



DPC: 25/30507781 DC

BSI Group Headquarters

389 Chiswick High Road London W4 4AL

Tel: +44 (0)20 8996 9000

Fax: +44 (0)20 8996 7400

www.bsigroup.com

Date: 22 May 2025

Origin: European

Latest date for receipt of comments: 15 July 2025

Project No. 2025/00164

Responsible committee: B/506 Chimneys

Interested committees:

Title: Draft BS EN 13384-1 Chimneys - Thermal and fluid dynamic calculation methods. Part 1: Chimneys serving one combustion appliance.

Please notify the secretary if you are aware of any keywords that might assist in classifying or identifying the standard or if the content of this standard

- i) has any issues related to 3rd party IPR, patent or copyright
- ii) affects other national standard(s)
- iii) requires additional national guidance or information

WARNING: THIS IS A DRAFT AND MUST NOT BE REGARDED OR USED AS A BRITISH STANDARD. THIS DRAFT IS NOT CURRENT BEYOND 15 July 2025

This draft is issued to allow comments from interested parties; all comments will be given consideration prior to publication. No acknowledgement will normally be sent. **See overleaf for information on the submission of comments.**

No copying is allowed, in any form, without prior written permission from BSI except as permitted under the Copyright, Designs and Patent Act 1988 or for circulation within a nominating organization for briefing purposes. Electronic circulation is limited to dissemination by e-mail within such an organization by committee members.

Further copies of this draft may be purchased from BSI Shop <http://shop.bsigroup.com> or from BSI Customer Services, Tel: +44(0) 20 8996 9001 or email cservices@bsigroup.com. British, International and foreign standards are also available from BSI Customer Services.

Information on the co-operating organizations represented on the committees referenced above may be obtained from <https://standardsdevelopment.bsigroup.com/>.

Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

For national standards, comments will be reviewed by the relevant UK national committee and the resulting standards published as a British Standard.

UK Vote

Please indicate whether you consider the UK should submit a negative (with supporting technical reasons) or positive vote on this draft. Please indicate if you are aware of any reason why this draft standard should not be published as a British Standard.

Submission of Comments

- **Annotated drafts are not acceptable and will be rejected.**
- All comments should be submitted online at <https://standardsdevelopment.bsigroup.com/>. You will need to register in order to comment.

Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
------------------	------------------------

1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/ Figure/Table/Note	Type of comment	Comment (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	

English Version

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

Conduits de fumée - Méthodes de calcul
thermoaéraulique - Partie 1: Conduits de fumée ne
desservant qu'un seul appareil à combustion

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

This draft European Standard is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee CEN/TC 166.

If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

This draft European Standard was established by CEN in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Türkiye and United Kingdom.

Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

Warning : This document is not a European Standard. It is distributed for review and comments. It is subject to change without notice and shall not be referred to as a European Standard.



EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

Contents

Page

European foreword	5
1 Scope.....	6
2 Normative references.....	6
3 Terms and definitions	6
4 Symbols and abbreviations	11
5 Calculation method for non-balanced flue chimneys	15
5.1 General principles	15
5.2 Pressure requirements.....	16
5.2.1 Negative pressure chimneys.....	16
5.2.2 Positive pressure chimneys	17
5.3 Temperature requirement.....	18
5.4 Calculation procedure.....	19
5.5 Flue gas data characterising the combustion appliance.....	19
5.5.1 General.....	19
5.5.2 Flue gas mass flow and combustion air mass flow	20
5.5.3 Flue gas temperature.....	21
5.5.4 Minimum draught for the combustion appliance (P_w) for negative pressure chimney	21
5.5.5 Maximum draught for the combustion appliance (P_{wmax}) for negative pressure chimney	22
5.5.6 Maximum differential pressure of the combustion appliance (P_{w0}) for positive pressure chimney	22
5.5.7 Minimum differential pressure of the combustion appliance (P_{w0min}) for positive pressure chimney	22
5.6 Characteristic data for the calculation.....	22
5.6.1 General.....	22
5.6.2 Mean value for roughness (r)	22
5.6.3 Thermal resistance ($1/\lambda$)	22
5.7 Basic values for the calculation	23
5.7.1 Air temperatures.....	23
5.7.2 External air pressure (p_L)	25
5.7.3 Gas constant.....	25
5.7.4 Density of the external air (ρ_L).....	25
5.7.5 Specific heat capacity of the flue gas (c_p)	26
5.7.6 Condensing temperature (T_{sp})	26
5.7.7 Correction factor for temperature instability (S_H)	26
5.7.8 Flow safety coefficients (S_E and S_{EB})	26
5.8 Determination of the temperatures.....	26
5.8.1 General.....	26
5.8.2 Calculation of the coefficient of cooling (K).....	27
5.8.3 Coefficient of heat transmission (k_b)	27
5.9 Determination of the density of the flue gas and the velocity of the flue gas.....	29
5.9.1 Density of the flue gas (ρ_m)	29
5.9.2 Velocity of the flue gas (w_m)	30

5.10	Determination of the pressures	30
5.10.1	Pressure at the flue gas inlet into the chimney.....	30
5.10.2	Theoretical draught available due to chimney effect (P_H).....	31
5.10.3	Pressure resistance of the chimney (P_R)	31
5.10.4	Wind velocity pressure (P_L)	33
5.11	Minimum draught required at the flue gas inlet into the chimney and maximum allowed draught (P_{Ze} and P_{Zemax}) and maximum and minimum differential pressure at the flue gas inlet into the chimney (P_{ZOe} and P_{ZOemin})	33
5.11.1	General	33
5.11.2	Minimum and maximum draught for the combustion appliance (P_W and P_{Wmax}) and maximum and minimum differential pressure of the combustion appliance (P_{Wo} and $P_{Wo min}$).....	34
5.11.3	Effective pressure resistance of the connecting flue pipe (P_{FV})	34
5.11.4	Pressure resistance of the air supply (P_B)	36
5.12	Calculation of the inner surface temperature at the chimney outlet (T_{iob})	37
6	Secondary air for negative pressure chimneys	38
6.1	General	38
6.2	Calculation method.....	39
6.3	Basic values for the calculation of secondary air	39
6.3.1	General	39
6.3.2	Mixing calculations	39
6.4	Pressures	40
6.4.1	Pressure resistance for the air supply with secondary air (P_{BNL})	40
6.4.2	Draught required for the secondary air devices (P_{NL}).....	42
6.4.3	Pressure resistance for that part of the connecting flue pipe before the secondary air device (P_{FV1})	43
6.4.4	Pressure requirement with secondary air	43
6.5	Temperature requirement with secondary air	43
7	Calculation method for balanced flue chimneys	43
7.1	General principles	43
7.2	Pressure requirements.....	44
7.3	Temperature requirements.....	45
7.4	Calculation procedure.....	45
7.5	Flue gas data characterizing the combustion appliance	46
7.6	Characteristic data for the calculation.....	46
7.7	Basic values for the calculation	46
7.7.1	Air temperatures	46
7.7.2	Other basic values	47
7.8	Determination of the temperatures.....	47
7.8.1	Non-concentric (separate) ducts.....	47
7.8.2	Concentric ducts.....	47
7.8.3	Mean temperatures for pressure calculation.....	62
7.9	Determination of densities and velocities.....	63
7.9.1	Density and velocity of the flue gas	63
7.9.2	Density and velocity of the combustion air.....	63
7.10	Determination of pressures.....	65
7.10.1	Pressures in the flue duct and the connecting flue pipe.....	65
7.10.2	Pressures in the air supply duct and the connecting air supply pipe.....	65
7.11	Calculation of the inner surface temperature at the flue duct outlet (T_{iob})	68
8	Consideration of the condensation heat of the flue gas water vapour	69
8.1	General	69
8.2	Onset of condensation.....	70

8.3	Calculation of the flue gas temperature at the outlet of a chimney segment with condensation ($j \geq N_{seg}K$).....	72
9	Consideration of chimney fans.....	77
9.1	General.....	77
9.2	Inline fans	78
9.3	Exhaust fans	79
Annex A (informative)	Calculation of thermal resistance	80
Annex B (informative)	Default values for non-available product information	81
Annex C (informative)	Chimney outlet with regard to adjacent buildings	100
Annex D (informative)	Determination of the gas constant R considering the condensation	101
Annex E (informative)	Example for a report about input and output data of the calculation	102
Bibliography.....		111

European foreword

This document (prEN 13384-1:2025) has been prepared by Technical Committee CEN/TC 166 “Chimneys”, the secretariat of which is held by ASI.

This document is currently submitted to the CEN Enquiry.

This document will supersede EN 13384-1:2015+A1:2019.

In comparison to EN 13384-1-2015+A1:2019 the following technical changes are given:

- editorial mistakes have been corrected;
- in Table B.1 new fuels have been added;
- a clarification is made for the ζ -values of terminals, linked to static pressure;
- the calculation methods were extended to include the O₂ content of the flue gas;
- for concentric duct the simplified heat transfer calculation method based on S_{rad} has been deleted. Therefore, the detailed calculation method has been modified;
- the pressure requirements for negative pressure chimneys have been modified for a possible connection of a positive pressure combustion appliance with a total or partly positive pressure connection pipe;
- remarks are added for the temperature requirement;
- introduction of a new mass flow factor for on all sides open fire places;
- introduction of a new formula for calculation of thermal resistance of the air gap;
- remarks are added for calculation of draught regulators for balanced flue chimneys;
- a new Annex E “Example for a report about input and output data of the calculation” has been created.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

EN 13384, “Chimneys — Thermal and fluid dynamic calculation methods” consists of three Parts:

- Part 1: *Chimneys serving one combustion appliance*
- Part 2: *Chimneys serving more than one combustion appliance*
- Part 3: *Methods for the development of diagrams and tables for chimneys serving one heating appliance*

1 Scope

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

The methods in this part of this document are applicable to negative or positive pressure chimneys with wet or dry operating conditions. It is valid for chimneys with combustion 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 document are applicable to chimneys with one inlet connected with one combustion appliance.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 1443:2019, *Chimneys - General requirements*

EN 1749, *Classification of gas appliances according to the method of supplying combustion air and of evacuation of the combustion products (types)*

EN 15287-1:2023, *Chimneys - Design, installation and commissioning - Part 1: Chimneys and connecting flue pipes for non-roomsealed combustion appliances*

EN 15287-2:2023, *Chimneys - Design, installation and commissioning - Part 2: Chimneys and connecting flue pipes for roomsealed combustion appliances*

EN 16475-2:—,¹ *Chimneys - Accessories - Part 2: Chimney fans - Requirements and test methods*

EN 16475-3:—,² *Chimneys - Accessories - Part 3: Draught regulators, standstill opening devices and combined secondary air devices - Requirements and test methods*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1443:2019, EN 15287-1:2023, EN 15287-2:2023 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1

heat output

Q

amount of heat produced by a combustion appliance per unit of time

¹ Under preparation. Stage at time of publication: prEN 16475-2:2025

² Under preparation. Stage at time of publication: prEN 16475-3:2025

3.1.1**nominal heat output** **Q_N**

continuous heat output specified in the documentation of the combustion appliance related to specified fuels

3.1.2**heat output range**

range of output below the nominal heat output specified in the documentation over which the combustion appliance can be used

3.2**heat input** **Q_F**

amount of heat in unit time which is supplied to the combustion appliance by the fuel based on its net caloric value H_u

3.3**efficiency of the combustion appliance** **η_w**

ratio of the heat output (Q) from the combustion appliance to the heat input (Q_F)

3.4**flue gas mass flow** **$\dot{m}$**

mass of flue gas leaving the combustion 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 combustion appliance and the axis of the flue gas inlet into the chimney

Note 1 to entry 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

minimum draught at the flue gas inlet into the chimney

P_z

difference between the minimum theoretical draught and the sum of the maximum pressure resistance of the chimney and the wind velocity pressure

3.12

maximum draught at the flue gas inlet into the chimney

P_{Zmax}

difference between the maximum theoretical draught and the minimum pressure resistance in the chimney

3.13

minimum draught for the combustion appliance

P_w

difference between the static air pressure of the room of installation of the combustion appliance and the static pressure of the flue gas at the chimney outlet of the combustion appliance which is necessary to maintain the correct operation of the combustion appliance

3.14

maximum draught for the combustion appliance

P_{Wmax}

difference between the static air pressure of the room of installation of the combustion appliance and the static pressure of the flue gas at the outlet of the combustion appliance which is the maximum allowed to maintain the correct operation of the combustion appliance

3.15

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

3.16

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 combustion appliance at the same height

3.17**minimum draught required at the flue gas inlet into the chimney** **P_{ze}**

sum of the minimum draught required for the combustion 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

3.18**maximum allowed draught at the flue gas inlet into the chimney** **P_{zemax}**

sum of the maximum draught allowed for the combustion 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

3.19**maximum positive pressure at the flue gas inlet into the chimney** **P_{zo}**

difference of the maximum pressure resistance and the minimum theoretical draught of the chimney added by the wind velocity pressure

3.20**minimum positive pressure at the flue gas inlet into the chimney** **P_{zomin}**

difference of the minimum pressure resistance and the maximum theoretical draught of the chimney

3.21**maximum differential pressure of the combustion appliance** **P_{wo}**

maximum difference between the static pressure of the flue gas at the chimney outlet of the combustion appliance and the static pressure of the air at the inlet to the combustion appliance specified for its correct operation

3.22**minimum differential pressure of the combustion appliance** **$P_{wo\min}$**

minimum difference between the static pressure of the flue gas at the outlet of the combustion appliance and the static pressure of the air at the inlet to the combustion appliance specified for its correct operation. This can be a negative value.

3.23**maximum differential pressure at the flue gas inlet into the chimney** **P_{zoe}**

difference between the maximum differential pressure of the combustion appliance and the sum of the effective pressure resistance of the connecting flue pipe and the effective pressure resistance of the air supply

3.24**secondary air**

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

3.25

minimum differential pressure at the flue gas inlet into the chimney

P_{zoemin}

difference between the minimum differential pressure of the combustion appliance and the sum of the effective pressure resistance of the connecting flue pipe and the effective pressure resistance of the air supply

3.26

secondary air device

draught regulator or a draught diverter

3.27

draught regulator

component which automatically supplies ambient air to the chimney, the connecting flue pipe or the combustion appliance

3.28

draught diverter

device, placed in the combustion products passage of the combustion appliance, that is intended to maintain the quality of combustion within certain limits and to keep the combustion stable under certain conditions of up draught and down draught

3.29

temperature limit of the inner surface

T_g

allowed minimum temperature of the inner surface of the chimney outlet

3.30

air-supply duct

component or components parallel to the chimney (separate or concentric) that conveys combustion air from the outside atmosphere to the inlet of the connecting air supply pipe

3.31

balanced flue chimney

chimney where the point of air entry to the air supply duct is adjacent to the point of discharge of combustion products from the flue, the inlet and outlet being so positioned that wind effects are substantially balanced

3.32

chimney segment

calculation part of a chimney

3.33

condensate mass flow

$\Delta \dot{m}_D$

mass of water vapour of the flue gas condensed in the combustion appliance, connecting flue pipe or the chimney per time unit

3.34

connecting air supply pipe

component or components connecting the air supply duct outlet with the room-sealed combustion appliance combustion air inlet

3.35 condensation factor

f_k

proportion of the theoretical maximum condensation mass flow usable in the calculation

3.36 chimney fan

exhaust fan or inline fan

3.36.1 exhaust fan

fan positioned on the outlet of the chimney

3.36.2 inline fan

fan positioned as a section of the connecting flue

4 Symbols and abbreviations

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 sectional area	m^2
c	specific heat capacity	$\text{J}/(\text{kg} \cdot \text{K})$
c_p	specific heat capacity of flue gas	$\text{J}/(\text{kg} \cdot \text{K})$
d	thickness of the section	m
D	diameter	m
D_h	hydraulic diameter	m
E	heat flux ratio	–
g	acceleration due to gravity	m/s^2
H	effective height of the chimney	m
k	coefficient for heat transmission	$\text{W}/(\text{m}^2 \cdot \text{K})$
K	coefficient of cooling	–
L	length	m
l_c	proportion of condensation surface	–
$\dot{m}$	flue gas mass flow	kg/s
$\dot{m}_W$	flue gas mass flow of combustion appliance reduced by condensed water	kg/s
$\dot{m}_D$	condensate mass flow	kg/s
N_u	Nusselt number	–

Symbol	Terminology	Unit
N_{seg}	number of segments	–
p	static pressure	Pa
p_L	external air pressure	Pa
P_B	effective pressure resistance of the air supply	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 combustion appliance	Pa
$P_{W\text{max}}$	maximum draught for the combustion appliance	Pa
P_{W0}	maximum differential pressure of the combustion appliance	Pa
$P_{W0\text{min}}$	minimum differential pressure of the combustion appliance	Pa
P_Z	minimum draught at the flue gas inlet into the chimney	Pa
$P_{Z\text{max}}$	maximum draught at the flue gas inlet into the chimney	Pa
P_{Ze}	minimum draught required at the flue gas inlet into the chimney	Pa
$P_{Z\text{emax}}$	maximum allowed draught at the flue gas inlet into the chimney	Pa
P_{Z0}	maximum positive pressure at the flue gas inlet into the chimney	Pa
$P_{Z0\text{min}}$	minimum positive pressure at the flue gas inlet into the chimney	Pa
P_{Z0e}	maximum differential pressure at the flue gas inlet into the chimney	Pa
$P_{Z0\text{emin}}$	minimum differential pressure at the flue gas inlet into the chimney	Pa
$P_{Z\text{excess}}$	maximum allowed pressure from the designation of the chimney	Pa
$P_{ZV\text{excess}}$	maximum allowed pressure from the designation of the connecting flue pipe	Pa
Pr	Prandtl number	–
q_C	heat transfer from the flue to the outer surface	W
q_K	condensation heat	W
Q	heat output	kW
Q_F	heat input	kW

Symbol	Terminology	Unit
Q_N	nominal heat output	kW
r	mean value for roughness of the inner surface	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_e	flue gas temperature at the chimney inlet	K
T_g	temperature limit	K
T_{io}	inner surface temperature at chimney outlet	K
T_{iob}	inner surface temperature at the chimney outlet at temperature equilibrium	K
T_{irb}	flue gas temperature immediately before the additional insulation	K
T_L	external air temperature	K
T_m	mean temperature of the flue gas	K
T_o	flue gas temperature at the chimney outlet	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_{ul}	ambient air temperature for areas external to the building	K
T_{uo}	ambient air temperature at the chimney outlet	K
T_{ur}	the ambient air temperature immediately before the additional insulation	K
T_{uu}	ambient air temperature for unheated areas inside the house	K
T_W	flue gas temperature of the combustion appliance	K
T_{WN}	flue gas temperature of the combustion appliance at nominal heat output	K
T_{Wmin}	flue gas temperature of the combustion appliance at the lowest possible heat output	K

Symbol	Terminology	Unit
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
ε	proportion of black body radiation emitted by a surface	–
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 · s/m ²
η_w	efficiency of the combustion appliance	–
η_{wN}	efficiency of the combustion appliance at nominal heat output	–
λ	coefficient of thermal conductivity	W/(m · K)
ρ	density	kg/m ³
ρ_L	density of the external air	kg/m ³
ρ_m	mean density of flue gas averaged over a defined length and over the cross section	kg/m ³
$\sigma(\text{CO}_2)$	volume-concentration of CO ₂	%
$\sigma(\text{O}_2)$	volume-concentration of O ₂	%
$\sigma(\text{H}_2\text{O})$	volume-concentration of H ₂ O (vapour)	%
σ_{rad}	black body radiation number	W/(m ² · K ⁴)
ψ	coefficient of flow resistance due to friction of the flue	–
$\left(\frac{1}{\lambda}\right)$	thermal resistance	m ² · K/W

Table 2 — Additional subscripts

Subscript	Terminology	Unit
a	outside	–
A	flue gas	–
b	equilibrium temperature condition	–
B	combustion air	–
D	water vapour	–
e	inlet	–
F	open fire place	–
G	change in velocity	–
i	inside	–
K	condensation	–
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	combustion appliance	–

5 Calculation method for non-balanced flue chimneys

5.1 General principles

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

- the minimum draught at the flue gas inlet into the chimney shall be equal to or greater than the minimum draught required at the flue gas inlet into the chimney;
- the minimum 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 maximum draught at the flue gas inlet into the chimney shall be equal to or less than the maximum allowed draught at the flue gas inlet into the chimney;

- the temperature of the inner surface at the 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 four criteria:

- the maximum 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 maximum 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 minimum positive pressure at the flue gas inlet into the chimney shall be equal or greater than the minimum differential pressure at the flue gas inlet into the chimney;
- the temperature of the inner surface at the chimney outlet of the chimney shall be equal to greater than the temperature limit.

NOTE The pressure requirements for maximum draught or minimum positive pressure are only required if there is a limit for the maximum draught for the negative pressure combustion appliance or a minimum differential pressure of the positive pressure combustion appliance.

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

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

The input data and results of the calculation shall be reported. An example of the content is given in Annex E.

5.2 Pressure requirements

5.2.1 Negative pressure chimneys

The following relationships shall be verified:

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

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

and if $P_W < 0$ Pa and the connecting flue pipe is designated for negative pressure (N):

$$P_Z \geq P_B + P_{FV}, \text{ in Pa} \quad (3)$$

or if $P_W < 0$ Pa and the connecting flue pipe is designated for positive pressure (P, M or H):

$$P_{FV} - P_Z \leq P_{ZV_{\text{excess}}}, \text{ in Pa} \quad (4)$$

or if $P_W < 0$ Pa and only the first part of the connecting flue pipe is designated for positive pressure:

$$P_Z \geq P_B + P_{FV2}, \text{ in Pa} \quad (5)$$

$$P_{FV1} + P_{FV2} - P_Z \leq P_{ZV_{\text{excess}}}, \text{ in Pa} \quad (6)$$

and if appropriate

$$P_{Z\max} = P_H - P_R \leq P_{W\max} + P_{FV} + P_B = P_{Z\max}, \text{ in Pa} \quad (7)$$

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_{FV1} is the effective pressure resistance of a first, positive pressure part of the connecting flue pipe, in Pa;
- P_{FV2} is the effective pressure resistance of a second, negative pressure part 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 combustion appliance, in Pa;
- $P_{W\max}$ is the maximum draught for the combustion appliance, in Pa;
- P_Z is the minimum draught at the flue gas inlet into the chimney (see 5.10), in Pa;
- $P_{Z\max}$ is the maximum draught at the flue gas inlet into the chimney (see 5.11), in Pa;
- P_{Ze} is the minimum draught required at the flue gas inlet into the chimney, in Pa;
- $P_{Z\max}$ is the maximum allowed draught at the flue gas inlet into the chimney, in Pa.
- $P_{ZV\text{excess}}$ is the maximum allowed pressure from the designation of the connecting flue pipe, in Pa.

NOTE The values of P_H and P_R in Formulas (1) and (7) are normally different because the conditions are different.

5.2.2 Positive pressure chimneys

The following relationships shall be verified:

$$P_{Z0} = P_R - P_H + P_L \leq P_{W0} - P_B - P_{FV} = P_{Zoe}, \text{ in Pa} \quad (8)$$

$$P_{Z0} \leq P_{Z\text{excess}}, \text{ in Pa} \quad (9)$$

$$P_{Z0} + P_{FV} \leq P_{ZV\text{excess}}, \text{ in Pa} \quad (10)$$

and if appropriate

$$P_{Z0\min} = P_R - P_H \geq P_{W0\min} - P_B - P_{FV} = P_{Zoemin}, \text{ in Pa} \quad (11)$$

where

- P_B is the effective pressure resistance of air supply, 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_{W0}	is the maximum differential pressure of the combustion appliance, in Pa;
P_{W0min}	is the minimum differential pressure of the combustion appliance, in Pa;
P_{Z0}	is the maximum positive pressure at the flue gas inlet into the chimney, in Pa;
P_{Z0min}	is the minimum positive pressure at the flue gas inlet into the chimney, in Pa;
P_{Z0e}	is the maximum differential pressure at the flue gas inlet into the chimney, in Pa;
P_{Z0emin}	is the minimum differential pressure at the flue gas inlet into the chimney, in Pa;
$P_{Z\text{ excess}}$	is the maximum allowed pressure from the designation of the chimney, in Pa;
$P_{ZV\text{ excess}}$	is the maximum allowed pressure from the designation of the connecting flue pipe, in Pa.

NOTE The values of P_H and P_R in Formulas (8) and (11) are normally different because the conditions are different

5.3 Temperature requirement

The following relationship shall be verified:

$$T_{iob} \geq T_g, \text{ in K} \quad (12)$$

where

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

T_{ig} is the temperature limit, in K.

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

$$T_{irb} \geq T_g, \text{ in K} \quad (13)$$

where

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

The temperature limit T_{ig} 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_{ig} 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 surface temperature before the additional insulation T_{irb} with the admissible limit temperature of the flue gas T_{ig} is not necessary, if the value of the thermal resistance of the additional insulation is not more than 0,1 (m² · 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.

Particularly when replacing a combustion appliance on an existing chimney, compliance with the temperature condition can be waived in specific individual cases if the fire and operational safety of the system is not restricted. This can be assumed e.g. if at least one of the following conditions is met:

- After replacing a non-condensing combustion appliance by a similar kind of combustion appliance on an existing chimney for dry operation conditions, there is a risk of moistening if no adjustment of the cross section takes place.

- In the case of chimney for wet operating conditions the combustion appliance shuts down automatically before freezing which leads to blockage of the flue.
- In the case that the calculation for the lowest permissible heat output is carried out with higher values for the combustion air mass flow or for the flue gas temperature than specified in 5.5.2.2 or 5.5.3.2.

In these situations, a written agreement shall be settled separately between the owner of the installation and the installer, including advice about possible consequences.

5.4 Calculation procedure

For the calculation of the pressure and temperature values for the relationships of Formulas (1), (2), (3), (8), (9), (10), (11) and (12) the values of the flue gas data characterising according to 5.5 shall be obtained for the combustion appliance. The data specified in 5.6 shall be obtained for the chimney and its connecting flue pipe. For new built chimneys, a pre-estimated value for the flue size should be used.

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

In 5.5.3 and 5.8 the formulas for the calculations of the relevant temperatures are compiled. The formulas 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:

- either for the nominal heat output declared in the documentation of the combustion appliance;
- or for the nominal heat output and for the lowest value of the heat output range declared in the documentation of the combustion appliance

If the pressure requirement for maximum draught (3) or the temperature requirements (12) and (13) of negative pressure chimneys are not fulfilled the validation of the pressure condition or temperature condition can occasionally be achieved by taking additional secondary air to the flue gas into account according to Clause 6.

NOTE The temperature requirement need not be met for the following conditions provided that it is accepted that in case the requirement for temperature is not fulfilled no guarantee can be given that no moisture appears.

The conditions are:

- where the combustion appliance is replaced by a combustion appliance that has an output of < 30 kW, and
- that the flue gas loss of the combustion appliance is at least 8 %, and
- that the combustion appliance has a draught diverter which provides adequate ventilation in the chimney during standby periods or periods of low output. This may be achieved by over-sizing the combustion appliance output.

5.5 Flue gas data characterising the combustion appliance

5.5.1 General

For the calculation of temperatures and pressure values the relevant flue gas data which characterises the combustion appliance, consisting of flue gas mass flow, flue gas temperature and the minimum

draught required for the combustion appliance or the maximum differential pressure of the combustion appliance shall be obtained. Additionally the kind of the fuel supplied the volume concentration of CO₂ or O₂ 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 and B.1a.

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

5.5.2 Flue gas mass flow and combustion air mass flow

5.5.2.1 Flue gas mass flow and combustion air mass flow at nominal heat output of the combustion appliance

For the calculation of pressure and temperature values according to relationships of formulae (1), (2), (3), (8), (9), (10), (11) and (12) the flue gas mass flow and combustion air mass flow at nominal heat output conditions for the combustion appliance shall be obtained.

If the data are not available the flue gas mass flow, combustion air mass flow and the volume concentration of CO₂ or O₂ can be determined from the formulas in Tables B.1, B.2, B.3 or B.4.

If the chimney is connected to a multi-fuel combustion appliance, the calculation and dimensioning should be carried out by considering all the fuels suited to the combustion appliance.

In the case of combustion appliances with a draught diverter the flue gas mass flow downstream of the draught diverter shall be used.

If the data are not available, the flue gas mass flow $\dot{m}$ and combustion air mass flow $\dot{m}_B$ of an open fire place can be calculated using the following formulae:

$$\dot{m} = f_{mf} \cdot A_F, \text{ in kg/s} \quad (14)$$

$$\dot{m}_B = \dot{m}, \text{ in kg/s} \quad (15)$$

where

f_{mf} is the mass flow factor of an open fire place, in kg/(s·m²);

A_F is the cross section of the opening of the open fire place, in m²;

For open fire places with an opening height less than or equal its width $f_{mf} = 0,139 \text{ kg}/(\text{s} \cdot \text{m}^2)$.

For open fire places with an opening height greater than its width $f_{mf} = 0,167 \text{ kg}/(\text{s} \cdot \text{m}^2)$.

For open fire places with an opening on all sides $f_{mf} = 0,063 \text{ kg}/(\text{s} \cdot \text{m}^2)$.

The CO₂-content of the flue gas for open fire places may be taken as $\sigma(\text{CO}_2) = 1 \%$ or the O₂ content as $\sigma(\text{O}_2) = 20 \%$.

5.5.2.2 Flue gas mass flow and combustion air mass flow at the lowest permissible heat output

If the combustion appliance is designed to operate under modulating conditions an additional check shall be conducted for the pressure and temperature requirement of the flue gas mass flow and combustion air mass flow at the lowest possible and permissible heat output of the combustion appliance. If the flue gas data and combustion air mass data for the lowest heat output are not provided use a mass flow of one third of the flue gas mass flow and combustion air mass flow at nominal heat output.

5.5.2.3 Flue gas mass flow and combustion air mass flow at the maximum draught or minimum differential pressure of the combustion appliances

For the calculation of maximum draught or minimum positive pressure in a chimney, the flue gas mass flow and combustion air mass flow at maximum draught or minimum differential pressure of the combustion appliance shall be obtained in the documentation of the combustion appliance, if appropriate.

5.5.2.4 Flue gas mass flow with secondary air

If secondary air is supplied by a draught regulator or draught diverter the air flow shall be calculated according to 6.3 depending on the actual difference of the pressure in the room of installation of the combustion appliance and the chimney or connecting flue pipe.

5.5.3 Flue gas temperature

5.5.3.1 Flue gas temperature at nominal heat output (T_{WN})

The flue gas temperature at nominal heat output T_{WN} shall be taken from documentation of the combustion appliance. In the case of combustion appliances with a draught diverter, the flue gas temperature downstream of the draught diverter shall be used.

If the provided data showing flue gas temperature downstream of the draught diverter in relation to draught, such data shall be used for the calculation.

If the flue gas temperature T_{WN} of open fire places is not known a value of $t_{WN} = 80\text{ °C}$ ($T_{WN} = 353,15\text{ K}$) should be used.

5.5.3.2 Flue gas temperature at the lowest possible heat output (T_{Wmin})

The lowest designated flue gas temperature T_{Wmin} shall be taken from the documentation of the combustion appliance. If this data is not available, use as flue gas temperature 2/3 of the value of the flue gas temperature in °C at nominal heat output.

5.5.3.3 Flue gas temperature at the maximum draught or minimum differential pressure of the combustion appliances

For the calculation of maximum draught or minimum positive pressure in a chimney the flue gas temperature at maximum draught or minimum differential pressure of the combustion appliance shall be taken from the documentation of the combustion appliance if appropriate.

5.5.4 Minimum draught for the combustion appliance (P_W) for negative pressure chimney

For the calculation of a negative pressure chimney the value of the minimum draught for the combustion appliance P_W shall be taken from the documentation of the combustion appliance.

If no values are available, the relevant values of the minimum draught for the combustion appliance should be selected from relevant product standards for combustion appliances. If no values for boilers are available see Table B.3.

If the available value of the minimum draught is a negative number (implying a positive pressure operation) a value of $P_W = -P_{W0}$ shall be used in the calculations.

If no valid data for the draught diverter is available, for gas fired appliances designated as B₁ according to EN 1749 use a value of 3 Pa for the minimum draught and use the value of 10 Pa for all other gas fired appliances equipped with a draught diverter.

The minimum draught P_W for the operation of fire places should be calculated with the flue gas mass flow and the cross section of the chimney outlet of the open fire place. The theoretical draught available due to chimney effect in the open fire place and the flue gas collector should be neglected. The local resistance in the flue gas collector (gather) is considered by using a flow safety coefficient $S_E = 1,5$.

$$P_W = \frac{\dot{m}^2}{2 \cdot \rho_W \cdot A_W^2} \cdot S_E, \text{ in Pa} \quad (16)$$

where

- $\dot{m}$ is the flue gas mass flow, in kg/s;
- S_E is the flow safety coefficient;
- ρ_W is the density of flue gas in the chimney outlet of the open fire place, in kg/m³;
- A_W is the cross section of the chimney outlet of the open fire place, in m².

5.5.5 Maximum draught for the combustion appliance (P_{Wmax}) for negative pressure chimney

For the calculation of a negative pressure chimney the value of the maximum draught for the combustion appliance P_{Wmax} shall be taken from the documentation of the combustion appliance if appropriate.

5.5.6 Maximum differential pressure of the combustion appliance (P_{W0}) for positive pressure chimney

For the calculation of a positive pressure chimney the value of the maximum differential pressure for the combustion appliance P_{W0} shall be taken from the documentation of the combustion appliance.

5.5.7 Minimum differential pressure of the combustion appliance (P_{W0min}) for positive pressure chimney

For the calculation of a positive pressure chimney the value of the minimum differential pressure of the combustion appliance P_{W0min} shall be taken from the documentation of the combustion appliance if appropriate.

5.6 Characteristic data for the calculation

5.6.1 General

In order to calculate the relevant pressure and temperature values the roughness of the inner surface and the thermal resistance of the connecting flue pipe and the chimney shall be determined.

5.6.2 Mean value for roughness (r)

The mean value for roughness of the inner liner shall be declared considering increased soiling, deposits, possible wear of the inner lining (spalling, cracks, corroded surfaces), increased resistance at joints (e. g. putty joints, butt joints, plug-in joints, welding), accessories (e. g. cleaning openings, condensate drains). Typical mean values for roughness of inner liners of some materials are listed in Table B.4.

5.6.3 Thermal resistance ($1/\lambda$)

The thermal resistance $1/\lambda$ of the system chimney shall be declared.

The thermal resistance $1/\lambda$ of the components shall be declared and should include the effects of thermal bridges (e.g. joints).

Calculations involving thermal resistance for system chimneys and/or components should normally be undertaken using values obtained at the mean operating temperature. The thermal resistance value obtained at the designation temperature may be used.

For multiwall custom built chimneys, the thermal resistance shall be determined using the following formula:

$$\left(\frac{1}{\lambda}\right) = D_h \cdot \sum_n \left[\left(\frac{1}{\lambda}\right)_n \cdot \frac{1}{D_{h,n}} \right], \text{ in } \text{m}^2 \cdot \text{K/W} \quad (17)$$

where

D_h is the internal hydraulic diameter, in m;

$D_{h,n}$ is the hydraulic diameter of the inside of each layer, in m;

$\left(\frac{1}{\lambda}\right)_n$ is the thermal resistance of a pipe shell, referring to its internal surface, in $\text{m}^2 \cdot \text{K/W}$.

Where the specific data for individual components is not known the thermal resistance can be determined in accordance with Annex A.

The thermal resistance of closed air gaps is given in Table B.6.

5.7 Basic values for the calculation

5.7.1 Air temperatures

5.7.1.1 General

On chimneys which pass through heated areas, a differentiation shall be made between the external air temperature and the ambient air temperatures.

5.7.1.2 External air temperature (T_L)

The external air temperature T_L shall be taken as the maximum temperature of external air at which the chimney is intended to be used.

The external air temperature T_L for heating systems is normally calculated using

$T_L = 288,15 \text{ K}$ ($t_L = 15 \text{ °C}$) for the calculation of minimum draught or maximum positive pressure at the flue gas inlet into the chimney;

$T_L = 258,15 \text{ K}$ ($t_L = -15 \text{ °C}$) for the calculation of maximum draught or minimum positive pressure at the flue gas inlet into the chimney.

Other values for T_L may be used based on national accepted data.

5.7.1.3 Ambient air temperature (T_u)

To check that the pressure requirement for the minimum draught or maximum positive pressure has been met the ambient air temperature $T_u = T_L$ shall be used. To check that the pressure requirement for the maximum draught or minimum positive pressure and the temperature requirement have been met the following values for ambient air temperatures T_u shall be used:

— for chimneys without ventilated air gaps:

$T_{uo} = 258,15 \text{ K}$ ($t_{uo} = -15 \text{ °C}$) for chimneys operating under wet conditions

$T_{uo} = 273,15 \text{ K}$ ($t_{uo} = 0 \text{ °C}$) for chimneys operating under dry conditions

$T_{ub} = 288,15 \text{ K}$ ($t_{ub} = 15 \text{ °C}$)

$T_{uh} = 293,15 \text{ K}$ ($t_{uh} = 20 \text{ °C}$)

$$T_{ul} = T_{uo} \quad (t_{ul} = t_{uo})$$

$$T_{uu} = 273,15 \text{ K} \quad (t_{uu} = 0 \text{ °C})$$

— for chimneys with ventilated air gaps ventilated in the same direction as the flue gas:

$$T_{uo} = 258,15 \text{ K} \quad (t_{uo} = -15 \text{ °C}) \quad \text{for chimneys operating under wet conditions if the height of the unheated area inside the building and external to the building does exceed 5 m}$$

$$T_{uo} = 273,15 \text{ K} \quad (t_{uo} = 0 \text{ °C}) \quad \text{for chimneys operating under dry conditions and for chimneys operating under wet conditions if the height of the unheated area inside the building and external to the building does not exceed 5 m}$$

$$T_{ub} = 288,15 \text{ K} \quad (t_{ub} = 15 \text{ °C})$$

$$T_{uh} = 293,15 \text{ K} \quad (t_{uh} = 20 \text{ °C})$$

$$T_{ul} = 288,15 \text{ K} \quad (t_{ul} = 15 \text{ °C}) \quad \text{if the height of the unheated area inside the building and external to the building does not exceed 5 m}$$

$$T_{ul} = T_{uo} \quad (t_{ul} = t_{uo}) \quad \text{if the height of the unheated area inside the building and external to the building does exceed 5 m}$$

$$T_{uu} = 288,15 \text{ K} \quad (t_{uu} = 15 \text{ °C}) \quad \text{if the height of the unheated area inside the building and external to the building does not exceed 5 m}$$

$$T_{uu} = 273,15 \text{ K} \quad (t_{uu} = 0 \text{ °C}) \quad \text{if the height of the unheated area inside the building and external to the building does exceed 5 m}$$

Other values for T_{uo} may be used based on national accepted data.

Parts of the chimney which are in areas with different ambient air temperature should either be calculated in sections with the same ambient temperature or the ambient air temperature corresponding to the parts of the outer surface be determined for the calculation using the following formula:

$$T_u = \frac{(T_{ub} \cdot A_{ub}) + (T_{uh} \cdot A_{uh}) + (T_{uu} \cdot A_{uu}) + (T_{ul} \cdot A_{ul})}{A_{ub} + A_{uh} + A_{uu} + A_{ul}}, \text{ in K} \quad (18)$$

where

T_{uo} is the ambient air temperature at the chimney outlet, in K;

T_{ub} is the ambient air temperature for boiler room, in K;

T_{uh} is the ambient air temperature for heated areas, in K;

T_{ul} is the ambient air temperature for areas external to the building, in K;

T_{uu} is the ambient air temperature for unheated areas inside the building, in K;

A_{ub} is the outer surface area of the chimney in the boiler room, in m²;

A_{uh} is the outer surface area of the chimney in heated areas, in m²;

A_{ul} is the outer surface area of the chimney external to the building, in m²;

A_{uu} is the outer surface area of the chimney in unheated areas inside the building, in m^2 .

NOTE 1 If parts of the outer surface of chimneys without back ventilation in areas external to the building and unheated areas do not exceed $\frac{1}{4}$ of the total outer surface of the chimney, the ambient air temperature T_u may be taken as 288,15 K ($t_u = 15^\circ\text{C}$).

NOTE 2 If the height of chimneys with air gaps ventilated in the same direction as the flue gas in areas external to the building and unheated areas do not exceed 5 m, the ambient air temperature T_u may be taken as 288,15 K ($t_u = 15^\circ\text{C}$).

NOTE 3 If the height of chimneys with air gaps ventilated in the opposite direction as the flue gas in areas external to the building and unheated areas do not exceed 5 m, the ambient air temperature T_u may be taken as 273,15 K ($t_u = 0^\circ\text{C}$).

5.7.2 External air pressure (p_L)

The external air pressure p_L shall be determined as follows dependent on the height above sea level using the following formula:

$$p_L = 97000 \cdot e^{\frac{-g \cdot z}{R_L T_L}}, \text{ in Pa} \quad (19)$$

where

g is the acceleration due to gravity = 9,81 m/s^2 ;

R_L is the gas constant of the air, in $J/(kg \cdot K)$;

T_L is the external air temperature, in K;

z is the height above sea level, in m;

97000 is the external air pressure at sea level corrected for weather influence, in Pa.

5.7.3 Gas constant

5.7.3.1 Gas constant of the air (R_L)

The gas constant of the air R_L shall be taken as 288 $J/(kg \cdot K)$ (water content $\sigma(H_2O)$ as a volume fraction of 1,1 %).

5.7.3.2 Gas constant of the flue gas (R)

The gas constant of the flue gas R shall be determined using the formula in Tables B.1 and B.4.

5.7.4 Density of the external air (ρ_L)

The density of the external air ρ_L shall be calculated using the following formula:

$$\rho_L = \frac{p_L}{R_L \cdot T_L}, \text{ in } kg/m^3 \quad (20)$$

where

p_L is the external air pressure, in Pa;

R_L is the gas constant of the air, in $J/(kg \cdot K)$;

T_L is the external air temperature, in K.

5.7.5 Specific heat capacity of the flue gas (c_p)

The specific heat capacity c_p of the flue gas shall be calculated using the Formula (B.4) in Table B.1.

5.7.6 Condensing temperature (T_{sp})

For gas, domestic heating oil and chemically untreated wood, the condensing temperature T_{sp} of the flue gas shall be identified by the water dew point T_p . In these the cases:

$$T_{sp} = T_p \quad (21)$$

The water dew point T_p of the flue gas for different fuels and concentrations by volume of CO_2 or O_2 in the flue gas shall be calculated using the Formulas (B.5), (B.6) and (B.7).

For coal and residual fuel oil, the condensing temperature of the flue gas is the acid dew point T_{sp} . In these the cases:

$$T_{sp} = T_p + \Delta T_{sp} \quad (22)$$

The rise in the dew point through sulphur trioxide in the flue gas (ΔT_{sp}) can be calculated using formula in Table B.1. For the exact determination of the acid dew point, knowledge of the conversion from sulphur dioxide into sulphur trioxide (conversion factor K_f) is required. As an approximate value, it can be assumed that the concentration by volume of sulphur trioxide (SO_3) is approximately 2 % of that of the sulphur dioxide (SO_2).

5.7.7 Correction factor for temperature instability (S_H)

For the calculation of minimum draught or maximum positive pressure the correction factor S_H for temperature instability shall be 0,5.

For the calculation of maximum draught or minimum positive pressure the correction factor S_H for temperature instability shall be 1.

5.7.8 Flow safety coefficients (S_E and S_{EB})

For the calculation of minimum draught of negative pressure chimneys the safety coefficient $S_E = 1,5$ shall be used, except a value of 1,2 shall be used for strictly controlled combustion appliance and chimney installations (e.g. industrial installation with permanent supervision), and for room sealed combustion appliances with forced draught burners.

For the calculation of maximum positive pressure of positive pressure chimneys the safety coefficient S_E shall be a minimum value of 1,2.

For the calculation of maximum draught or minimum positive pressure the safety coefficient S_E shall be 1.

For the calculation of air supply duct, the flow safety coefficient S_{EB} shall be 1,2.

5.8 Determination of the temperatures

5.8.1 General

For the validation of pressure and temperature requirements, the mean flue gas temperature and the flue gas temperature at the chimney outlet shall be determined. Normally, the mean flue gas temperature needs to be determined iteratively, as the cooling coefficient is dependent on the mean flue gas temperature (circular reference).

The mean temperature of the flue gas T_m shall be calculated using the following formula:

$$T_m = T_u + \frac{T_e - T_u}{K} \cdot (1 - e^{-K}), \text{ in K} \quad (23)$$

The flue gas temperature at the chimney outlet T_o shall be calculated using the following formula:

$$T_o = T_u + (T_e - T_u) \cdot e^{-K}, \text{ in K} \quad (24)$$

The mean temperature of the flue gas in the connecting flue pipe T_{mV} shall be calculated in accordance using the following formula:

$$T_{mV} = T_u + \frac{T_W - T_u}{K_V} \cdot (1 - e^{-K_V}), \text{ in K} \quad (25)$$

The flue gas temperature at the chimney inlet T_e shall be calculated using the following formula:

$$T_e = T_u + (T_W - T_u) \cdot e^{-K_V}, \text{ in K} \quad (26)$$

where

- K is the coefficient of cooling (see 5.8.2);
- K_V is the coefficient of cooling of the connecting flue pipe (see 5.8.2);
- T_e is the flue gas temperature at the chimney inlet, in K;
- T_u is the ambient air temperature (see 5.7.1.3), in K;
- T_W is the flue gas temperature of the combustion appliance, in K.

5.8.2 Calculation of the coefficient of cooling (K)

The coefficient of cooling K shall be calculated using the following formula:

$$K = \frac{U \cdot k \cdot L}{\dot{m} \cdot c_p} \quad (27)$$

where

- c_p is the specific heat capacity of the flue gas (see 5.7.5), in J/(kg · K);
- k is the coefficient of heat transmission (see 5.8.3), in W/(m² · K);
- L is the length of the chimney, in m;
- $\dot{m}$ is the flue gas mass flow (see 5.5.2), in kg/s;
- U is the internal chimney circumference, in m.

For the coefficient of cooling K_V of the connecting flue pipe, the corresponding parameters for the connecting flue pipe shall be used.

5.8.3 Coefficient of heat transmission (k_b)

5.8.3.1 General

The coefficient of heat transmission of the chimney at temperature equilibrium k_b shall be calculated using the following formula:

$$k_b = \frac{1}{\frac{1}{\alpha_i} + \left(\frac{1}{\lambda}\right) + \frac{D_h}{D_{ha} \cdot \alpha_a}}, \text{ in W/(m}^2 \cdot \text{K)} \quad (28)$$

The coefficient of heat transmission of the chimney for no temperature equilibrium k shall be calculated using the following formula:

$$k = \frac{1}{\frac{1}{\alpha_i} + S_H \cdot \left[\left(\frac{1}{\lambda} \right) + \frac{D_h}{D_{ha} \cdot \alpha_a} \right]}, \text{ in W/(m}^2 \cdot \text{K)} \quad (29)$$

where

- D_h is the internal hydraulic diameter, in m;
- D_{ha} is the external hydraulic diameter, in m;
- S_H is the correction factor for temperature instability (see 5.7.7);
- α_a is the external coefficient of heat transfer (see 5.8.3.2, in W/(m² · K);
- α_i is the internal coefficient of heat transfer (see 5.8.3.2, in W/(m² · K);
- $\left(\frac{1}{\lambda} \right)$ is the thermal resistance (see 5.6.3), in m² · K/W.

5.8.3.2 Internal coefficient of heat transfer (α_i)

The coefficient of heat transfer in the chimney α_i shall be calculated using the following formula:

$$\alpha_i = \frac{\lambda_A \cdot Nu}{D_h}, \text{ in W/(m}^2 \cdot \text{K)} \quad (30)$$

where

- D_h is the internal hydraulic diameter, in m;
- Nu is the Nusselt number;
- λ_A is the coefficient of thermal conductivity of the flue gas, in W/(m · K).

The coefficient of thermal conductivity of the flue gas λ_A shall be calculated depending on the mean flue gas temperature using the formula in Table B.1 and B.9.

The mean Nusselt number Nu over the height of the chimney shall be calculated using the following formula:

$$Nu = \left(\frac{\psi}{\psi_{smooth}} \right)^{0,67} \cdot 0,0214 \cdot (Re^{0,8} - 100) \cdot Pr^{0,4} \cdot \left[1 + \left(\frac{D_h}{L_{tot}} \right)^{0,67} \right] \quad (31)$$

where

- D_h is the internal hydraulic diameter, in m;
- L_{tot} is the total length from flue gas inlet into the chimney to the chimney outlet, in m;
- Pr is the Prandtl number;
- Re is the Reynolds number;
- ψ is the coefficient of the flow resistance due to friction for hydraulically rough flow (see 5.10.3.3)
- ψ_{smooth} is the coefficient of the flow resistance due to friction for hydraulically smooth flow (see 5.10.3.3 for $r = 0$)

The formula can be used for $2\,300 < Re < 10\,000\,000$, $\left(\frac{\psi}{\psi_{\text{smooth}}}\right) < 3$ and $0,6 < Pr < 1,5$.

For mean flue gas velocity $w_m < 0,5$ m/s, take Nusselt number appropriate to $w_m = 0,5$ m/s.

For Reynolds numbers below 2 300, take Nusselt number appropriate to $Re = 2\,300$.

The Prandtl number Pr shall be calculated using the following formula:

$$Pr = \frac{\eta_A \cdot c_p}{\lambda_A} \quad (32)$$

The Reynolds number Re shall be calculated using the following formula:

$$Re = \frac{w_m \cdot D_h \cdot \rho_m}{\eta_A} \quad (33)$$

where

- c_p is the specific heat capacity of the flue gas, in J/(kg · K);
- D_h is the internal hydraulic diameter, in m;
- w_m is the mean flue gas velocity (see 5.9), in m/s;
- η_A is the dynamic viscosity of the flue gas, in N · s/m²;
- λ_A is the coefficient of thermal conductivity of the flue gas, in W/(m · K);
- ρ_m is the mean density of the flue gas (see 5.9), in kg/m³.

The dynamic viscosity η_A shall be calculated dependent on the flue gas temperature using Formula (B.10) in Table B.1.

The internal coefficient of heat transfer α_i can also be calculated on wet designated chimneys as indicated, if the heat of condensation is not taken into account.

For connecting flue pipes $\alpha_{i,v}$ should be calculated according to Formula (23). For connecting flue pipes with different diameter, it should be calculated for each segment.

5.8.3.3 External coefficient of heat transfer (α_a)

The external coefficient of heat transfer α_a shall be 8 W/(m² · K) for connecting flue pipes and chimneys, internal to the building, for connecting flue pipes and chimneys external to the building using 23 W/(m² · K).

For connecting flue pipes and chimneys which lie partially external to the building, the coefficient of heat transfer α_a shall be interpolated.

Where parts of the chimneys are external to the building but are shielded with an air gap of at least 1 cm but not more than 5 cm then the external coefficient of heat transfer α_a shall be 8 W/(m² · K).

For a chimney (including relined chimneys) with a ventilated air gap 8 W/(m² · K) shall be used. For non-ventilated parts of such a chimney if the non-ventilated length external to the building is $\leq 3 D_h$ then 8 W/(m² · K) shall be used, otherwise 23 W/(m² · K) shall be used.

5.9 Determination of the density of the flue gas and the velocity of the flue gas

5.9.1 Density of the flue gas (ρ_m)

The mean density of the flue gas ρ_m shall be determined using the following formula:

$$\rho_m = \frac{p_L}{R \cdot T_m}, \text{ in kg/m}^3 \quad (34)$$

where

- p_L is the external air pressure (see 5.7.2), in Pa;
- R is the gas constant of the flue gas (see 5.7.3.2), in J/(kg · K);
- T_m is the mean temperature of the flue gas (see 5.8.1), in K.

For the mean density of the flue gas ρ_{mv} in the connecting flue pipe, the corresponding values of the connecting flue pipe shall be used.

5.9.2 Velocity of the flue gas (w_m)

The mean flue gas velocity w_m shall be calculated using the following formula:

$$w_m = \frac{\dot{m}}{A \cdot \rho_m}, \text{ in m/s} \quad (35)$$

where

- A is the internal cross section of the chimney, in m²;
- $\dot{m}$ is the flue gas mass flow (see 5.5.1), in kg/s;
- ρ_m is the mean density of the flue gas, in kg/m³.

For the mean flue gas velocity w_{mv} in the connecting flue pipe, the corresponding values of the connecting flue pipe shall be used.

5.10 Determination of the pressures

5.10.1 Pressure at the flue gas inlet into the chimney

5.10.1.1 Draught at the flue gas inlet into the negative pressure chimney (P_Z and P_{Zmax})

The minimum and maximum draught at the flue gas inlet into the negative pressure chimney P_Z and P_{Zmax} are primarily dependent on the flue gas mass flow and the flue gas temperature, the effective chimney height, the cross-section and the characteristic values of design (roughness and thermal resistance) of the chimney.

The minimum and maximum draught at the flue gas inlet into the chimney P_Z and P_{Zmax} shall be calculated using the following formulas:

$$P_Z = P_H - P_R - P_L, \text{ in Pa} \quad (36)$$

$$P_{Zmax} = P_H - P_R, \text{ in Pa} \quad (37)$$

where

- 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_Z is the minimum draught at the flue gas inlet, in Pa;

$P_{Z\max}$ is the maximum draught at the flue gas inlet, in Pa.

NOTE The values of P_H and P_R in Formulas (29) and (29a) are normally different because the conditions are different.

5.10.1.2 Positive pressure at the flue gas inlet into the positive pressure chimney (P_{Z0} and $P_{Z0\min}$)

The maximum and minimum positive pressure at the flue gas inlet into the positive pressure chimney P_{Z0} and $P_{Z0\min}$ are primarily dependent on the flue gas mass flow and the flue gas temperature, the effective chimney height, the cross-section and the characteristic values of design (roughness and thermal resistance) of the chimney.

The maximum and minimum positive pressure at the flue gas inlet into the chimney P_{Z0} and $P_{Z0\min}$ shall be calculated using the following formulas:

$$P_{Z0} = P_R - P_H + P_L, \text{ in Pa} \quad (38)$$

$$P_{Z0\min} = P_R - P_H, \text{ in Pa} \quad (39)$$

where

P_H is the theoretical draught of the chimney, in Pa;

P_L is the wind velocity pressure, in Pa;

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

P_{Z0} is the maximum differential pressure at the flue gas inlet, in Pa;

$P_{Z0\min}$ is the minimum differential pressure at the flue gas inlet, in Pa.

NOTE The values of P_R and P_H in Formulas (38) and (39) are normally different because the conditions are different.

5.10.2 Theoretical draught available due to chimney effect (P_H)

The theoretical draught available due to chimney effect P_H shall be calculated using the following formula:

$$P_H = H \cdot g \cdot (\rho_L - \rho_m), \text{ in Pa} \quad (40)$$

where

H is the effective height of the chimney, in m;

g is the acceleration due to gravity = 9,81 m/s²;

ρ_L is the density of the external air (see 5.7.4), in kg/m³;

ρ_m is the mean density of the flue gas (see 5.9.1), in kg/m³.

5.10.3 Pressure resistance of the chimney (P_R)

5.10.3.1 General

The pressure resistance of the chimney P_R shall be calculated using the following formula:

$$P_R = S_E \cdot P_E + S_{EG} \cdot P_G, \text{ in Pa} \quad (41)$$

$$P_R = S_E \cdot \left(\psi \cdot \frac{L}{D_h} + \sum_n \zeta_n \right) \cdot \frac{\rho_m}{2} \cdot w_m^2 + S_{EG} \cdot P_G, \text{ in Pa} \quad (42)$$

For $P_G \geq 0$ $S_{EG} = S_E$

For $P_G < 0$ $S_{EG} = 1,0$

where

- D_h is the internal hydraulic diameter, in m;
- L is the length of chimney, in m;
- P_E is the pressure resistance due to friction and form resistance of the chimney, in Pa;
- P_G is the difference in pressure caused by change of velocity of the flue gas in the chimney, in Pa;
- S_E is the flow safety coefficient (see 5.7.8);
- S_{EG} is the flow safety coefficient for difference in pressure through velocity change;
- w_m is the mean flue gas velocity (see 5.9.2), in m/s;
- ρ_m is the mean density of the flue gas (see 5.9.1), in kg/m³;
- ψ is the coefficient of flow resistance due to the friction of the flue;
- $\sum_n \zeta_n$ sum of the coefficients of flow resistance due to directional and/or cross sectional and/or mass flow changes in the flue.

5.10.3.2 Difference in pressure caused by change of velocity of the flue gas in the chimney (P_G)

The difference in pressure caused by the change of velocity of the flue gas in the chimney P_G shall be calculated using the following formula:

$$P_G = \frac{\rho_2}{2} \cdot w_2^2 - \frac{\rho_1}{2} \cdot w_1^2, \text{ in Pa} \quad (43)$$

where

- w_1 is the flue gas velocity before velocity change, in m/s;
- w_2 is the flue gas velocity after velocity change, in m/s;
- ρ_1 is the density of the flue gas before velocity change, in kg/m³;
- ρ_2 is the density of the flue gas after velocity change, in kg/m³.

For w_1 and w_2 as well ρ_1 and ρ_2 the mean values of section before and after the change of the velocity may be used.

5.10.3.3 Coefficient of flow resistance due to friction of the flue (ψ)

The coefficient of flow resistance due to friction of the flue ψ for different roughness shall be calculated using the following formula:

$$\frac{1}{\sqrt{\psi}} = -2 \cdot \lg \left(\frac{2,51}{Re \cdot \sqrt{\psi}} + \frac{r}{3,71 \cdot D_h} \right) \quad (44)$$

where