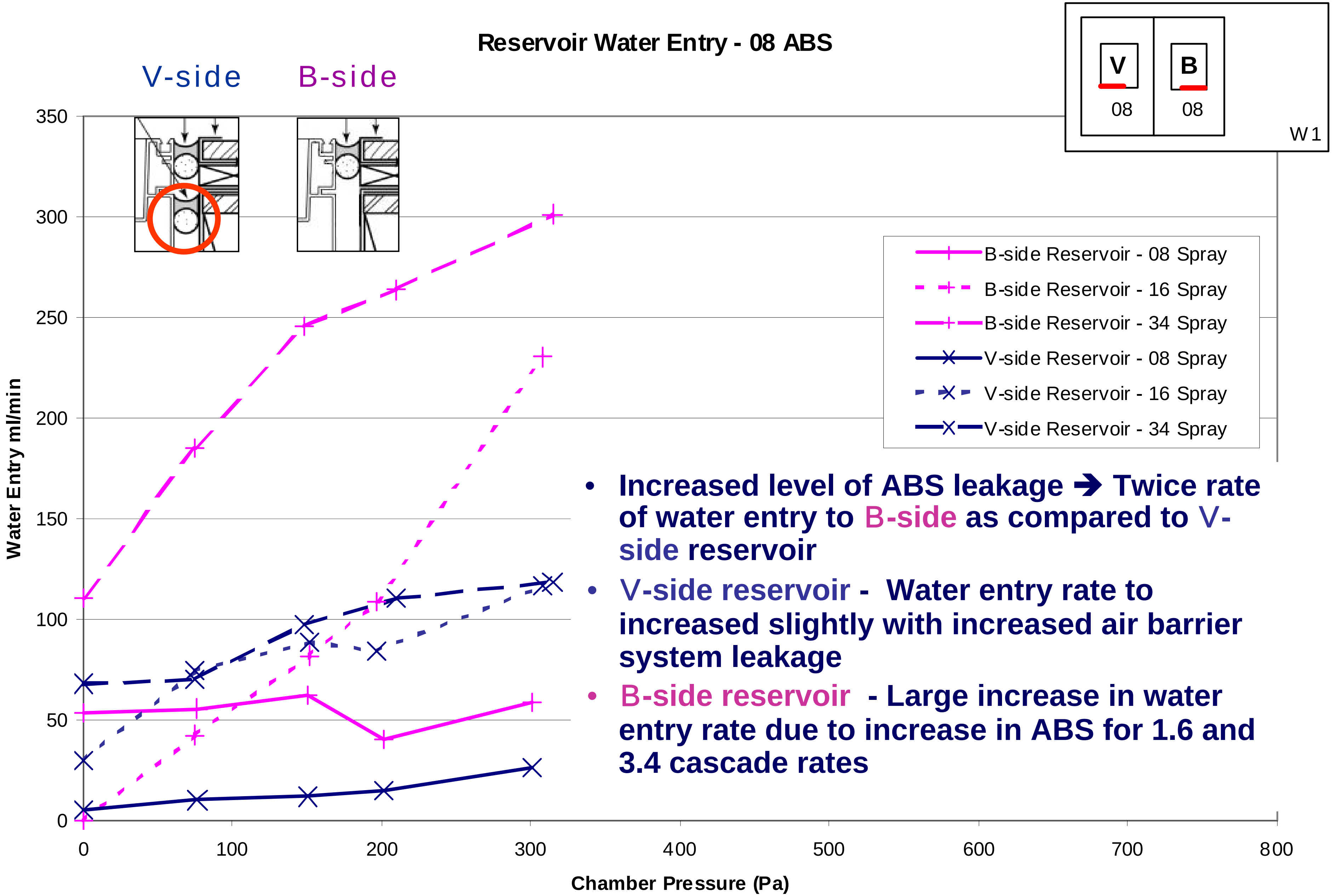


Much larger rate of water entry to reservoirs on both sides of wall - compared to "No Deficiency"

- ***effect dependent on chamber pressure and more pronounced on B-side***



Water Management + Deficiency



- **Increased level of ABS leakage ➔ Twice rate of water entry to B-side as compared to V-side reservoir**
- **V-side reservoir - Water entry rate to increased slightly with increased air barrier system leakage**
- **B-side reservoir - Large increase in water entry rate due to increase in ABS for 1.6 and 3.4 cascade rates**

Overview - Specimen Details

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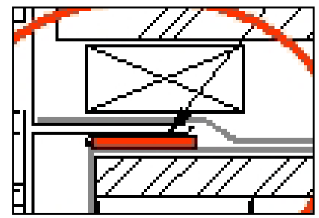
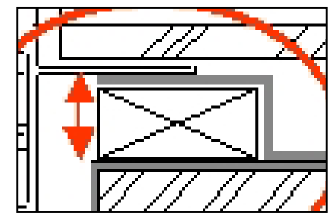
Specimen Details - W3

- *Clear cavity behind siding (furring strips)*
- *Combination window, solid PVC with integral flange – top slider, bottom fixed*
- *Variation: Two subsill drainage methods of a flat sill with back dam*

V-side



B-side



Shims provide gap

Window installed over furring strips

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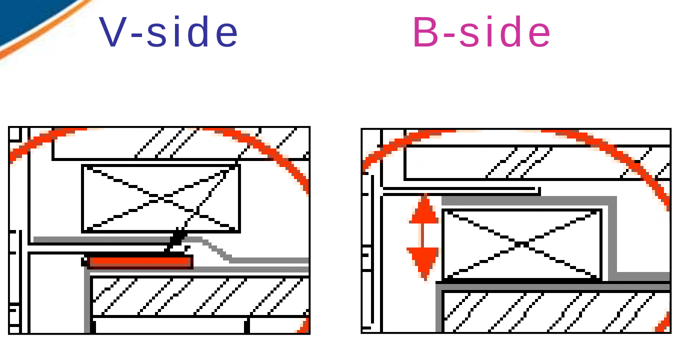
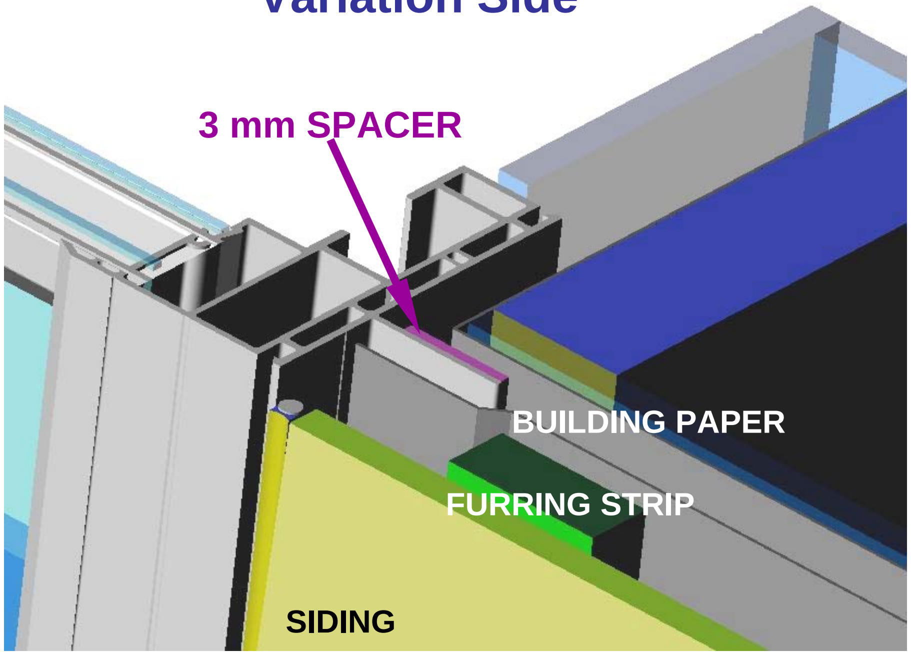
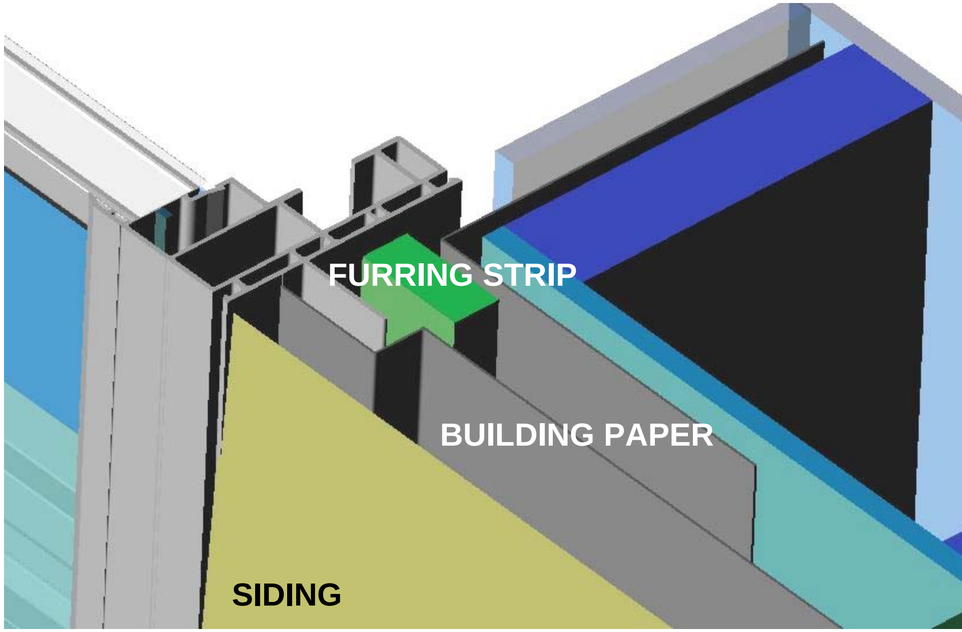
Wall 3

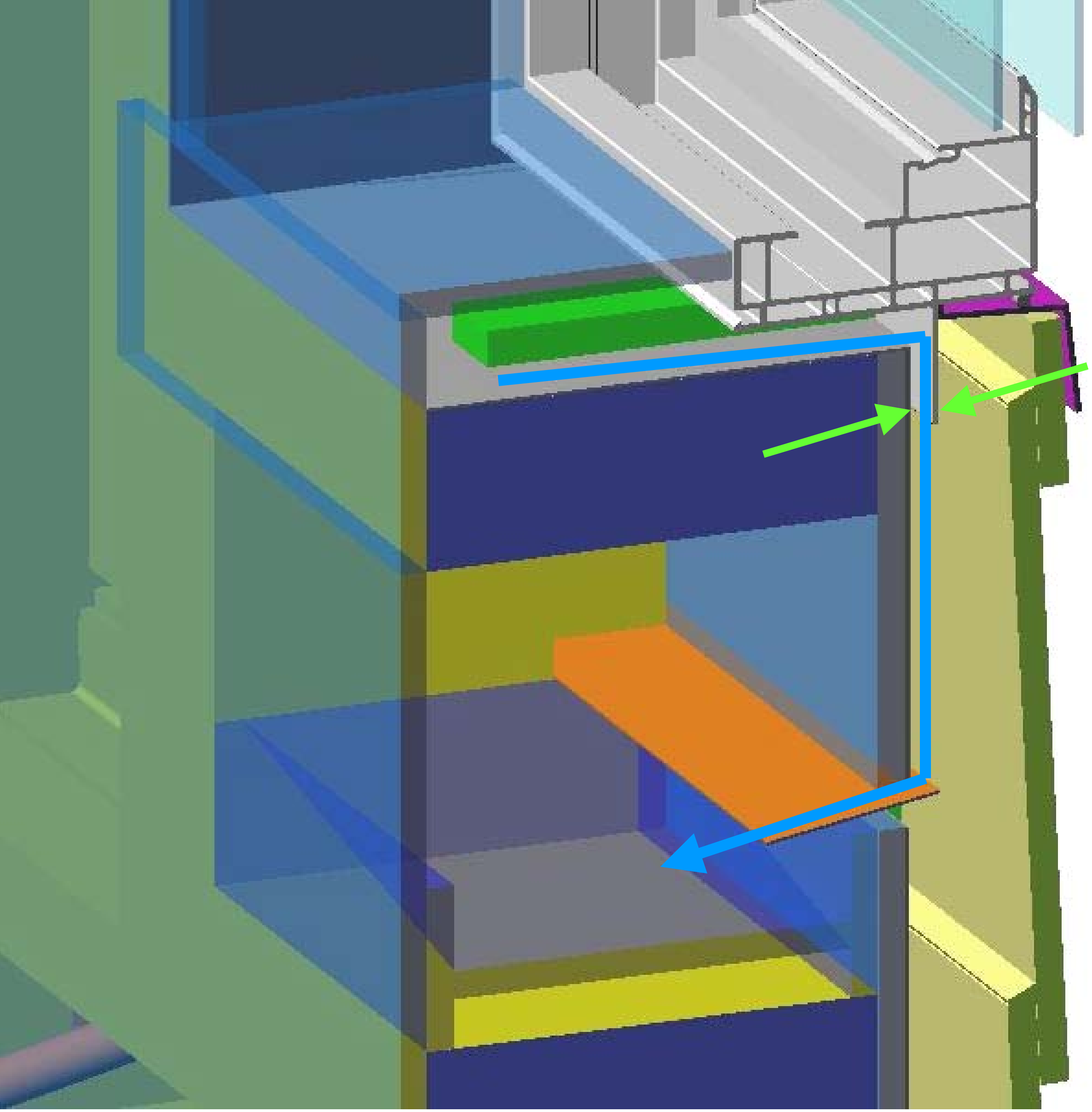


Exploded View
Variation Side



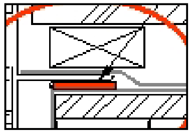
Exploded View
Selected Practice Side

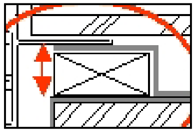




W3 – “V”

V-side B-side





Variation Side:

- **3-mm spacers create gap between window flange and backup wall, allowing drainage from rough sill area**

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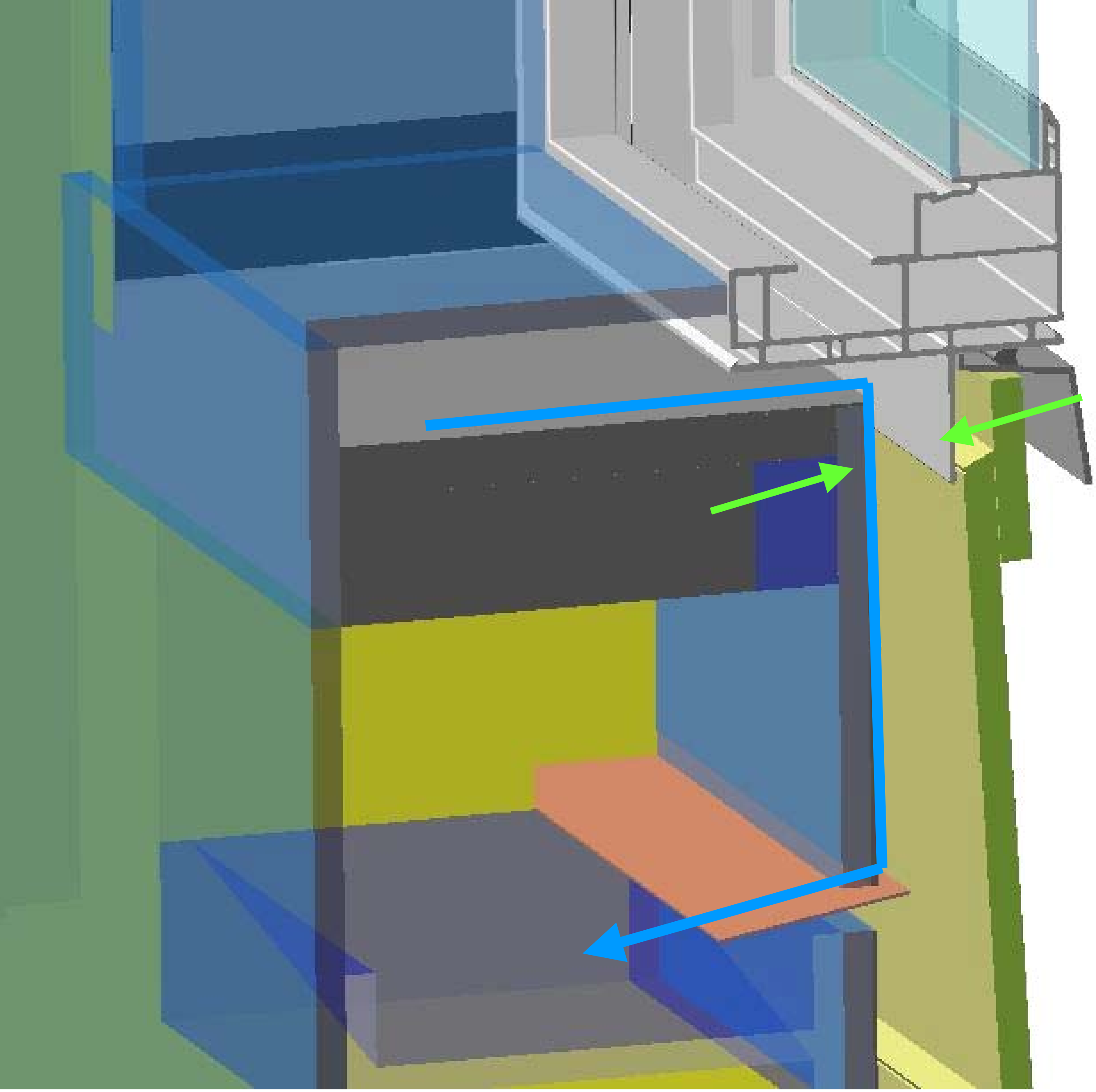
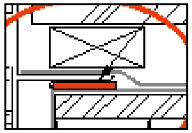
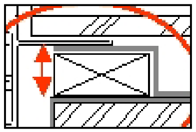


W3 – “B”

V-side B-side





Selected Practice:

- **Furring strips create 19-mm gap between window mounting flange and backup wall**
- **Permits water to drain from subsill area**
- **Collected in “upper” trough**

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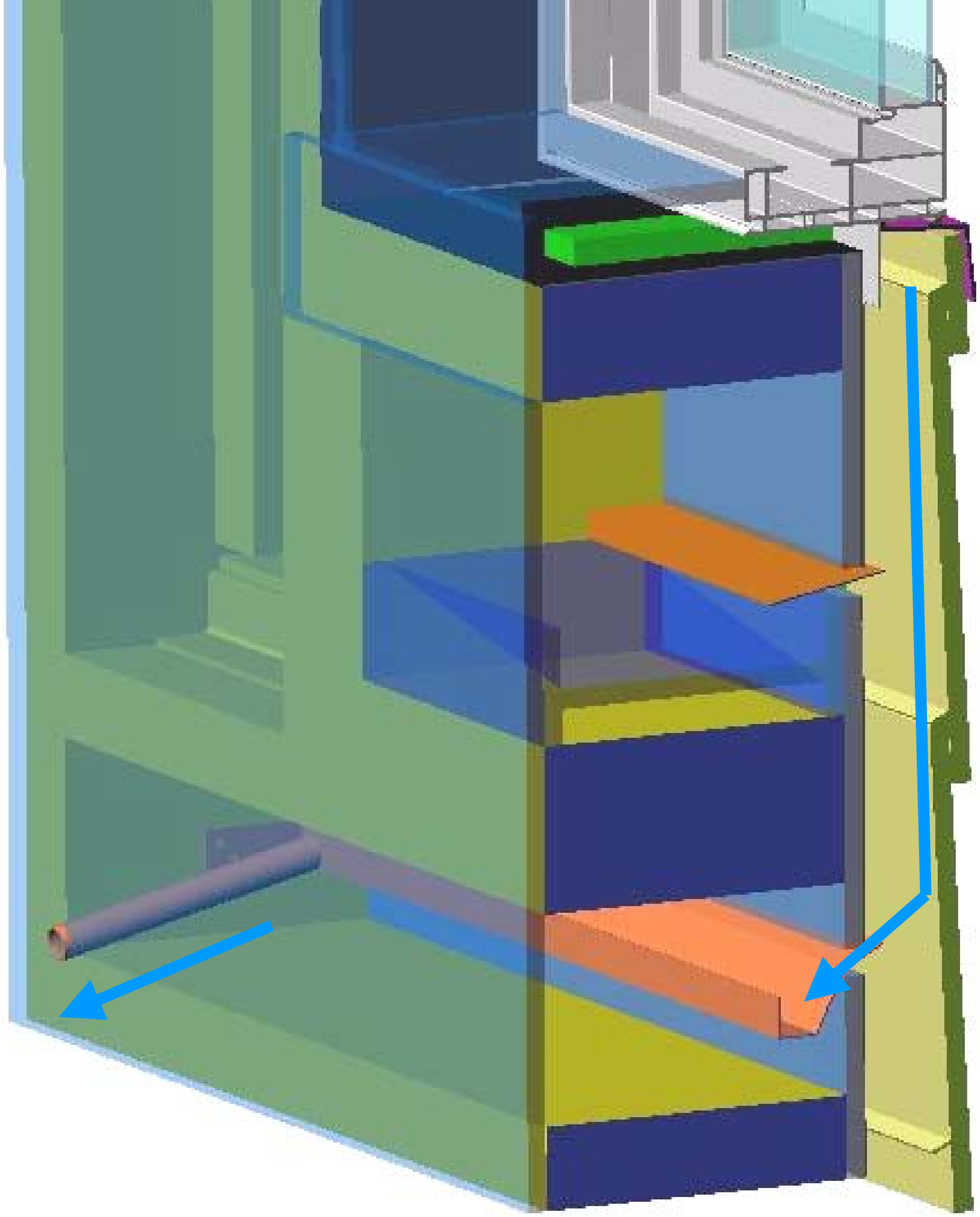

W3

- For both sides of wall, 19-mm space behind siding expected to prevent water from reaching backup wall
- Water runs down cladding and is collected in lower collection trough

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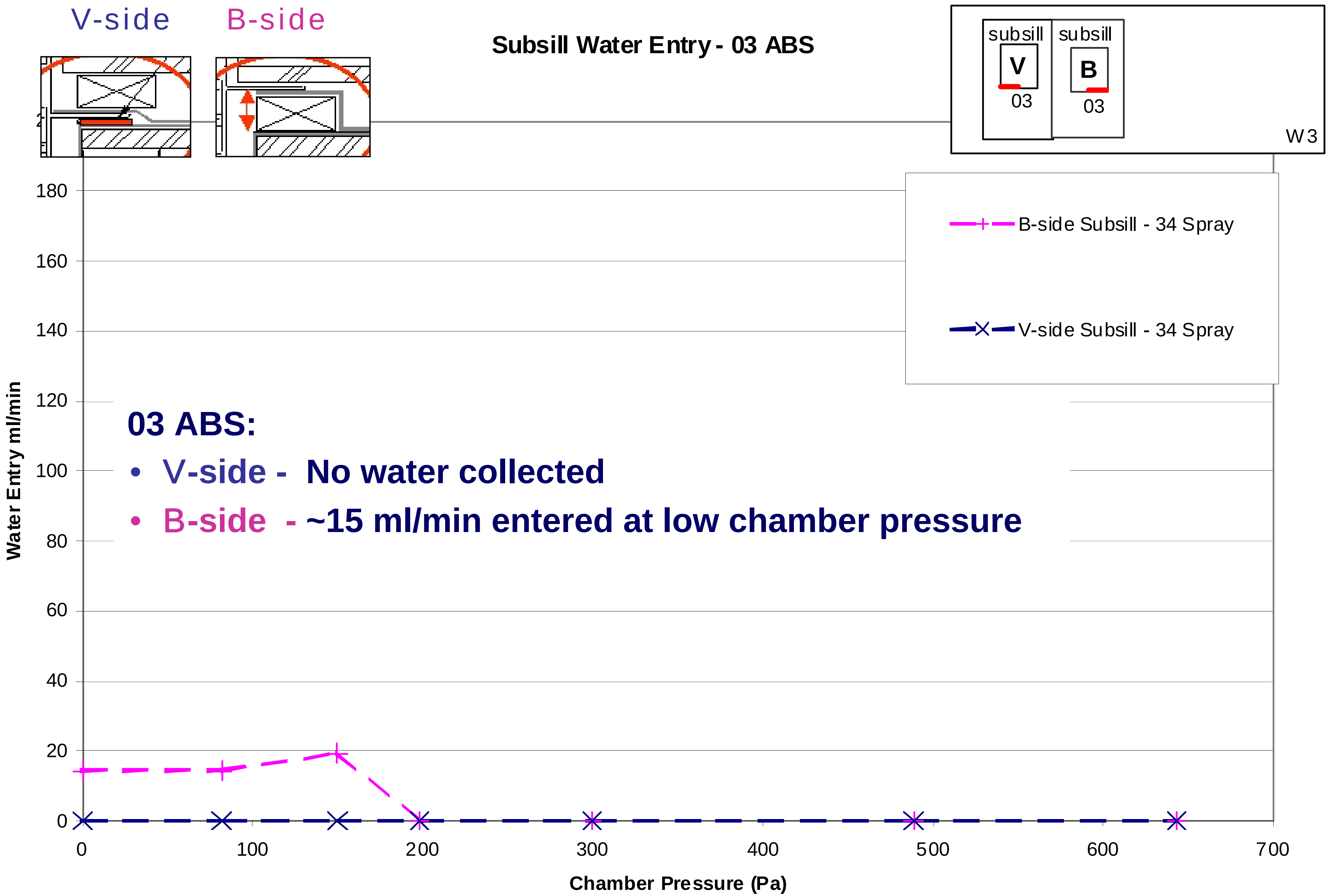
Water Management with Step 2

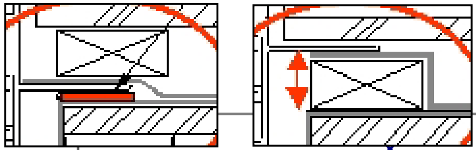


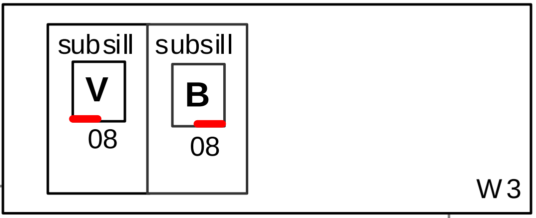
03 ABS:

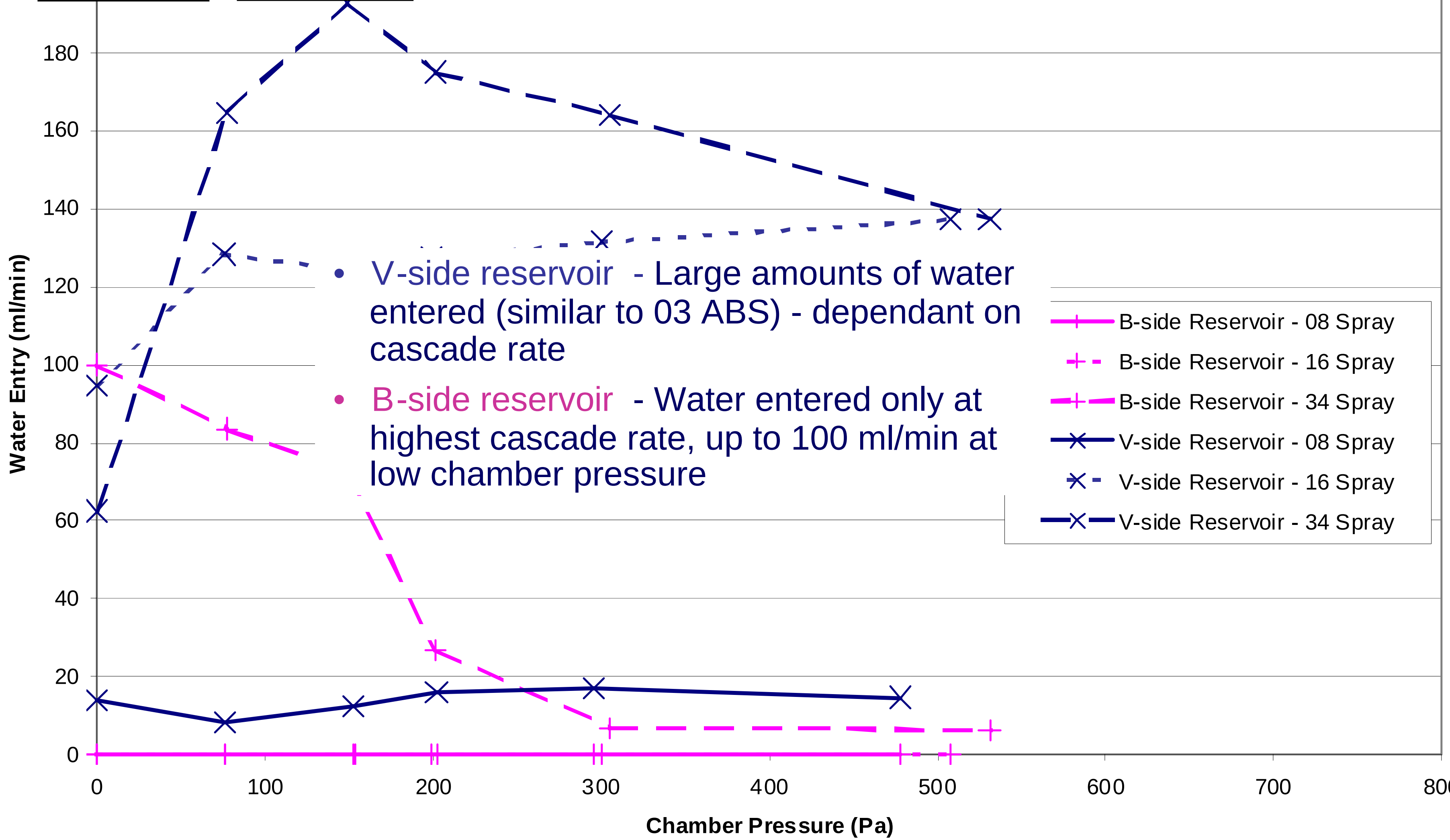
- **V-side - No water collected**
- **B-side - ~15 ml/min entered at low chamber pressure**

Water Management with Step 2

V-side B-side







- V-side reservoir - Large amounts of water entered (similar to 03 ABS) - dependant on cascade rate
- B-side reservoir - Water entered only at highest cascade rate, up to 100 ml/min at low chamber pressure

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W3 - Water entry summary

- *Combination window permitted substantial amounts of water to enter at high pressures*
- *No deficiencies - both sides of wall performed similarly*
  - *B-side allowed small rates of water to enter "reservoir" collection trough at low chamber pressures,*
  - *At higher pressures, rates were reduced given that water was diverted through window*
- *With deficiency (Same as W1 - caulking removed from outside corner of window)*
  - *caused significant amounts of water to enter V-side reservoir*
- *For this deficiency*
  - *B-side had reduced water entry as compared to V–side - water only entering reservoir and subsill at highest cascade rate*

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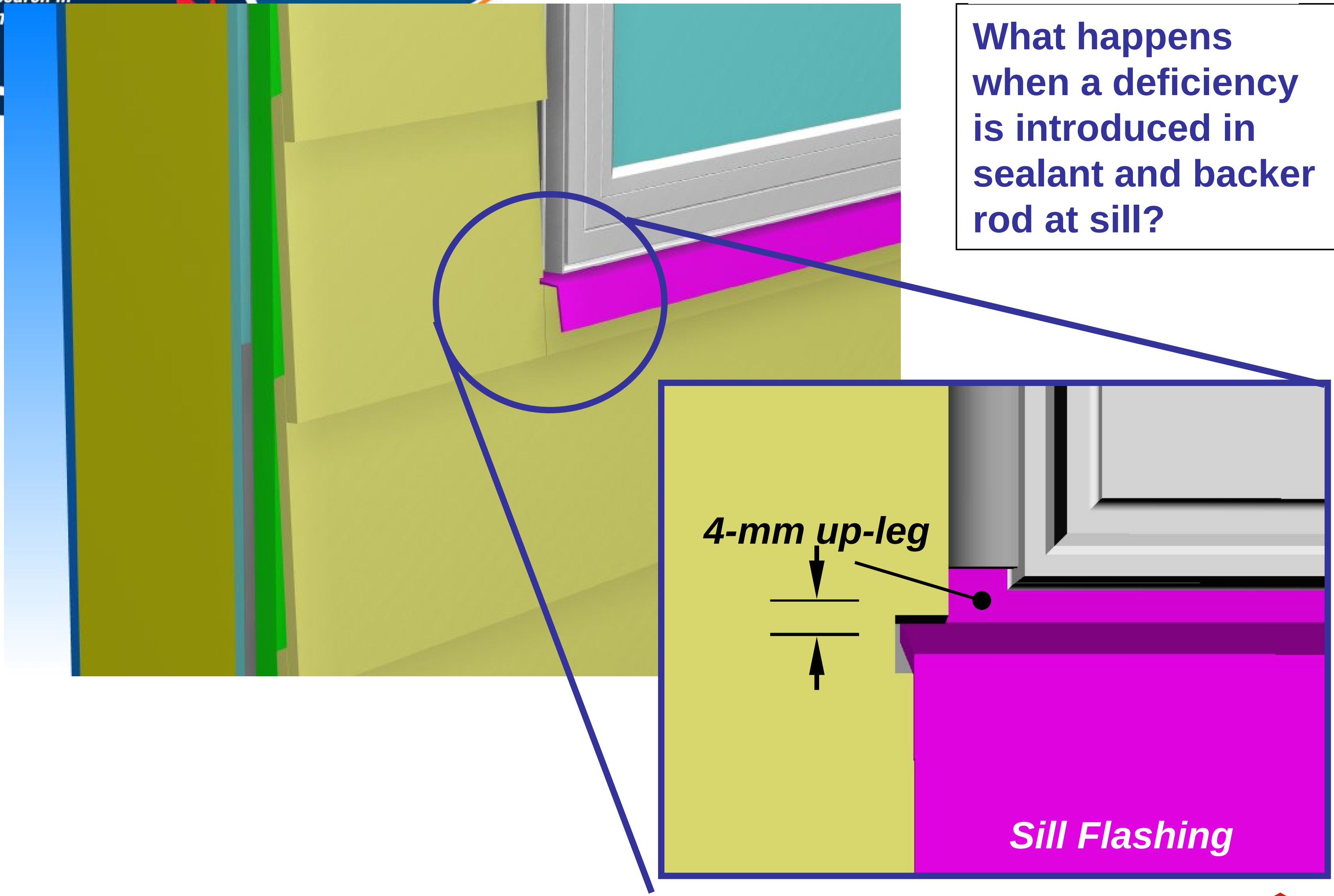
W3

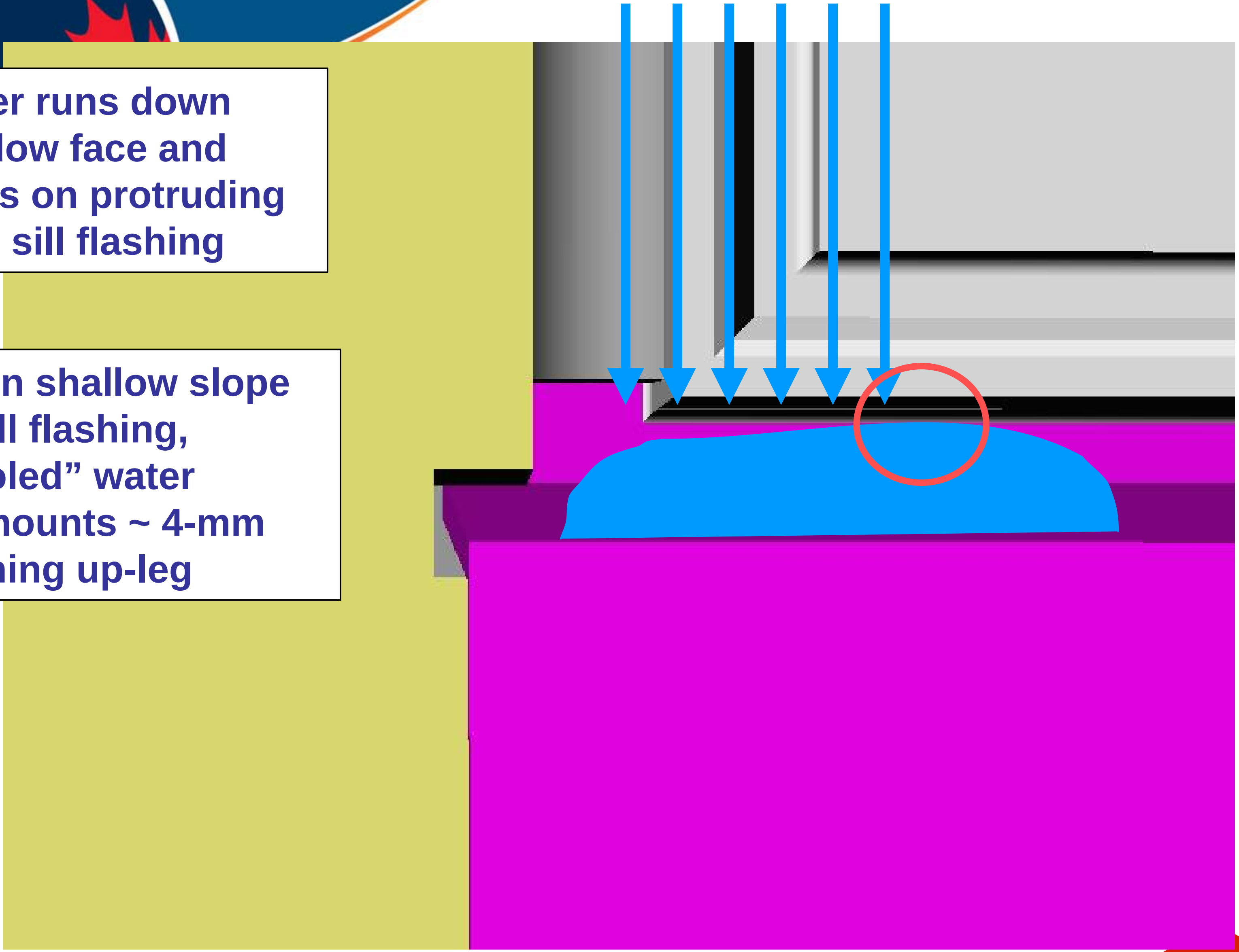
What happens when a deficiency is introduced in sealant and backer rod at sill?



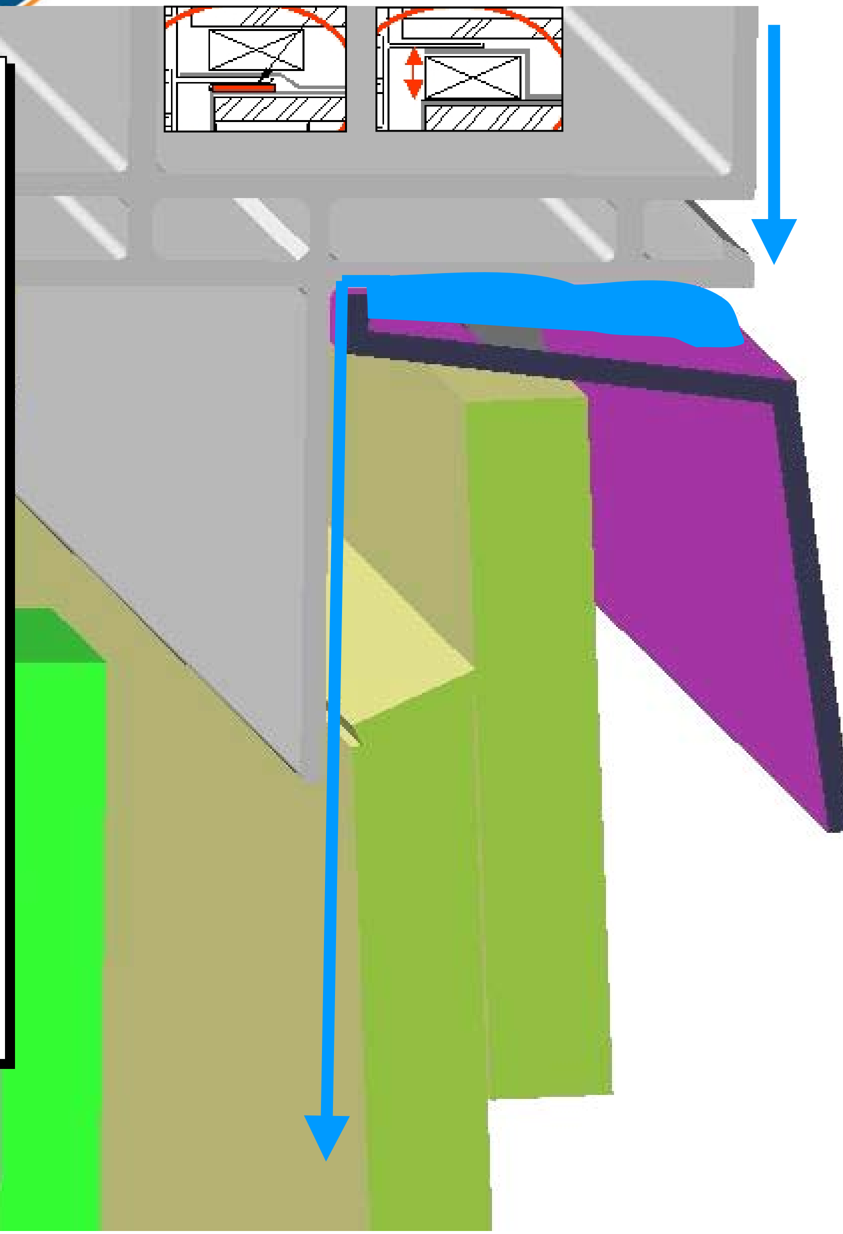
W3

Water runs down window face and pools on protruding rigid sill flashing

Given shallow slope of sill flashing, “pooled” water surmounts ~ 4-mm flashing up-leg



W3 – "B"



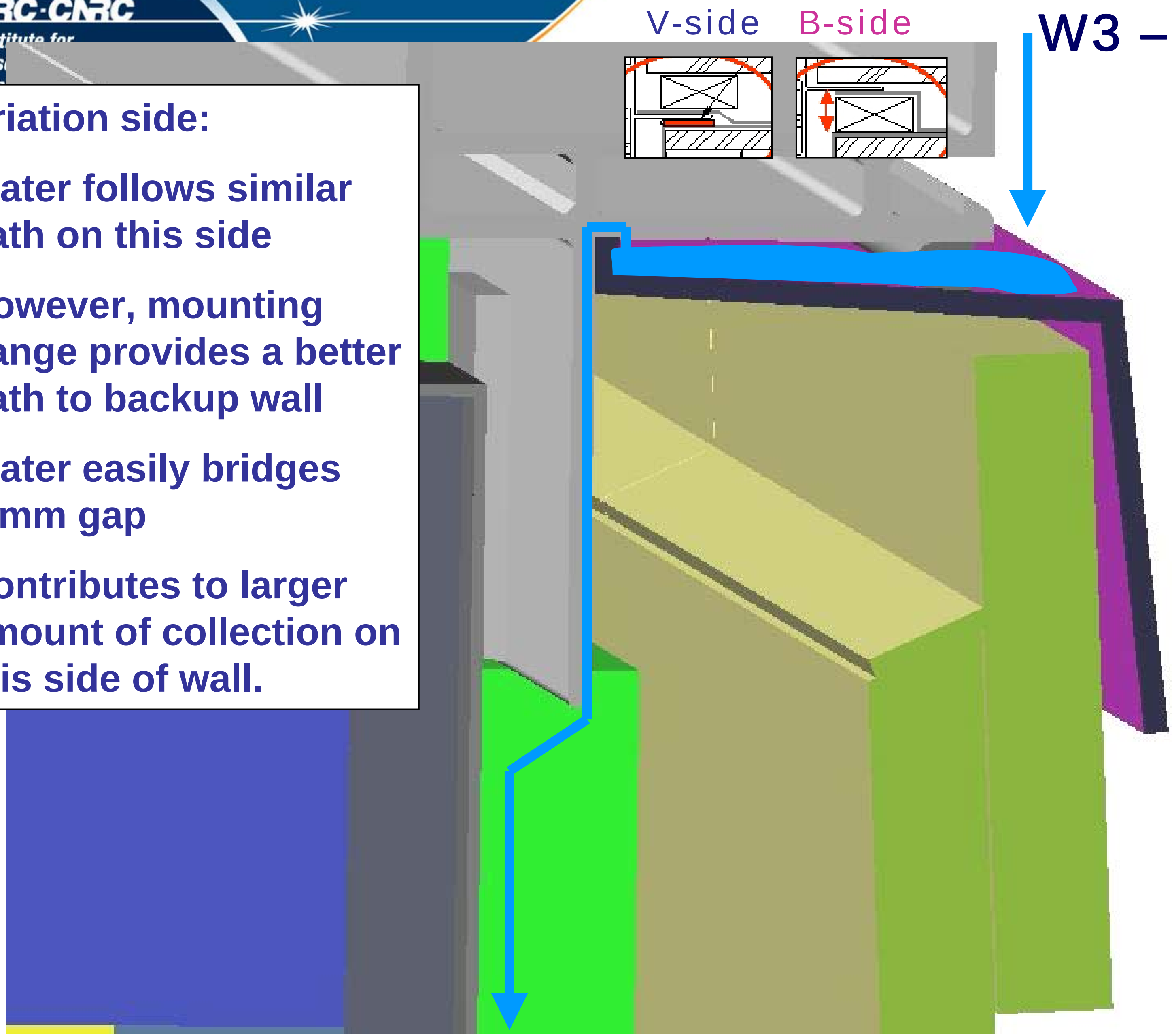
Selected practice side "B":

- Once water passes behind rigid sill flashing - runs down window mounting flange
- 19-mm gap created behind cladding proves difficult, but not impossible to bridge
- Portion of water attains backup wall and is collected by trough
- Remainder runs down interior of cladding and collected at base of wall

W3 – "V"

Variation side:

- **Water follows similar path on this side**
- **However, mounting flange provides a better path to backup wall**
- **Water easily bridges 3-mm gap**
- **Contributes to larger amount of collection on this side of wall.**



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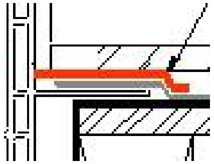
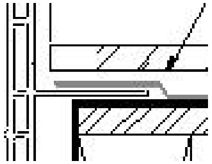
Specimen Details- W4

- *No clear cavity behind siding (no furring strips)*
- *No J-trim or Drip cap Head Flashing*
- *Combination window, solid PVC with integral flange – top slider, bottom fixed*
- *Sealing as compared to not sealing WRB to window flange*





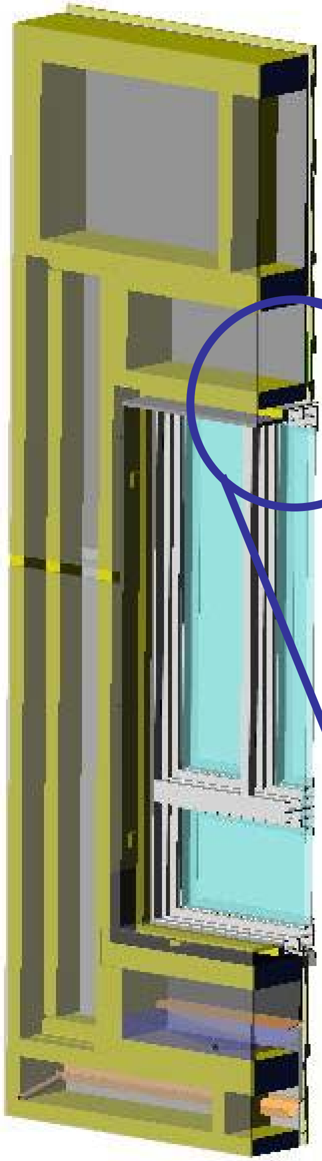
Self-adhered Membranes

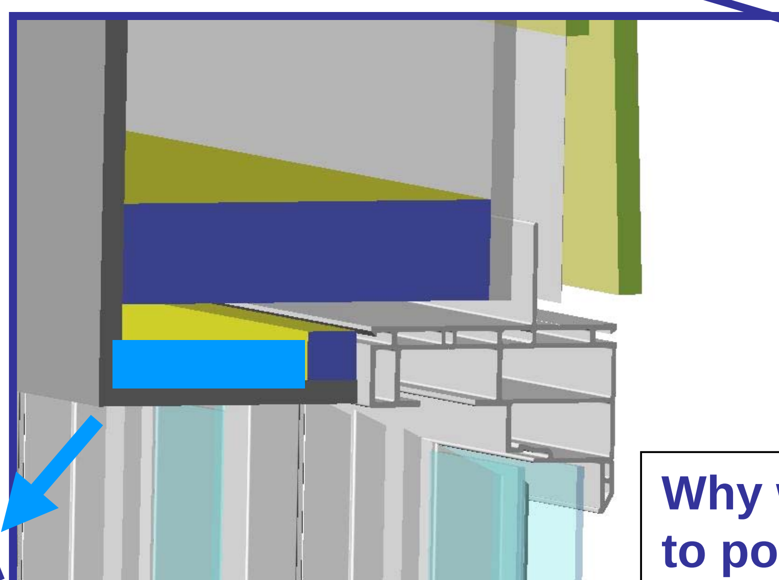
– *Strip of self-adhered flashing membrane <u>over</u> joint between window flange and sheathing membrane (not at sill)*

Self-adhered Membranes

Test Observations

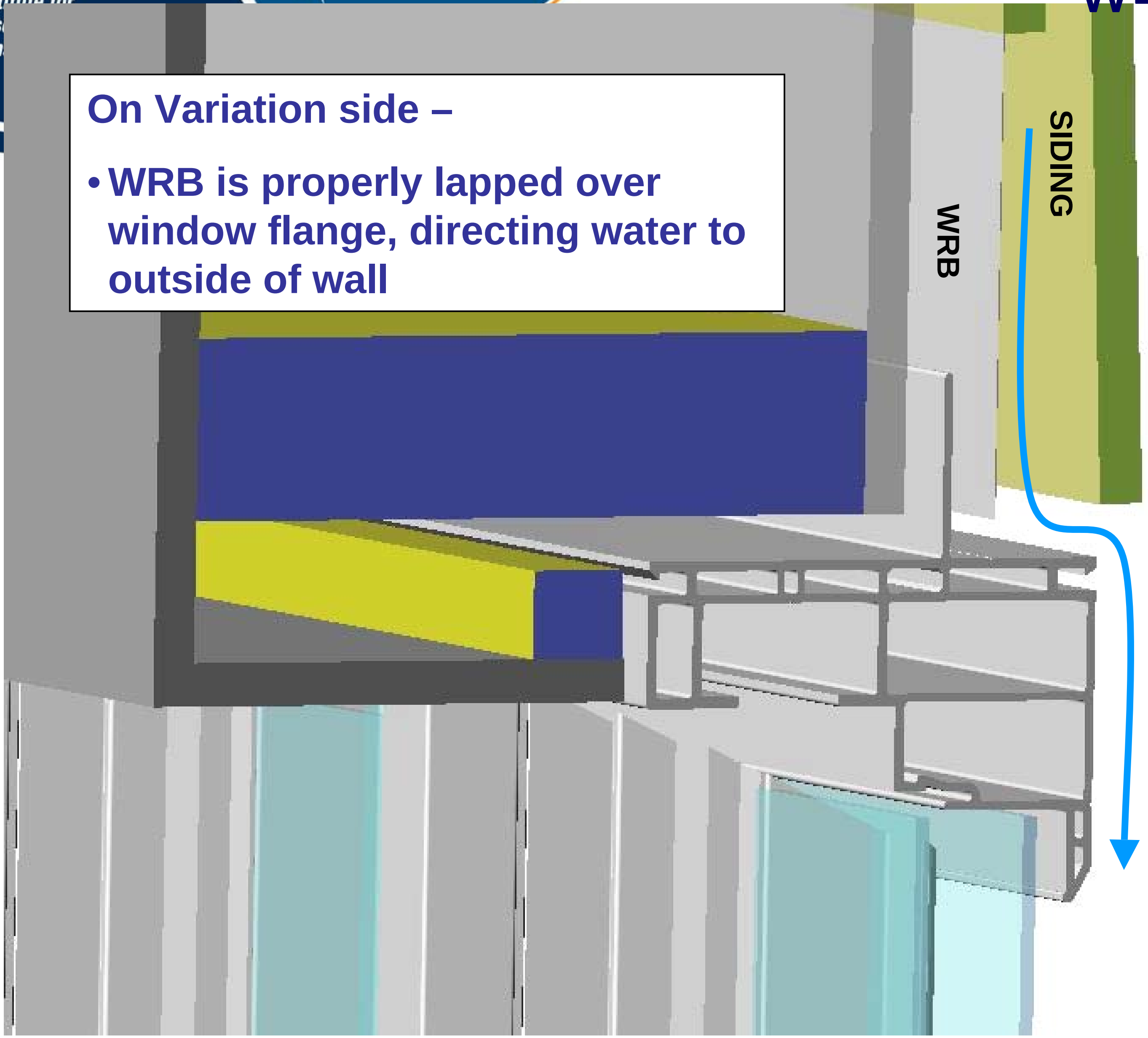
- ***Sealing joints between window and wall using such approaches - not 100% effective, given that:***
  - ***Water found its way to interior via reverse lapping***
  - ***Created funnels that channelled water to inside***
  - ***Some water was trapped inside assembly***





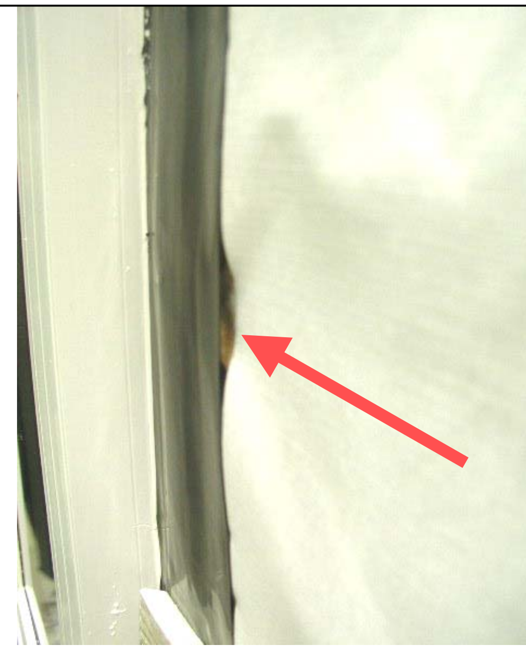
Why was water observed to pool at head of window on Selected Practice side?

W4 – “V”

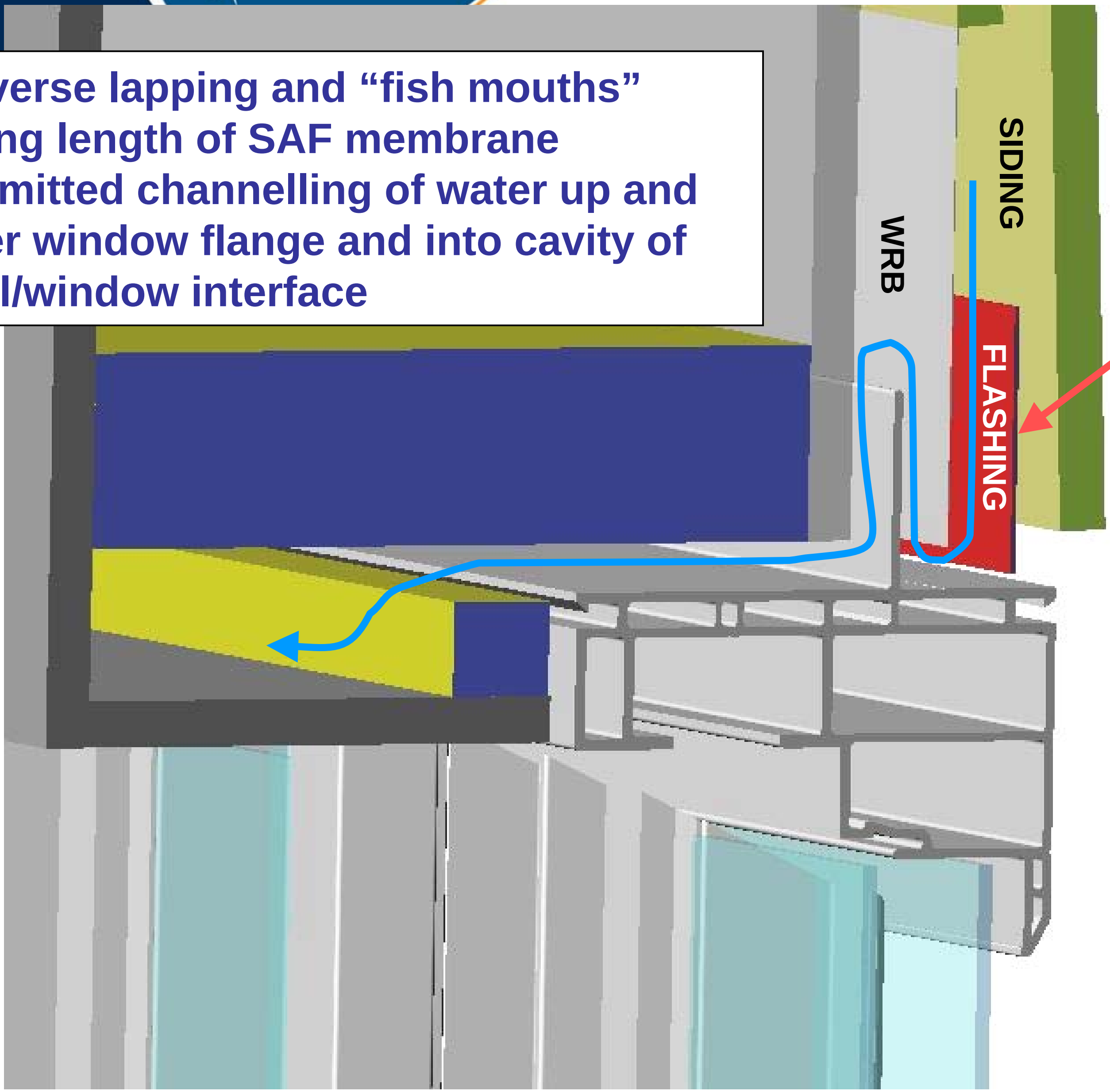

On Variation side –
• WRB is properly lapped over window flange, directing water to outside of wall
WRB
SIDING

W4 – “B”

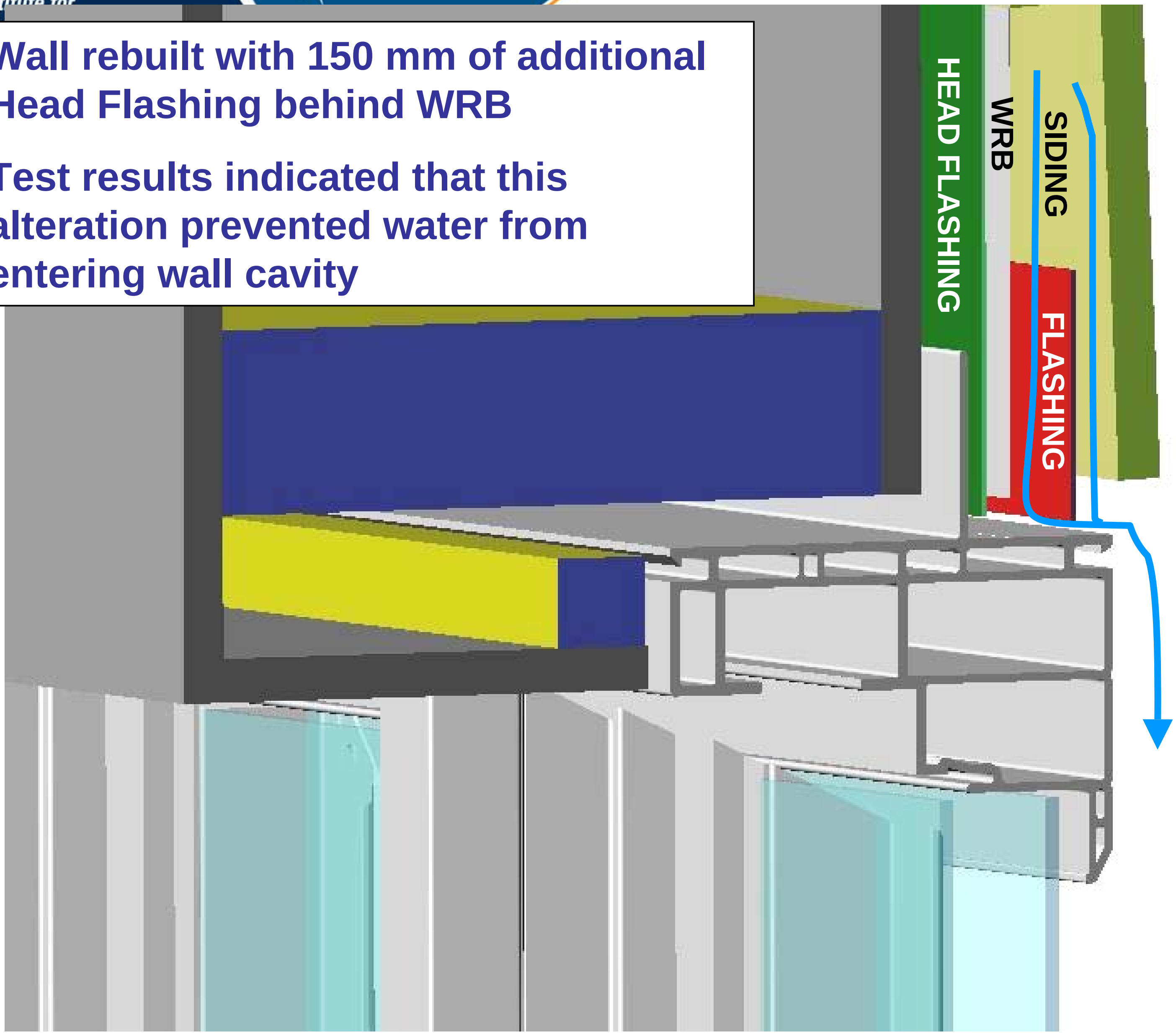
- **Review of Selected Practice side showed delamination of flashing membrane from WRB**
- **Creation of openings for water entry - “fish mouths”**



Reverse lapping and "fish mouths" along length of SAF membrane permitted channelling of water up and over window flange and into cavity of wall/window interface



- Wall rebuilt with 150 mm of additional Head Flashing behind WRB
- Test results indicated that this alteration prevented water from entering wall cavity



Observations - Wall Response

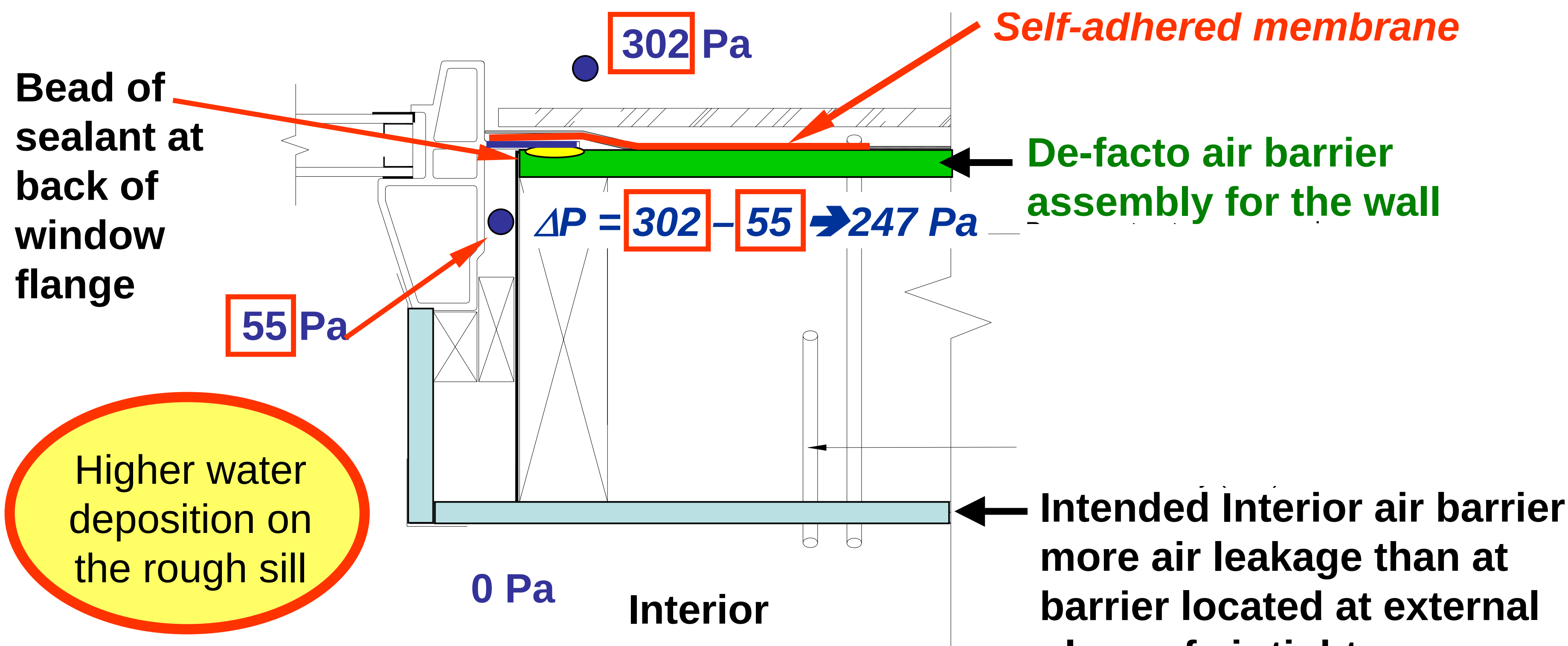
Air Pressure Difference

- ***Effect on water accumulation on rough sill as related to:***
  - ***Location of highest air pressure drop in relation to location of plane of wetness***
  - ***Air leakage rate***

Observations - Wall Response

Effects of Pressure Distribution

Specimen A:
<u>High</u> pressure drop (ΔP) across wetted airtight external plane

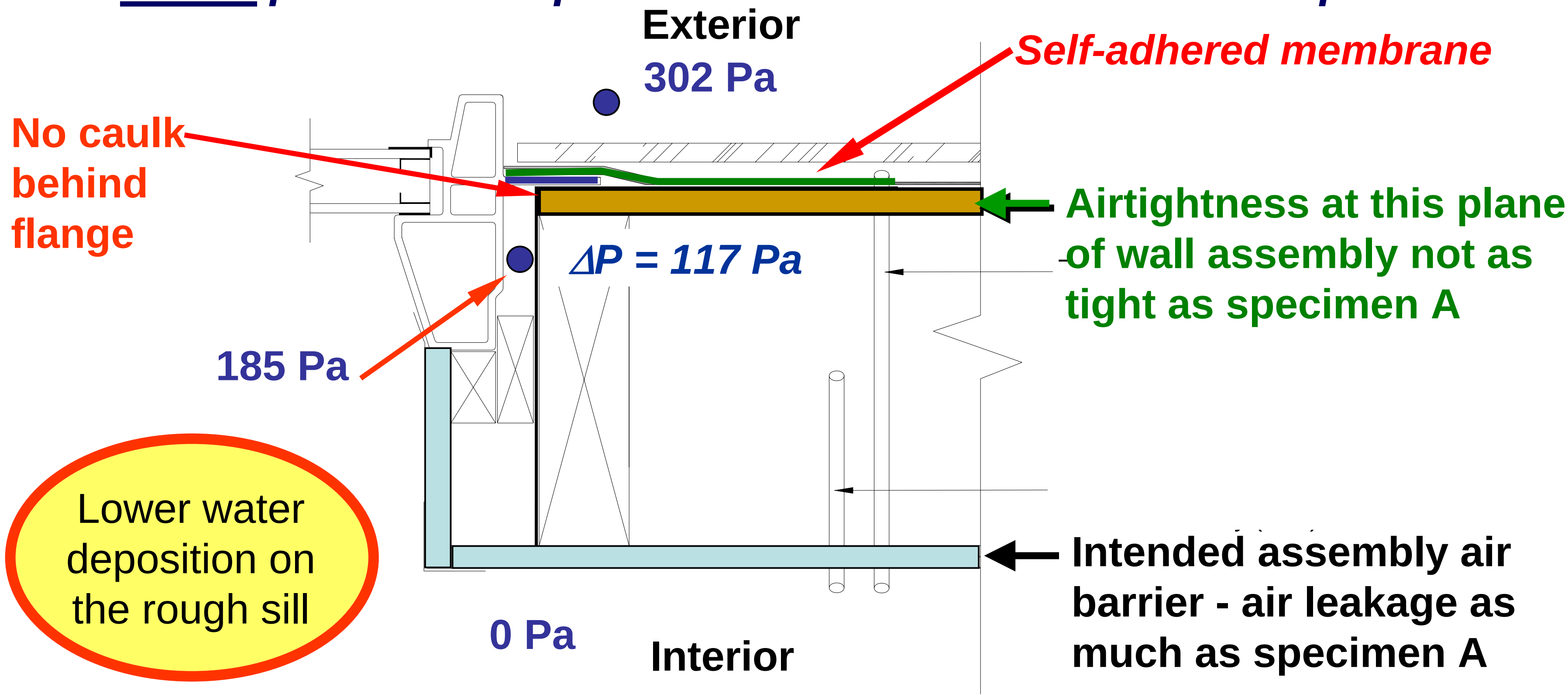


Jamb detail
(horz. sectional view)

Observations - Wall Response

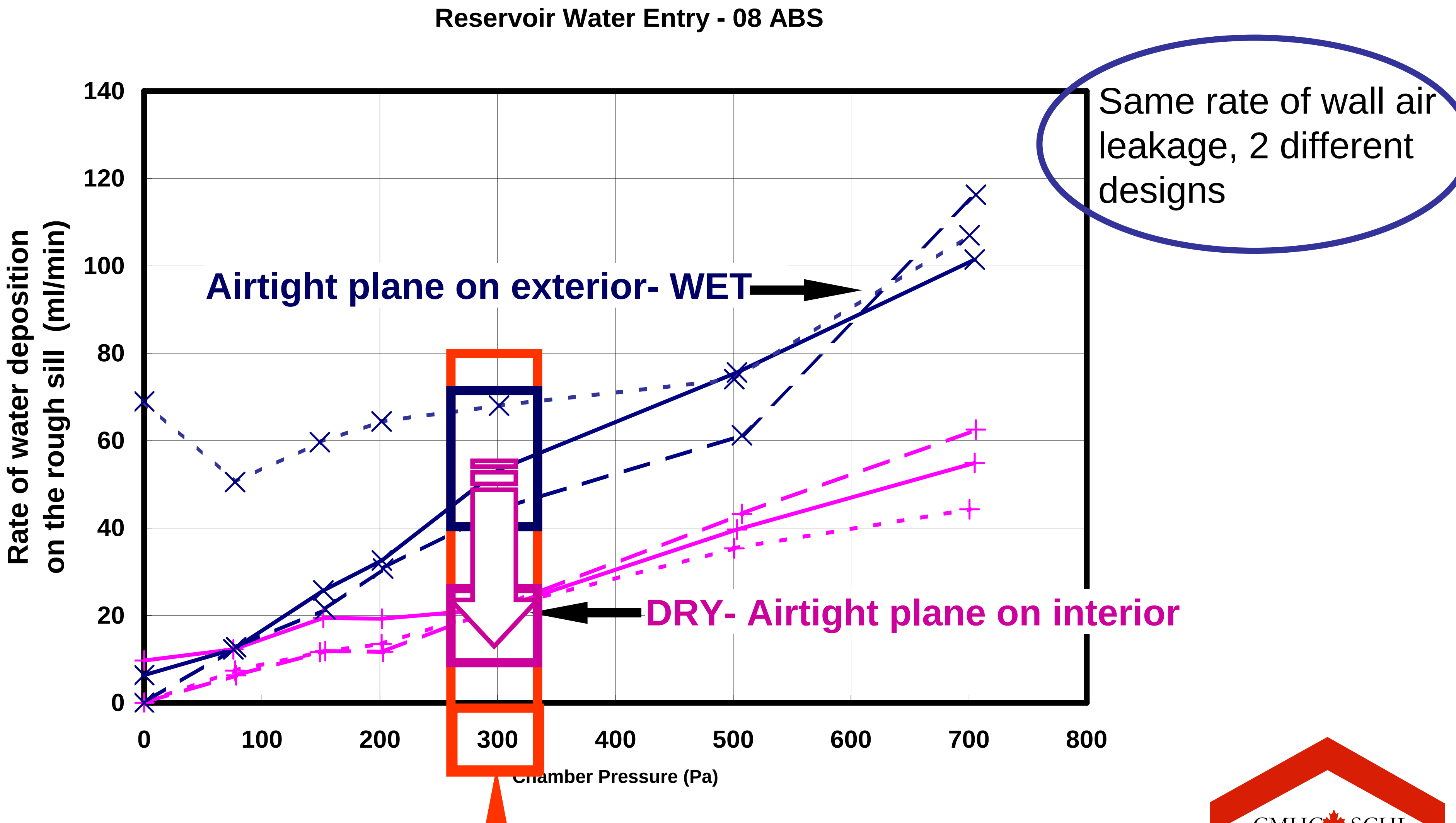
Effects of Pressure Distribution

Specimen B:
<u>Lower</u> pressure drop across wetted “vented” external plane



Jamb detail
(horz. sectional view)

Observations - Wall Response Effect of Location of Plane of Airtightness



Results - Practical considerations

- ***Design decisions in regard to choice of:***
  - ***Method of installation in relation to climate loads***
  - ***Components***
    - ***Windows & window openings***
    - ***Self-adhered flashing membrane and tape***
    - ***Jointing products***
  - ***Redundancy in design***
    - ***Boxed windows – two seals or one?***
    - ***Cladding and sills***
- ***Care and sequence of installation***

Installation related to climate loads

- *Water penetration at interface (in some instances) dependent on climate elements – i.e. water deposition, air pressure difference*
- *Generally (and as expected!)*
  - *Increasing water load on cladding increased likelihood of water entry – hence:*
    - *Reducing loads on cladding and window proper likewise reduces chance for water entry*
  - *Increasing pressure across interface also increases likelihood of water entry*
    - *Location of plane of air tightness in relation to presence of water - important*

Lesson #1: The Rough Opening Will Get Wet: Drain it Out

- ***Flash and drain the rough opening***
  - *Protect moisture-sensitive materials from water absorption*
  - *Provide drainage path to outside, i.e. include*
    - *Sloped rough sill*
    - *Back dam*
    - *Water impermeable rough sill; up 150 mm on jambs*
    - *Provide ease of drainage from rough sill - out of wall assembly*
    - *Integrate with other elements that contribute to control of rainwater ingress (i.e. shingle lapping, sequencing)*

ROUGH SILL FLASHING SYSTEM

Lesson #2: Keep Air Barrier Tight and Dry

- ***Current practice aims at sealing joints that can get wet: the joint between window frame (flange) and sheathing membrane***
- ***Imperfect seals at which both water and higher pressure differences coexist drive water through seal imperfections***
- ***Plane of higher pressure drop (Air Barrier System) should be in dry location, towards interior of joint***

Future work

- ***Report on Phase 1 expected in June 2006***
  - ***A select set of windows and installation details investigated amongst many different possible combinations***
- ***On-going testing with industry partners – Phase 2 BDTI and DuPont***
  - ***Report on Phase 2 expected in fall of 2006***
- ***Preparations for final Phase of project with PWGSC***
  - ***Specimen preparation and testing – 2006; Results – 2007***
- ***Additional interest by others in industry - Issues of interest:***
  - ***Use of spray in-place foam for control of air leakage – how does use of foam affect rainwater intrusion and drainage?***
  - ***Use of pan flashing – Is this approach a panacea for leaky windows?***
    - ***What are the key installation details to ensure watertightness?***
    - ***Does pan flashing affect thermal performance or risk to condensation at the window frame?***

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From Discovery to Innovation...

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For

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