SLOVENSKI STANDARD
SIST EN 13384-1:2003

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Dimniki - Raļunske metode termodinamike in dinamike fluidov - Dimniki za eno ogrevalno napravo

Chimneys - Thermal and fluid dynamic calculation methods - Part 1 : Chimneys serving one appliance

Abgasanlagen - Wärme- und strömungstechnische Berechnungsverfahren - Teil 1 : Abgasanlagen mit einer Feuerstätte

Conduits de fumée - Méthodes de calcul thermo-aéraulique - Partie 1 : Conduits de fumée ne desservant qu'un seul appareil

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Contents

Foreword

This document (EN 13384-1:2002) has been prepared by Technical Committee CEN/TC 166, "Chimneys", the secretariat of which is held by UNI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2003, and conflicting national standards shall be withdrawn at the latest by June 2003.

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association and supports essential requirements of EU Directives.

Annexes A, B, C and D are informative.

This European Standard “Chimneys – Thermal and fluid dynamic calculation methods” consists of two Parts:

- *Part 1: Chimneys serving one heating appliance.*
- *Part 2: Chimneys with multiple inlets and one inlet with multiple appliances.*

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

1 Scope

This European Standard specifies methods for the calculation of the thermal and fluid dynamic characteristics of chimneys serving one appliance.

The methods in this Part of this European Standard are applicable to negative or positive pressure chimneys with wet or dry operating conditions. It is valid for chimneys with heating appliances for fuels subject to the knowledge of the flue gas characteristics which are needed for the calculation.

The methods in this Part of this European Standard are applicable to chimneys with one inlet connected with one appliance. The methods in Part 2 of this European Standard are applicable to chimneys with multiple inlets and one inlet with multiple appliances.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to, or revisions of, any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 1443:1999, *Chimneys - General requirements.*

prEN 1856-1, *Chimneys – Requirements for metal chimneys – Part 1: System chimney products.*

EN 1859, *Chimneys - Metal chimneys Test Methods.*

EN 13502, *Chimneys - Requirements and test methods for clay/ceramic flue terminals*

CR 1749, *European scheme for the classification of gas appliances according to the method of evacuation of the products of combustion (Types)*

3 Terms and definitions

For the purposes of this European Standard, the terms and definitions given in EN 1443:1999 and the following apply.

3.1
heat output (*Q*)
amount of heat produced by a heating appliance per unit of time

3.1.1
nominal heat output (Q_N)
continuous heat output specified by the manufacturer of the heating appliance related to specified fuels

3.1.2
heat output range
range of output below the nominal heat output specified by the manufacturer over which the appliance can be used

3.2
heat input (Q_F)
amount of heat in unit time which is supplied to the heating appliance by the fuel based on its net caloric value H_u

3.3
efficiency of the heating appliance (η_W)
ratio of the heat output (Q) from the appliance to the heat input (Q_F)

3.4
flue gas mass flow ($\dot{m}$)
mass of flue gas leaving the heating appliance through the connecting flue pipe per time unit

3.5
effective height of the chimney (H)
difference in height between the axis of the flue gas inlet into the chimney and the outlet of the chimney

3.6
effective height of the connecting flue pipe (H_V)
difference in height between the axis of the flue gas chimney outlet of the heating appliance and the axis of the flue gas inlet into the chimney

In the case of open fire chimneys, H_V is the difference in height between the height of the upper frame of the furnace and the axis of the flue gas inlet into the chimney.

3.7
draught
positive value of the negative pressure in the flue

3.8
theoretical draught available due to chimney effect (P_H)
pressure difference caused by the difference in weight between the column of air equal to the effective height outside a chimney and the column of flue gas equal to the effective height inside the chimney

3.9
pressure resistance of the chimney (P_R)
pressure which is necessary to overcome the resistance of the flue gas mass flow which exists when carrying the flue gases through the chimney

3.10
wind velocity pressure (P_L)
pressure generated on the chimney due to wind

3.11
draught at the flue gas inlet into the chimney (P_Z)
difference between the theoretical draught at the height of the axis of the flue gas inlet into the chimney and the pressure resistance in the flue at the same height

3.12
minimum draught for the heating appliance (P_W)
difference between the static air pressure of the room of installation of the heating appliance and the static pressure of the flue gas at the chimney outlet of the appliance which is necessary to maintain the correct operation of the heating appliance

3.13
effective pressure resistance of the connecting flue pipe (P_{FV})
static pressure difference between the axis of the inlet of the connecting flue pipe and the axis of the chimney outlet due to the theoretical draught and pressure resistance

3.14
effective pressure resistance of the air supply (P_B)
difference between the static pressure in the open air and the static air pressure in the room of installation of the heating appliance at the same height

3.15
draught required at the flue gas inlet into the chimney (P_{Ze})
sum of the minimum draught required for the heating appliance and the draught required to overcome the effective pressure resistance of the connecting flue pipe and the effective pressure resistance of the air supply

3.16
positive pressure at the flue gas inlet into the chimney (P_{ZO})
sum of the difference of the pressure resistance and the theoretical draught of the chimney and the wind velocity pressure

3.17
maximum differential pressure of the heating appliance (P_{WO})
maximum difference between the static pressure of the flue gas at the chimney outlet of the appliance and the static pressure of the air at the inlet to the heating appliance specified for its correct operation

3.18
maximum differential pressure at the flue gas inlet into the chimney (P_{ZOe})
difference between the maximum differential pressure of the heating appliance and the sum of the effective pressure resistance of the connecting flue pipe and the effective pressure resistance of the air supply

3.19
secondary air
ambient air added to the flue gas in addition to the nominal flue gas mass flow

3.20
secondary air device
draught regulator or a draught diverter

3.21
draught regulator
component which automatically supplies ambient air to the chimney, the connecting flue pipe or the heating appliance

3.22
draught diverter
device, placed in the combustion products passage of the heating appliance, that is intended to maintain the quality of combustion within certain limits and to keep the combustion stable under certain conditions of updraught and downdraught

3.23
temperature limit of the inner wall (T_g)
allowed minimum temperature of the inner wall of the chimney outlet

4 Symbols, terminology and units

The symbols given in this clause can be completed by one or more indices to indicate location or materials if necessary.

Table 1 - Symbols, terminology and units

Symbol	Terminology	Unit
A	cross section area	m^2
c	specific heat capacity	J/(kg·K)
c_p	specific heat capacity of flue gas	J/(kg·K)
d	thickness of the section	m
D	diameter	m
D_h	hydraulic diameter	m
H	effective height of the chimney	m
k	coefficient for heat transmission	$W/(m^2.K)$
K	coefficient of cooling	--
L	length	m
$\dot{m}$	flue gas mass flow	kg/s
Nu	Nusselt number	--
p	static pressure	Pa
p_L	external air pressure	Pa
P_B	pressure resistance of the air supply for a flue gas mass flow	Pa
P_E	pressure resistance due to friction and form resistance of the chimney	Pa
P_{FV}	effective pressure resistance of the connecting flue pipe	Pa
P_G	difference in pressure caused by change of velocity of flue gas in the chimney	Pa
P_H	theoretical draught available due to chimney effect	Pa
P_{HV}	theoretical draught available due to chimney effect of the connecting flue pipe	Pa
P_L	wind velocity pressure	Pa
P_{NL}	draught required for secondary air devices	Pa
P_R	pressure resistance of the chimney	Pa
P_{RV}	pressure resistance of the connecting flue pipe	Pa
P_W	minimum draught for the heating appliance	Pa
P_{WO}	maximum differential pressure of the heating appliance	Pa
P_Z	draught at the flue gas inlet into the chimney	Pa
P_{Ze}	draught required at the flue gas inlet into the chimney	Pa
P_{ZO}	positive pressure at the flue gas inlet into the chimney	Pa

Table 1 *(continued)*

Symbol	Terminology	Unit
P_{ZOe}	maximum differential pressure at the flue gas inlet into the chimney	Pa
Pr	Prandtl number	--
Q	heat output	kW
Q_F	heat input	kW

Q_N	nominal heat output	kW
r	mean value of roughness of the inner wall	m
R	gas constant of the flue gas	J/(kg·K)
R_L	gas constant of the air	J/(kg·K)
Re	Reynolds number	--
s	cross section	m
S_E	flow safety coefficient	--
S_H	correction factor for temperature instability	--
t	temperature	°C
T	temperature, absolute	K
T_g	temperature limit	K
T_{io}	inner wall temperature at chimney outlet	K
T_{iob}	inner wall temperature at the chimney outlet at temperature equilibrium	K
T_L	external air temperature	K
T_m	mean temperature of the flue gas	K
T_p	water dew point	K
T_{sp}	condensing temperature	K
T_u	ambient air temperature	K
T_{ub}	ambient air temperature of the boiler room	K
T_{uh}	ambient air temperature for heated areas	K
T_{uo}	ambient air temperature at the chimney outlet	K
T_{ul}	ambient air temperature for areas external to the building	K
T_{uu}	ambient air temperature for unheated areas inside the house	K
T_W	flue gas temperature of the appliance	K
T_{WN}	flue gas temperature of the appliance at nominal heat output	K
T_{Wmin}	flue gas temperature of the appliance at the lowest possible heat output	K
U	internal chimney segment parameter	m
w	mean velocity within a cross section	m/s
w_m	mean velocity over a defined length	m/s
y	form value	--
z	height above sea level	m
α	coefficient of heat transfer	W/(m^2·K)
β	ratio of the combustion air mass flow to the flue gas mass flow	--
γ	angle between flow directions	°
δ	wall thickness	m

Table 1 *(concluded)*

Symbol	Terminology	Unit
ζ	coefficient of flow resistance due to a directional and/or cross sectional and/or mass flow change in the flue	-
η	dynamic viscosity	$N \cdot s/m^2$
η_W	efficiency of the heating appliance	--
η_{WN}	efficiency of the heating appliance at nominal heat output	--
λ	coefficient of thermal conductivity	$W/(m \cdot K)$
ρ	density	kg/m^3
ρ_L	density of the external air	
ρ_m	mean density of flue gas averaged over a defined length and over the cross section	kg/m^3
σ (CO_2)	volume-concentration of CO_2	%
σ (H_2O)	volume-concentration of H_2O (vapour)	%
ψ	coefficient of flow resistance due to friction of the flue	--
$\left(\frac{1}{\Lambda}\right)$	thermal resistance	$m^2 \cdot K/W$

Table 2 - Additional subscripts

Subscript	Terminology	Unit
a	outside	--
A	flue gas	--
b	equilibrium temperature condition	--
B	combustion air	--
e	entrance	--
G	change in velocity	--
i	inside	--
L	open air (outside)	--
m	mean value	--
M	mixture	--
n	counting index	--
N	nominal value	--
NL	secondary air	--
o	chimney outlet	--
O	positive pressure	--
tot	totalized over all sections (segments)	--
u	ambient air	--
V	connecting flue pipe	--
W	heating appliance	--

5 Calculation method

5.1 General principles

The calculation of inside dimensions (cross section) of negative pressure chimneys is based on the following three criteria:

- the draught at the flue gas inlet into the chimney shall be equal to or greater than the draught required at the flue gas inlet into the chimney;
- the draught at the flue gas inlet to the chimney shall be equal to or greater than the effective pressure resistance of the air supply;
- the temperature of the inner wall at the chimney outlet of the chimney shall be equal to or greater than the temperature limit.

The calculation of inside dimensions (cross section) of positive pressure is based on the following three criteria:

- the comparison between the positive pressure at the flue gas inlet into the chimney shall be equal or less than the maximum differential pressure at the flue gas inlet into the chimney;
- the positive pressure in the connecting flue pipe and in the chimney shall not be higher than the excess pressure for which both are designated;
- the temperature of the inner wall at the chimney outlet of the chimney shall be equal to greater than the temperature limit.

In order to verify the criteria two sets of external conditions are used:

- the calculation of the pressure (draught) is made with conditions for which the capacity of the chimney is minimal (i.e. high outside temperature), and also
- the calculation of inner wall temperature with conditions for which the inside temperature of the chimney is minimal (i.e. low outside temperature).

5.2 Pressure requirements

5.2.1 Negative pressure chimneys

The following relationships shall be verified:

$$P_Z = P_H - P_R - P_L \geq P_W + P_{FV} + P_B = P_{Ze} \quad \text{in Pa} \quad (1)$$

$$P_Z \geq P_B \quad \text{in Pa} \quad (2)$$

Where

P_B is the effective pressure resistance of air supply (see 5.11.3), in Pa;

P_{FV} is the effective pressure resistance of the connecting flue pipe, in Pa;

P_H is the theoretical draught available due to chimney effect, in Pa;

P_L is the wind velocity pressure, in Pa;

P_R is the pressure resistance of the chimney, in Pa;

P_W is the minimum draught for the heating appliance, in Pa;

P_Z is the draught at the flue gas inlet into the chimney (see 5.10), in Pa;

P_{Ze} is the draught required at the flue gas inlet into the chimney (see 5.11), in Pa.

5.2.2 Positive pressure chimneys

The following relationships shall be verified:

$$P_{ZO} = P_R - P_H + P_L \leq P_{WO} - P_B - P_{FV} = P_{ZOe} \quad \text{in Pa} \quad (3)$$

$$P_{ZO} \leq P_{Z\,excess} \quad \text{in Pa} \quad (4)$$

$$P_{ZO} + P_{FV} \leq P_{ZV\,excess} \quad \text{in Pa} \quad (5)$$

Where

P_{WO} is the maximum differential pressure of the heating appliance, in Pa;

P_{ZO} is the positive pressure at the flue gas inlet into the chimney, in Pa;

P_{ZOe} is the maximum differential pressure at the flue gas inlet into the chimney, in Pa;

$P_{Z\,excess}$ is the maximum allowed pressure from the designation of the chimney, in Pa;

P_R is the pressure resistance of the chimney, in Pa.

5.3 Temperature requirement

The following relationship shall be verified:

$$T_{iob} \geq T_g \quad \text{in K} \quad (6)$$

Where

T_{iob} is the inner wall temperature at the chimney outlet at temperature equilibrium, in K;

T_g is the temperature limit, in K.

If the chimney above the roof has additional insulation the following relationship shall also be verified:

$$T_{irb} \geq T_g \quad \text{in K} \quad (7)$$

Where:

T_{irb} is the inner wall temperature immediately before the additional insulation, in K.

The temperature limit T_g of chimneys with dry operating conditions shall be taken as the condensing temperature T_{sp} of the flue gas (see 5.7.6).

The temperature limits T_g of chimneys with wet operating conditions shall be taken as 273,15 K which prevents the formation of ice at the chimney outlet.

NOTE The comparison of the inner wall temperature before the additional insulation T_{irb} with the admissible limit temperature of the flue gas T_g is not necessary, if the value of the thermal resistance of the additional insulation is not more than 0,1 ($m^2 \cdot K$)/W.

For chimneys operating under wet conditions the comparison is not necessary, if the value of the ambient air temperature immediately before the additional insulation is ≥ 0 °C.

5.4 Calculation procedure

For the calculation of the pressure and temperature values for the relationships of equations (1), (2), (3), (4), (5) and (6) the values of the flue gas data characterising according to 5.5 shall be obtained for the appliance. The data specified in 5.6 shall be obtained for the chimney and its connecting flue pipe.

5.7 to 5.11 provide calculations needed to finalise the chimney thermal and fluid dynamic calculations. In 5.7 the formulae provide the calculation of the basic data which are needed for further calculation.

In 5.5.2 and 5.8 the formulae for the calculations of the relevant temperatures are compiled. The formulae for the density of the flue gas and its velocity are compiled in 5.9.

The procedure in 5.10 and 5.11 shall be used to validate the pressure requirement. The procedure in 5.12 shall be used to validate the temperature requirement.

The validation for pressure and temperature requirement shall be conducted twice:

- for the nominal heat output of the heating appliance;
- for the lowest value of the heat output range which is indicated by the manufacturer of the heating appliance.

If the temperature requirements in equations (6) and (7) of negative pressure chimneys are not fulfilled the validation of the temperature condition can occasionally be done by taking additional secondary air to the flue gas into account according to clause 6.

5.5 Flue gas data characterising the heating appliance for nominal heat output

5.5.1 General

For the calculation of temperatures and pressure values the relevant flue gas data which characterises the heating appliance, consisting of flue gas mass flow, flue gas temperature and the minimum draught required for the heating appliance or the maximum differential pressure of the heating appliance shall be obtained. Additionally the kind of the fuel supplied, the volume concentration of CO_2 of the flue gas and the geometry of the connecting flue pipe shall be specified.

Typical data for some fuels are given in Table B.1.

Typical data for some heating appliances are given in Tables B.2 and B.3.

5.5.2 Flue gas mass flow

5.5.2.1 Flue gas mass flow at nominal heat output of the heating appliance

For the calculation of pressure and temperature values according to relationships of equations (1), (2) (3), (4), (5) and (6) the flue gas mass flow at nominal heat output conditions for the heating appliance shall be obtained.