VALIDATION OF THE CONDENSATION FEATURE (TRISCO) ACCORDING TO ASHRAE HANDBOOK

1. Introduction

Vapour pressure profile (Glaser or Dew-point) analysis of ASHRAE (2013) handbook contains 2 examples of an interstitial condensation calculation.

The following validation examples will be simulated with the CONDENSATION feature in the software TRISCO.

2. Example 8 (page 27.8): Typical wood-framed assembly

EX8.trc

Example 8 from the ASHRAE Handbook outlines a calculation process for determining the risk for interstitial condensation under winter conditions. The example assumes a monthly mean condition of 21°C, RH 40% indoors and −6.6°C, RH 50% outdoors. The corresponding indoor and outdoor vapour pressures are given as 995 Pa and 175 Pa, respectively. The wall of instance is a typical wood-framed assembly, as illustrated in Figure 1.

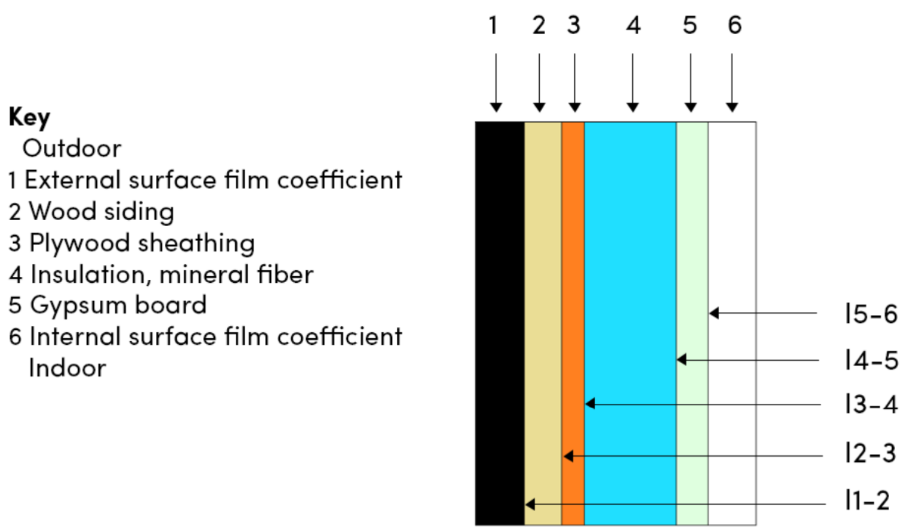


Figure 1. Wall layers and interfaces

The material input parameters in TRISCO software are the thermal conductivity (λ-value) and vapour diffusion resistance factor (μ-value). However, ASHRAE lists the properties in terms of overall thermal resistance (R) and vapour diffusion resistance (Z), without mentioning the layer thickness. Therefore we first convert these to a material thickness (d), thermal conductivity (λ) and vapour diffusion resistance factor (μ).

a. Calculation steps:

- Step 1: Assign Conductivity Values:
  The thermal conductivity (λ) for each material in the wall assembly must be assigned based on typical values for wood, insulation, and other building materials.

- Step 2: Calculate Material Thickness:
  Once the thermal conductivity is assigned, the thickness (d) of each material can be calculated from the given thermal resistance (R) using the formula:
$$R = \frac{d}{\lambda}$$
- Step 3: Calculate the μ value:
  The vapour diffusion resistance (Z) is provided, and from this, the equivalent air layer thickness (μ.d) can be calculated. The vapour diffusion resistance is given in m^2.s.Pa/ng, so, we first convert to Pa.s.m^2/kg by dividing by 10^{12} (1 kg = 10^{12} ng). From that the μ-value can be derived by the relationship between Z and μ.d:
$$Z = \frac{\mu . d}{\delta a}$$

  With Z (Pa.s.m^2/kg), d(m) and δ_a vapour permeability of air (2.10^{-10} kg/(m.s.Pa).

After calculations, we will obtain the thickness, conductivity, and μ value as shown in the table.

	Air film / Material	Thermal resistance R (m2.K/W)	Thermal conductivity λ (W/mK)	Vapour diffusion resistance Z (Pa.s.m2/ng)	Thickness d (m)	Water vapor resistance factor μ (-)	Color code
	Outside				1.000		170
1	Surface film coefficient	0.03	1	0.00002	0.030	0.13	0
2	Wood siding	0.18	0.13	0.0005	0.023	4.27	15
3	Plywood sheathing	0.11	0.13	0.03448	0.014	482.24	124
4	Insulation	1.9	0.03	0.00059	0.057	2.07	133
5	Gypsum board	0.08	0.25	0.00345	0.020	34.50	161
6	Surface film coefficient	0.12	0.25	0.000109	0.030	0.73	1
	Inside				1.000		174

Figure 2. Material properties

In the European standard (EN ISO 13788) and thus in TRISCO, film surfaces for diffusion are neglected, whereas ASHRAE handbook take this resistance into account for surface layers. In order to account for these surface resistances for vapour diffusion, an artificial material is inserted between the surface and the boundary conditions. These blocks have a thermal conductivity and thickness corresponding to the given surface heat transfer resistance and a μ-value matching the given surface resistance for vapour diffusion.

b. Boundary Conditions and Setup in TRISCO

For the reason outlined in the previous paragraph the boundary conditions are then imposed (via type BC_SIMPL) with high heat transfer surface coefficients to ensure surface temperatures on blocks used as 'artificial' surface coefficients.

The Condensation calculation feature must be enabled in Settings.

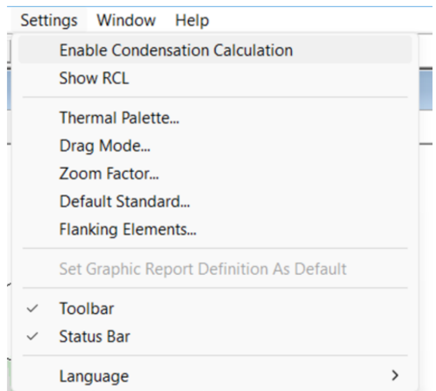


Figure 3. Condensation calculation feature

Within the TRISCO software, for each material layer, the calculated conductivity and μ value are manually inserted. While the software provides a material library, custom values can be set to ensure the materials match those used in the analysis as in Figure 5.

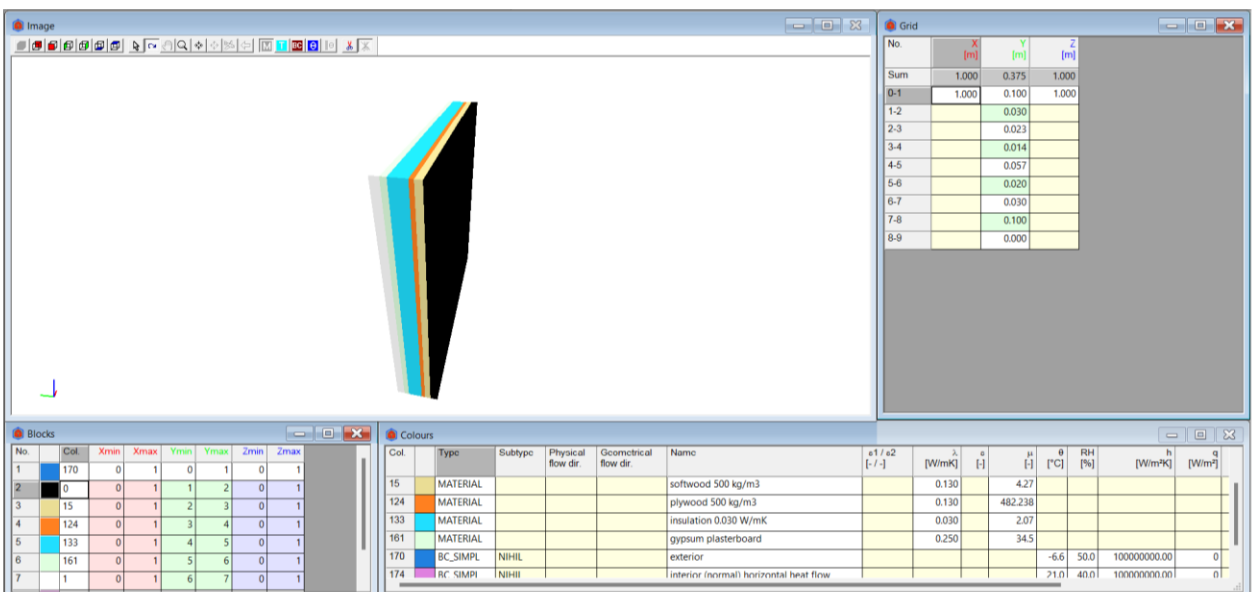
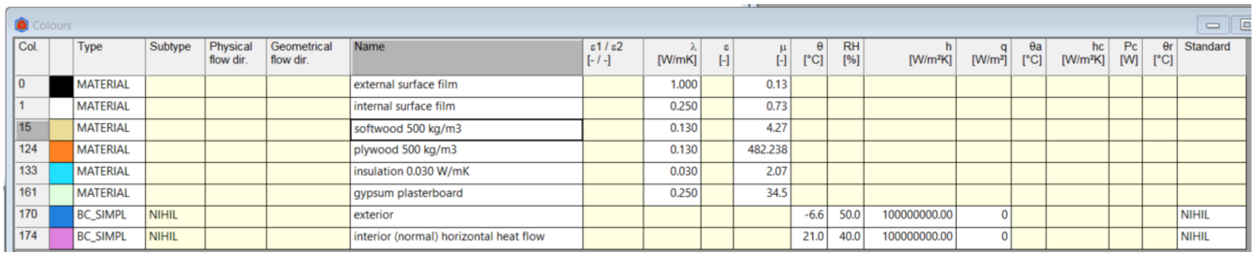


Figure 4. Material properties in TRISCO



Col.		Type	Subtype	Physical flow dir.	Geometrical flow dir.	Name	ε1 / ε2 [- / -]	λ [W/mK]	ε [-]	μ [-]	θ [°C]	RH [%]	h [W/m²K]	q [W/m²]	θa [°C]	hc [W/m²K]	Pc [W]	θr [°C]	Standard
0		MATERIAL				external surface film		1.000		0.13									
1		MATERIAL				internal surface film		0.250		0.73									
15		MATERIAL				softwood 500 kg/m3		0.130		4.27									
124		MATERIAL				plywood 500 kg/m3		0.130		482.238									
133		MATERIAL				insulation 0.030 W/mK		0.030		2.07									
161		MATERIAL				gypsum plasterboard		0.250		34.5									
170		BC_SIMPL	NIHIL			exterior					-6.6	50.0	100000000.00	0					NIHIL
174		BC_SIMPL	NIHIL			interior (normal) horizontal heat flow					21.0	40.0	100000000.00	0					NIHIL

Figure 5. Material properties setup

The vapour permeability of air is set to 2.10^{-10} kg/(m.s.Pa) and condensation only on surface (Calculation parameters).

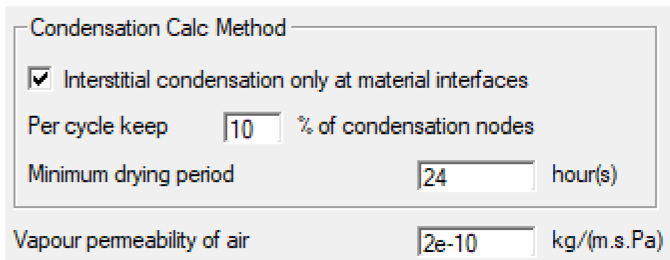


Figure 6. Condensation Calculation parameters

c. Simulation and Results

After running the analysis in TRISCO, the graphical output will highlight the layers where moisture accumulates, in this case interface 3-4 between plywood sheathing layer and insulation.

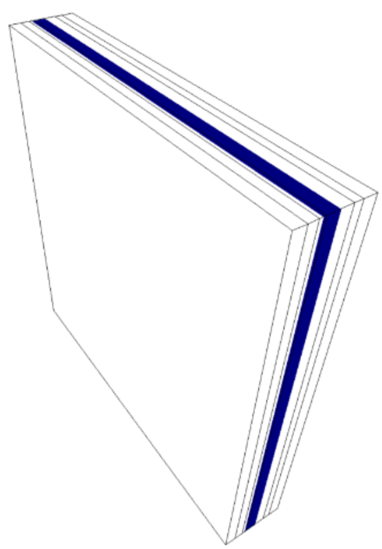


Figure 7. Graphic output in TRISCO

The report generated by TRISCO provides a detailed breakdown of the condensation amounts. In this example, the total amount of accumulated water over a 30-day period is calculated to be **300 grams**, which exactly aligns with the results given in the ASHRAE Handbook.

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TRISCO - Interstitial Condensation Calculation Results

TRISCO data file: EX8.trc

Number of nodes = 28
Vapour flow divergence for total object = 2.05067e-13 %
Vapour flow divergence for worst node = 8.45091e-11 %

Net interstitial condensation rate in entire object (last calculation period)
Condensation - evaporation = 300.049 g/(30 days)
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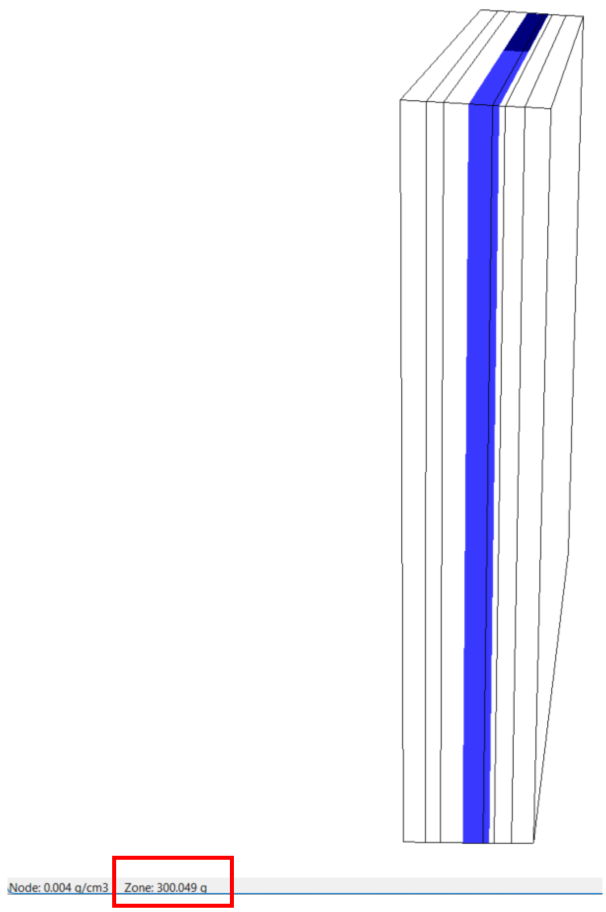

Figure 8. Output in TRISCO

3. Example 9 (page 27.9): Typical wood-framed assembly with moisture accumulation.

EX9 _Winter.trc
EX9 _Summer.trc

A wood-framed construction experienced moisture accumulation in the OSB sheathing due to rain infiltration around the windows, resulting in an excess moisture content of up to 4.8 kg/m^2. The goal of this validation example is to determine the drying rate of the OSB. Two different monthly conditions were analysed: winter (21°C, 40% RH indoors, -6.6°C, 50% RH outdoors) and summer (25°C, 70% RH indoors, 23°C, 70% RH outdoors). The wall structure is illustrated in Figure 9.

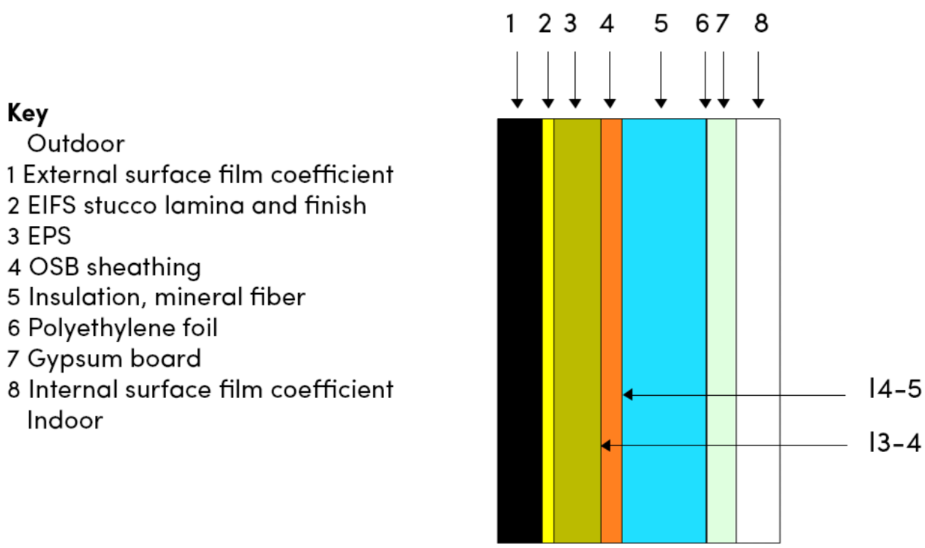

Figure 9. Wall layers and interfaces

Following the approach outlined in Example 8, material properties such as conductivity and vapour resistance values (μ-values) were calculated as the table below.

	Air film / Material	Thermal resistance R (m2.K/W)	Thermal conductivity λ (W/mK)	Vapour diffusion resistance Z (Pa.s.m2/ng)	Thickness d (m)	Water vapor resistance factor μ (-)	Color code
	Outside				1		170
1	Surface film coefficient	0.030	1	0.00002	0.030	0.13	0
2	EIFS stucco	0.010	0.8	0.005	0.008	125	7
3	EPS	1.000	0.032	0.014	0.032	87.50	151
4	OSB sheathing	0.055	0.22	0.034	0.012	561.98	124
5	Insulation, mineral fiber	1.900	0.03	0.001	0.057	3.51	133
6	Polyethylene	0.001	0.33	2.299	0.0002	2299000	46
7	Gypsum board	0.079	0.25	0.003	0.020	30.38	161
8	Surface film coefficient	0.120	0.25	0.0001	0.030	0.67	1
	Inside				1		174

Figure 10. Calculated material properties

By clicking in Edit → Initial Moisture, TRISCO allows for the input of excess moisture and its specific location within the layers.

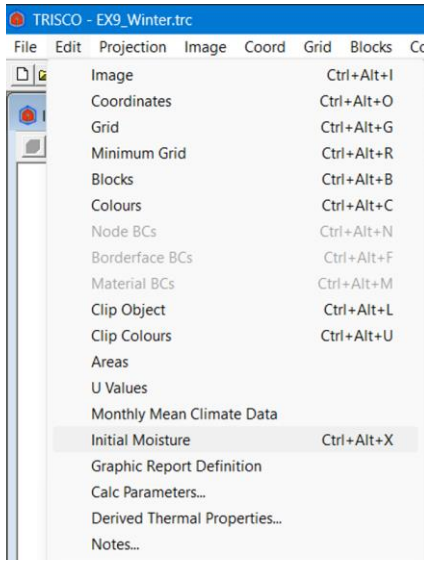

Figure 11. Enable Initial moisture

The excess moisture content of **4.8kg/m²** (or 4800g/m²) was imposed at interface 3-4, between OBS sheathing (colour code 151) and EPS (colour code 124).

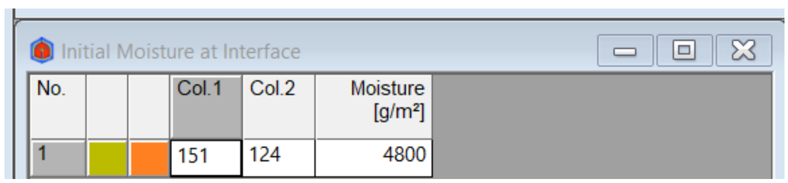

Figure 12. Initial Moisture input

The simulation was run for one month to assess the drying process. Evaporation was shown at the inferface between colour 151 and 124 in Graphic Output.

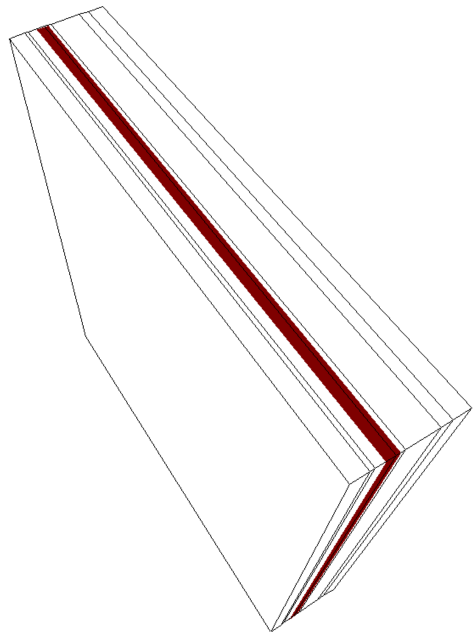

Figure 13. Evaporation in TRISCO Graphic Output

In the Graphic Output and Text Output, the amount of evaporation in the 30 days period in winter is **74 g/m^2**, in accordance with ASHRAE handbook result.

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TRISCO - Interstitial Condensation Calculation Results

TRISCO data file: EX9_Winter.trc

Number of nodes = 36
Vapour flow divergence for total object = 9.20553e-10 %
Vapour flow divergence for worst node = 7.47237e-08 %

Net interstitial condensation rate in entire object (last calculation period)
Condensation - evaporation = -74.4517 g/(30 days)
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Figure 14. TRISCO Output in winter case

Similarly, the simulation was repeated for summer conditions for which a drying rate of 130 $g/m^2/30$ day is found. This also matched the results from the ASHRAE Handbook.