SLOVENSKI STANDARD
SIST EN 13384-2:2003

01-september-2003

Dimniki ï Raļ unske metode termodinamike in dinamike fluidov ï Dimniki za veļ kot eno ogrevalno napravo

Chimneys - Thermal and fluid dynamic calculation methods - Part 2: Chimneys serving more than one heating appliance

Abgasanlagen - Wärme- und strömungstechnische Berechnungsverfahren - Teil 2: Abgasanlagen mit mehreren Feuerstätten

Conduits de fumée - Méthodes de calcul thermo-aéraulique - Partie 2: Conduits de fumée desservant plus d'un appareil de chauffage

Ta slovenski standard je istoveten z: **EN 13384-2:2003**

ICS:

91.060.40 Dimniki, jaški, kanali Chimneys, shafts, ducts

SIST EN 13384-2:2003 **en**

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 13384-2

May 2003

ICS 91.060.40

English version

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

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Ref. No. EN 13384-2:2003 E

Contents

Foreword

This document EN 13384-2:2003 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of an identical text or by endorsement, at the latest by November 2003, and conflicting national standards shall be withdrawn at the latest by November 2003.

This draft is one of a series of standards prepared by CEN/TC 166 comprising product standards and execution standards for chimneys.

Annexes A and B are informative.

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, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom.

Introduction

The calculation described in this standard is complex and is intended to be solved by using a computer programme. The general principles of this calculation method of EN 13384-1 also apply to this standard.

This standard is in support of the execution standards for a chimney installation serving more than one heating appliance.

The execution standard identifies limitations and safety considerations associated with the design, installation, commissioning and maintenance of a chimney serving more than one heating appliance (not dealt within the calculation method).

1 Scope

This part of EN 13384 specifies methods for calculation of the thermal and fluid dynamic characteristics of chimneys serving more than one heating appliance.

This part of EN 13384 covers both the cases, either

(1) where the chimney is connected with more than one connecting flue pipe from individual or several appliances in a multi-inlet arrangement or

(2) where the chimney is connected with an individual connecting flue pipe connecting more than one appliance in a cascade arrangement.

The case of multiple inlet cascade arrangement is covered by the case (1).

This part of EN 13384 deals with chimneys operating under negative pressure conditions (there can be positive pressure condition in the connecting flue pipe) and is valid for chimneys serving heating appliances for liquid, gaseous and solid fuels.

This part of EN 13384 does not apply to:

- chimneys with different thermal resistance or different cross-section in the various chimney segments. This part does not apply to calculate energy gain.
- chimneys with open fire places, e.g. open fire chimneys or chimney inlets which are normally intended to operate open to the room
- chimneys which serve a mixture of fan assisted or forced draught burners or natural draught appliances. Fan assisted appliances with draught diverter between the fan and the chimney are considered as natural draught appliances.
- chimneys with multiple inlets from more than 5 storeys. (This does not apply to balanced flue chimney.)
- chimneys serving heating appliances with open air supply through ventilation openings or air ducts, which are not installed in the same air supply pressure region (e.g. same side of building).

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 *Chimneys - General requirements.*

prEN 12391-1 *Chimneys - Metal chimneys – Part 1:Execution standard.*

EN 13384-1:2002 *Chimneys - Thermal and fluid dynamic calculation methods - Part 1: Chimneys serving one appliance.*

3 Terms and definitions

For the purposes of this European Standard, the terms and definitions given in EN 1443, EN 13384-1:2002 and prEN 12391-1 and the following apply.

3.1
chimney segment

part of a chimney between two consecutive flue gas connections or between the last flue gas connection and the chimney outlet

3.2
collector segment

part of a connecting flue pipe between two consecutive flue gas connections or between the last flue gas connection and the chimney inlet

3.3
air-flue gas system

system of concentric or non concentric ducts or parallel ducts for transport of combustion air from the open air to the heating appliances and products of combustion from the heating appliances to the open air

3.4
flue gas mass flow ($\dot{m}$)

mass of the flue gas leaving the heating appliance through the connecting flue pipe per unit of time. In case of a chimney serving more than one heating appliance, the air being transported through an appliance which is out of action is also given the term flue gas mass flow.

3.4.1
declared flue gas mass flow ($m_{W,j}$)

flue gas mass flow given by the manufacturer of the heating appliance j with respect to the heat output used in the calculation

3.4.2
calculated flue gas mass flow ($\dot{m}_{Wc,j}$)

flue gas mass flow calculated with respect to calculated draught and the working conditions of the heating appliance j

3.5
calculated flue gas temperature ($T_{Wc,j}$)

flue gas temperature at the outlet of the heating appliance j depending on the calculated flue gas mass flow

3.6
calculated draught of the flue gas of the heating appliance ($P_{Wc,j}$)

draught at the flue gas outlet of the heating appliance j depending on the calculated flue gas mass flow

3.7
flue damper

device to close or partially close the flue

3.8
balanced flue chimney

chimney where the point of air entry to the combustion air 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

3.9
cascade arrangement

arrangement where two or more appliances situated in the same space are connected by a common connecting flue pipe to the chimney

3.10
uulti inlet arrangement

arrangement where two or more appliances situated in different spaces are connected to the chimney by individual connecting flue pipes

3.11
air duct

independent duct in a building or a structural part of a flue terminal conveying combustion air to a room-sealed appliance

3.12
pressure equalising opening

opening or duct that directly connects the air duct with the flue at its base

4 Symbols, terminology, units

Symbols, terminology and units are given to make the text of this standard understandable, although a part of them is already listed in part 1 of this standard series. Indices added to symbols for purposes of the calculation method for chimneys serving more than one heating appliance relate to one chimney segment and/or connection flue pipe section. An example of an indices numbering scheme is given in Figures 1 and 2. Indices numbering shall begin at the lowest, farthest appliance connection. For more than one cascade system/connection, the indices numbering scheme for the calculation formula should be adopted in a similar manner to that for a single cascade scheme. Symbols assigned to a specific section will be indicated by the number of the section after the comma (e. g. $H_{,1}$ is the effective height of a section of a chimney segment between the outlet of the connecting flue pipe of the heating appliance in the lowest position and the outlet of the connecting flue pipe of the next heating appliance).

Table 1 - Symbols, terminology, units

Symbols	Terminology	Units
A	cross sectional area of the chimney	m^2
c_p	specific heat capacity of flue gas	J/(kg·K)
D	diameter	m
D_h	hydraulic diameter	m
g	acceleration due to gravity = 9,81	m/s^2
$H_{,j}$	effective height of the chimney segment j	m
$H_{V,j}$	effective height of the connecting flue pipe j	m
$K_{,j}$	coefficient of cooling of the chimney segment j	-
k_j	coefficient of heat transmission of the chimney segment j	$W/(m^2 \cdot K)$

$k_{ob,j}$	coefficient of heat transmission at upper end of the chimney segment j	W/(m²·K)
$K_{V,j}$	coefficient of cooling of the connecting flue pipe j	-
$L_{,j}$	length of the chimney segment j	m
$\dot{m}_{,j}$	flue gas mass flow in the chimney segment j	kg/s
$\dot{m}_{V,j}$	flue gas mass flow in the connecting flue pipe j	kg/s
$\dot{m}_{W,j}$	declared flue gas mass flow of the heating appliance j	kg/s
$\dot{m}_{Wc,j}$	calculated flue gas mass flow of the heating appliance j	kg/s
N	number of heating appliances serving the chimney	-
Nu	Nusselt number	-
$Q_{min,j}$	minimum heat output of the heating appliance j	kW
$Q_{N,j}$	nominal heat output of the heating appliance j	kW
$P_{B,j}$	pressure resistance of the air supply j of the heating appliance j	Pa
$P_{Bc,j}$	calculated pressure resistance of the air supply of the heating appliance j	Pa
$P_{H,j}$	theoretical draught available due to chimney effect in chimney segment j	Pa
P_L	wind velocity pressure	Pa
p_L	external air pressure	Pa
$P_{R,j}$	pressure resistance of the chimney segment j	Pa
Pr	Prandtl number	-
$P_{W,j}$	minimum draught for the heating appliance j	Pa
$P_{Wc,j}$	calculated draught of the heating appliance j	Pa
$P_{Z,j}$	draught at the flue gas inlet into the chimney segment j	Pa
$P_{V,j}$	calculated pressure resistance of the connecting flue pipe j	Pa
R	gas constant of the flue gas	J/(kg·K)
r	mean value of roughness value of the inner wall	m
Re	Reynolds number	-
R_L	gas constant of the air	J/(kg·K)
S_E	flow safety coefficient	-
S_H	correction factor of temperature instability	-
$T_{e,j}$	flue gas temperature at the inlet of the chimney segment j	K
$T_{g,j}$	temperature limit of the chimney segment j	K
$T_{iob,j}$	inner wall temperature at the outlet of chimney segment j at temperature equilibrium	K
T_L	external air temperature	K
$T_{m,j}$	mean temperature of the flue gas in the chimney segment j	K
$T_{o,j}$	flue gas temperature at the outlet of the chimney segment j	K
$T_{u,j}$	ambient air temperature of the chimney segment j	K
$T_{W,j}$	declared flue gas temperature of the heating appliance j	K
$T_{Wc,j}$	calculated flue gas temperature of the heating appliance j	K
U	internal circumference of the chimney	m

$w_{m,j}$	mean velocity over the length and over the cross section of the chimney segment j	m/s
α_i	internal coefficient of heat transfer of the flue	W/(m²·K)
γ	angle between flow directions e. g. between connecting flue pipe and the chimney segment	deg
η_A	dynamic viscosity of flue gas	N·s/m²
$\frac{1}{\Lambda}$	thermal resistance	m²·K/W
λ_A	coefficient of thermal conductivity of flue gas	W/(m·K)
$\rho_{m,j}$	density of flue gas averaged over the length and over the cross section of the chimney segment j	kg/m³
ψ	coefficient of flow resistance due to friction of the flue	-
ζ	coefficient of flow resistance due to a directional and/or cross sectional and/or mass flow change in the flue	-

5 Calculation method

5.1 General principles

The calculation is based upon determining the mass flow distribution in the chimney which fulfils the pressure equilibrium condition (formula 1) at each flue gas inlet to the chimney (see Figure 1). After such a distribution has been found three requirements shall be verified:

(1) the mass flow requirement (formulae 4 and 5)

(2) the pressure requirement (formula 6)

(3) the temperature requirement (formula 7)

NOTE The calculation is affected by the specific installation design. For recommendations for the installation of appliance and connection flue pipes see annex A.

The validation of the mass flow requirement and pressure requirement shall be done at following working conditions, using the external and ambient air temperatures specified in EN 13384-1.

– All heating appliances are simultaneously operating at nominal heat output.
– All heating appliances are simultaneously operating at minimum heat output
– A single heating appliance operating at nominal heat output and all other appliances out of action (all possible cases)
– A single heating appliance operating at minimum heat output and all other appliances out of action (all possible cases)

If the control of the installation guarantees that not all appliances will be in operation simultaneously, the validation of the mass flow requirement and pressure requirement may be done with the maximum number of appliances which will be in operation under the most adverse condition.

The validation for the mass flow requirement and pressure requirement for working conditions with heating appliances at minimum heat output is not required in the following cases:

– the heating appliances do not have any heat output range
– the heating appliances have a heat output which is limited to a fixed value as specified on a label on the appliance. In this case the nominal heat output is the given heat output on the label.
– heating appliances heated with solid fuels without fan and appliances with regulated air supply.

The validation of the mass flow requirement for working conditions with appliances at nominal heat output is not required in the following case:

- the heating appliances have a flue gas mass flow at minimum heat output higher than or equal to the flue gas mass flow at nominal heat output.

The temperature requirement shall be validated for the following relevant working condition, using the ambient and external air temperatures as specified in EN 13384-1:

- heating appliances for solid fuels without fan and heating appliances with regulated air supply are in operation at nominal heat output,
- heating appliances with a draught diverter which provide domestic hot water only are out of action. These heating appliances operate with a considerable secondary air (These operate only a short time and therefore it can be assumed that condensation will not cause damage or a lack in safety);
- heating appliances with a fixed output range are in operation at this (nominal) heat output;
- all other heating appliances are in operation at minimum heat output.

When chimneys suitable for operating under wet conditions are located inside a building the check of the temperature requirement is necessary only for the top of the chimney.

The validation of the temperature requirement is not necessary when the chimney serves only domestic gas fired water heaters with instantaneous production and domestic gas fired storage water heaters.

If the chimney system includes a draught regulator, the system is handled as a cascade system.

5.2 Pressure equilibrium condition

The following formulae shall be fulfilled for each chimney segment j at all relevant working conditions:

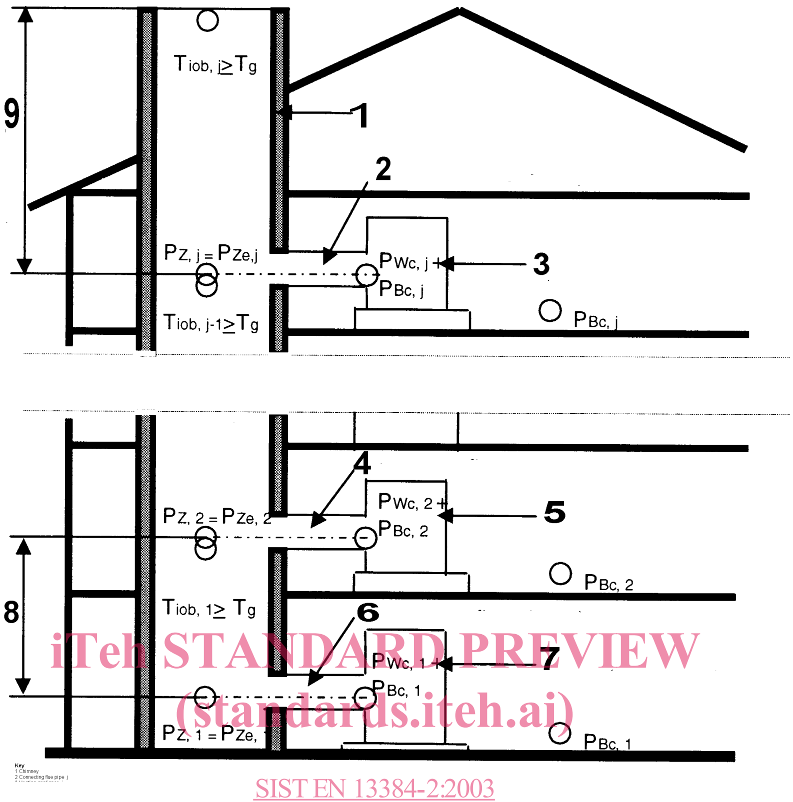
$$\left| P_{\mathrm{Z},j} - P_{\mathrm{Ze},j} \right| \leq 0{,}1 \qquad \text{in Pa} \qquad (1)$$

$$P_{\mathrm{Z},j} = -P_{\mathrm{L}} + \sum_{k=j}^{N} \left(P_{\mathrm{H,k}} - P_{\mathrm{R,k}} \right) \qquad \text{in Pa} \qquad (2)$$

$$P_{\mathrm{Ze,j}} = P_{\mathrm{Wc,j}} + P_{\mathrm{V,j}} + P_{\mathrm{Bc,j}} \qquad \text{in Pa} \qquad (3)$$

Where:

$P_{\mathrm{Z,j}}$	draught at the flue gas inlet to the chimney segment j	in Pa
$P_{\mathrm{H,k}}$	theoretical draught due to chimney effect in chimney segment k	in Pa
$P_{\mathrm{R,k}}$	pressure resistance of the chimney segment k	in Pa
$P_{\mathrm{Wc,j}}$	calculated draught of the heating appliance	in Pa
$P_{\mathrm{V,j}}$	calculated pressure resistance of the connecting flue pipe of chimney segment j	in Pa
$P_{\mathrm{Bc,j}}$	calculated pressure resistance of the air supply for the heating appliance j	in Pa
$P_{\mathrm{Ze,j}}$	required draught at the flue gas inlet to the chimney segment j	
P_{L}	wind velocity pressure	
N	number of heating appliances	



Key

1 Chimney

2 Connecting flue pipe j

3 Heating appliance j

4 Connecting flue pipe 2

5 Heating appliance 2

6 Connecting flue pipe 1

7 Heating appliance 1

8 Chimney segment 1

9 Chimney segment j

Figure 1 - Example of multiple inlet arrangement and numbering pressure values and temperature values of a chimney serving more than one heating appliance

5.3 Mass flow requirement

Formulae 4 resp. 5 shall be verified for all relevant working conditions (see 5.6).

For each heating appliance in operation at nominal or minimum heat output :

$$\dot{m}_{Wc,j} \geq \dot{m}_{W,j} \qquad \text{in kg/s} \qquad (4)$$

and for each heating appliance out of action:

$$\dot{m}_{Wc,j} \geq 0 \qquad \text{in kg/s} \qquad (5)$$

Where:

$\dot{m}_{Wc,j}$	calculated mass flow of the heating appliance	in kg/s
$\dot{m}_{W,j}$	declared mass flow of the heating appliance	in kg/s

Where a damper is applied, flow resistance shall be taken as 0 unless additional data are available.

5.4 Pressure requirement

Additionally it has to be checked that the negative pressure (draught) in the chimney ($P_{Z,j}$) is more than or equal to the negative pressure in the room where the heating appliance is placed at calculated draught conditions for air supply. The check on the pressure requirement shall be done using the same conditions as specified for the check on the mass flow requirement (see 5.3 and 5.6). The following relations shall be verified:

$$P_{Z,j} \geq P_{Bc,j} \qquad \text{in Pa} \qquad (6)$$

Where:

$P_{Z,j}$	draught at the inlet to the chimney segment j	in Pa
$P_{Bc,j}$	calculated pressure resistance of the air supply for the heating appliance j	in Pa

5.5 Temperature requirement

The relations (7) shall be verified for all relevant working conditions (see 5.6).

The check of the temperature requirement shall be done with a separate calculation using the newly calculated flue mass flows that fulfil the pressure equilibrium conditions at an external air temperature of $T_{uo,j}$ (see EN 13384-1)

$$T_{iob,j} \geq T_{g,j} \qquad \text{in K} \qquad (7)$$

Where:

$T_{iob,j}$	temperature of the inner wall of the chimney segment j at the end	in K
$T_{g,j}$	temperature limit for chimney segment j	in K

The temperature limit $T_{g,j}$ for chimneys suitable for operating under dry conditions is equal to the condensing temperature $T_{sp,j}$ of the flue gas (see 8.6). $T_{g,j} = T_{sp,j}$

The temperature limit $T_{g,j}$ for chimneys suitable for operating under wet conditions is equal to the freezing point of water: $T_{g,j}$ = 273,15 K.

NOTE The following cases can be exempted from meeting the temperature requirement provided that it is accepted that in case the requirement for temperature should be not fulfilled no guarantee can be given that no moisture appears. In this cases insulation is recommended.

– heating appliances which are substituted to a usual chimney which is already in operation and

- the heat output of the heating appliances which are connected and/or substituted does not exceed 30 kW for each and
- the flue gas losses are not more or equal than 8 % and
- an effective air conditioning of the chimney during standstill periods is given by draught diverters or dampers and
- sufficient standstill periods are given (e. g. the minimum steady state heat output of the heating appliance is not less than 20 % as the required heat).

5.6 Calculation procedure

For the calculation of the pressure and temperature values in a chimney serving more than one heating appliance an iterative procedure is necessary. This calculation procedure is based on the application of mass and energy conservation formulae under quasi steady state conditions.

In each point of connection between various ducts (at the end of connecting flue pipes, the begin and the end of the chimney segments), all called nodes (see Figure 2), the following procedure shall be used:

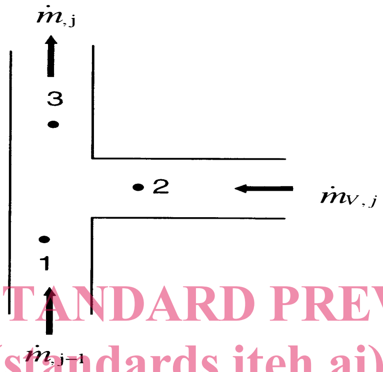


Figure 2 - Designation of flow numbering for each node *j* (see formulae 8 and 9)

- The mass flow and the temperature shall be calculated with formulae 8 and 9.

$$\dot{m}_{,j-1} + \dot{m}_{V,j} = \dot{m}_{,j}$$ in kg/s (8)

$$\dot{m}_{,j-1} \cdot c_{p,j-1} \cdot T_{o,j-1} + \dot{m}_{V,j} \cdot c_{pV,j} \cdot T_{oV,j} = \dot{m}_{,j} \cdot c_{p,j} \cdot T_{e,j}$$ in J/s (9)

where:

$\dot{m}_{,j-1}$	flue gas mass flow in chimney segment j-1	in kg/s
$\dot{m}_{V,j}$	flue gas mass flow in connecting flue pipe	in kg/s
$\dot{m}_{,j}$	flue gas mass flow in chimney segment j	in kg/s
$c_{p,j-1}$	specific heat capacity of flue gas in chimney segment j-1	in J/(kg·K)
$c_{pV,j}$	specific heat capacity of flue gas in connecting flue pipe j	in J/(kg·K)
$c_{p,j}$	specific heat capacity of flue gas in chimney segment j	in J/(kg·K)
$T_{o,j-1}$	temperature of the flue gas at the end of chimney segment j-1	in K
$T_{oV,j}$	temperature of the flue gas at the end of connecting flue pipe j	in K
$T_{e,j}$	temperature of the flue gas at the inlet of chimney segment j	in K

- The draught at the begin of the chimney segment (at point 3), is derived from the draught of this chimney segments and all succeeding sections according to formula 2.