DERIVING THE MINIMAL TEMPERATURE FACTOR TO AVOID SURFACE CONDENSATION ACCORDING TO EN ISO 13788

1. Introduction

A practical implementation of the standard EN ISO 13788:2012 "Hygrothermal performance of building components and building elements — Internal surface temperature to avoid critical surface humidity and interstitial condensation — Calculation methods" is discussed.

2. Indoor climate classes

For maritime[1] climates EN ISO 13788 defines 5 classes of internal humidity load (Figure 1 and Table 1). For condensation risk evaluation it is recommended to use the upper borders (for example border 4-5 (red line) for class 4).

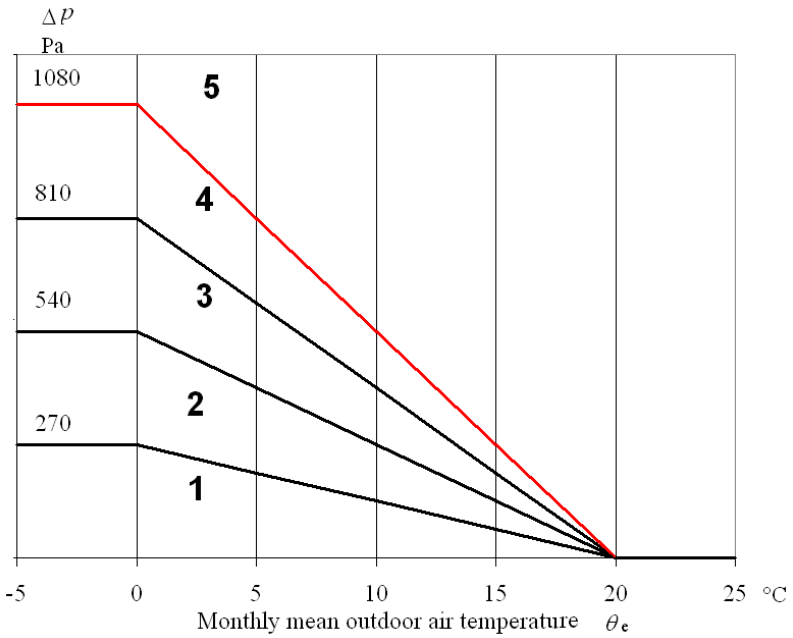


Figure 1. Indoor-outdoor vapour pressure difference as a function of the outdoor temperature for the 5 humidity classes according to EN ISO 13788:2012.

Humidity class	Building
1	Unoccupied buildings, storage of dry goods
2	Offices, dwellings with normal occupancy and ventilation
3	Buildings with unknown occupancy
4	Sports halls, kitchens, canteens
5	Special buildings, e.g. laundry, brewery, swimming pool

Table 1. Relation between humidity class and building type.2

[1] Also continental and tropical climates are discussed in the standard.

3. Minimum temperature factor at the internal surface to avoid critical surface humidity.

The minimal temperature factor $f_{Rsi,min}$ required to avoid critical surface condensation depends on the following parameters:

1) The *outdoor temperature.*
2) The *outdoor humidity* (relative humidity or vapour pressure).
3) The *indoor temperature.*
4) The *indoor humidity* (relative humidity or vapour pressure) or the *humidity class*: indeed from the parameters 1-3 and the climate class, the indoor humidity can be calculated.
5) The *maximum acceptable relative humidity at the surface.*

The spreadsheet file Surface_Condensation_EN_ISO_13788_Climate_Creator.xlsm allows to calculate $f_{Rsi,min}$ as a function of these parameters.

					duration	outdoors mean minimum temperature	outdoors relative humidity	outdoors vapour pressure	indoors temperature	indoors relative humidity	indoors vapour pressure	minimum acceptable saturation vapour pressure	minimum acceptable surface temperature	**minimum temperature factor f_{Rsi}**
Select station	**Uccle**				[days]	[°C]	[%]	[Pa]	[°C]	[%]	[Pa]	[Pa]	[°C]	[-]
Select indoors climate class	**3-4**		1	Jan	31	2.5	87.0	635.9	20.0	57.5	1344.7	1344.7	11.4	**0.51**
Enter indoors temperature column			2	Feb	28	3.2	83.0	637.6	20.0	56.4	1318.0	1318.0	11.1	**0.47**
			3	Mar	31	5.7	80.0	732.3	20.0	56.1	1311.5	1311.5	11.0	**0.37**
Maximum acceptable relative humidity at surface	**1**		4	Apr	30	8.7	76.0	854.5	20.0	56.2	1312.2	1312.2	11.0	**0.20**
normally 0.8, window frames 1			5	May	31	12.7	75.0	1100.9	20.0	59.8	1396.5	1396.5	11.9	**-0.10**
			6	Jun	30	15.5	77.0	1355.2	20.0	65.8	1537.5	1537.5	13.4	**-0.46**
			7	Jul	31	17.2	78.0	1529.8	20.0	70.3	1643.2	1643.2	14.4	**-0.99**
			8	Aug	31	17.0	78.0	1510.6	20.0	69.8	1632.1	1632.1	14.3	**-0.89**
			9	Sep	30	14.4	83.0	1360.9	20.0	67.9	1587.7	1587.7	13.9	**-0.09**
			10	Oct	31	10.4	86.0	1084.1	20.0	63.0	1472.9	1472.9	12.8	**0.25**
			11	Nov	30	6.0	88.0	822.5	20.0	59.5	1389.5	1389.5	11.9	**0.42**
			12	Dec	31	3.4	88.0	685.7	20.0	58.1	1358.0	1358.0	11.5	**0.49**
			1			-15.0	85.0	140.0	20.0	40.7	950.0	950.0	6.2	**0.61**
			2			-12.5	85.0	176.1	20.0	42.2	986.1	986.1	6.8	**0.59**
			3			-10.0	85.0	220.4	20.0	44.1	1030.4	1030.4	7.4	**0.58**
			4			-7.5	85.0	274.7	20.0	46.4	1084.7	1084.7	8.2	**0.57**
			5			-5.0	85.0	341.0	20.0	49.3	1151.0	1151.0	9.0	**0.56**
			6			-2.5	85.0	421.5	20.0	52.7	1231.5	1231.5	10.1	**0.56**
			7			0.0	85.0	518.9	20.0	56.9	1328.9	1328.9	11.2	**0.56**
			8			2.5	85.0	621.3	20.0	56.9	1330.0	1330.0	11.2	**0.50**
			9			5.0	85.0	741.1	20.0	57.7	1348.6	1348.6	11.4	**0.43**
			10			7.5	85.0	880.8	20.0	59.4	1387.1	1387.1	11.8	**0.35**

Figure 2. Input sheet of file Surface_Condensation_EN_ISO_13788_Climate_Creator.xlsm

In evaluating critical surface condensation, EN ISO 13788 distinguishes

- normal construction elements (typically thermal bridges)
- low thermal inertia elements (typically windows).

The value of $f_{Rsi,min}$ needs to be derived in a different way for both type of elements, i.e. different values of the 5 parameters mentioned above need to be used.

1) The *outdoor temperature.*

2) The *outdoor relative humidity.*
   For normal construction elements monthly mean temperatures need to be used.
   The spreadsheet file contains a limited but extendable database of monthly climate values. The $f_{Rsi,min}$ value is calculated for each month. The maximum value needs to be selected for further analysis.
   For low thermal inertia elements the lowest daily mean temperature needs to be used. The corresponding relative humidity can be assumed to be 0.85. The spreadsheet file doesn't contain a lowest daily mean temperature database but allows entering its value.
   For Belgium the values can be read from Figure 3.

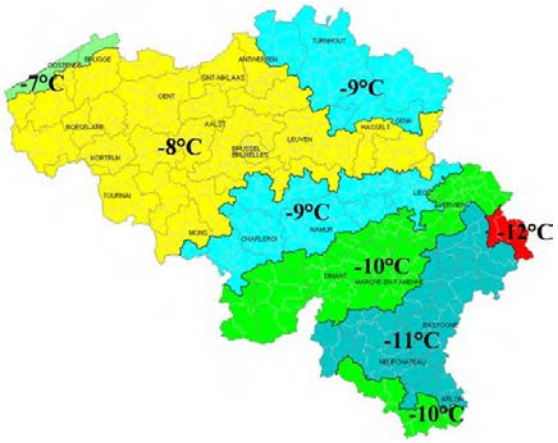


Figure 3. Lowest daily mean temperature for Belgium

3) The *indoor temperature.*
   EN ISO 13788 doesn't contain requirements for the indoor temperature.
   As explained further in the discussion its value is quite important.

4) The *indoor humidity class.*
   The spreadsheet allows selecting a border between 2 climate classes. To derive the value of $f_{Rsi,min}$ for e.g. climate class 3 the selection of the border 3-4 is recommended.

5) The *maximum acceptable relative humidity at the surface.*
   For normal construction elements a value of 0.8 should be taken. The value expresses that the monthly mean surface relative humidity at the surface should be less than 80 % in order to avoid mould growth.
   For low thermal inertia elements (windows) a value of 1 should be taken. The value considers that mould growth is rarely a problem on window frames.

Example 1A.

For a normal construction element with
- the outdoor climate of Uccle (Brussels)
- indoor temperature = 20 °C
- climate class 3
- a maximum acceptable relative humidity = 80 %

$f_{Rsi,min}$ = 0.70 (January)

Example 2A.

For a low thermal inertia element with
- the lowest daily mean temperature = -8 °C, with relative humidity = 85 %
- indoor temperature = 20 °C
- climate class 3
- a maximum acceptable relative humidity = 100 %

$f_{Rsi,min}$ = 0.56

4. Temperature factor at the internal surface.

The temperature factor f_{Rsi} of a construction element (thermal bridge, window) is defined as

$$f_{R_{si}} = \frac{\theta_{si} - \theta_e}{\theta_i - \theta_e}$$

with
- θ_i indoor temperature [°C]
- θ_e outdoor temperature [°C]
- θ_{si} lowest internal surface temperature [°C]
- R_{si} the internal surface resistance [m^2K/W] = 1 / h_i
- h_i the internal heat transfer coefficient [W/m^2K]

The R_{si} value is mentioned as a subscript because its value has an important effect on the temperature factor value. EN ISO 13788 (paragraph 4.4.1) prescribes the following values of R_{si} (and thus of h_i) to be used in numerical simulations in condensation and mould growth analysis:

- for opaque surfaces: R_{si} = 0.25 m^2K/W or **h_i = 4 W/m^2K**
- for windows and doors:
  - horizontal heat flow: R_{si} = 0.13 m^2K/W or **h_i = 7.7 W/m^2K**
  - upwards heat flow: R_{si} = 0.10 m^2K/W or **h_i = 10.0 W/m^2K**
  - downwards heat flow: R_{si} = 0.17 m^2K/W or **h_i = 5.9 W/m^2K.**

For the external surface resistance in all cases R_{si} = 0.4 m^2K/W of h_i = 25 W/m^2K should be used.

Example 1B – TRISCO data 3D_roof_junction_surface_condensation.trc

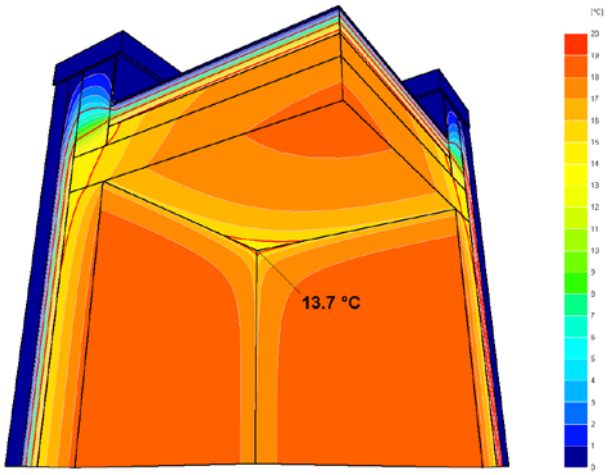


Figure 4. 3D roof junction: isotherms.

For a 3D roof junction between indoor at 20 °C and outdoor at 0 °C the simulated isotherms are shown in Figure 4. An overall surface heat transfer coefficient h_i = 4.0 W/m^{2}K is used in the simulation (whereas in heat loss simulations a heat transfer coefficient h_i = 7.7 W/m^{2}K is used on the vertical walls and h_i = 10.0 W/m^{2}K on the ceiling). The lowest internal surface temperature is 13.7 °C. Thus the temperature factor $\mathbf{f_{0.25} = 0.68}$. Applying the minimal temperature factor of example 1A $f_{Rsi,min}$ = 0.70 the criterion to avoid mould growth isn't fulfilled.

Example 2B – BISCO data alu_frame_glazing_alu_spacer.bsc.

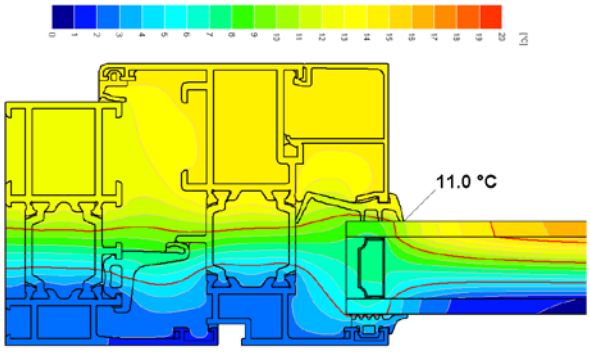


Figure 5. Aluminium frame with double glazing with aluminium spacer: isotherms.

For an aluminium frame with double glazing with aluminium spacer between indoor at 20 °C and outdoor at 0 °C the simulated isotherms are shown in Figure 5. An overall surface heat transfer coefficient h_i = 7.7 W/m^{2}K is used in the simulation (whereas in thermal transmittance (U-value) simulations supplementary a reduced surface heat transfer coefficient h_i is considered in corner zones). The lowest internal surface temperature is 11 °C. Thus the temperature factor $\mathbf{f_{0.13} = 0.55}$. Applying the minimal temperature factor of example 2A $f_{Rsi,min}$ = 0.56 the criterion to avoid surface condensation isn't fulfilled.

5. Discussion

- EN ISO 13788 distinguishes normal and low inertia constructions. A different evaluation of the condensation or mould growth risk needs to be applied for both construction types. For window-wall junctions it isn't clear how to do the evaluation and thus recommended to perform both simulations.

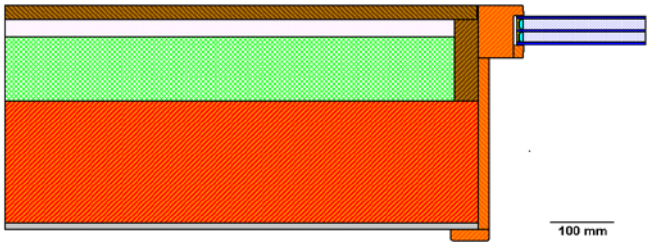


Figure 6. Sample window-wall junction.

- The minimal temperature factor $f_{Rsi,min}$ depends on the outdoor temperature. Figure 7 shows the relation for an indoor temperature 20 °C and a climate class 3.
  In the range –15 °C – 0°C the $f_{Rsi,min}$ value is quite constant. Therefore the different choice of the outdoor temperature for both construction types - monthly (January) average temperature for normal constructions and lowest daily mean temperature for low inertia construction - is not that relevant. It would be simpler to use the same outdoor temperature for both construction types.

- The minimal temperature factor $f_{Rsi,min}$ depends on the indoor temperature. Figure 8 shows the relation for an outdoor temperature 0 °C and a climate class 3. The indoor temperature has an important effect on the $f_{Rsi,min}$ value. The EN standard doesn't prescribes a value and therefore this topic should be treated with attention by regional authorities.

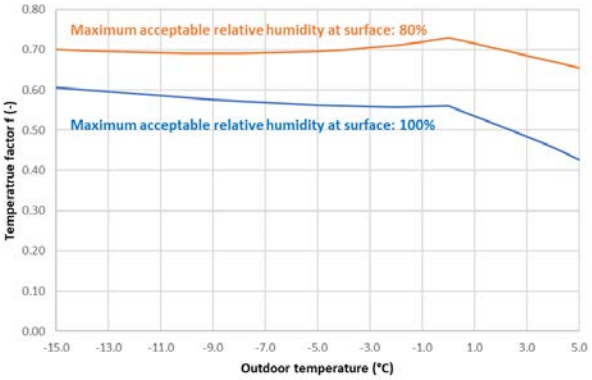


Figure 7. Minimal temperature factor as a function of the outdoor temperature (climate class 3, indoor temperature 20°C)

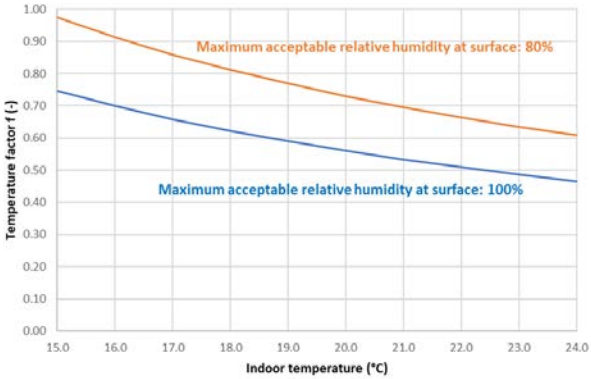
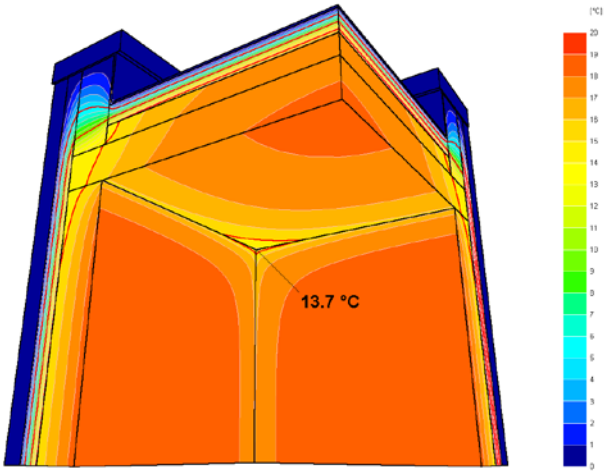


Figure 8. Minimal temperature factor as a function of the indoor temperature. (climate class 3, outdoor temperature 0°C)

- EN ISO 13788 prescribes for low inertia elements such as (vertical) window frames an overall internal heat transfer coefficient h_i = 7.7 W/m^{2}K. The reduced surface heat transfer coefficient h_i = 5 W/m^{2}K to be applied in corner zones according to EN ISO 10077-2 is omitted.
  The reduced h_i-value corresponds to a physical reality (reduced long wave radiation) and by omitting it the internal surface temperatures are too high compared to physical reality. A more detailed approach would be applying detailed infra-red radiation at the interior boundary condition (type BC_SKY).

- Nowadays, more and more specific thresholds for the inner temperature and inner relative humidity are project defined. As a consequence the use of the minimal temperature factor becomes redundant. Instead, the maximum relative humidity can be directly used.
  For example:

Example 1B



$f_{0.25}$ = 0.68 (-)

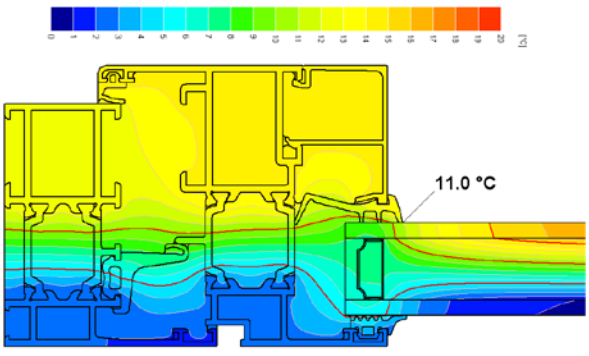
Belgium:
Coldest monthly mean temperatures = 2.5°C
Inner temperature 20°C

For these conditions and geometry the lowest inner surface temperature is: 14.4°C

With the spreadsheet available in Knowledge Base document 'Humid air' it can be found that the inner relative humidity may not exceed **56.1%** in order to avoid relative humidity value higher than 80% on the surface.

Oslo:
$T_{min,month,outdoor}$=-2.8°C
T_{indoor}=20°C
$T_{s,min}$=12.7°C
$RH_{max,indoor}$=50.1%

Example 2B



$f_{0.13}$=0.55 (-)

Belgium:
Coldest daily mean temperatures = -8°C
Inner temperature 20°C
For these conditions and geometry the lowest inner surface temperature is: 7.4°C
With the spreadsheet available in Knowledge Base document 'Humid air' it can be found that the inner relative humidity may not exceed **44%** in order to condensation on the surface.

Oslo:
$T_{min,daily,outdoor}$=-15.9°C
T_{indoor}=20°C
$T_{s,min}$=3.85°C
$RH_{max,indoor}$= 34.3%