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One off tiled/mortared stoves — Calculation method

Ortsfest gesetzte Kachelöfen/Putzöfen — Berechnungsverfahren

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Content

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Foreword

This document TC 295 WI was prepared by Technical Comitee CEN/TC 295 „Residential solid fuel burning appliances“, the secretariat of which is held by BSI.

This document is a working document.

Preliminary note

This calculation method fort he dimensioning of Kachelöfen/Putzöfen (one off tiled/mortared stoves) is based on appropriate literature as well as European standards EN 12831 und EN 13384-1, whereat besides deducible formulas also experiental determined correlations are used.

1 Scope

This standard contains basic principles fort he dimensioning of one off Kachelöfen/Putzöfen (one off tiled/mortared stoves). The rules can be used for wood log fired Kachelöfen/tiled stoves with maximum loads from 10 to 40 kg and nominal heating times from 8 to 24 hours.

This standard is not valid for combinations with water heat exchangers for central heating etc. and is also not valid for combinations with Kachelofen/Putzofen-Einsätzen.

This calculation method can be used to proof requirements of emissions and energy efficiency.

2 Normative references

3 Terms and definitions

3.1
construction with air gap
construction, with an air gap between the inner and the outer shell

3.2
construction without air gap
construction, with no air gap between the inner and the outer shell

3.3
combustion chamber base A_{BR}
horizontal cut through the combustion chamber at the height of the fire box opening

3.4
combustion chamber height H_{BR}
mean vertical distance between combustion chamber base and combustion chamber ceiling

3.5
combustion chamber surface O_{BR}
Sum of the inner surface of the combustion chamber

3.6
combustion chamber temperature t_{BR}
Value to calculate the thermal lift in the combustion chamber

3.7
burning rate m_{BU}
mean fuel load divided by burning time

3.8
combustion chamber admeasurement U_{BR}
admeasurement of the combustion chamber base

3.9
gas groove
additional opening for the conduction of the flue gas

3.10
flue pipe length L_Z
length of the connecting line of all geometric centres of the flue pipe profiles from the combustion chamber exit to the connecting pipe entrance

3.11
Kachelofen/tiled stove
One off slow heat release appliance, which is adapted individually to the local conditions and whose visible surface is predominantly made of tiles

3.12
short flue pipe section
section of the flue pipe, where the length of the section is shorter than the hydraulic diameter

3.13
minimum flue pipe length L_{Zmin}
minimal acceptable length of the flue pipe

3.14
maximum load m_B
load of the fuel at nominal heat output

3.15
minimum load m_{Bmin}
load of the fuel at the lowest reduced heat output

3.16
Putzofen/mortared stove
One off slow heat release appliance, which is adapted individually to the local conditions and whose visible surface is predominantly mortared

3.17
partial heating
operation, where just a part of the heating load is supplied

3.18
full capacity heating
operation, where the heating load is fully supplied

4 Calculations

4.1 Design of the nominal heat output

4.1.1 Nominal heat output at full capacity heating

If the Kachelofen/Putzofen (tiled/mortared stove) is designed for full capacity heating, the nominal heat output has to fulfil the needs of the heating load calculated due to EN 12831.

$P_n = P_{NH}$	(1)

with:

P_n nominal heat output (kW)

P_{NH} heating load due to EN 12831 (kW)

4.1.2 Nominal heat output at patial heating

The heating load has to be calculated due to EN 12831. The Kachelofen/Putzofen (tiled/mortared stove) just needs to meet parts of the need of the heating load.

$P_n \angle P_{NH}$	(2)

4.2 Design of the load of fuel

4.2.1 Design of the maximum load

The maximum load of fuel is calculated as follows:

$m_B = \frac{P_n \cdot t_n}{3{,}25}$	(3)

with:

m_B maximum load (kg)

P_n nominal heat output (kW)

t_n nominal heating time (h)

4.2.2 Design of the minimum load

The minimum load is fixed with 50 % of the maximum load.

$m_{Bmin} = 0{,}5 \cdot m_B$	(4)

with:

m_B maximum load (kg)

m_{Bmin} minimum load (kg)

4.3 Design of the essential dimensions

4.3.1 Combustion chamber dimensions

The design of the dimensions of the combustion chamber is necessary, because on one hand enough room to place the fuel in it is needed and on the other hand the requirements for clean combustion have to be fulfilled.

4.3.1.1 Combustion chamber surface

The dimension of the combustion chamber surface has to be calculated as follows:

$$O_{BR} = 900 \cdot m_B \quad (5)$$

with:

m_B maximum load (kg)

O_{BR} combustion chamber surface (cm^2)

For the calculation of the combustion chamber surface all its walls, the ceiling and the base including the area of the combustion chamber opening and the combustion chamber exit for the flue gas have to be regarded equally.

4.3.1.2 Combustion chamber base

The combustion chamber base can be varied between a minimum and a maximum value.

The minimum value results from the requirement that at maximum load a height of the fuel of 33 cm shall not be exceeded. Therefore a base of 100 cm² per kg fuel is needed.

$$A_{BRmin} = 100 \cdot m_B \quad (6)$$

with:

m_B maximum load (kg)

A_{BRmin} minimum combustion chamber base (cm^2)

The maximum area of the base of the combustion chamber is defined through equations (5) and (8) as follows:

$$A_{BRmax} = \frac{900 \cdot m_B - (25 + m_B) \cdot U_{BR}}{2} \quad (7)$$

with:

m_B maximum load (kg)

A_{BRmax} maximum combustion chamber base (cm^2)

U_{BR} combustion chamber admeasurement (cm)

When the base is square, the proportion of length to width can be varied from 1 to 2, a minimum width of 23 cm is required.

4.3.1.3 Combustion chamber height

The minimum combustion chamber height is calculated as follows::

$H_{BR} \geq 25 + m_B$	(8)

with:

m_B maximum load (kg)

H_{BR} combustion chamber height (cm)

The combustion chamber height is calculated as follows:

$H_{BR} = \frac{900 \cdot m_B - 2 \cdot A_{BR}}{U_{BR}}$	(9)

With:

m_B maximum load (kg)

A_{BR} combustion chamber base (cm^2)

H_{BR} combustion chamber height (cm)

U_{BR} combustion chamber admeasurement (cm)

4.3.2 Minimum flue pipe length

4.3.2.1 Construction without air gap

The minimum flue pipe length is calculated as follows:

$L_{Zmin} = 1{,}3 \cdot \sqrt{m_B}$	(10a)

with:

m_B maximum load (kg)

L_{Zmin} minimum flue pipe length (m)

4.3.2.2 Construction with air gap

Die Mindestzuglänge ist nach folgender Formel zu ermitteln:

$L_{Zmin} = 1{,}5 \cdot \sqrt{m_B}$	(10b)

with:

m_B maximum load (kg)

L_{Zmin} minimum flue pipe length (m)

4.3.3 Gas groove profile

The gas groove profil eis calculated as follows:

$A_{GS} = 1 \cdot m_B$	(11)

with

A_{GS} profile of the gas groove (cm^2)

m_B maximum load (kg)

4.4 Calculation of the burning rate

The burning rate is calculated as follows:

$m_{BUopt} = 0{,}78 \cdot m_B$	(12)

with:

m_B maximum load (kg)

m_{Buopt} burning rate (kg · h^{-1})

4.5 Fixing of the air ratio

A combustion in a Kachelofen/Putzofen (tiled/mortared stove) is a process, which is not stationary. The mean air ratio is fixed as follows:

$\lambda = 2{,}95$	(13)

With:

λ air ratio

4.6 Combustion air, flue gas

4.6.1 Combustion air flow rate

The mean combustion air flow rate is calculated as follows:

$\dot{V}_L = 0{,}002\,56 \cdot m_B \cdot f_t \cdot f_s$	(14)

with:

$\dot{V}_L$ combustion air flow rate (m^3·s^{-1})

m_B maximum load (kg)

f_t temperature correction factor

f_s altitude correction factor

4.6.1.1 Temperature correction

The temperature correction factor is calculated as follows:.

$f_f = \frac{273 + t_f}{273}$	(15)

with:

f_t temperature correction factor

f_L temperature of the combustion air at air inlet (°C)

4.6.1.2 Altitude correction

The altitude correction factor is calculated as follows:

$f_s = \frac{1}{e^{(-9,81*z)/78624}}$	(16)

with:

f_s altitude correction factor

z geodetical height (m)

4.6.2 Flue gas flow rate

The knowledge of the flue gas flow rate is important fort he calculation of the flue pipe diameter. It is calculated as follows:

$\dot{V}_G = 0{,}002\,73 \cdot m_B \cdot f_t \cdot f_s$	(17)

With:

$\dot{V}_G$ flue gas flow rate ($m^3 \cdot s^{-1}$)

m_B maximum load (kg)

f_t temperature correction factor

f_s altitude correction factor

f_t is calculated using the flue gas temperature of the flue pipe section. This means that along the flue pipe and the decreasing temperature leads to a lower flue gas flow rate.

4.7 Calculations of the density

4.7.1 Combustion air density

The density of the combustion air at standard conditions (0 °C, ≈ 1 013 mbar) is 1,293 kg · m^{-3}. As the combustion air is not in standard conditions a correction is necessary. The decrease of the density at higher temperatures is described by the temperature correction factor, the decrease at higher altitudes is described by the altitude correction factor.

$$\rho_L = \frac{1{,}293}{f_t \cdot f_s} \qquad (18)$$

with:

ρ_L combustion air density (kg·m^{-3})

f_t temperature correction factor

f_s altitude correction factor

4.7.2 Flue gas density

The density of the combustion air at standard conditions is 1,282 kg · m^{-3}. It is calculated as follows.

$$\rho_G = \frac{1{,}282}{f_t \cdot f_s} \qquad (19)$$

with:

ρ_G flue gas density (kg·m^{-3})

f_t temperature correction factor

f_s altitude correction factor

4.8 Calculation of the flue gas temperature

4.8.1 Combustion chamber temperature

The combustion chamber temperature is necessary to calculate the buoyancy in the combustion chamber. Due to the calculation of the combustion chamber surface the calculation temperature of all combustion chambers is similar. The temperature is fixed as follows:

$$t_{BR} = 700 \qquad (20)$$

with:

t_{BR} combustion chamber temperature (°C)

4.8.2 Flue gas temperature in the flue pipe

The decrease of the temperature along the flue pipe is calculated as follows:

$t = 550 \cdot e^{\frac{-0{,}83 \cdot L_Z}{L_{Zmin}}}$	(21)

with:

t temperature (°C)

L_Z flue pipe length (m)

L_{Zmin} minimum flue pipe length (m)

This development of the temperature is valid from the combustion chamber exit to the connecting pipe..

4.8.3 Flue gas temperature in the connecting pipe

The flue gas temperature in the connecting pipe is calculated based EN 13384-1.

4.8.4 Flue gas temperature at chimney entrance, mean flue gas temperature of the chimney and temperature of the chimney wall at the top of the chimney

The flue gas temperature at chimney entrance, the mean flue gas temperature of the chimney and the temperature of the chimney wall at the top of the chimney are calculated based on EN 13384-1.

4.9 Calculation of flow mechanics

4.9.1 Calculation of buoyancy

The buoyancy results in the difference between the densities of the flue gas and the air.

It is calculated as follows:

$p_h = g \cdot H \cdot (\rho_L - \rho_G)$	(22)

with:

p_h buoyancy (Pa)

g acceleration of gravity (= 9,81 m · s^{-2})

H effective height (m)

ρ_L air density (kg · m^{-3})

ρ_G flue gas density (kg · m^{-3})

The effective height ist he vertical difference between the flue gas exit and the flue gas entrance of a flue pipe section, the connecting pipe ort he chimney. For the combustion the combustion chamber height has to be used. The air density has to be calculated due to equiation (18) using a temperature of 0°C, the flue gas density has to be calculated due to equiation (19) using the temperature in the middle of the flue pipe section, connecting pipe or chimney. For the combustion chamber the combustion chamber temperature is used.

4.9.2 Calculation of the flow velocity

The velocity is calculated by using the air- or flue gas flow rates divided by the profile.

$v = \frac{\dot{V}}{A}$	(23)

with:

v flow velocity (m·s^{-1})

$\dot{V}$ air- or flue gas flow rate (m^3 · s^{-1})

A profile (m^2)

The flow velocity in the flue pipe, the connecting pipe and the chimney has to be between 1,2 and 6 m · s^{-1}.

4.9.3 Calculation of the static friction

The calculation of the static friction in the flue pipe, the connecting pipe and the chimney is calculated due to EN 13384-1 as follows:

$p_\mathrm{R} = \frac{\lambda_\mathrm{f} \cdot p_\mathrm{d} \cdot L}{D_\mathrm{h}}$	(24)

with:

ρ_r static friction (Pa)

ρ_d dynamic pressure (Pa)

λ_f friction coefficient

L length of flue pipe section, connecting pipe or chimney (m)

D_h hydraulic diameter (m)

4.9.3.1 Dynamic pressure

The dynamic pressure is calculated as follows:

$p_\mathrm{d} = \frac{\rho \cdot v^2}{2}$	(25)

Hierin bedeutet:

ρ_d dynamic pressure (Pa)

ρ density (kg·m^{-3})

v flow velocity (m·s^{-1})

4.9.3.2 Friction coefficient

The friction coefficient is calculated according to an approximation as follows:

$\lambda_f = \frac{1}{(1{,}14 + 2{,}0 * \lg \frac{D_h}{k_f})^2}$	(26)

with:

λ_f friction coefficient

k_f roughness height (m)

D_h hydraulic diameter (m)

The roughness height of some materials is displayed in table 1.

Tabelle 1 — values für k_f

material	Roughness height (m)
Chamotte pipes	0,002
Chamotte slabs	0,003

4.9.3.3 Hydraulic diameter

The hydraulic diameter is calculated as follows:

$D_h = \frac{4 \cdot A}{U}$	(27)

with:

D_h hydraulic diameter (m)

A profile (m^2)

U admeasurement (m)

4.9.4 Calculation of the resistance due to direction change

The resistance due to direction change is calculated by multiplication of the dynamic pressure with the resistance coefficient.

$p_u = \zeta \cdot p_d$	(28)

with:

p_u resistance due to direction change (Pa)

ζ resistance coefficient due to direction change

p_d dynamic pressure (Pa)

For standard geometric designs the resistance coefficient is displayed in table 2.

Table 2 — resistance coefficient for standard geometric designs

Geometric design	ζ-value
angle 10°	0,1
angle 30°	0,2
angle 45°	0,4
Circular arg 60	0,7
angle 60°	0,8
angle 90°	1,2

Interim values are interpolated linear.

If a flue pipe section is shorter than its hydraulic diameter (short flue pipe section: L < Dh), the resistances of the direction changes before and after the section are not fully effective Therefore the calculation of the resistance coefficient is done as follows:

$$\zeta_1 = \zeta_{\alpha 1} + \frac{\alpha_1}{\alpha_1 + \alpha_2} \cdot \left(\zeta_{\alpha 3} - \zeta_{a2} - \zeta_{a1}\right) \cdot \left(1 - \frac{L_Z}{D_h}\right) \quad (29)$$

$$\zeta_2 = \zeta_{\alpha 2} + \frac{\alpha_2}{\alpha_1 + \alpha_2} \cdot \left(\zeta_{\alpha 3} - \zeta_{a2} - \zeta_{a1}\right) \cdot \left(1 - \frac{L_Z}{D_h}\right) \quad (30)$$

with:

D_h hydraulic diameter (m)

L_Z flue pipe length (m)

α_1 angle between flue pipe section in front and short flue pipe section (°)

α_2 angle between short flue pipe section and flue pipe section after (°)

α_3 angle between flue pipe section in front of and flue pipe section after short flue pipe section (°)

ζ_1 modified resistance coefficient for $\alpha 1$

ζ_2 modified resistance coefficient for $\alpha 2$

$\zeta_{\alpha 1}$ resistance coefficient for α_1

$\zeta_{\alpha 2}$ resistance coefficient for α_2

$\zeta_{\alpha 3}$ resistance coefficient for $\alpha 3$

4.10 Operation control

4.10.1 Pressure condition

At nominal heat ouput the sum of all buoyancies has to be compared with the sum of all resistances.

The calculation has to be done section by section starting with the air inlet till the exit of the chimney. For the calculation the conditions (temperature, velocity) in the middle of the section have to be taken. The following term has to be fulfilled:

$\sum \rho_r + \sum \rho_u \leq \sum \rho_h \leq 1{,}05 \cdot \left(\sum \rho_r + \sum \rho_u\right)$	(31)

with:

$\sum \rho_r$ sum of all static frictions (Pa)

$\sum \rho_u$ sum of all resistances due to direction change (Pa)

$\sum \rho_h$ sum of all buoncies (Pa)

4.10.2 Dew point condition

At lowest load the temperature of the chimney wall at its top is compared with the dew point temperature of the flue gas.

The following term has to be fulfilled:

$t_{i,2} \geq 45$	(32)

with:

$t_{i,2}$ chimney wall temperature at its top (°C)

For this calculation a temperature of 45 °C for the dew point temperature is used. The chimney wall temperature at its top is calculated based on EN 13384-1.

Annex A
(informative)