Università degli Studi di Padova

Dipartimento di Ingegneria Industriale

Energy and buildings

Surface condensation in buildings

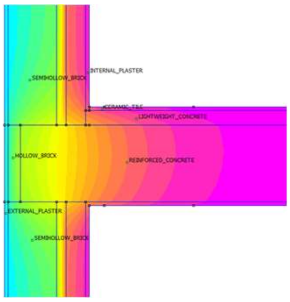
Thermal bridge

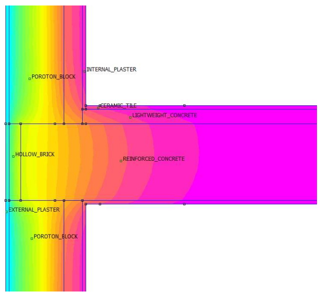
Change of thermal transmittance due to a discontinuity in the **materials** or **geometry** of the building envelope

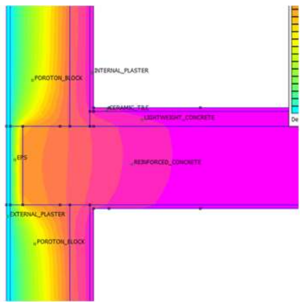
- Additional heat flow has an impact on **energy needs**
- Local decrease of internal surface temperature may cause **surface condensation** problems

Objectives

(1) Calculate **additional heat flow** in thermal bridges according to ISO 10211





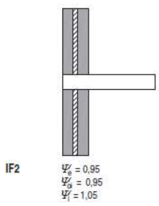


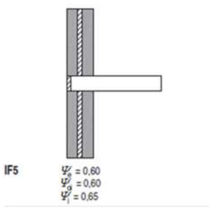
Objectives

(1) Calculate **additional heat flow** in thermal bridges according to ISO 10211

	TB1	IF2 - EN 14683
ψ_i [W/(m K)]	0.95	1.05
ψ_e [W/(m K)]	0.72	0.95

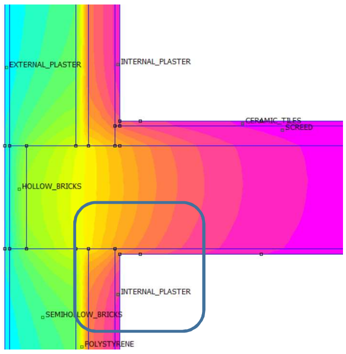
	TB2	TB3	IF5 - EN 14683
ψ_i [W/(m K)]	0.78	0.36	≈0.65
ψ_e [W/(m K)]	0.57	0.15	≈0.60

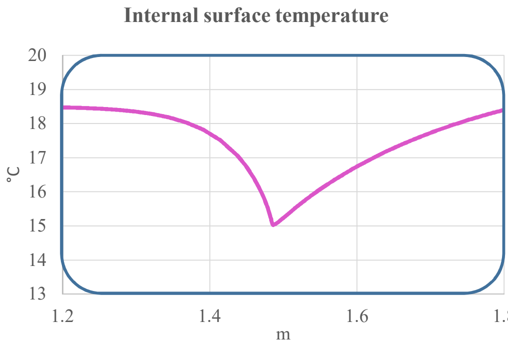




Objectives

(2) Assess the **risk of surface condensation** according to ISO 13788





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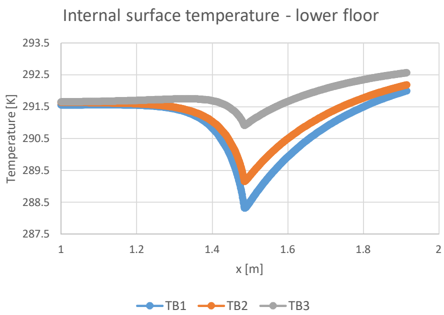

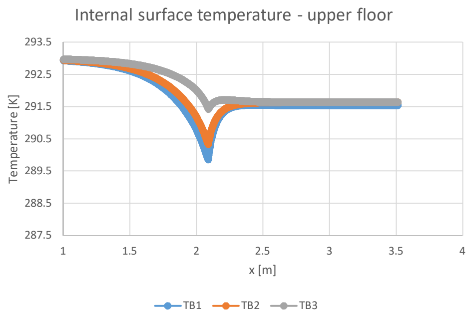

Surface condensation

According to EN ISO 13788:

Surface condensation can cause **damage** to unprotected **building materials** that are sensitive to moisture.


Surface condensation

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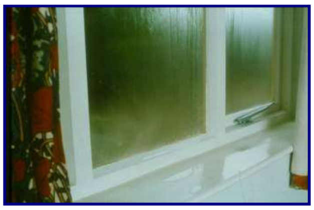
Surface condensation can cause **damage** to unprotected **building materials** that are sensitive to moisture.

It can be accepted temporarily and in small amounts, e.g. on windows and tiles in bathrooms, if the surface does not absorb the moisture and adequate measures are taken to prevent its contact with adjacent sensitive materials.



Surface condensation

According to World Health Organization (WHO):

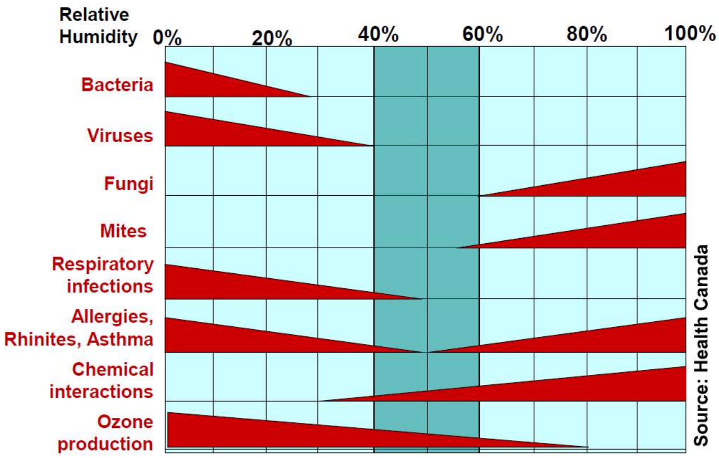
- Excess moisture on almost all indoor materials leads to growth of **microbes, such as mould, fungi and bacteria**, which subsequently emit spores, cells, fragments and volatile organic compounds into indoor air.
- Moreover, dampness (humidity) initiates **chemical or biological degradation of materials**, which also pollutes indoor air [source: WHO, 2009].

Surface condensation

According to World Health Organization (WHO):

- Therefore, excess moisture is a threat for air quality, with consequence risks for human health particularly with regard to **asthma and respiratory symptoms** (e.g. cough and wheeze).
- The health risks of biological contaminants of indoor air could thus be addressed by considering **dampness as the risk indicator**. [source: WHO, 2009].

Surface condensation

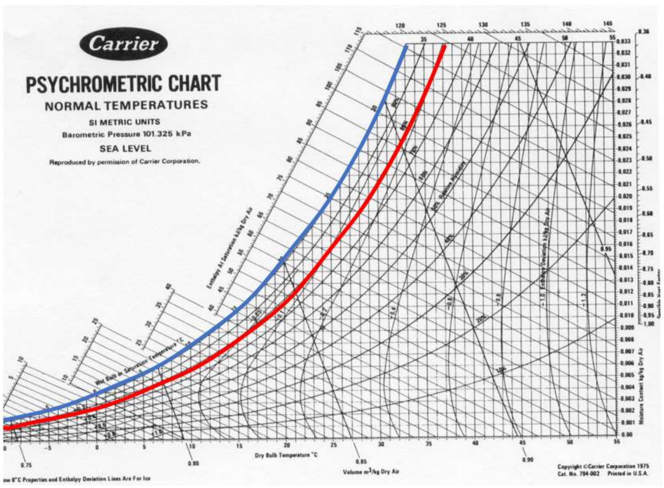


Surface condensation

Surface condensation

occurs when the surface temperature reaches the

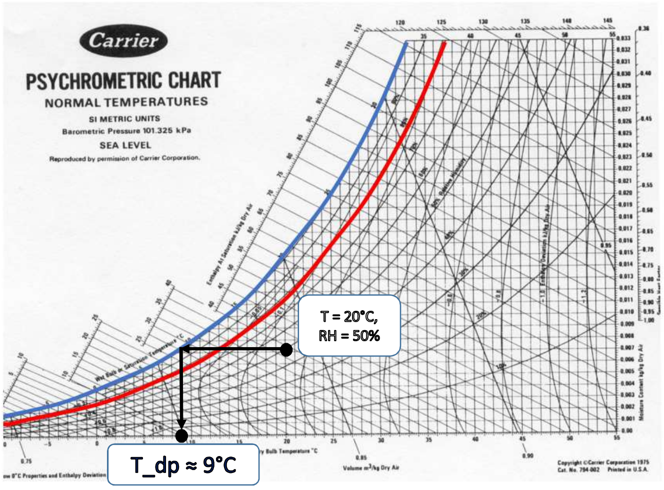
dew-point temperature



Psychrometrics

Dew-point temperature

Dew-point temperature is the temperature of moist air saturated at pressure p, with the **same specific humidity *x*** as that of the given sample of moist air.

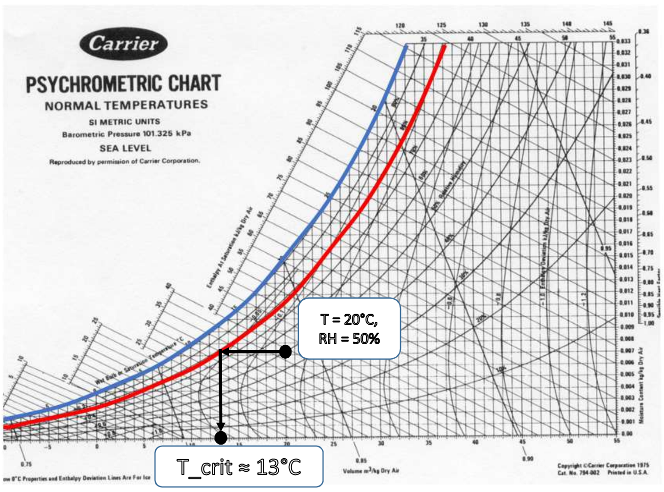


Surface condensation

There is risk of mould growth

when monthly mean surface relative humidities are above a **critical relative humidity**, which should be taken as **80%** unless specified differently by National Regulation [ISO 13788].

$$T_{si} > T(RH = 80\%)$$



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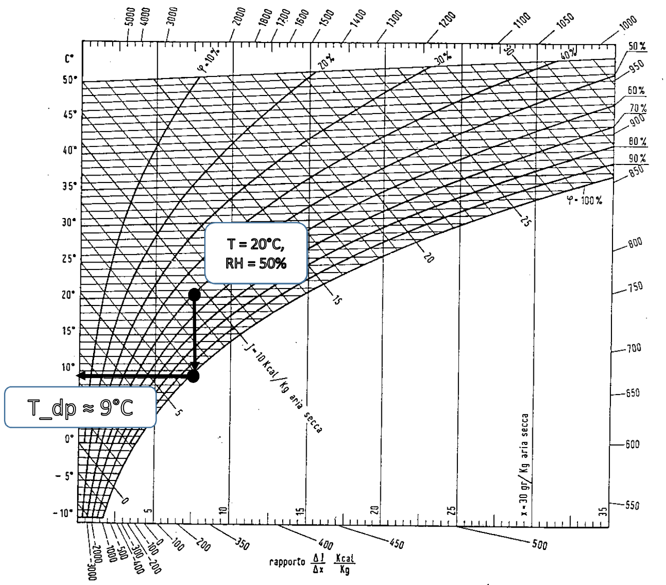


Internal surface temperature

A poor thermal insulation (typical for old unrefurbished buildings) leads to low internal surface temperatures in winter.

ENV_OLD			
Layer	t [m]	lambda [W/(m K)]	R [(m2 K)/W]
internal plaster	0.015	0.9	0.017
semihollow bricks	0.220	0.7	0.314
external plaster	0.015	0.7	0.021
Rwall	0.352	(m2 K)/W	
U	1.93	W/(m2 K)	

ENV_NEW			
Layer	t [m]	lambda [W/(m K)]	R [(m2 K)/W]
internal plaster	0.015	0.9	0.017
porous bricks	0.300	0.14	2.143
insulation material	0.080	0.04	2.000
external plaster	0.015	0.7	0.021
Rwall	4.181	(m2 K)/W	
U	0.230	W/(m2 K)	

	Rse	Rwall	Rsi	Rtot	R1	K [-]	Tsi [°C]
ENV_OLD	0.040	0.352	0.125	0.517	0.392	3.14	15.2
ENV_NEW	0.040	4.181	0.125	4.346	4.221	33.77	19.4

EXAMPLE

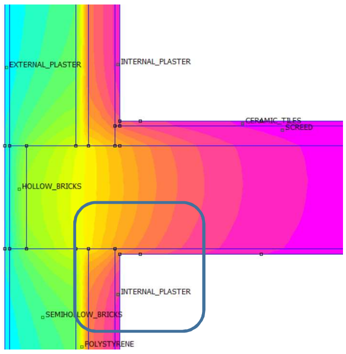
Boundary conditions: Ti = 20°C, Te = 0°C

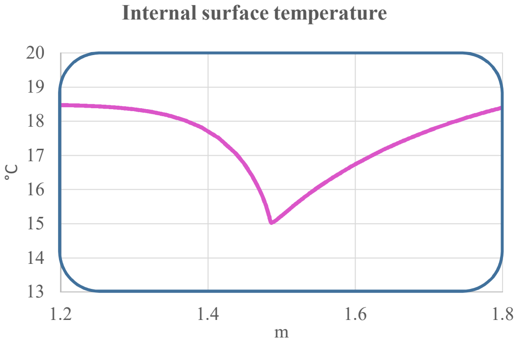
Parameters:
Old building U = 1.93 W/(m² K); new building U = 0.23 W/(m² K)

Internal surface temperature:
Tsi = 15.2°C in the old building, Tsi = 19.4°C in the new building

Internal surface temperature

Also buildings with good thermal insulation may have low internal surface temperature in case of thermal bridges with low insulation





Internal surface temperature

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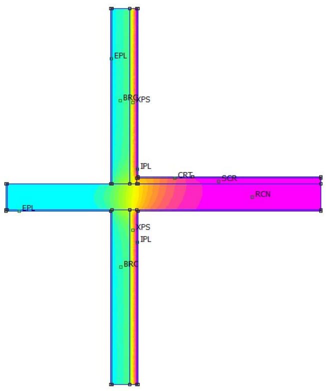
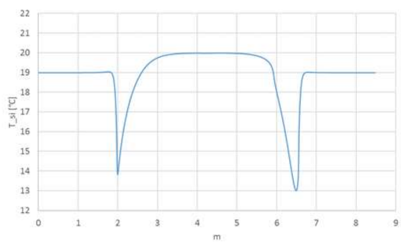




EXAMPLE

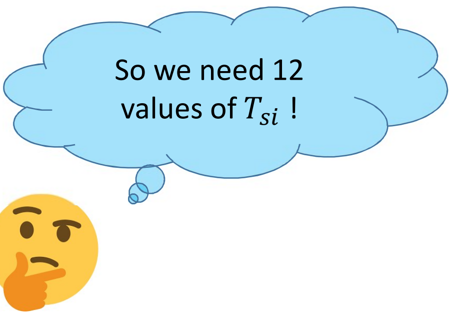
Boundary conditions:
Ti = 20°C, Te = 0°C

Parameters:
External wall U = 0.40 W/(m2 K); concrete balcony slab 2.3 W/(m2 K)

Avg. internal surface temperature of external walls: Tsi = 19.0°C
Min. internal surface temperature of the thermal bridge Tsi = 13.0°C

Internal surface temperature

- Surface temperature depends on the boundary conditions T_i and T_e
- Mean monthly relative humidity at internal surface should be kept below 80% according to EN ISO 13788



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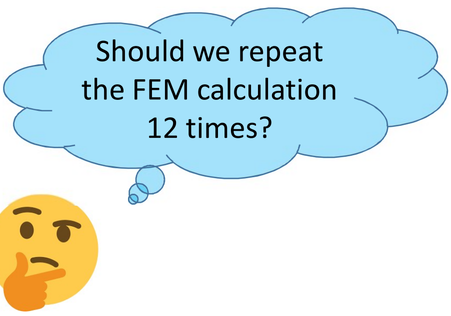
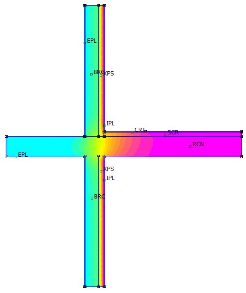


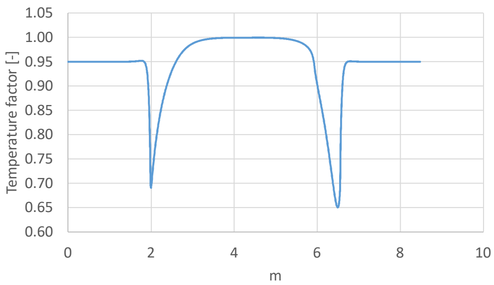
Temperature factor

Temperature factor at the internal surface (EN ISO 13788)



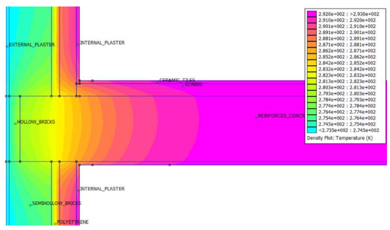
$$f_{R_{si}} = \frac{T_{si}(x,y) - T_e}{T_i - T_e}$$

Thermal insulation	LOW	HIGH
Surface temperature	$T_{si} \rightarrow T_e$	$T_{si} \rightarrow T_I$
Temperature factor	$f_{R_{si}} \rightarrow 0$	$f_{R_{si}} \rightarrow 1$



Temperature factor

Temperature factor at the internal surface



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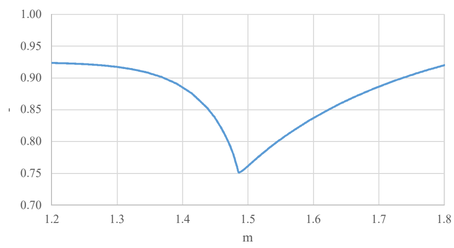
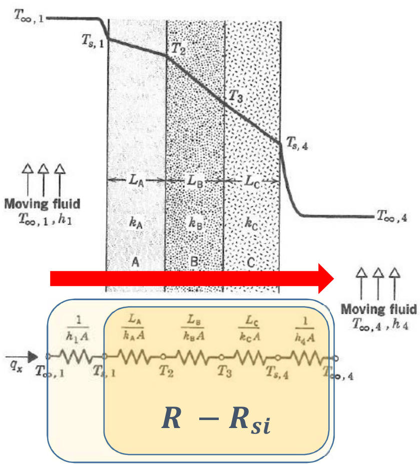


Temperature factor



Temperature factor at the internal surface for plane building elements

$$T_{si} - T_e = q\,(R - R_{si})$$

$$T_i - T_e = q\,R$$

$$f_{R_{si}} = \frac{q\,(\mathrm{R} - R_{si})}{q\,\mathrm{R}} = 1 - \frac{R_{si}}{R}$$

$$\boxed{f_{R_{si}} = 1 - R_{si}U}$$

Temperature factor

Design temperature factor at the internal surface

Minimum acceptable temperature factor at the internal surface $f_{R_{si,min}}$

Criteria to avoid mould growth at the internal surface

$$f_{R_{si}} \geq f_{R_{si,min}}$$

The criteria shall be met for each month of the year :

→1 value of $f_{R_{si}}$ (it describes the internal surface temperature of the thermal bridge)

→12 values of $f_{R_{si,min}}$ (they describe the mean monthly critical temperatures)

Psychrometrics

Relative and specific humidity (humidity ratio)

$$RH(p_v, T) = \frac{p_v}{p_{v,sat}(T)}$$

$$x(V,T) = \left.\frac{m_v}{m_a}\right|_{V,T}$$

Psychrometrics

Moist air can be treated as ideal mixture of ideal gases, where the two gas components are “dry-air” (a) and “water vapour” (v)

Dalton law

$$p_{atm} = p_a + p_v$$

Ideal gas law

$$\frac{p}{\rho} = R\,T$$

Psychrometrics

With these assumptions, the **specific humidity** can be rewritten as:

$$x(V,T) = \left.\frac{m_v}{m_a}\right|_{V,T} = \left.\frac{\rho_v}{\rho_a}\right|_T$$

$$x = \frac{R_a}{R_v}\frac{p_v}{p_{atm} - p_v}$$

$$x = 0.622\frac{p_v}{p_{atm} - p_v}$$

Psychrometrics

Steady-state vapour mass balance in a room/building

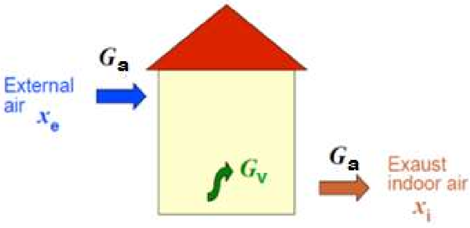
Inside the building there are sources of water vapour, such as:

- people
- personal hygiene (e.g. showers)
- cooking
- clothes washing and drying..

In general, the vapour pressure in the indoor environment is higher than the outdoor water vapour pressure and the difference between the two is called **moisture excess**.

Psychrometrics

Steady-state vapour mass balance in a room/building



$$G_a x_e + G_v = G_a x_i$$

$$G_a = \rho_a n\, V$$

$$x_i = x_e + \frac{G_v}{\rho_a n\, V}$$

Psychrometrics

Internal water vapour pressure

$$\begin{cases} x_i = x_e + \dfrac{G_v}{\rho_a n\, V} \\ x = 0.622\, \dfrac{p_v}{p_{atm} - p_v} \end{cases}$$

$$p_{v,i} = p_{v,e} + \frac{p_{atm}}{0.622} \frac{G_v}{\rho_a n\, V}$$

The internal water vapour pressure depends on: (1) external vapour pressure, (2) internal water vapour generation, (3) ventilation rate

Standard EN ISO 13788

Procedure to avoid mould growth on internal surfaces

1. Calculate the **temperature factor** of the thermal bridge $\boldsymbol{f_{R_{si}}}$
2. Set **external boundary conditions**: mean monthly air temperature T_e and partial vapor pressure p_e (UNI 10349)

Standard EN ISO 13788

External boundary conditions

Mean monthly air temperature T_e and partial vapor pressure p_e according to National Standard UNI 10349 for Italy

N°	Sigla Provincia	Località	Altitudine m	GEN. °C	FEB. °C	MAR. °C	APR. °C	MAG. °C	GIU. °C	LUG. °C	AGO. °C	SET. °C	OTT. °C	NOV. °C	DIC. °C
38	IM	Imperia	10	8,6	9,4	11,6	14,7	17,9	21,7	24,5	24,1	21,8	17,4	12,7	9,5
39	IS	Isernia	423	5,5	5,7	8,6	11,2	15,5	20,1	23,1	22,8	19,7	14,7	10,3	6,9
40	KR	Crotone	8	9,5	9,8	11,5	14,7	18,4	22,9	26,2	26,0	23,5	19,3	15,1	11,2
41	LC	Lecco	214	3,9	5,7	9,6	13,3	16,0	20,1	22,8	22,1	19,2	14,3	9,2	5,3
42	LD	Lodi	87	0,9	3,3	8,6	13,5	17,8	22,5	24,5	23,4	19,6	13,4	7,3	2,5
43	LE	Lecce	49	9,0	9,3	11,4	14,7	18,9	23,4	26,1	25,9	23,0	18,5	14,3	10,7
44	LI	Livorno	3	7,5	8,2	11,1	13,9	17,3	21,8	24,4	24,1	21,5	17,1	12,7	9,0
45	LT	Latina	21	8,3	9,0	10,9	13,5	16,9	20,9	23,7	23,8	21,5	17,3	12,9	9,5
46	LU	Lucca	19	6,1	7,2	10,1	13,3	17,1	21,2	23,8	23,6	20,9	15,8	10,9	7,3
47	MC	Macerata	315	3,8	5,3	8,3	12,4	16,3	20,7	23,5	23,2	19,9	14,4	9,5	5,7
48	ME	Messina	3	11,7	12,0	13,2	15,7	19,2	23,5	26,4	26,5	24,2	20,3	16,6	13,3
49	MI	Milano	122	1,7	4,2	9,2	14,0	17,9	22,5	25,1	24,1	20,4	14,0	7,9	3,1
50	MN	Mantova	19	1,0	3,3	8,4	13,3	17,4	22,0	24,3	23,6	20,0	14,0	8,0	2,9
51	MO	Modena	34	1,4	3,5	8,6	13,3	17,2	21,8	24,3	23,8	20,1	14,0	8,1	3,1
52	MS	Massa-Carrara	65	6,8	7,4	10,3	13,2	16,9	21,2	23,7	23,3	20,6	15,9	11,3	7,9
53	MT	Matera	200	7,7	8,4	10,5	14,2	18,5	23,6	26,7	26,2	22,9	18,0	13,3	9,3
54	NA	Napoli	17	10,5	10,6	13,2	16,0	19,5	24,1	26,7	26,5	23,8	19,6	15,5	12,1
55	NO	Novara	159	0,9	3,3	8,4	13,1	17,4	21,8	24,3	23,3	19,2	12,9	7,1	2,4
56	NU	Nuoro	546	6,2	6,7	9,5	12,4	15,7	21,1	24,3	24,1	20,9	15,7	11,2	7,6
57	OR	Oristano	9	9,6	10,2	12,3	14,5	17,4	21,4	23,5	24,1	22,6	18,7	14,4	10,8
58	PA	Palermo	14	11,1	11,6	13,1	15,5	18,8	22,7	25,5	25,4	23,6	19,8	16,0	12,6
59	PC	Piacenza	61	0,1	2,4	7,7	12,9	16,3	20,7	23,2	22,3	18,9	12,8	6,9	2,0
60	PD	Padova	12	1,9	4,0	8,4	13,0	17,1	21,3	23,6	23,1	19,7	13,8	8,2	3,6

N°	Sigla Provincia	Località	Altitudine m	GEN. Pa	FEB. Pa	MAR. Pa	APR. Pa	MAG. Pa	GIU. Pa	LUG. Pa	AGO. Pa	SET. Pa	OTT. Pa	NOV. Pa	DIC. Pa
38	IM	Imperia	10	651	703	767	939	1360	1480	1873	2123	1696	1306	1046	730
39	IS	Isernia	423	744	735	820	946	1280	1666	1886	1906	1718	1312	1047	826
40	KR	Crotone	8	820	870	873	1251	1525	1876	1674	2089	1813	1349	1350	981
41	LC	Lecco	214	676	735	875	1106	1314	1666	1844	1855	1671	1285	988	754
42	LD	Lodi	87	548	618	820	1121	1435	1913	2006	1950	1709	1225	885	627
43	LE	Lecce	49	1003	1084	979	1009	1204	1507	1735	2073	1808	1504	1121	1097
44	LI	Livorno	3	829	856	958	1151	1402	1841	1997	2001	1887	1471	1175	920
45	LT	Latina	21	863	894	947	1121	1375	1748	1938	1979	1887	1484	1186	943
46	LU	Lucca	19	770	808	903	1106	1388	1779	1946	1964	1831	1385	1079	844
47	MC	Macerata	315	672	716	803	1037	1334	1728	1921	1935	1737	1292	1004	772
48	ME	Messina	3	921	916	966	1134	1548	1935	2123	2001	1880	1438	1282	1099
49	MI	Milano	122	590	645	943	1163	1326	1840	1736	2012	1921	1412	958	671
50	MN	Mantova	19	552	618	809	1106	1408	1862	1989	1964	1746	1265	923	645
51	MO	Modena	34	570	628	820	1106	1395	1841	1989	1979	1756	1265	928	654
52	MS	Massa-Carrara	65	799	817	914	1098	1375	1779	1938	1942	1803	1392	1101	871
53	MT	Matera	200	812	775	848	893	1174	1274	1657	1660	1564	1225	968	881
54	NA	Napoli	17	849	870	933	1157	1402	1851	1823	2043	1776	1472	1192	922
55	NO	Novara	159	624	619	802	850	1176	1534	1825	1797	1560	1031	831	550
56	NU	Nuoro	546	748	968	949	1118	1453	1679	2167	2031	1740	1512	1161	1009
57	OR	Oristano	9	917	952	1025	1196	1408	1800	1921	2001	1989	1577	1266	1001
58	PA	Palermo	14	888	901	824	1064	1259	1681	1771	1834	1849	1467	1162	928
59	PC	Piacenza	61	595	635	718	968	1378	1409	2235	1922	1560	1299	964	564
60	PD	Padova	12	591	652	809	1083	1388	1790	1929	1928	1718	1252	934	677

Standard EN ISO 13788

Procedure to avoid mould growth on internal surfaces

1. Calculate the **temperature factor** of the thermal bridge $\boldsymbol{f_{R_{si}}}$
2. Set **external boundary conditions**: mean monthly air temperature T_e and partial vapor pressure p_e (UNI 10349)
3. Set **internal boundary conditions**: internal air temperature T_i and partial vapor pressure p_i
   a) p_i from humidity class
   b) p_i from monthly mean RH_i
   c) p_i from constant RH_i (if controlled by HVAC)

Standard EN ISO 13788

Internal boundary conditions (method a)

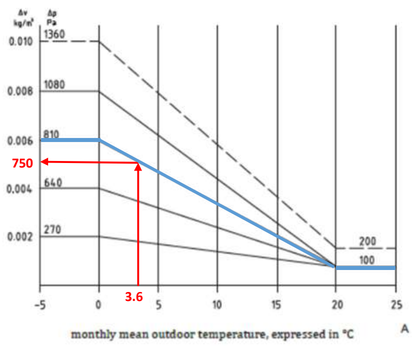
$$T_i = \begin{cases} 20°C \quad if\ heating\ is\ on \\ 18°C \quad if\ heating\ is\ off\ and\ T_e < 18°C \\ T_e\ otherwise \end{cases}$$

$$p_i = p_e + \Delta p_v$$

$$\Delta p_v = f(T_e, humidity\ class)$$

Table A.1 — Internal humidity classes

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



Standard EN ISO 13788

Internal boundary conditions (method b)

$$T_i = \begin{cases} 20°C \quad if\ heating\ is\ on \\ 18°C \quad if\ heating\ is\ off\ and\ T_e < 18°C \\ T_e\ otherwise \end{cases}$$

Mean monthly RH_i is known

→ $p_{sat,i} = f(T_i)$

→ $p_i = RH_i\, p_{sat,i}$

BS EN ISO 13788:2012
ISO 13788:2012(E)

Annex E
(informative)

Relationships governing moisture transfer and water vapour pressure

E.1 Water vapour saturation pressure as a function of temperature

The following empirical formulae give the saturated vapour pressure of water as a function of temperature

$$p_{sat} = 610{,}5\, e^{\frac{17{,}269\, \theta}{237{,}3 + \theta}} \text{ for } \theta \geq 0\ °C \tag{E.1}$$

$$p_{sat} = 610{,}5\, e^{\frac{21{,}875\, \theta}{265{,}5 + \theta}} \text{ for } \theta < 0\ °C \tag{E.2}$$

These may be inverted to allow the calculation of the temperature corresponding to any saturated vapour pressure.

$$\theta = \frac{237{,}3 \log_e\left(\frac{p_{sat}}{610{,}5}\right)}{17{,}269 - \log_e\left(\frac{p_{sat}}{610{,}5}\right)} \text{ for } p_{sat} \geq 610{,}5 \text{ Pa} \tag{E.3}$$

$$\theta = \frac{265{,}5 \log_e\left(\frac{p_{sat}}{610{,}5}\right)}{21{,}875 - \log_e\left(\frac{p_{sat}}{610{,}5}\right)} \text{ for } p_{sat} < 610{,}5 \text{ Pa} \tag{E.4}$$

Standard EN ISO 13788

Internal boundary conditions (method c)

$$T_i = \begin{cases} 20°C \quad if\ heating\ is\ on \\ 18°C \quad if\ heating\ is\ off\ and\ T_e < 18°C \\ T_e\ otherwise \end{cases}$$

Constant RH_i (humidity control is on) is known

→ $p_{sat,i} = f(T_i)$

→ $p_i = RH_i\, p_{sat,i}$

Standard EN ISO 13788

Procedure to avoid mould growth on internal surfaces

1. Calculate the **temperature factor** of the thermal bridge $\boldsymbol{f_{R_{si}}}$
2. Set **external boundary conditions**: mean monthly air temperature T_e and partial vapor pressure p_e (UNI 10349)
3. Set **internal boundary conditions**: internal air temperature T_i and partial vapor pressure p_i
4. Evaluate **critical conditions** on the internal surface, i.e. $\boldsymbol{f_{R_{si,min}}}$

Standard EN ISO 13788

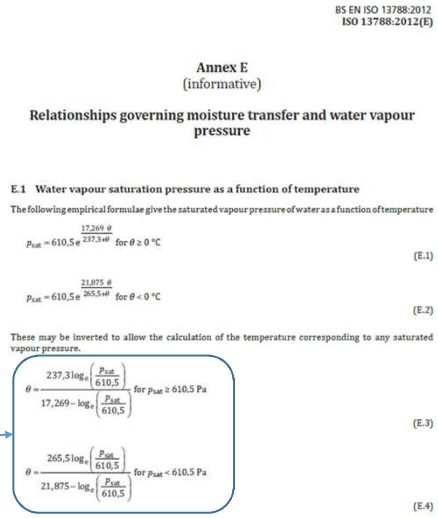
Critical conditions on the internal surface

- $RH_{si,crit} = \frac{p_i}{p_{sat,crit}} = 0.80$ (mould growth)

$$\rightarrow \ p_{sat,crit} = \frac{p_i}{0.80}$$

- $T_{si,crit} = f(p_{sat,crit})$

- $f_{R_{si,min}} = \frac{T_{si,crit} - T_e}{T_i - T_e}$ <u>FOR 12 MONTHS!</u>



BS EN ISO 13788:2012
ISO 13788:2012(E)

Annex E
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Relationships governing moisture transfer and water vapour pressure

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These may be inverted to allow the calculation of the temperature corresponding to any saturated vapour pressure.

$$\theta = \frac{237{,}3 \log_e\left(\frac{p_{sat}}{610{,}5}\right)}{17{,}269 - \log_e\left(\frac{p_{sat}}{610{,}5}\right)} \text{ for } p_{sat} \geq 610{,}5 \text{ Pa} \quad (E.3)$$

$$\theta = \frac{265{,}5 \log_e\left(\frac{p_{sat}}{610{,}5}\right)}{21{,}875 - \log_e\left(\frac{p_{sat}}{610{,}5}\right)} \text{ for } p_{sat} < 610{,}5 \text{ Pa} \quad (E.4)$$

Standard EN ISO 13788

Procedure to avoid mould growth on internal surfaces

1. Calculate the temperature factor of the thermal bridge $f_{R_{si}}$
2. Set external boundary conditions: mean monthly air temperature T_e and partial vapor pressure p_e (UNI 10349)
3. Set internal boundary conditions: internal air temperature T_i and partial vapor pressure p_i (from internal humidity class)
4. Evaluate critical conditions on the internal surface, i.e. $f_{R_{si,min}}$
5. Verify that $f_{R_{si}} \geq f_{R_{si,min}}$ each month!

Standard EN ISO 13788

Different assumptions for low inertia building components

Low inertia building components show fast response to temperature changes. There are two main differences in the procedure:

- The **external temperature** is defined the average, taken over several years, of the lowest daily mean temperature.
- The **maximum acceptable relative humidity** at the frame surface is $RH_{si,crit}$ = 100% because mould growth is rarely a problem on window frames.

Measures against surface condensation

Building envelope

Criteria to avoid mould growth at the internal surface

$$f_{R_{si}} \geq f_{R_{si,min}}$$

Increase $f_{R,si}$ by increasing the thermal insulation and correct thermal bridges

Measures against surface condensation

Temperature setpoint

Criteria to avoid mould growth at the internal surface

$$f_{R_{si}} \geq f_{R_{si,min}}$$

Increase of energy needs for space heating!

Decrease $f_{Rsi,min}$ by increasing the temperature setpoint

Measures against surface condensation

Ventilation

Criteria to avoid mould growth at the internal surface

$$f_{R_{si}} \geq f_{R_{si,min}}$$

Increase of energy needs for space heating ← Decrease $f_{Rsi,min}$ by increasing the air change rate

References

ASHRAE Handbook—Fundamentals (2005).

Cavallini, Rossetto, Zarrella. Aria umida: teoria e applicazioni, Edizioni Libreria Progetto, Padova, 2020.

EN ISO 10211:2017 Thermal bridges in building construction - Heat flows and surface temperatures - Detailed calculations.

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

UNI EN ISO 13788:2013 Prestazione igrotermica dei componenti e degli elementi per edilizia - Temperatura superficiale interna per evitare l'umidita' superficiale critica e la condensazione interstiziale - Metodi di calcolo. *[Italian]*

UNI 10349-1:2016 Riscaldamento e raffrescamento degli edifici - Dati climatici - Parte 1: Medie mensili per la valutazione della prestazione termo-energetica dell'edificio e metodi per ripartire l'irradianza solare nella frazione diretta e diffusa e per calcolare l'irradianza solare su di una superficie inclinata. *[Italian]*

WHO guidelines for indoor air quality: dampness and mould. World Health Organization (2009).