Window Condensation - Theory into Practice

Alex McGowan, P.Eng., WSP Victoria

Outline of Presentation

- Introduction – Theory and Tools
- Case Study 1 – Designing the Problem in
- Case Study 2 – Building the Problem in
- Case Study 3 – Solving the Problem via litigation

Condensation on Windows

Case Studies in Window Condensation

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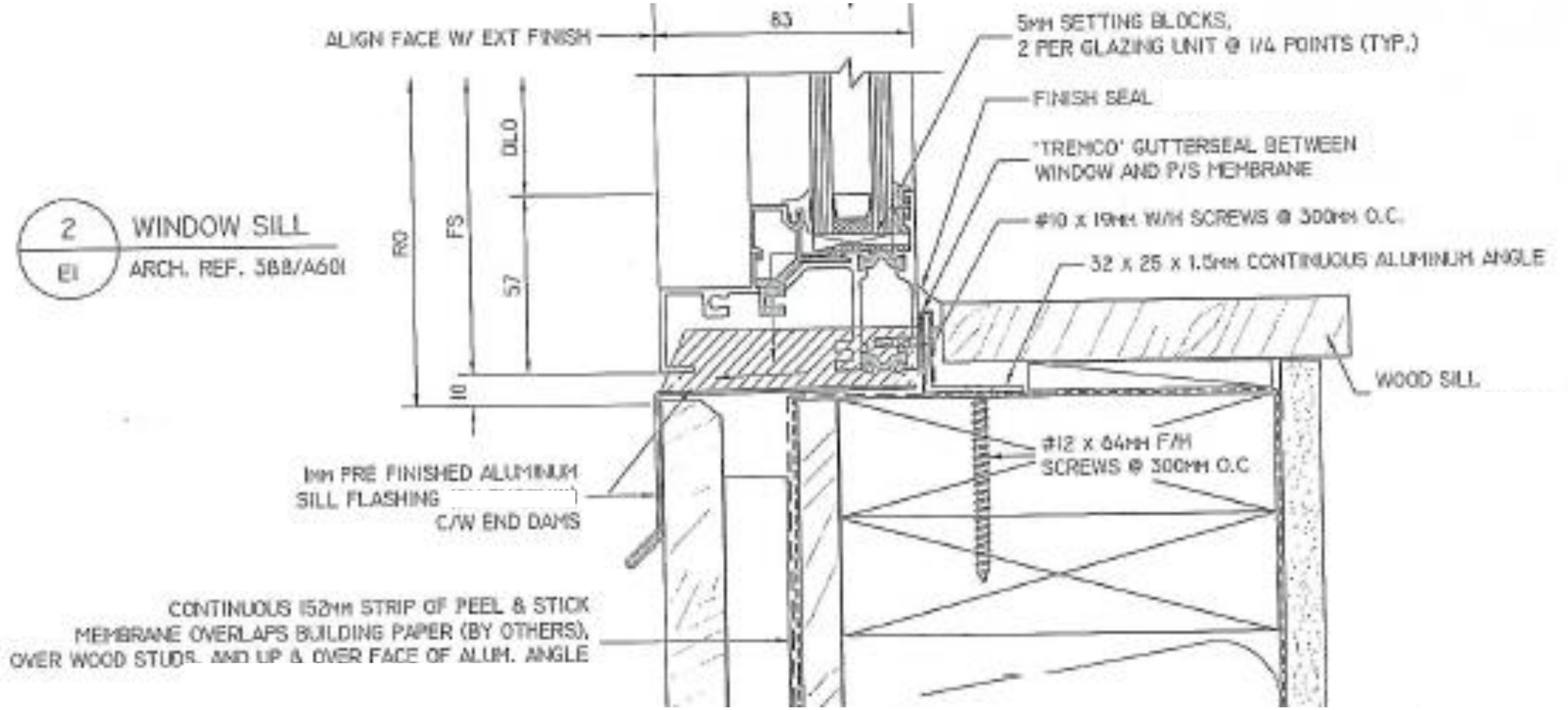
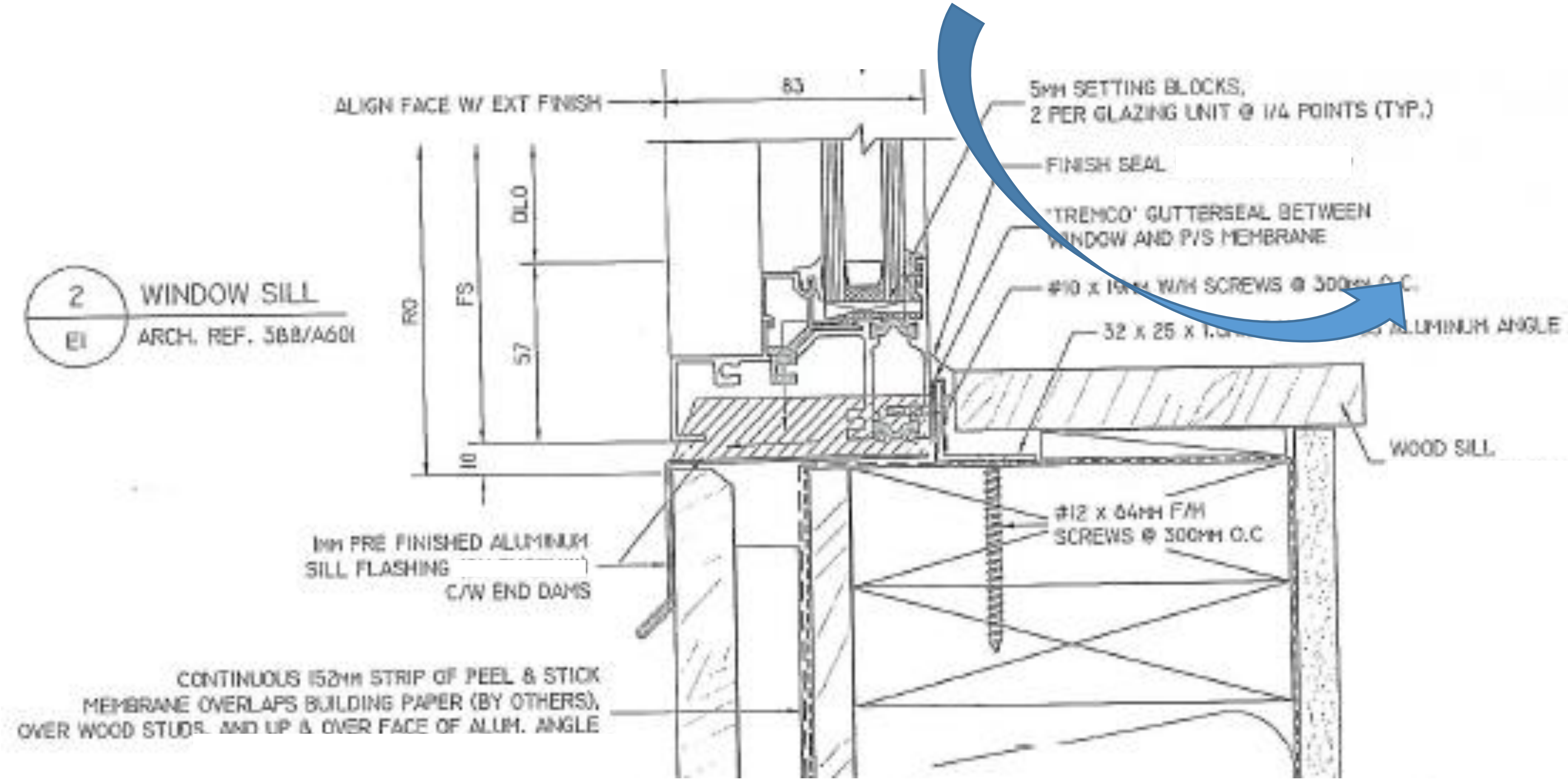
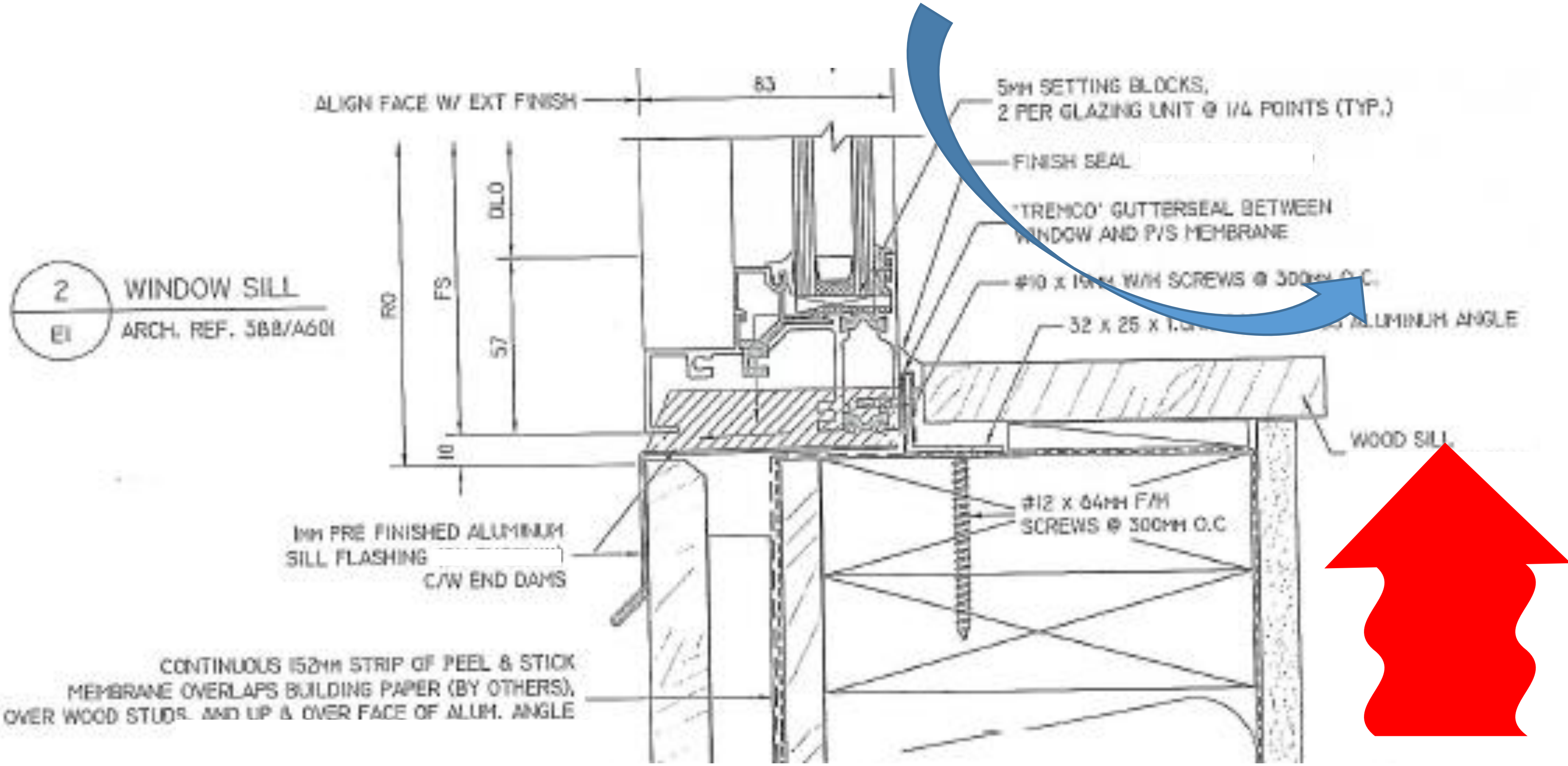
Condensation on Windows



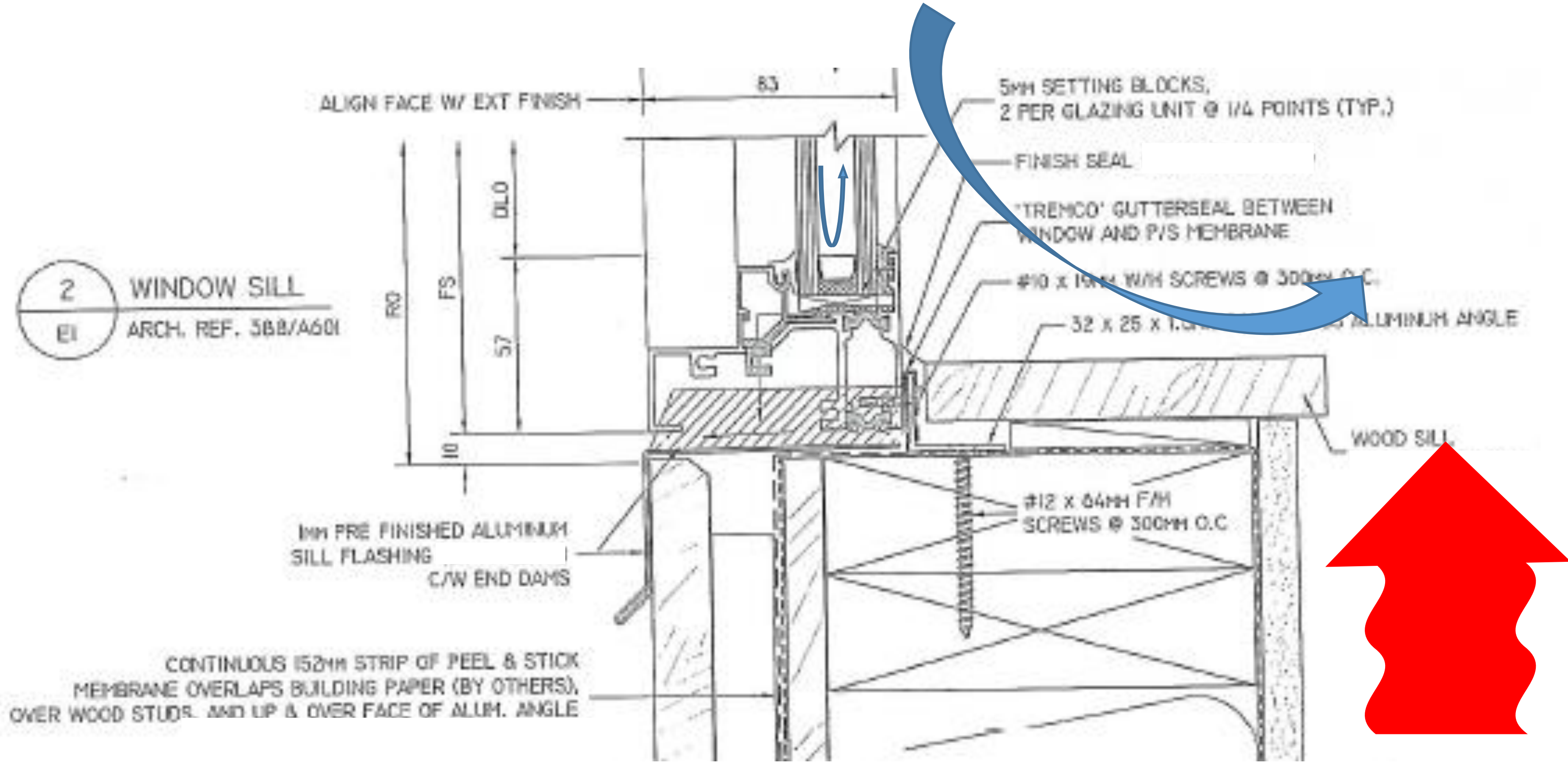
Condensation on Windows



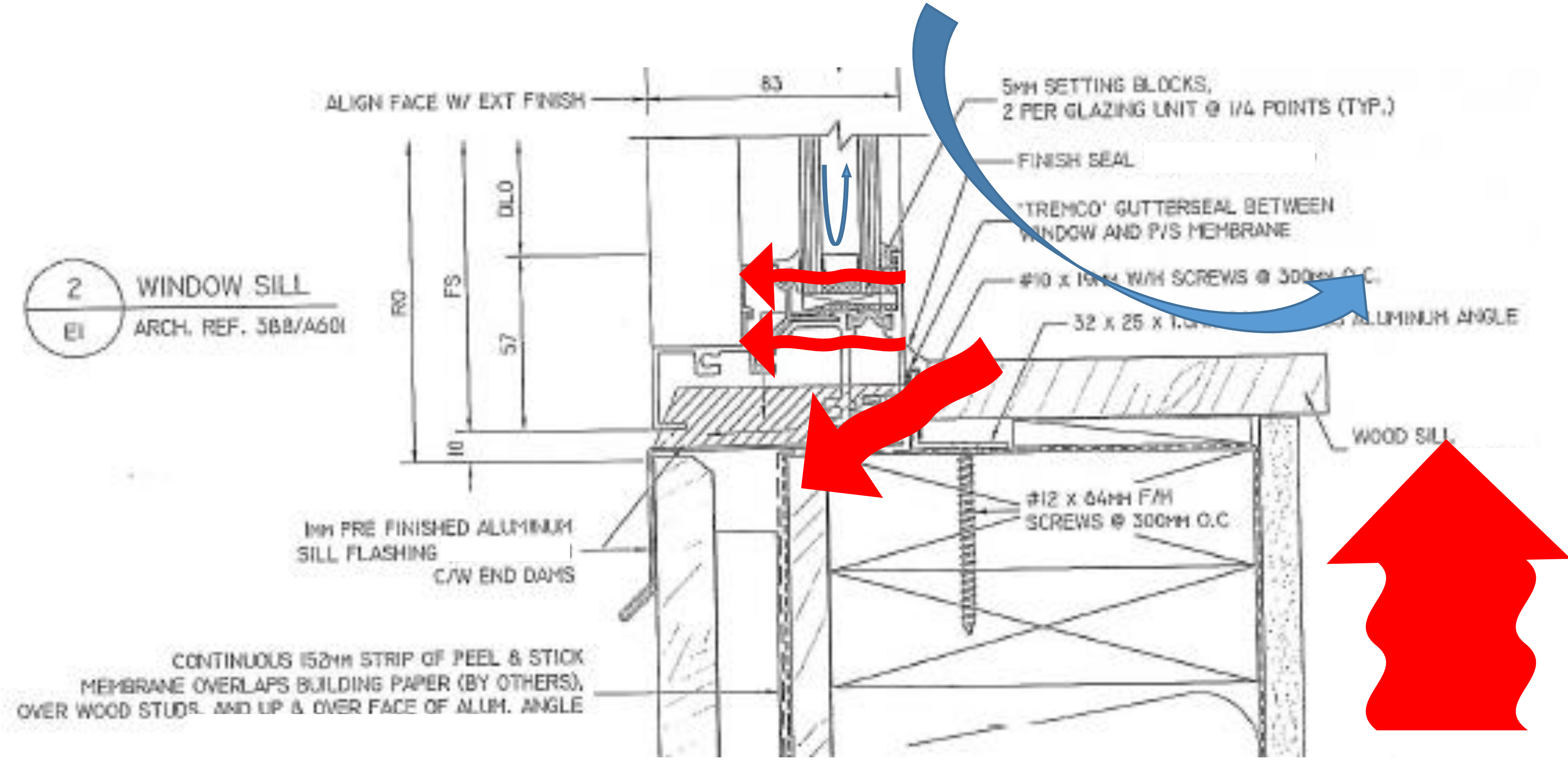
Condensation on Windows



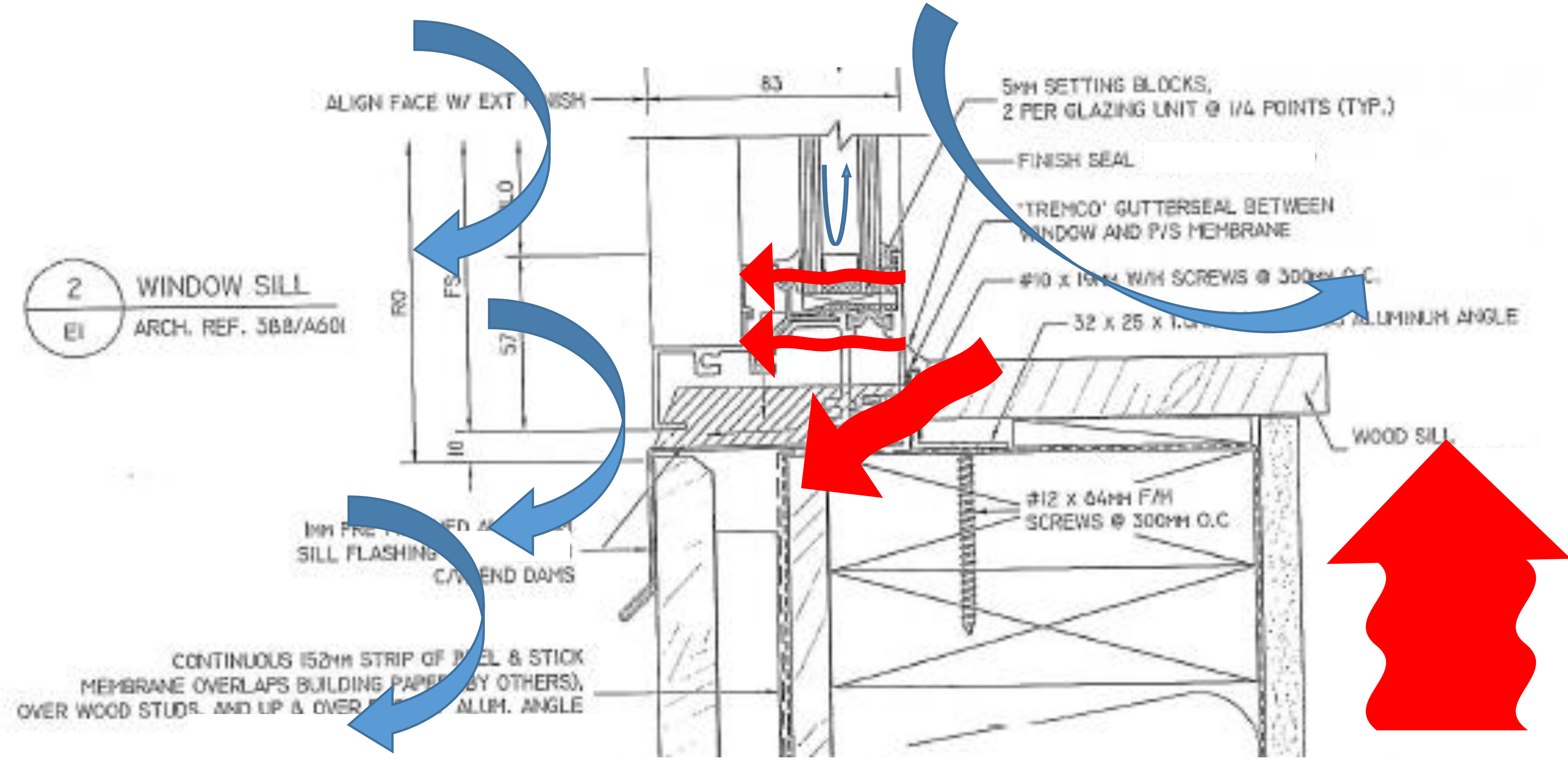
Condensation on Windows



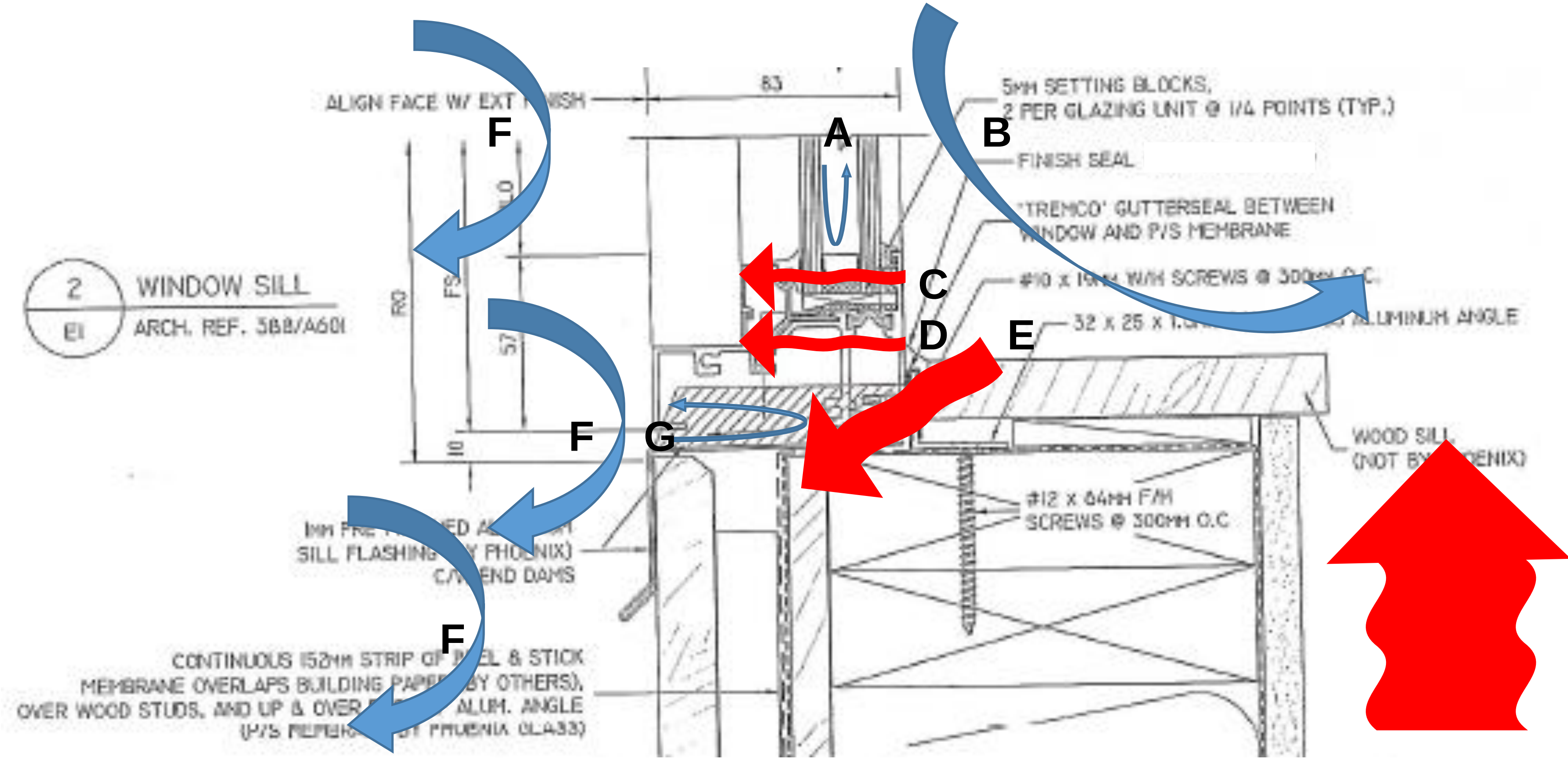
Condensation on Windows

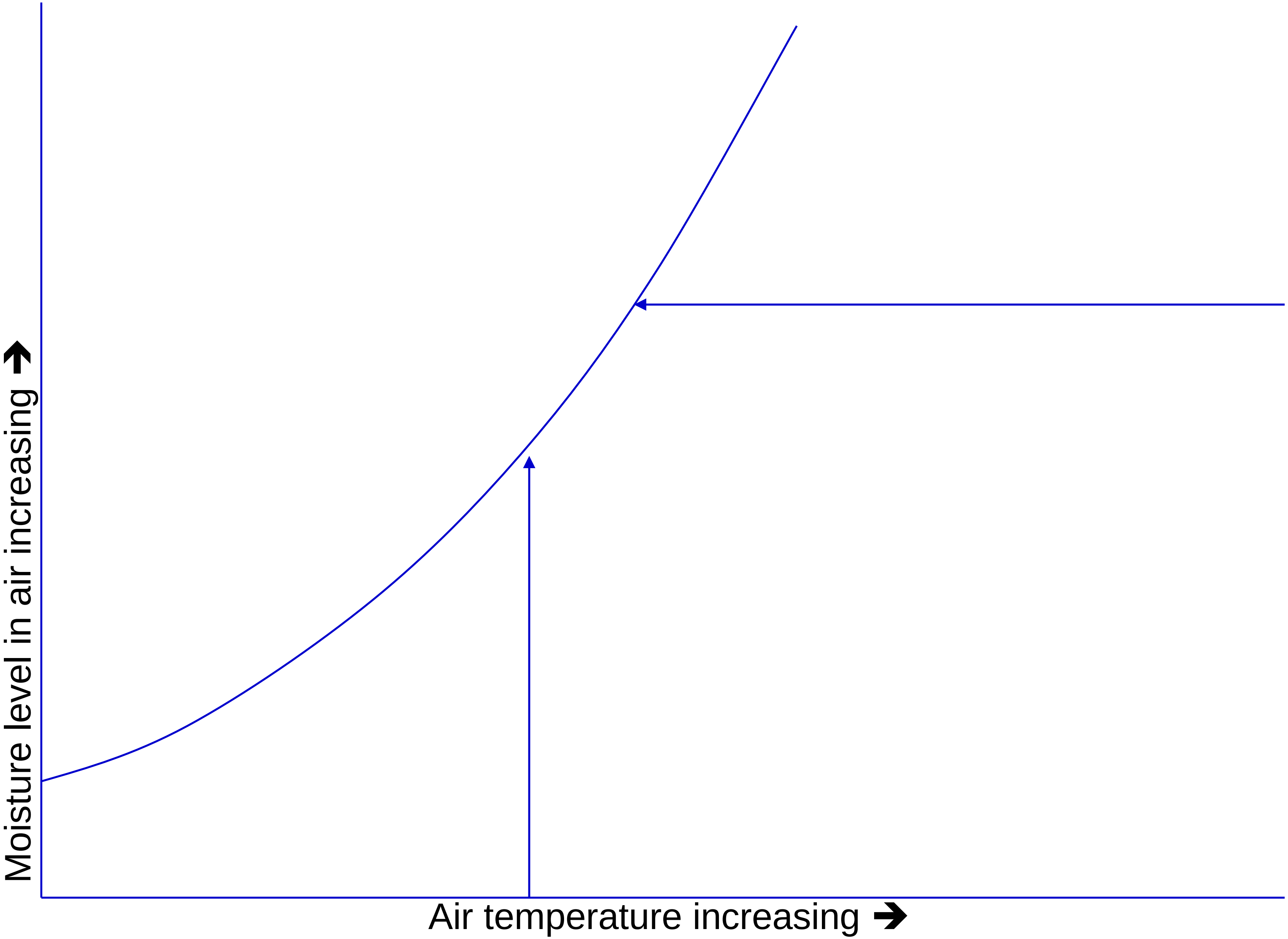


Condensation on Windows

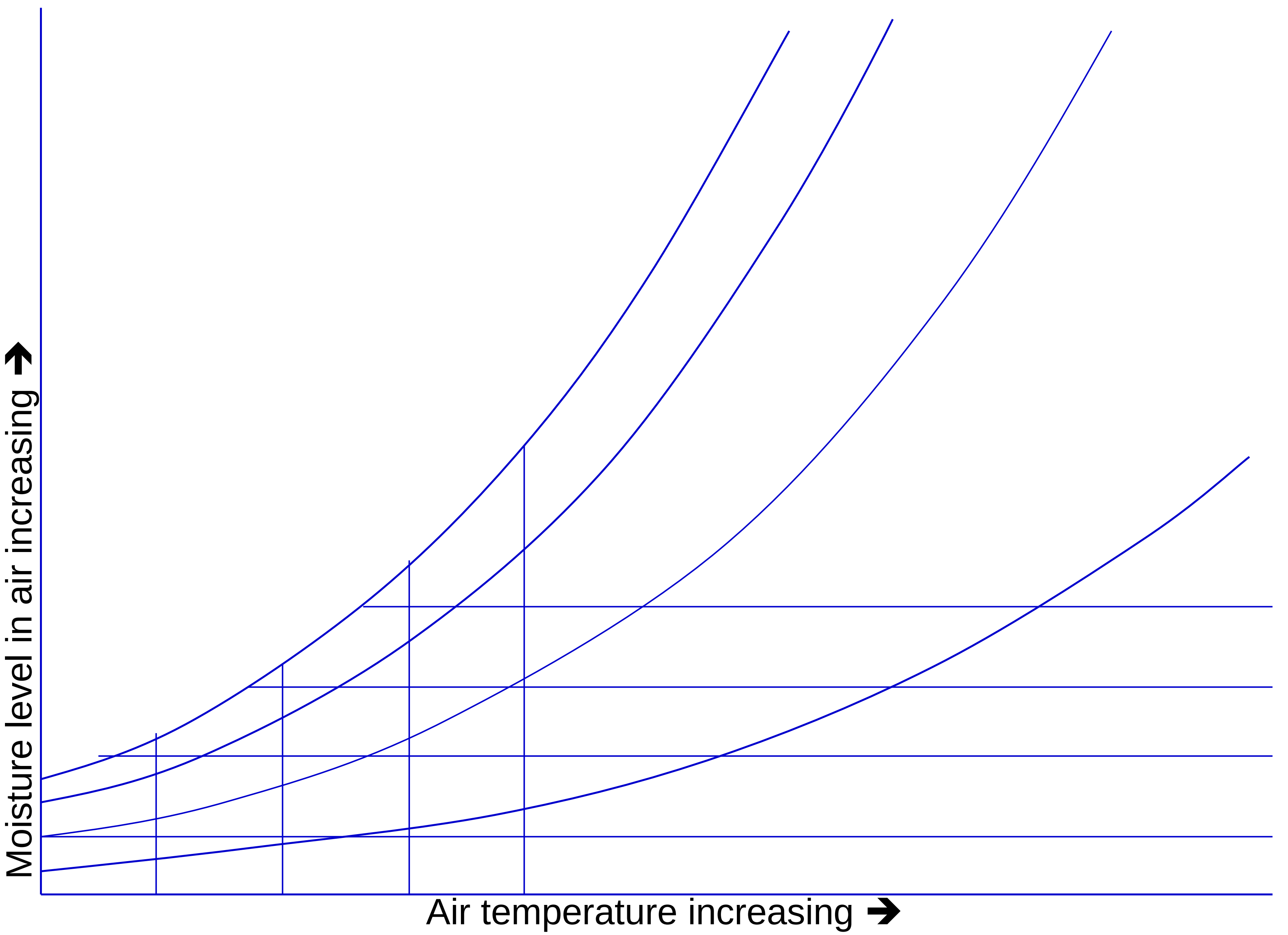


Condensation on Windows





Moisture level in air increasing
Air temperature increasing


Moisture level in air increasing
Air temperature increasing

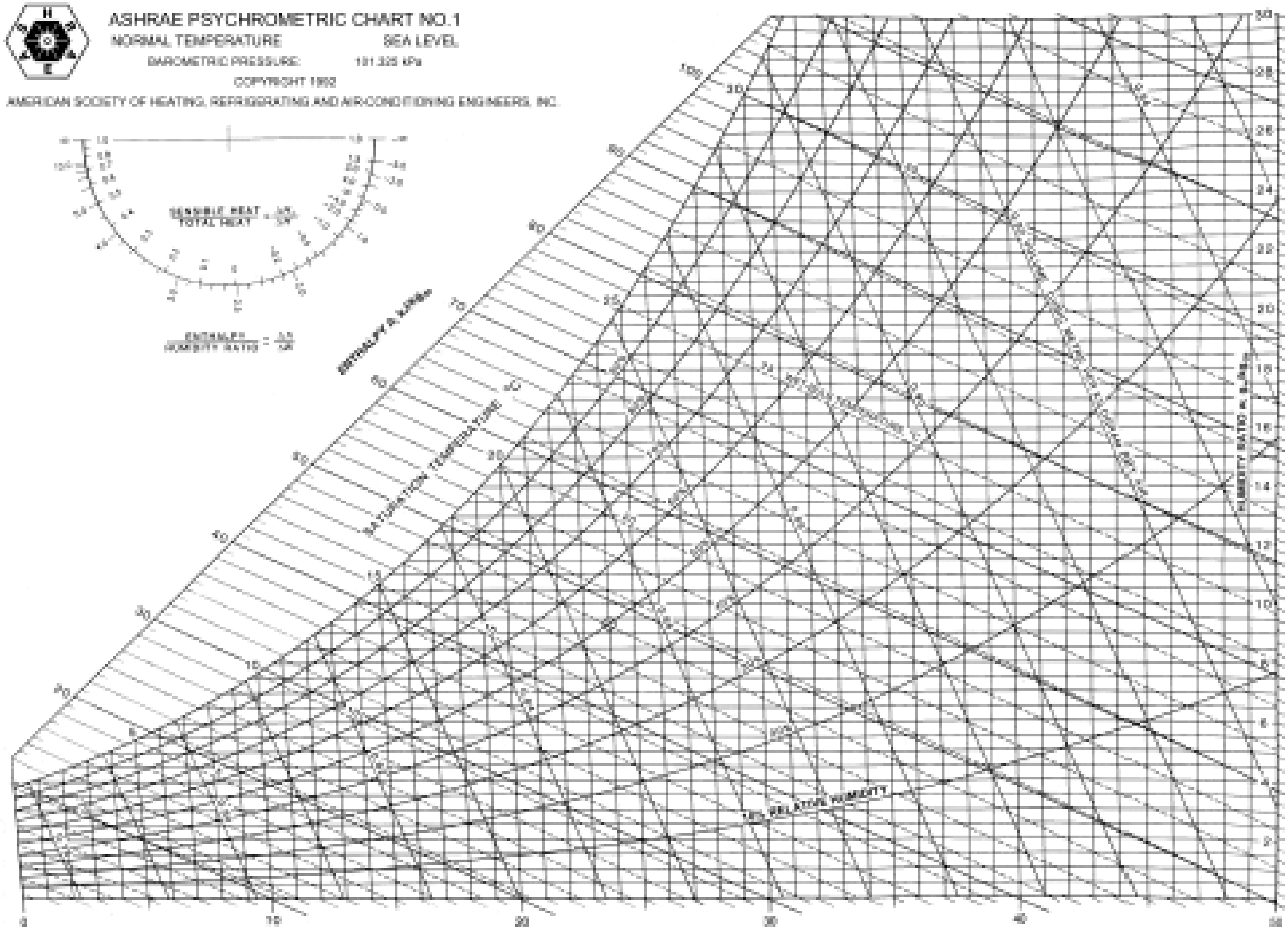
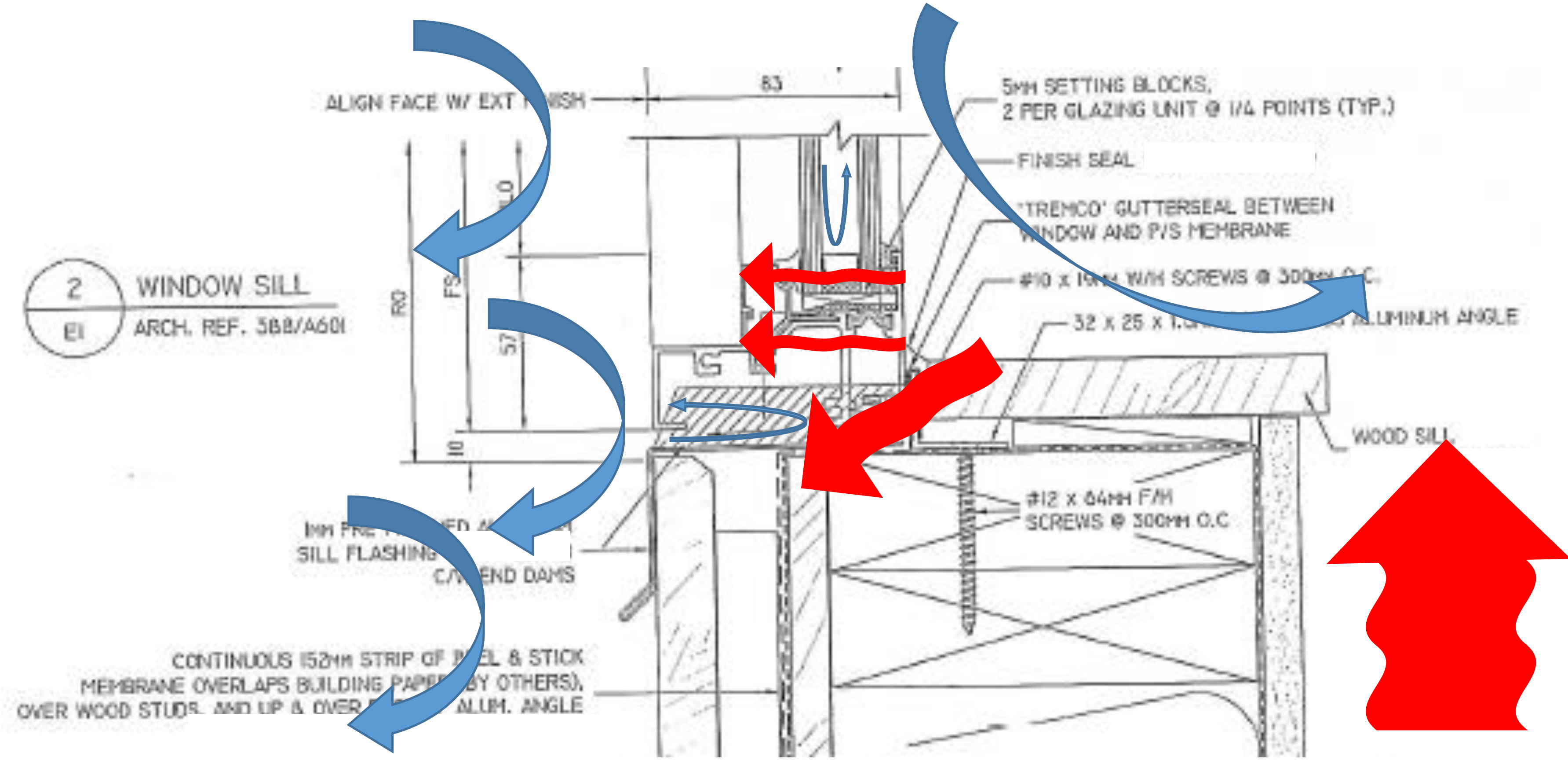
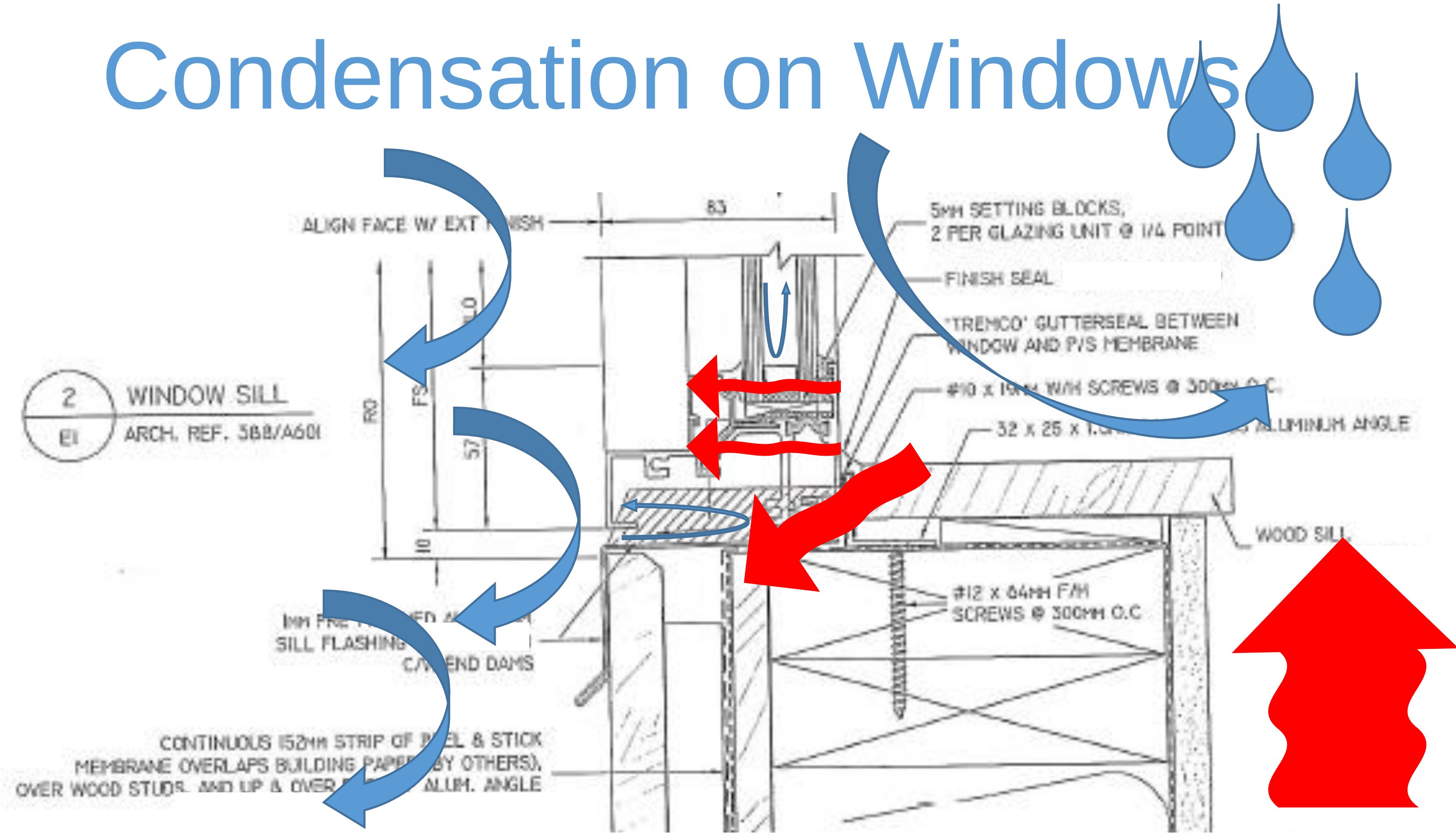


Fig. 1 ASHRAE Psychrometric Chart No. 1

Condensation on Windows



Condensation on Windows



The condensation resistance of fenestration systems is assessed by determining the product's Temperature Index (TI). TI is a non-dimensional parameter, which is defined as [3]:

$$TI = \frac{T_{sp} - T_c}{T_h - T_c} x100 \qquad (1)$$

where: T_{sp} specimen surface temperature, °C

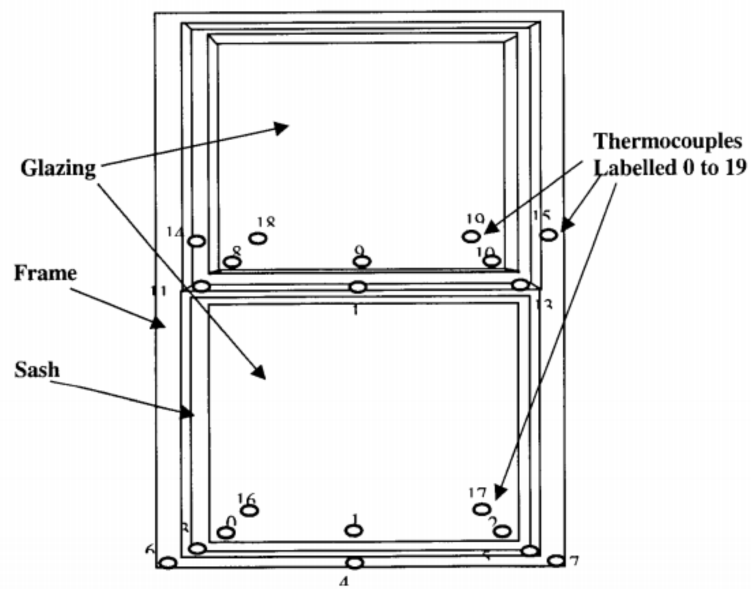
T_c weather (cold) side temperature, °C

T_h warm (room) side temperature, °C

T_{sp} is measured at specific locations on the glass, frame and sash members of the product, as shown in Figure 1. T_h and T_c. are measured at the main stream on the warm and cold side of the window, respectively.

T_h is maintained at 20±1°C, where as T_c is kept at -18±1°C. The film heat transfer coefficients were kept at 8±1 W/(m^2.K) on the warm side (natural convection) and at 30±2 W/(m^2.K) on the cold side. More details about the test procedure, sample mounting, data reduction and other specifics can be found in Reference 1.

The Temperature Index is determined for the glazing, frame and sash members of the unit, and lowest value is used to "rate" the window for condensation resistance.



https://c.ymcdn.com/sites/nfrccommunity.site-ym.com/resource/resmgr/technical_documents/nfrc_500-2010_e0a1.pdf

The final CR_c shall be calculated by area weighting these non-dimensional numbers for the center-of-glazing, divider, and edge-of-divider areas as given in Equation 4-2.

$$CR_c = \left\{ 1 - \left\{ \frac{\sum_k SS_{d_k} A_{d_k} + \sum_k SS_{deog_k} A_{deog_k} + \sum_k SS_{cog_k} A_{cog_k}}{\sum_k A_{d_k} + \sum_k A_{deog_k} + \sum_k A_{cog_k}} \right\}^{1/3} \right\} \times 100$$

Equation 4-2

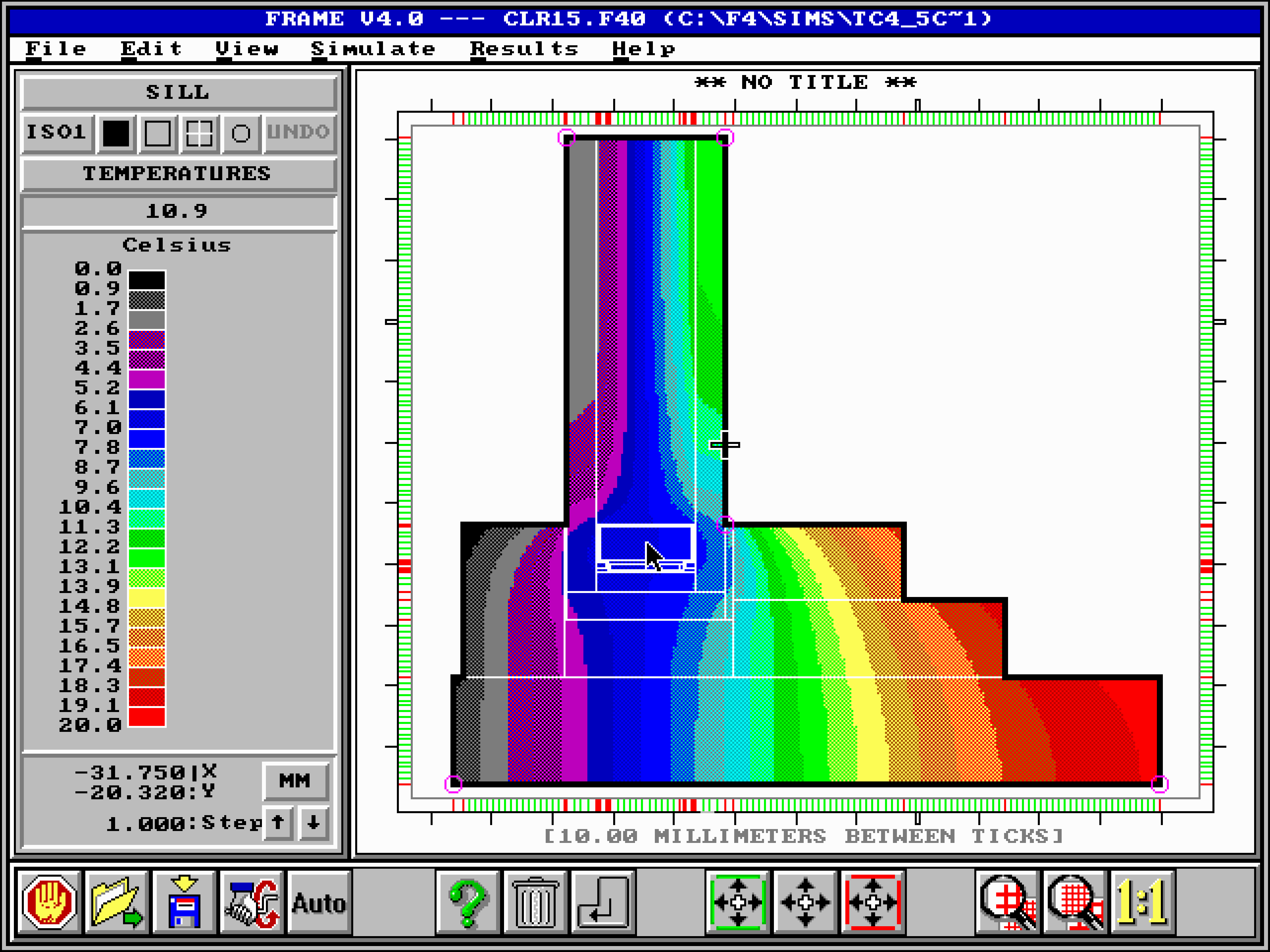
k=center-of-glazing, divider, edge-of-divider sections, respectively

Where for each frame cross-section, k:

$$SS_{d_k} = \frac{\sum_j (S_d)_{j=RH\,@30\%,50\%,70\%}}{3}$$

$$SS_{doeg_k} = \frac{\sum_j (S_{deog})_{j=RH\,@30\%,50\%,70\%}}{3}$$

$$SS_{cog_k} = \frac{\sum_j (S_{cog})_{j=RH\,@30\%,50\%,70\%}}{3}$$


FRAME V4.0 --- CLR15.F40 (C:\F4\SIMS\TC4_5C~1)
File Edit View Simulate Results Help
SILL
ISO1
UNDO
TEMPERATURES
10.9
Celsius
0.0
0.9
1.7
2.6
3.5
4.4
5.2
6.1
7.0
7.8
8.7
9.6
10.4
11.3
12.2
13.1
13.9
14.8
15.7
16.5
17.4
18.3
19.1
20.0
-31.750|X
-20.320:Y
MM
1.000:Step
** NO TITLE **
[10.00 MILLIMETERS BETWEEN TICKS]
Auto
1:1

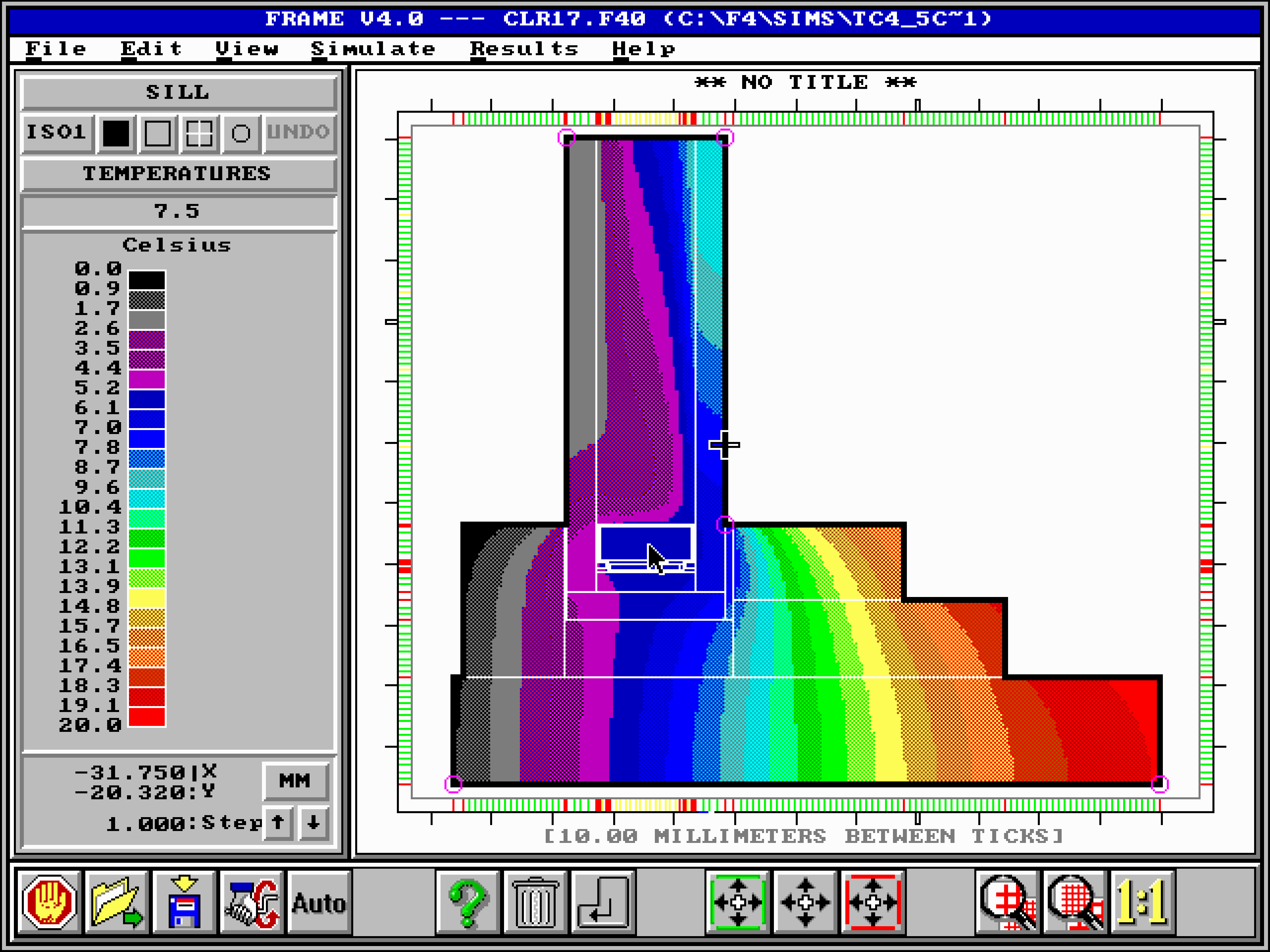
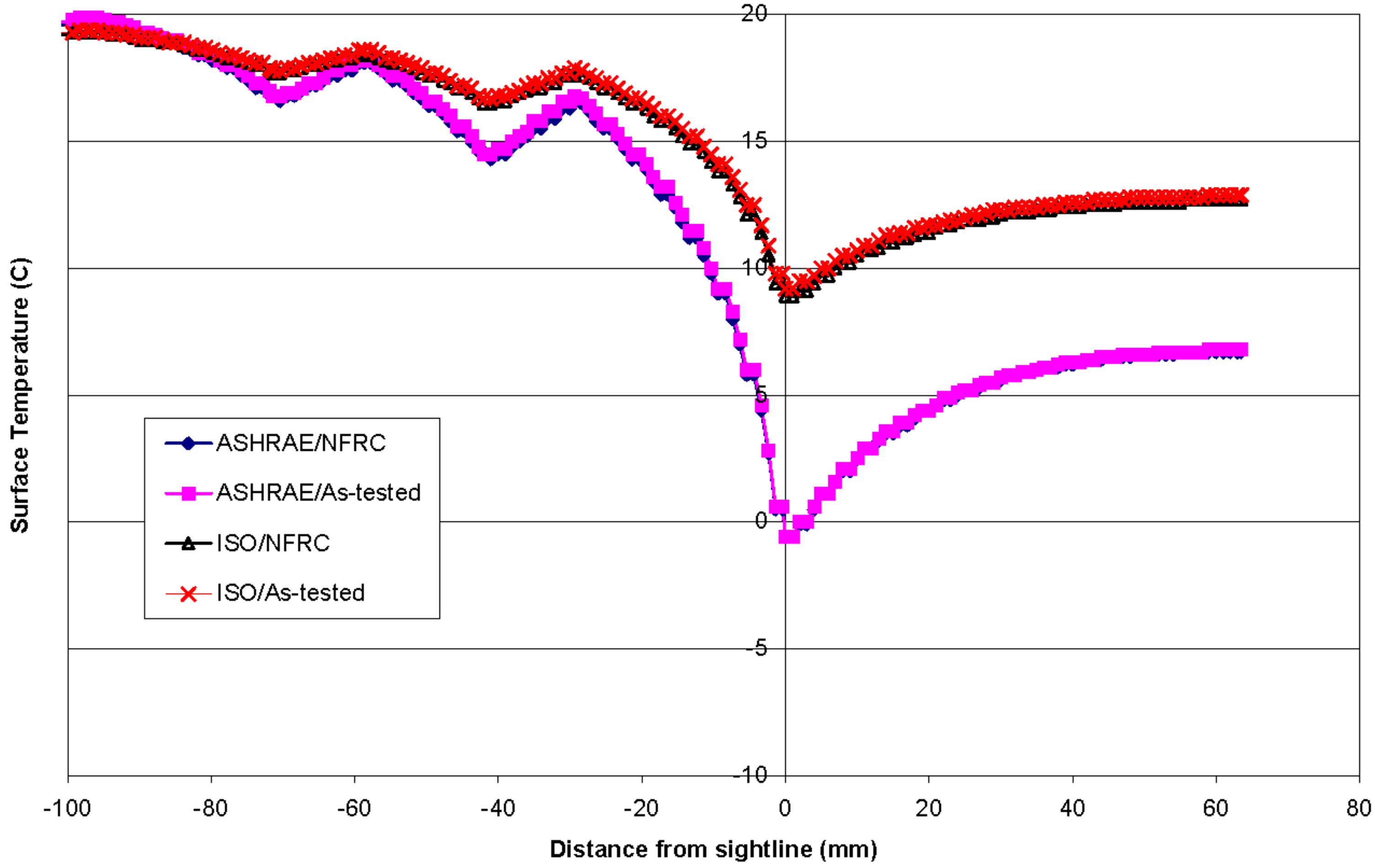

FRAME V4.0 --- CLR17.F40 (C:\F4\SIMS\TC4_5C~1)
File Edit View Simulate Results Help
SILL
ISO1
UNDO
TEMPERATURES
7.5
Celsius
0.0
0.9
1.7
2.6
3.5
4.4
5.2
6.1
7.0
7.8
8.7
9.6
10.4
11.3
12.2
13.1
13.9
14.8
15.7
16.5
17.4
18.3
19.1
20.0
-31.750|X
-20.320:Y
MM
1.000:Step
** NO TITLE **
[10.00 MILLIMETERS BETWEEN TICKS]
Auto
1:1

Figure 11. clrclr at Various Conditions



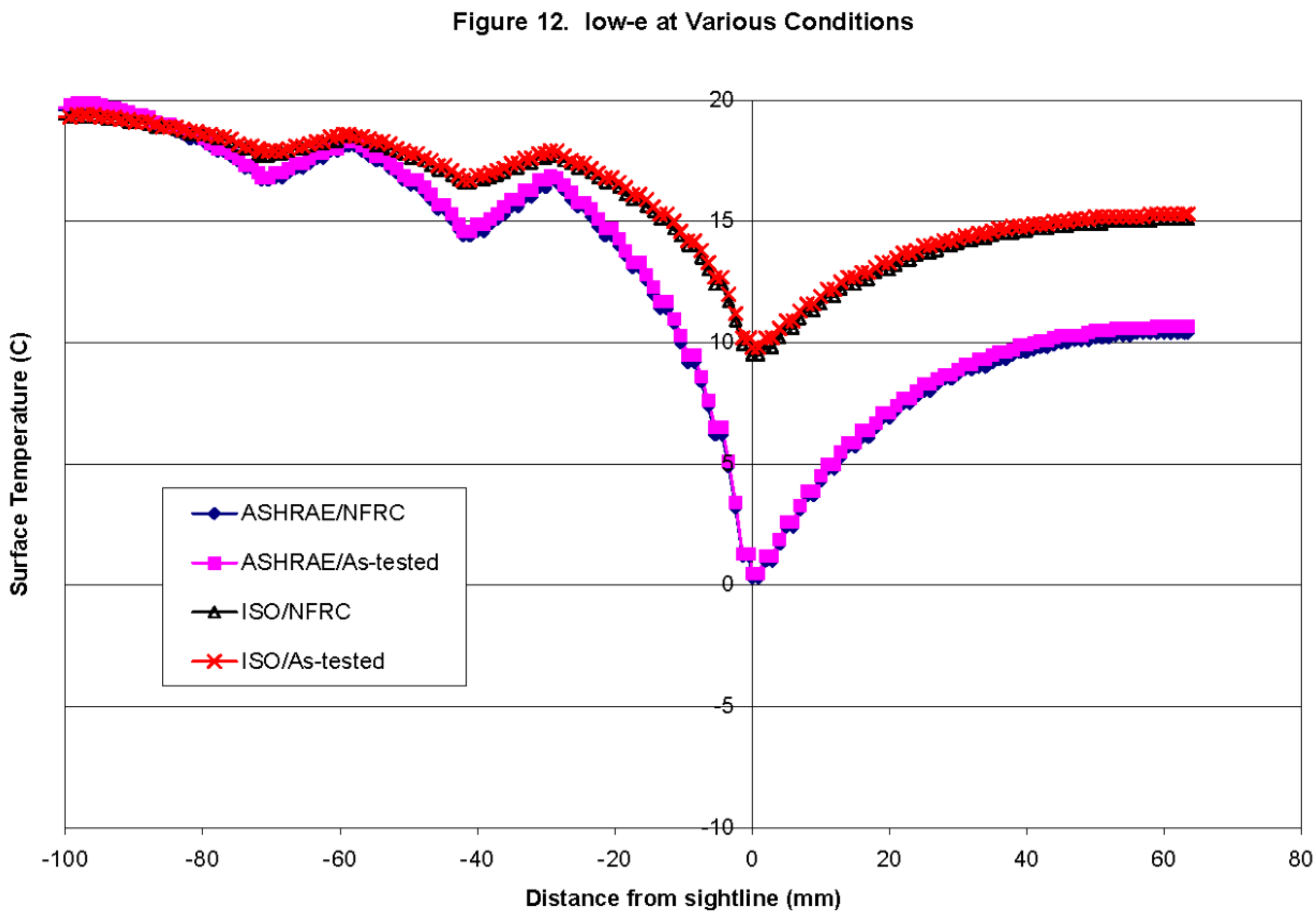


Figure 12. low-e at Various Conditions
Surface Temperature (C)
20
15
10
5
0
-5
-10
-100
-80
-60
-40
-20
0
20
40
60
80
Distance from sightline (mm)
ASHRAE/NFRC
ASHRAE/As-tested
ISO/NFRC
ISO/As-tested


THERMO
MEM
HYGRO
MIN
MAX
CLEAR
MIN
MAX
RadioShack
DIGITAL THERMO-HYGRO
LogTag
LogTag
INTERFACE
12 : 1
Distance : Target
CE
DAFM3

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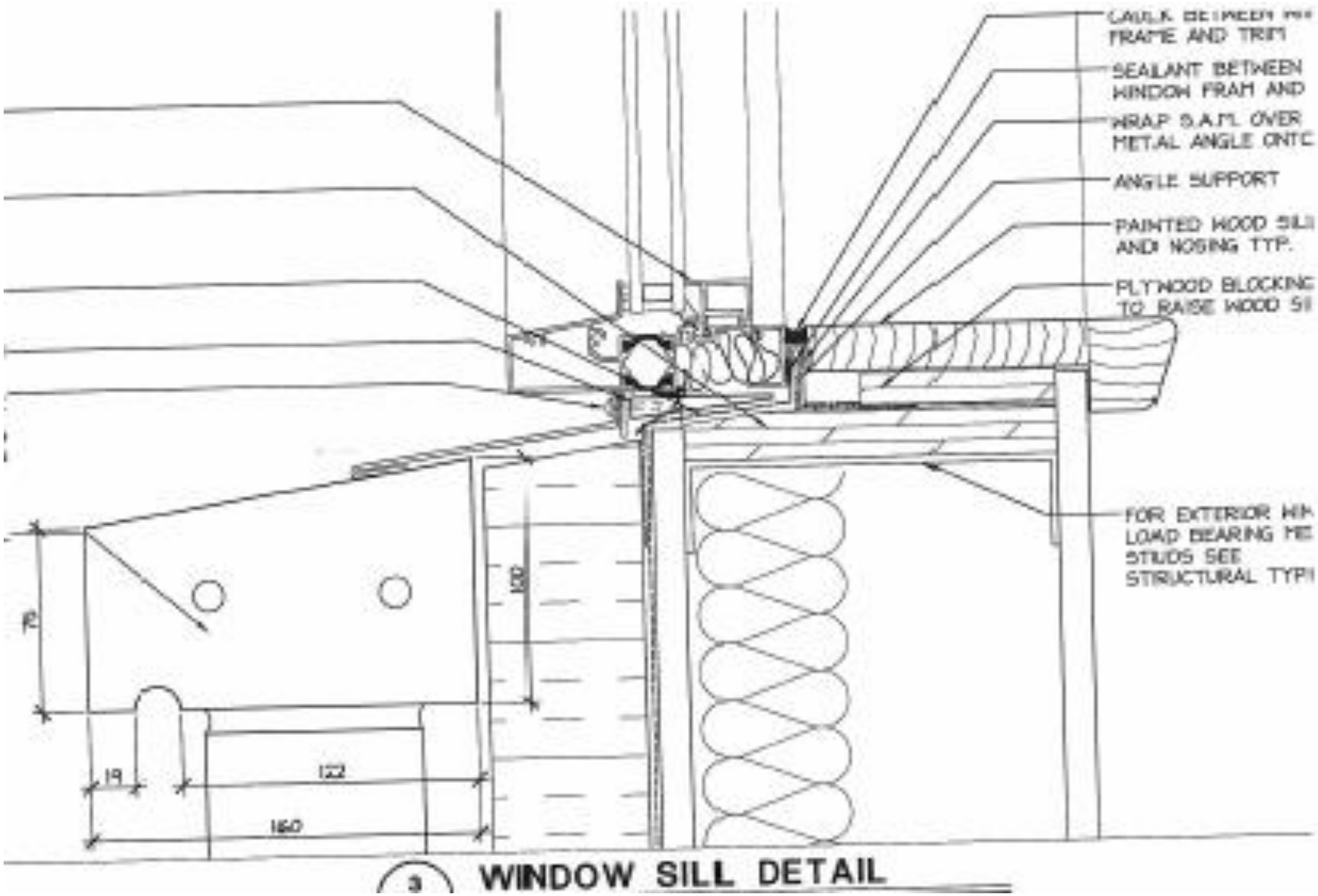
Case Study #1



FRAME AND TRIM
SEALANT BETWEEN
WINDOW FRAM AND
WRAP S.A.M. OVER
METAL ANGLE ONTC
ANGLE SUPPORT
PAINTED WOOD SIL
AND NOSING TYP.
PLYWOOD BLOCKING
TO RAISE WOOD SI
FOR EXTERIOR WI
LOAD BEARING ME
STUDS SEE
STRUCTURAL TYP
19
122
160
3
WINDOW SILL DETAIL

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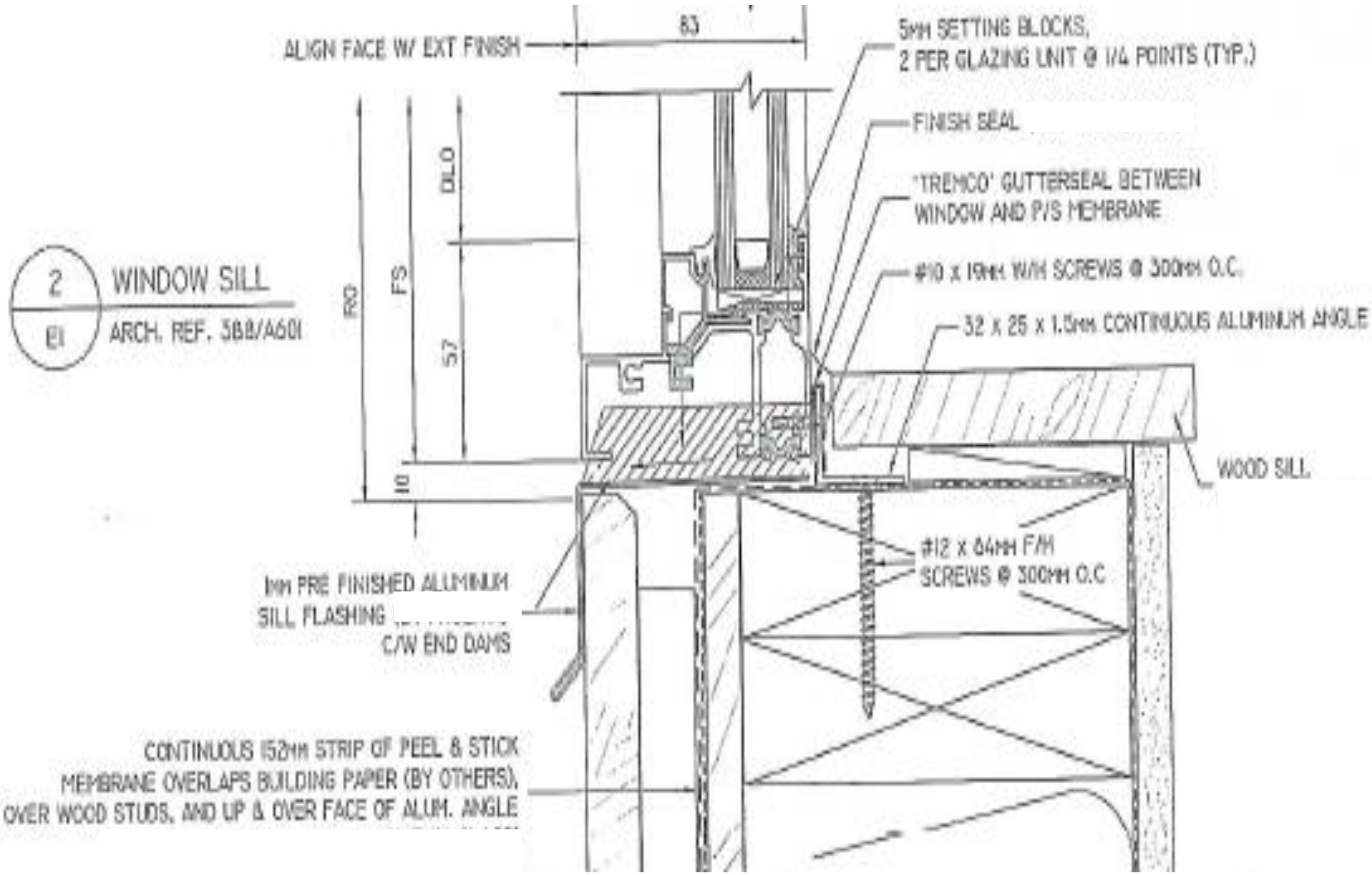
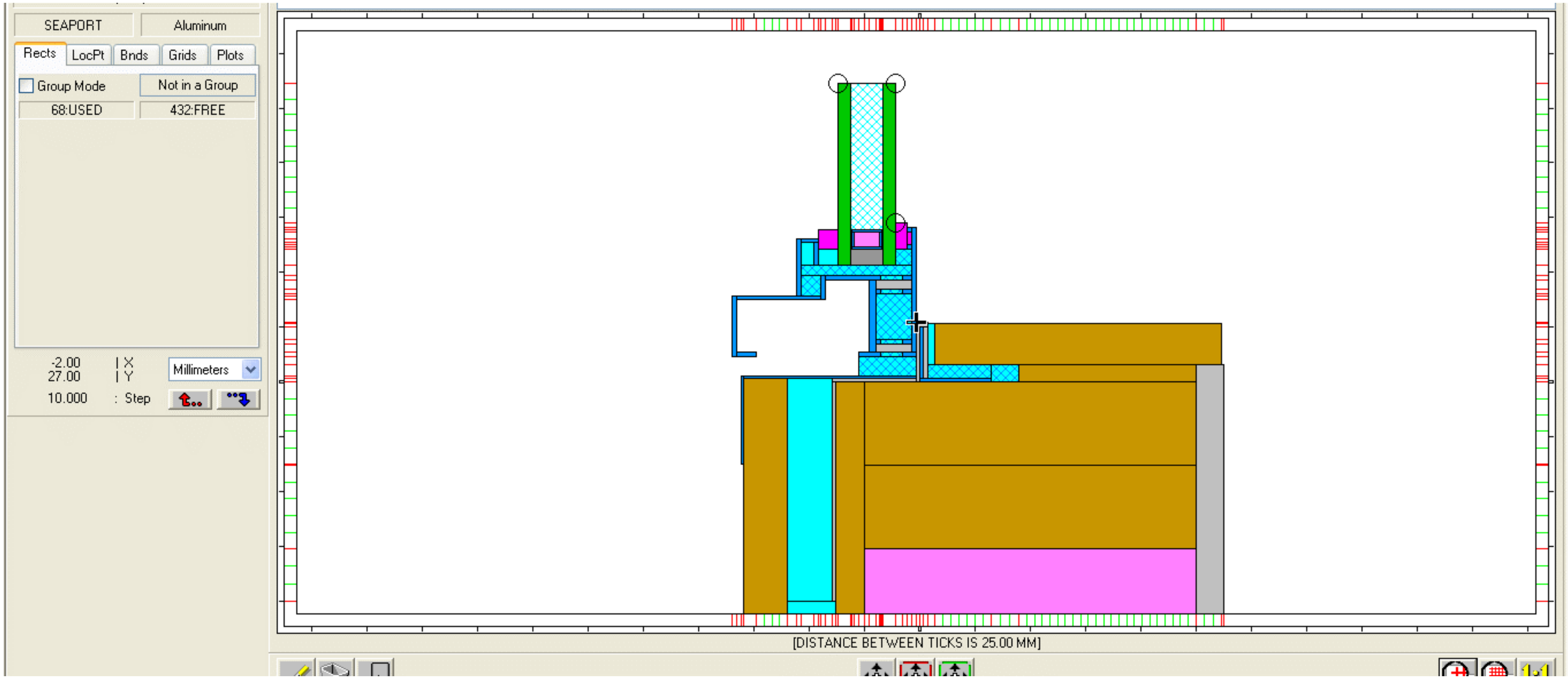
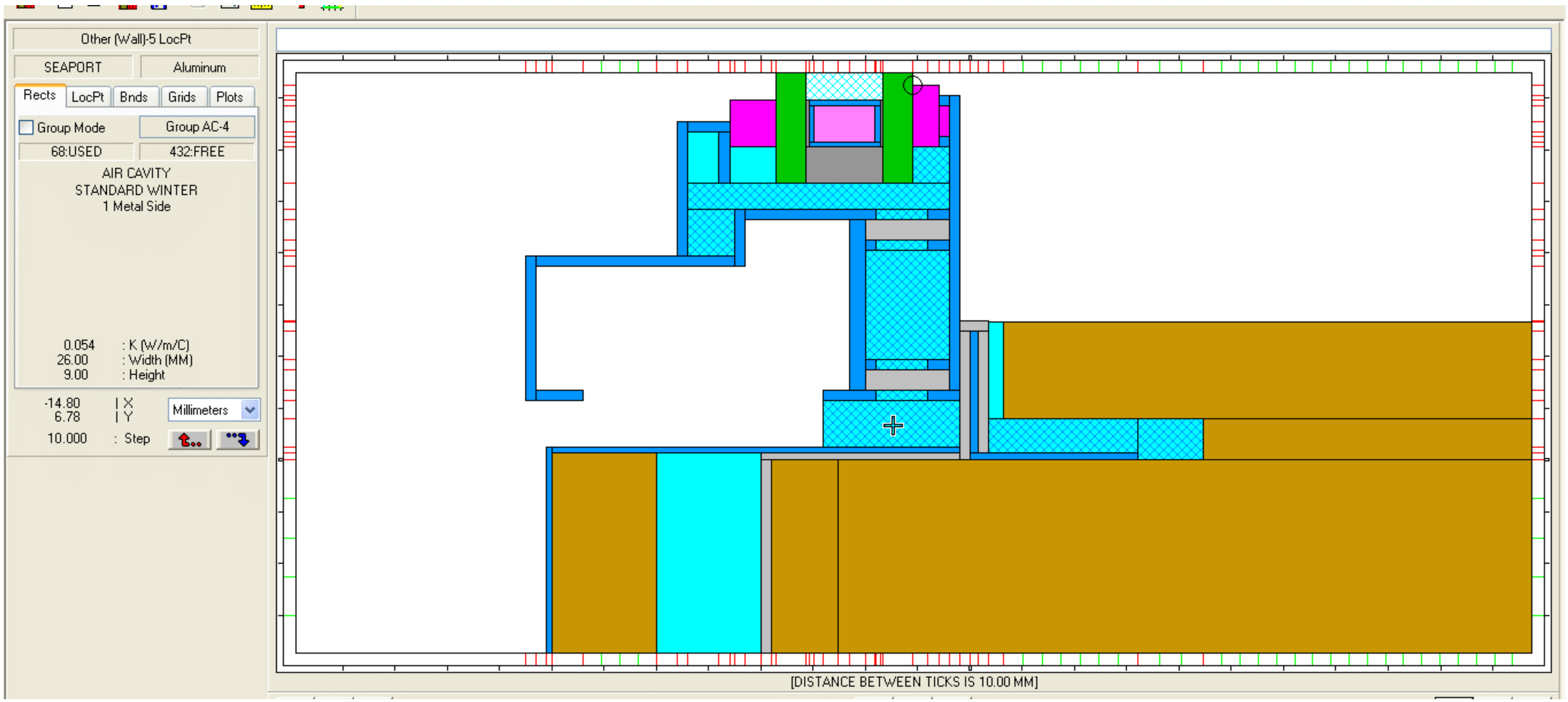
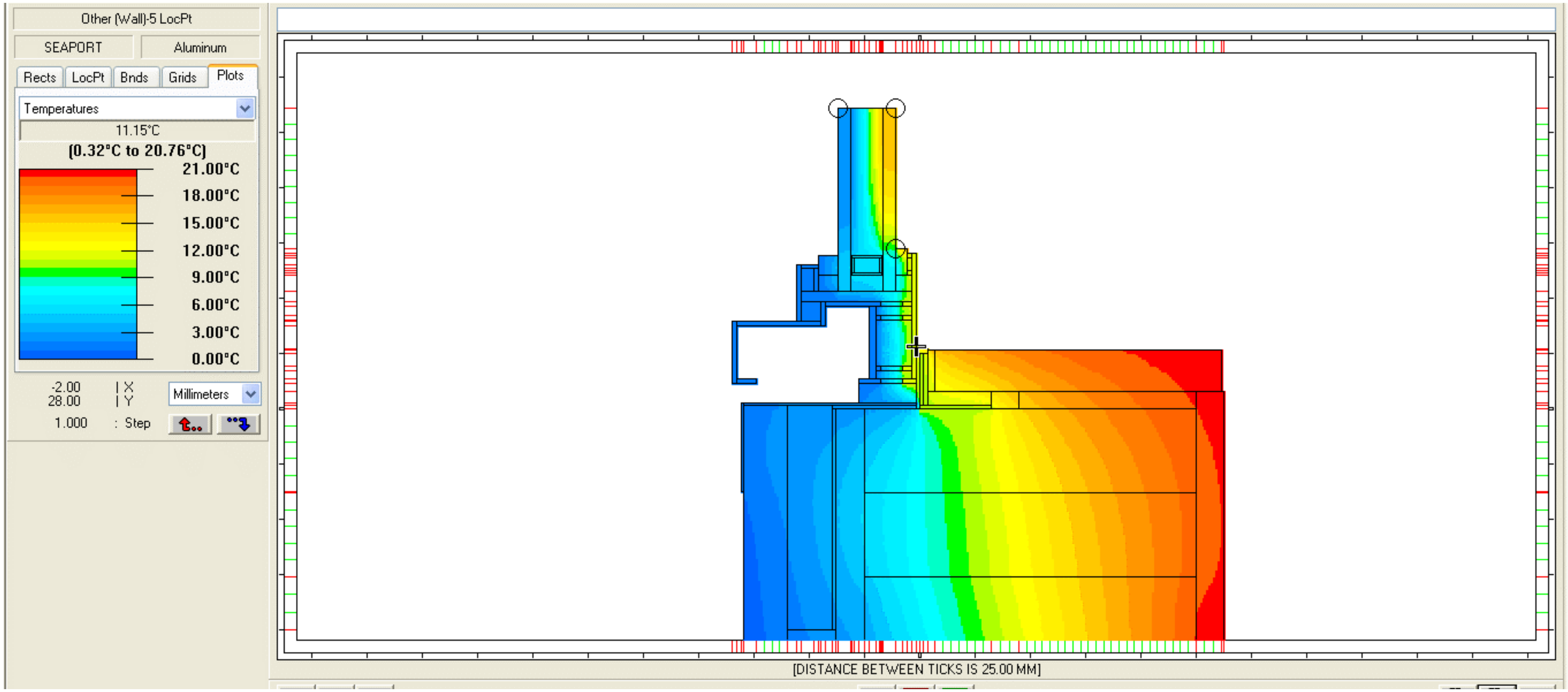

2
E1
WINDOW SILL
ARCH. REF. 388/A601
ALIGN FACE W/ EXT FINISH
83
DLO
FS
RO
57
10
5MM SETTING BLOCKS,
2 PER GLAZING UNIT @ 1/4 POINTS (TYP.)
FINISH SEAL
'TREMCO' GUTTERSEAL BETWEEN
WINDOW AND P/S MEMBRANE
#10 x 19MM W/H SCREWS @ 300MM O.C.
32 x 25 x 1.5MM CONTINUOUS ALUMINUM ANGLE
WOOD SILL
#12 x 64MM F/H
SCREWS @ 300MM O.C
1MM PRE FINISHED ALUMINUM
SILL FLASHING
C/W END DAMS
CONTINUOUS 152MM STRIP OF PEEL & STICK
MEMBRANE OVERLAPS BUILDING PAPER (BY OTHERS),
OVER WOOD STUDS, AND UP & OVER FACE OF ALUM. ANGLE



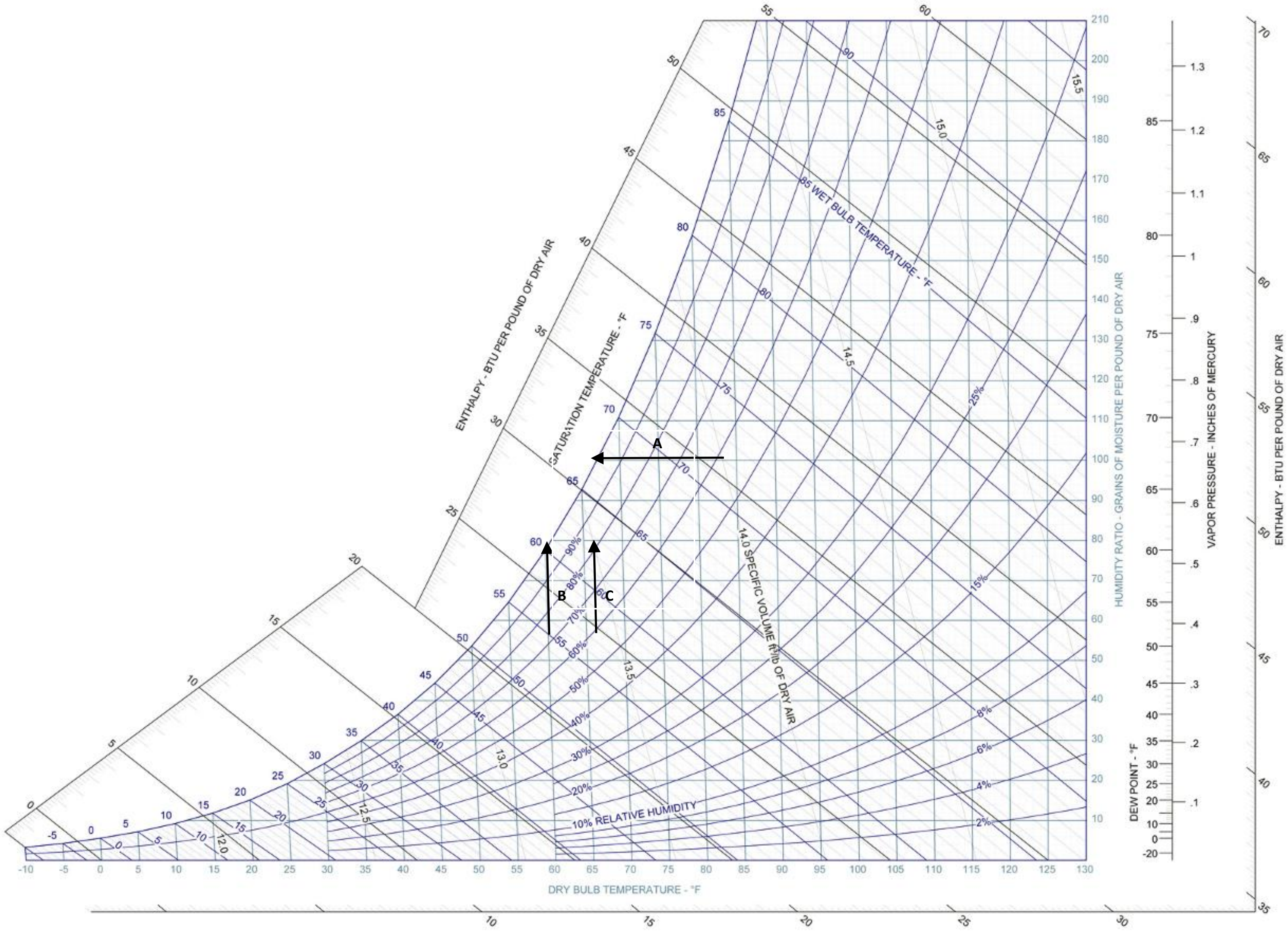
SEAPORT
Aluminum
Rects
LocPt
Bnds
Grids
Plots
Group Mode
Not in a Group
68:USED
432:FREE
-2.00 | X
27.00 | Y
Millimeters
10.000 : Step
[DISTANCE BETWEEN TICKS IS 25.00 MM]



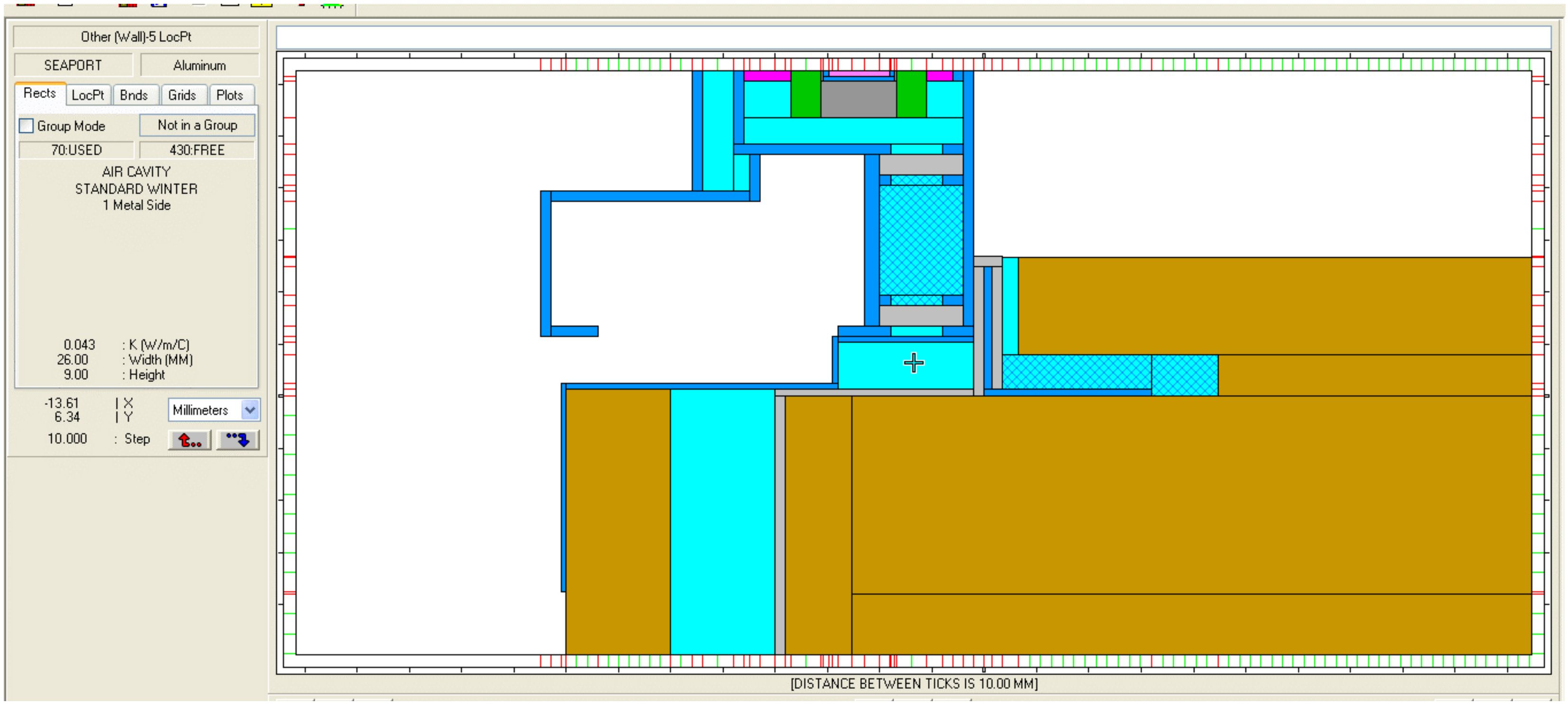
Other (Wall)-5 LocPt
SEAPORT
Aluminum
Rects
LocPt
Bnds
Grids
Plots
Group Mode
Group AC-4
68:USED
432:FREE
AIR CAVITY
STANDARD WINTER
1 Metal Side
0.054 : K (W/m/C)
26.00 : Width (MM)
9.00 : Height
-14.80 | X
6.78 | Y
Millimeters
10.000 : Step
[DISTANCE BETWEEN TICKS IS 10.00 MM]

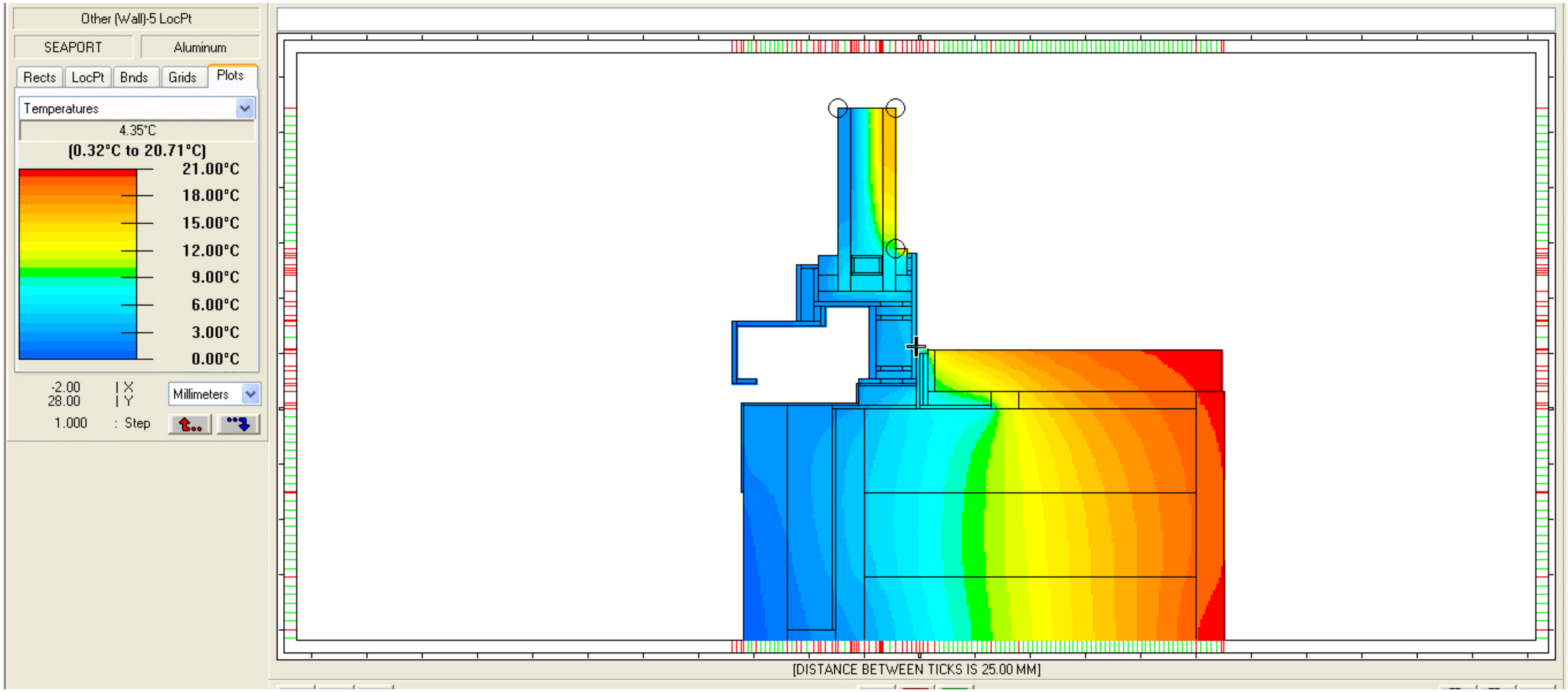


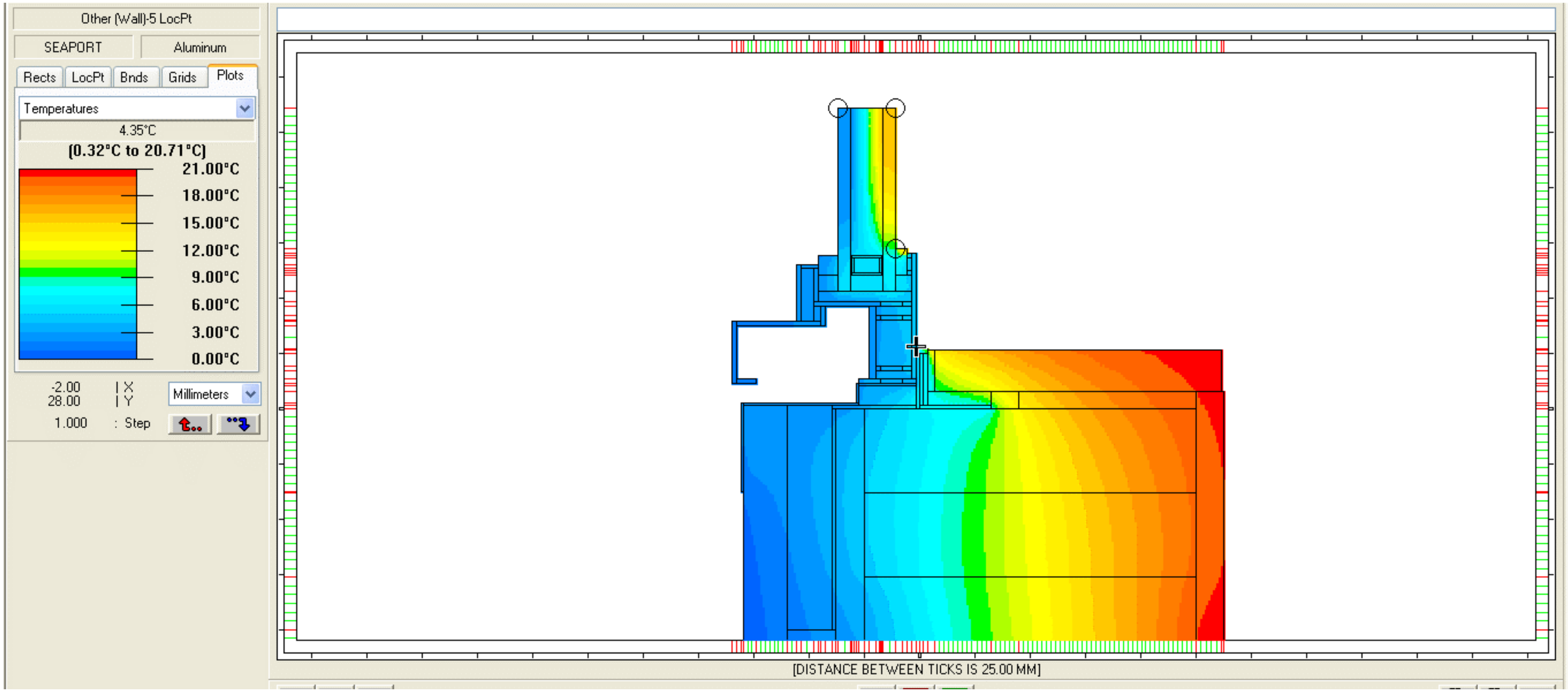
Other (Wall)-5 LocPt
SEAPORT
Aluminum
Rects
LocPt
Bnds
Grids
Plots
Temperatures
11.15°C
(0.32°C to 20.76°C)
21.00°C
18.00°C
15.00°C
12.00°C
9.00°C
6.00°C
3.00°C
0.00°C
-2.00
28.00
X
Y
Millimeters
1.000
Step
[DISTANCE BETWEEN TICKS IS 25.00 MM]



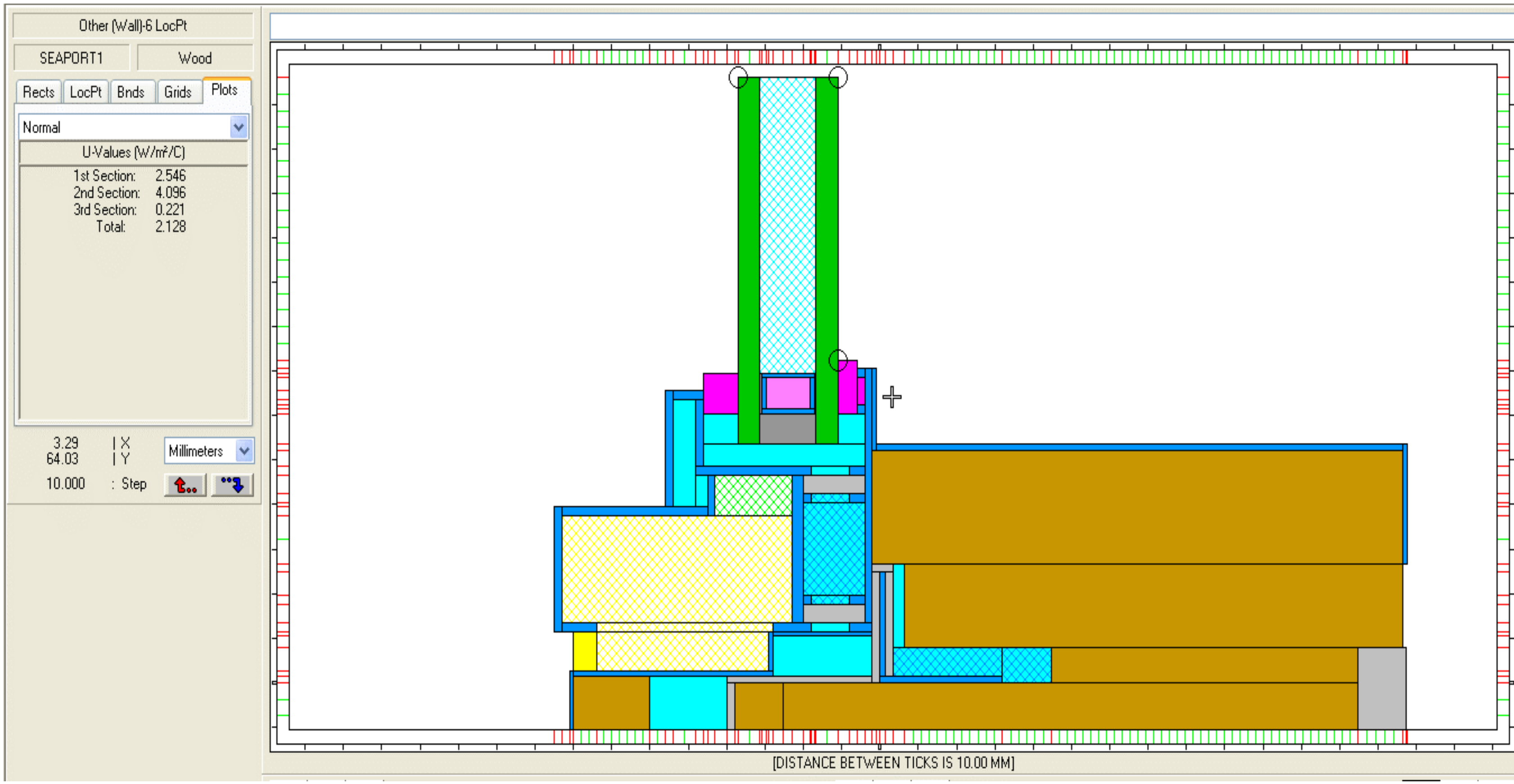
ENTHALPY - BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE - °F
85 WET BULB TEMPERATURE - °F
14.0 SPECIFIC VOLUME ft³/lb OF DRY AIR
10% RELATIVE HUMIDITY
HUMIDITY RATIO - GRAINS OF MOISTURE PER POUND OF DRY AIR
DEW POINT - °F
VAPOR PRESSURE - INCHES OF MERCURY
DRY BULB TEMPERATURE - °F
A
B
C


Other (Wall)-5 LocPt
SEAPORT
Aluminum
Rects
LocPt
Bnds
Grids
Plots
Group Mode
Not in a Group
70:USED
430:FREE
AIR CAVITY
STANDARD WINTER
1 Metal Side
0.043 : K (W/m/C)
26.00 : Width (MM)
9.00 : Height
-13.61 | X
6.34 | Y
Millimeters
10.000 : Step
[DISTANCE BETWEEN TICKS IS 10.00 MM]


Other (Wall)-5 LocPt
SEAPORT
Aluminum
Rects
LocPt
Bnds
Grids
Plots
Temperatures
4.35°C
[0.32°C to 20.71°C]
21.00°C
18.00°C
15.00°C
12.00°C
9.00°C
6.00°C
3.00°C
0.00°C
-2.00 | X
28.00 | Y
Millimeters
1.000 : Step
[DISTANCE BETWEEN TICKS IS 25.00 MM]



Other (Wall)-5 LocPt
SEAPORT
Aluminum
Rects
LocPt
Bnds
Grids
Plots
Temperatures
4.35°C
[0.32°C to 20.71°C]
21.00°C
18.00°C
15.00°C
12.00°C
9.00°C
6.00°C
3.00°C
0.00°C
-2.00 | X
28.00 | Y
Millimeters
1.000 : Step
[DISTANCE BETWEEN TICKS IS 25.00 MM]


Other (Wall)-6 LocPt
SEAPORT1
Wood
Rects
LocPt
Bnds
Grids
Plots
Normal
U-Values (W/m²/C)
1st Section: 2.546
2nd Section: 4.096
3rd Section: 0.221
Total: 2.128
3.29 | X
64.03 | Y
Millimeters
10.000 : Step
[DISTANCE BETWEEN TICKS IS 10.00 MM]

Option	Configuration	Sill Temperature	Difference from base case
0	Base case (as discovered)	12.0 °C	-
1	Remove backleg of sill flashing, reduce thermal bridge	12.1	0.1 °C
2	Lower interior sill liner to expose sill frame	12.4	0.4
3	Close in exterior cavity to reduce wind-washing (+ Option 2)	13.4	1.4
4	Separate sill flashing from frame (+ Option 2)	16.3	4.3
5	Separate sill flashing from frame (+ Options 2 and 3)	16.6	4.6
6	Remove sill flashing from interior frame (+ Option 2)	17.4	5.4
7	Remove sill flashing from interior frame (+ Options 2 and 3)	17.6	5.6
8	Heat sink on the horizontal face of the sill liner	15.5	3.5
9	Heat sink on horizontal and vertical faces of the sill liner	15.8	3.8
10	Base case, but with interior blinds closed	10.6	-1.4

Time of measurement	Room air temperature	Relative humidity	Dew-point Temperature
09:35	23 °C	73%	17.8 °C
10:20	22 °C	64%	15.2 °C
10:40	21.5 °C	61%	13.5 °C

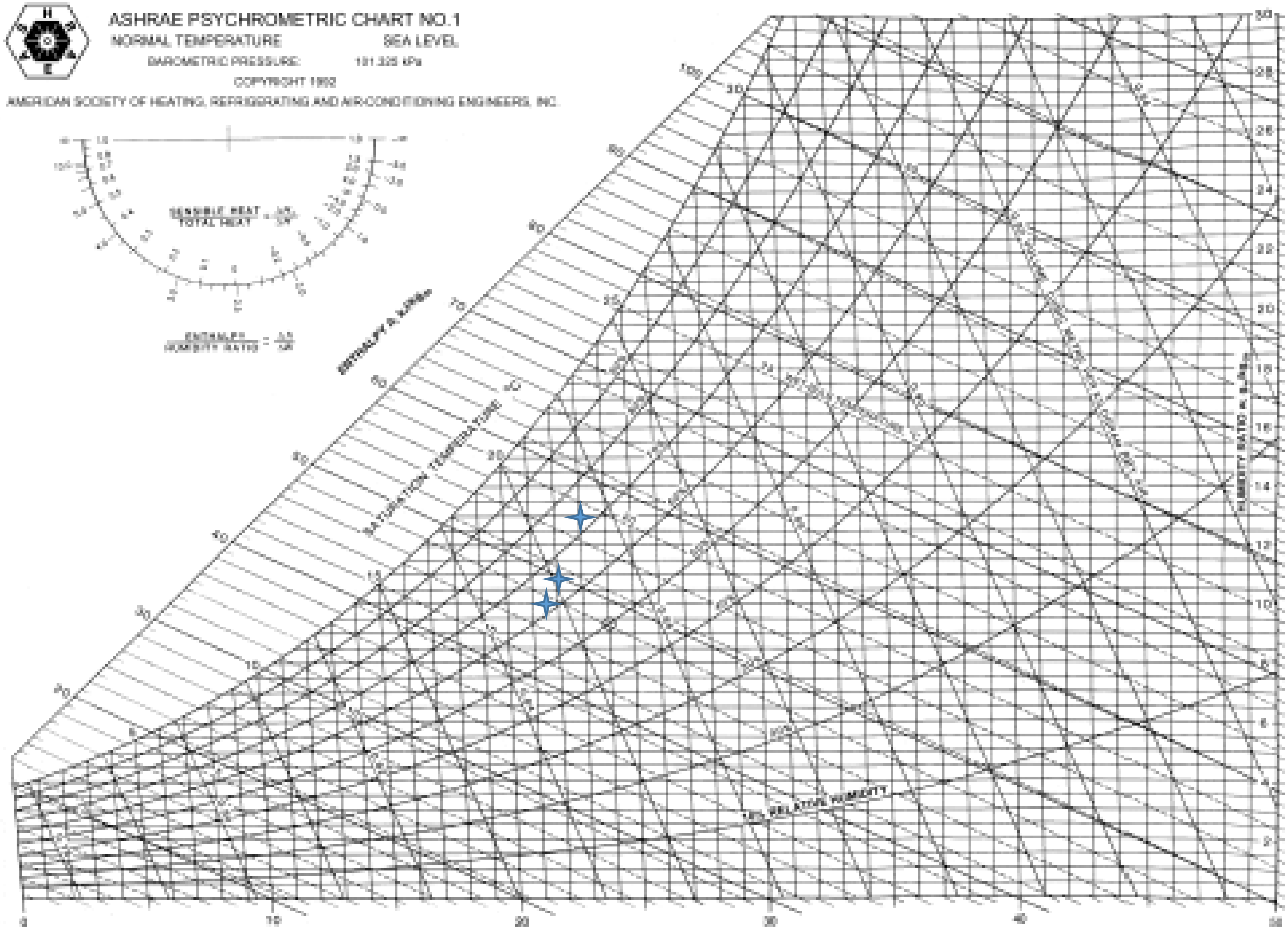


Fig. 1 ASHRAE Psychrometric Chart No. 1

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$$Q = E\ F\ A\ \sigma\ (T_h^4 - T_c^4)$$

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Questions?