

Free-standing chimneys —

Part 4: Brick liners — Design and execution

The European Standard EN 13084-4:2005 has the status of a
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National foreword

This British Standard is the official English language version of EN 13084-4:2005, including Corrigendum May 2006. It supersedes BS EN 13084-4:2002 which is withdrawn.

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Contents

	Page
Foreword	5
1 Scope	6
2 Normative references	6
3 Terms, definitions and symbols	6
3.1 Terms and definitions	6
3.2 Symbols	8
4 Material	8
4.1 General	8
4.2 Brickwork	8
4.2.1 General	8
4.2.2 Thermal effects	9
4.2.3 Classification and chemical attack	9
4.3 Insulation	10
5 General design requirements	11
5.1 General	11
5.2 Minimum wall thickness	11
5.3 Liner supports	11
5.4 Openings	12
5.5 Ventilation	12
5.6 Protective coatings	12
5.7 Accessories	12
5.7.1 Joints	12
5.7.2 Compensators	13
5.7.3 Ducts and fans	13
6 Structural design	13
6.1 Actions	13
6.1.1 General	13
6.1.2 Wind actions	13
6.1.3 Seismic actions	13
6.1.4 Thermal effects	13
6.1.5 Internal pressure and explosions	14
6.2 Resistances	14
6.3 Verification	14
6.3.1 Ultimate limit state	14
6.3.2 Serviceability limit state	17
6.3.3 Stress calculations in the ultimate limit state	17
6.3.4 Elastic stability	18
7 Execution	18
7.1 Imperfections	18
7.2 Tolerances	18
8 Inspection and maintenance	19
8.1 General	19
8.2 Inspection aspects	19
8.2.1 Brick liner	19
8.2.2 Insulation	20
8.3 Frequency	20
8.4 Performance	20

Annex A (informative) Structural design of base supported liners	22
A.1 General	22
A.2 Elastic stability.....	22
A.2.1 General	22
A.2.2 Elastic stability of the uncracked tube	22
A.2.3 Elastic stability of free standing vertical columns	24
A.2.4 Elastic stability of a half tube.....	25
A.2.5 Comparison of the three calculation methods and conclusions	26
Annex B (normative) Openings	29
Annex C (informative) Compensators.....	30
Annex D (informative) Dynamic effects	32
Annex E (informative) Strengthening – reinforced brickwork.....	35
E.1 Steel bands, fitted outside the liner.....	35
E.1.1 Stresses in the liner	35
E.1.2 Plain steel bands.....	36
E.1.3 Steel bands fitted with springs	36
E.2 Reinforced brickwork	39
E.2.1 General	39
E.2.2 Dimensioning	39
E.2.3 Materials	39
E.2.4 Corrosion protection	39
E.2.5 Execution.....	40
Annex F (informative) Thermal effects.....	41
Thermal stresses	41
Annex G (informative) Drying and start up	43
G.1 New Liners.....	43
G.1.1 General	43
G.1.2 Externally insulated liners.....	43
G.1.3 Uninsulated liners	43
G.2 Old brick liners.....	44

Figures

Figure A.1 — The critical height of a free standing uncracked brick liner	24
Figure A.2 — The critical height of cracked and uncracked brick liners	27
Figure C.1 — Example of a liner joint with compensator	31
Figure D.1 — Lowest relevant mode shape of liner.....	34
Figure D.2 — Relationship between h/r and γ	34
Figure E.1 — Steel bands fitted with springs	38
Figure E.2 — Integral reinforcement section with shaped bricks	40

Tables

Table 1 — Main symbols	8
Table 2 — Minimum wall thickness for brickwork liners	11
Table 3 — Characteristic values of mechanical properties of brickwork.....	14
Table 4 — Combination of actions for persistent design situations ^a	16

Table 5 N – Partial safety factors γ_G and γ_{Qi} for actions..... 16

Table 6 N — Partial Safety factors γ_M for brickwork 17

Table A.1 — Critical height as a function of wall thickness 25

Table A.2 — Calculation results with given tube dimensions 26

Table A.3 — Maximum liner height and minimum wall thickness as a function of diameter 28

Foreword

This document (EN 13084-4:2005) has been prepared by Technical Committee CEN/TC 297 “Free-standing industrial chimneys”, the secretariat of which is held by DIN.

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 February 2006, and conflicting national standards shall be withdrawn at the latest by February 2006.

This document is part 4 of a package of standards as listed below:

- EN 13084-1, Free-standing industrial chimneys - Part 1: General requirements.
- EN 13084-2, *Free-standing chimneys - Part 2: Concrete chimneys.*
- EN 13084-4, *Free-standing chimneys - Part 4: Brick liners – Design and execution.*
- EN 13084-5, *Free-standing chimneys - Part 5: Materials for brick liners - Product specifications.*
- EN 13084-6, *Free-standing chimneys - Part 6: Steel liners - Design and execution.*
- EN 13084-7, *Free-standing chimneys – Part 7: Product specifications of cylindrical steel fabrications for use in single wall chimneys and steel liners.*
- EN 13084-8, *Free-standing chimneys – Part 8: Design and execution of mast construction with satellite components.*

Additionally applies:

- EN 1993-3-2, *Eurocode 3: Design of steel structures – Part 3-2: Towers, masts and chimneys – Chimneys*

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

1 Scope

This European Standard specifies special requirements and performance criteria for the design and construction of lining systems made of brickwork for free-standing industrial chimneys. Current European practice favours sectional liners and the statements of the standard are mainly devoted to such solutions but are also largely applicable to base supported independent and stayed liners. This European Standard identifies requirements to ensure mechanical resistance and stability of liners in accordance with the general requirements given in EN 13084-1.

Lining systems comprise some or all of the following:

- chimney liner including duct entry;
- insulation;
- liner support;
- space between liner and concrete windshield.

Gas flow calculations to determine liner sizes are covered by EN 13084-1.

2 Normative references

The following referenced documents are indispensable for the application 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 1052-1, *Methods of test for masonry — Part 1: Determination of compressive strength*.

EN 1052-2, *Methods of test for masonry — Part 2: Determination of flexural strength*.

EN 13084-1:2000, *Free-standing industrial chimneys — Part 1: General requirements*.

EN 13084-5:2005, *Free-standing chimneys — Part 5: Materials for brick liners — Product specifications*.

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this European Standard, the terms and definitions given in EN 13084-1:2000 together with the following apply.

3.1.1

base supported liner

liner which is supported vertically only at the liner base

3.1.2

independent liner

base supported liner which has no other horizontal support or restraint

3.1.3

stayed liner

base supported liner which has horizontal restraints

3.1.4

sectional liner

liner which is supported vertically at a number of elevations

3.1.5

liner support

load bearing component which supports the liner

3.1.6

duct entry

part of the liner which introduces the flue gases into the liner

3.1.7

thermal gradient

temperature difference between outer and inner wall surface related to the thickness of the wall

3.1.8

thermal shock

effect on the liner of rapid changes in flue gas temperature, giving stresses. This can typically occur due to uncontrolled shutdowns, a fire or sudden by-pass of an energy conservation or flue gas desulphurisation unit

3.1.9

compensator

any systems which allows the movement of the joint in any direction maintaining its gas tightness

3.2 Symbols

The main symbols used in this document are given in Table 1.

Table 1 — Main symbols

Symbol	Denomination	Unit
Safety factor:		
γ	partial safety factor	-
Material properties:		
f	strength	N/mm ²
E	modulus of elasticity	N/mm ²
σ	stress	N/mm ²
α_T	coefficient of thermal expansion	K ⁻¹
Actions:		
T	thermal effects	-
G	permanent actions	-
W	wind actions	-
a	acceleration	m/s ²
Dimensions:		
d	diameter	m
h	height	m
t	wall thickness	m
Subscripts:		
c	compression	-
t	tensile	-
y	yield	-
k	characteristic	-
M	material	-

4 Material

4.1 General

The choice of material will depend upon the service required.

4.2 Brickwork

4.2.1 General

The type of brickwork used is largely determined by the resistance to chemical attack of the bricks and mortars. In addition, when thermal shocks are expected, brick types will be selected on the basis of their resistance to spalling and other mechanical damage caused by the same.

Brickwork covered by this document consists of brick types in accordance with EN 13084-5:2005, 5.1 and mortar types in accordance with EN 13084-5:2005, 5.2

4.2.2 Thermal effects

According to the requirements as specified in EN 13084-1:2000, 5.2.3.4 the temperature effect on brickwork shall be considered particularly with regard to:

- limit temperature of the various components;
- thermal gradients through the brickwork components in steady and transient conditions;
- uniform temperature;
- expansion;
- thermal shock.

Calculations based on the maximum temperature of flue gas and the maximum expected ambient temperature shall show that all the materials are operating below their allowable temperatures.

Thermal gradients, if not limited, could cause cracks in liners especially in those made of bricks type BT1, BT2 and BT3.

Thermal shock can cause spalling and cracks on bricks type BT1, BT2 and BT3. It normally causes only shallow cracks but the thermal gradient may cause these to grow.

4.2.3 Classification and chemical attack

4.2.3.1 General

Depending on the degree of chemical attack given in EN 13084-1:2000, Table 3 the following brickwork classes may be used for the construction of chimney liners:

- brickwork class A: resistant to "very high chemical attack";
- brickwork class B: resistant to "high chemical attack";
- brickwork class C: resistant to "medium chemical attack";
- brickwork class D: resistant to "low chemical attack";
- brickwork class E: not subject to "chemical attack".

Mortar type MT3 based on Portland cement may be used only for brickwork classes D and E.

NOTE For all brickwork classes in the presence of alkalis with temperatures above 680 °C, bricks with a low true porosity (10 % maximum) are recommended.

4.2.3.2 Brickwork class A: resistant to "very high chemical attack"

This will normally consist of:

- bricks type BT1;
- mortar type MT1 (in the case of very high chemical attack due only to acids: mortar type MT2).

If abnormal temperature deviations are expected the limit in service temperature of mortars type MT1 shall be taken into account.

Brickwork class A using mortar type MT1 can also withstand alkaline condensates.

4.2.3.3 Brickwork class B: resistant to "high chemical attack"

This will normally consist of:

- bricks type BT2;
- mortar type MT2.

The use of mortar type MT2 allows its use up to 1000 °C; if thermal shocks are expected the resistance to thermal cycling of the bricks will be a factor of major importance.

Brickwork class B is not resistant to alkaline condensates.

4.2.3.4 Brickwork class C: resistant to "medium chemical attack"

This will normally consist of:

- bricks type BT3;
- mortar type MT2.

The use of mortar type MT2 allows its use up to 1000 °C; if thermal shocks are expected the resistance to thermal cycling of the bricks will be a factor of major importance.

Brickwork class C is not resistant to alkaline condensates.

4.2.3.5 Brickwork class D: resistant to "low chemical attack"

This will normally consist of:

- bricks type BT4;
- mortar type MT3.

4.2.3.6 Brickwork class E: not subjected to chemical attack

This will normally consist of:

- bricks type BT4 or BT5;
- mortar type MT3.

Brickwork class E may be used in liners that are always operating safely above the dew point.

Bricks type BT5 may only be used provided that mechanical actions such as erosion or abrasion are not expected.

4.3 Insulation

Insulation may be used to reduce the thermal gradient in the liner as well as in the windshield and to reduce the heat loss of the flue gases.

The following types of insulating materials are widely available for the purpose:

- insulating bricks;
- mineral wool blankets;

- cellular glass blocks;
- vermiculite/perlite preformed blocks;
- calcium silicate blocks;
- glass wool blankets;
- ceramic fibre lancets.

Stability of insulation shall be ensured even in the case of vibrations due to possible pulsation of flue gas pressure.

5 General design requirements

5.1 General

A gas tight floor shall be provided no more than 1,0 m from the bottom of the lowest duct entry.

Adequate means shall be provided to drain acid condensate to a safe location.

5.2 Minimum wall thickness

For the determination of the minimum wall thickness of the liner see Table 2.

Table 2 — Minimum wall thickness for brick liners

	1	2	3	4
	Internal diameter, d , of liner in m	Minimum wall thickness, in mm, for		
		bricks without tongue and groove	shaped bricks with lateral tongue and groove	shaped bricks with continuous tongue and groove
1	$0 < d \leq 4,0$	115	100	64
2	$4,0 < d \leq 6,0$	115	100	80
3	$6,0 < d \leq 8,0$	115	100	100
4	$8,0 < d \leq 10,0$	—	120	120
5	$10,0 < d \leq 12,0$	—	140	140

5.3 Liner supports

Brick liner supports shall be designed with adequate rigidity to avoid imposing unacceptable non-uniform support reactions on the liner. In addition, in the case of multiflue chimneys, the deformation of the supporting platforms shall be such that the required clearance between the top of the liner and the upper platform is respected. Supports comprising segmental beams, supported by discrete corbels projecting from the windshield, shall be provided with torsional continuity by in-situ reinforced concrete joints or other means.

5.4 Openings

In order to limit the effects of differential temperatures around the circumference of the liner, openings introducing gases at different temperatures should be so arranged that a good mixing of the separate gas streams is ensured. They should be positioned at elevations as near to each other as possible in order to increase mixing between gas streams and reduce temperature differences which can otherwise cause additional stresses in the brickwork.

5.5 Ventilation

Brick liners are normally used when flue gas pressure is lower than the ambient pressure outside the brickwork at the same elevation. Positive pressure excursions of limited duration are permitted, but these should be taken into account in assessing the chemical load.

If the gas flow calculations show that significant operating periods are expected with flue gas pressure higher than the pressure in the space between liner and windshield, pressurisation of the space – by the use of fans – and the provision of compensators are required.

Where access is required into the space between liner and windshield during operation of a liner, ventilation shall be sufficient to ensure that no flue gas leaks through the liner. The ventilation system shall comply with the requirements of EN 13084-1:2000, 4.5.

Air ventilation can also be used to cool and avoid significant thermal stresses within the liner supports.

5.6 Protective coatings

Concrete surfaces inside the windshield may be protected by a suitable chemical resistant coating or membrane, whose viability and long term integrity has been demonstrated in wet and dry conditions of exposure to flue gas at the anticipated operating temperatures.

An acid resistant coating shall be applied to all parts of the support system that are not easily accessible for regular inspection and maintenance. In addition, an acid resistant membrane shall be provided between the support and the supported brickwork. This membrane may be of lead or a chemical resistant coating.

In the case of an accessible space the interior surface of the windshield requires protection particularly if significant periods of operation characterised by flue gas positive pressure are expected.

Horizontal surfaces of structures for inspection or support (slabs, beams etc.) shall be provided with a condensates draining system when the formation of aggressive condensate is expected.

5.7 Accessories

5.7.1 Joints

At joints between liner sections, the liner shall have at least 30 mm clearance under operating conditions in every direction between it and the other liner or its support.

NOTE In the cases of "very high" and "high" chemical attack the brickwork tends in time to show an irreversible expansion due to a chemical reaction between the brickwork and the acid condensate. This irreversible expansion can be as much as 0,15 %.

The joints cause a loss of gas tightness of the liner and, to prevent collection of debris and condensates, joints can be filled by blankets, ropes and similar materials whose properties will be chosen according to the operating gas conditions.

5.7.2 Compensators

A compensator should be a suitable system for sealing the structural joints between brick liner sections to improve the gas tightness of the liner (see Annex C).

5.7.3 Ducts and fans

The vibrations of ducts or fans outside the chimney can cause vibrations of the liner. Provisions shall be made to prevent transmission of such vibrations.

6 Structural design

6.1 Actions

6.1.1 General

Actions to be considered are given in EN 13084-1. In addition the following specifications apply.

6.1.2 Wind actions

As the liner is protected from the wind by the windshield, the only effect of wind in the case of sectional liners is that induced by the dynamic response of the concrete windshield, i.e. the stress in the liner sections is assumed to be caused only by the acceleration of the windshield at the liner support elevation.

NOTE 1 The concrete windshield responds dynamically only to that part of the fluctuating wind gusts which represents their dynamic effect (as opposed to that part representing background turbulence). Also, higher modes of the concrete windshield's response to these gusts are unimportant. Thus only the loads induced by the windshield's fundamental response need to be considered. Similar considerations apply to those discussed in Annex D, i.e. there is no magnification due to resonance, when these loads are considered. For typical chimneys, the resulting peak acceleration in the liner amounts to less than 0,05 g and is negligible.

In case of sectional liners whose height is much smaller than the height of the windshield, no resonance due to wind excitation will occur and therefore wind loading may be neglected except for the top protruding section above the windshield, if any.

NOTE 2 It is recommended that the protruding section be protected by a separate concentric concrete or brickwork windshield.

6.1.3 Seismic actions

Seismic actions cause stresses in the liner sections due to the acceleration of the windshield at the liner support elevation. The determination of the dynamic effects is given in Annex D.

6.1.4 Thermal effects

Thermal effects in the brick liner shall be considered in the following cases of heat flow causing thermal gradients across the liner:

- steady heat flow;
- transient heat flow.

Thermal stresses for both the steady heatflow and the transient heat flow can be calculated according to Annex F.

The maximum thermal effect for steady heat flow is caused by the maximum expected operating temperature and the minimum ambient design temperature.