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Specification for **Steel chimneys**

Spécification des cheminées d'acier

Spezifikation für Stahlblechschornsteine

British Standards Institution

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CONTENTS	Page		Page
Foreword	Inside front cover	TABLES	
Cooperating organizations	Back cover	1. Temperature coefficient, K_t	3
SPECIFICATION		2. Corrosion allowances	4
1. Scope	1	3. Insulation values	9
2. References	1	4. Values of K for different types of construction	12
3. Definitions	1	FIGURE	
4. Chimney shells	2	1. Effective height of chimney shell	14
5. Supporting structures	6		
6. Chimney linings	6		
7. Exterior insulation	8		
8. Protective treatments	9		
APPENDICES			
A. Inspection and maintenance	11		
B. Wind excited oscillations	11		
C. Recommendations for the use of stainless and other steels	13		

FOREWORD

This standard, which has been prepared under the direction of the Codes of Practice Committee for Civil Engineering, was first published in 1966. Since that date three amendments have been issued which have dealt with the effect of wind on circular chimney shafts in order to maintain the relationship with CP 3: Chapter V: Part 2 'Wind loads'. A general revision of the standard has become necessary, after the requirements of this standard had been applied and additional experience had been gained in its application during the intervening years. The opportunity has also been taken to metricate the standard in accordance with BSI policy.

The clause dealing with corrosion has been expanded and the corrosion allowance amended in the light of experience. In view of the fact that the majority of chimney shafts are now welded, it has been considered essential that provision be made in this standard to ensure that such welding is carried out in a satisfactory manner. As a result of this development it is now more than ever necessary that adequate consideration be given to wind effect upon smooth shafts of this construction. Appendix B has therefore been revised and expanded to accord with the latest

technical information on this very important and controversial subject. Although more research is needed in this field, it is hoped that the information contained in the appendix will prove of assistance to designers.

It has been assumed in the drafting of this standard that the design of steel chimney shafts will be entrusted to appropriately qualified engineers for whose guidance it has been prepared, and that the work will be executed under the direction of appropriately qualified supervisors.

It cannot be too strongly stressed that it is essential at the enquiry stage that all relevant information be provided so that the contractor has complete and sufficient information. Any special design or site considerations (e.g. foundations, which are not normally designed by a specialist chimney contractor) should be included so that a satisfactory estimate can be given. This will avoid any misunderstandings arising from inadequate information.

Attention is also drawn to the fact that statutory consent may be necessary in certain cases, for example, The Greater London Council, under Part IV of the London Building Acts (Amendment) Act 1939.

BRITISH STANDARD SPECIFICATION FOR
STEEL CHIMNEYS

1. SCOPE

This standard relates to the structural design and construction of steel chimneys, with or without linings, and their supports, and to the application of lining or cladding to such chimneys, where required. Recommendations with regard to inspection and maintenance are given in appendix A. The principles described in this standard apply generally to chimneys varying widely in height, shape, purpose and design. The design of chimneys of other than circular cross section is not included in this standard. Chimneys in pairs, rows or groups, and those near other structures of comparable height, may be subject to exceptional wind force and particularly wind-induced oscillation greater than that allowed for in this standard. Appropriate expert advice should therefore be obtained in these cases.

The purpose for which the chimney is required will determine whether lining, insulation or cladding is necessary.

2. REFERENCES

The titles of the standards publications referred to in this standard are listed on the inside back cover.

3. DEFINITIONS

For the purposes of this British Standard the following definitions apply:

- 3.1 access door.** A door for the entry of personnel.
- 3.2 access hooks.** Fittings welded to a chimney to permit the attachment of steeplejack's equipment (see BS 3678).
- 3.3 aerodynamic stabilizer.** A device fitted to the structural shell to reduce wind-excited oscillations by modifying vortex shedding.
- 3.4 base cone.** A truncated cone incorporated immediately above the baseplate of a chimney to reduce deflection.
- 3.5 baseplate.** A horizontal plate fixed to the base of a chimney.
- 3.6 base gussets.** Triangular fins of steel fixed to the shell of the chimney and to the baseplate.
- 3.7 base stool.** A construction comprising two vertical plates, welded to the chimney shell and to the baseplate, supporting a horizontal plate through which the holding-down bolts pass.
- 3.8 blanking-off plate.** An imperforate plate fitted immediately beneath the inlet of a chimney to prevent the waste gases reaching the lower portion of the chimney.

3.9 boiler-mounted chimney. A chimney supported by a boiler and its foundation.

3.10 bracket. A construction providing resistance to lateral displacement of the chimney, and/or supporting part or all of the weight of the chimney.

3.11 bracketed chimney. A chimney in which not all external applied loads (e.g. wind) are carried exclusively by the structural shell and for which brackets are provided to ensure stability.

3.12 cap plate. A sloping plate fitted to the top of the structural shell, covering the area between it and the liners and incorporating cravats through which the liners protrude.

3.13 cleaning door. A door, normally at the base of the chimney, to permit the removal of flue dust.

3.14 cope band. A steel section attached to the top of the chimney around its perimeter to give added strength and corrosion resistance at this level.

3.15 cope hood. A hood fitted externally to the top of a liner, covering the upstand of the cap plate, to prevent the ingress of rain water.

3.16 corrosion test piece. A fixed or removable steel plate insert, generally of lesser thickness than the shell of the chimney, in contact with the waste gases and fitted at strategic points where maximum corrosion is expected to occur.

3.17 cowl. A conical or dished cap fitted to the top of the chimney to reduce the ingress of rain water.

3.18 cravat. An upstand fixed to the roof, roofplate or cap plate to prevent the ingress of rain water.

3.19 doubling plate. A plate fixed to the shell to reinforce it where increased stresses occur.

3.20 double skin chimney. A chimney consisting of an outer load-bearing steel shell and an inner steel liner which carries the flue gases.

3.21 guy. A wire rope attached at one end to a chimney and anchored at the other so as to provide tensile resistance to the lateral displacement of the chimney.

3.22 guy band. A steel section fitted around the outside of a chimney with provision for the attachment of guys.

3.23 guyed chimney. A chimney in which not all externally applied loads (e.g. wind) are carried exclusively by the structural shell and for which guys are provided to ensure stability.

BS 4076: 1978

3.24 holding-down bolts. Bolts built into a concrete foundation, brick base or supporting framework to provide anchorage at the base of the chimney.

3.25 inlet. A short duct fixed to the shell or baseplate of a chimney for the entry of flue gases.

3.26 intermediate cone. A truncated cone incorporated in the chimney shell at an intermediate level to reduce deflection.

3.27 jointing flange. A steel section fitted to the end of a chimney section to enable sections to be connected together.

3.28 lateral supports. Supports positioned at appropriate levels within the structural shell to locate the liners and to allow for their independent expansion.

3.29 liners. Ducts contained within a structural shell.

3.30 liner base. A suitable support positioned at a convenient height above the baseplate of the structural steel shell to carry the weight of the liners.

3.31 multi-flue chimney. A group of two or more chimneys within a structural framework or a group of two or more liners within a structural shell.

3.32 roofplate. A plate which follows the contour of the roof round the chimney where it passes through the roof.

3.33 self-supporting chimney. A chimney in which externally applied loads (e.g. wind) are carried exclusively by the structural shell and which, together with the foundation, will remain stable under all design conditions without additional support.

3.34 stay. A rigid member providing both tensile and compressive resistance to the lateral displacement of the chimney.

3.35 stayed chimney. A chimney in which not all externally applied loads (e.g. wind) are carried exclusively by the structural shell and for which stays are provided to ensure stability.

3.36 structural shell. The main external structure of the chimney, excluding any flanges.

3.37 top cone. A truncated cone or other device fitted at the top of a chimney to increase the gas exit velocity, in order to minimize cold air inversion (see 7.1). It is sometimes incorrectly referred to as a venturi.

3.38 tundish. A conical or sloping blanking-off plate provided with facilities for drainage.

3.39 weatherhood. A hood designed to shed rain water clear of the cravat and prevent its entry into the building.

4. CHIMNEY SHELLS

4.1 Loading. The determination of dead load, wind load and other loads shall be in accordance with the recommendations of CP 3: Chapter V: Part 1 and Part 2, and subject to the following provisos.

(a) Force coefficient. The force coefficient for a circular chimney of smooth construction, i.e. with no external ribs or plate projections exceeding 1/150 of the diameter, other than horizontal ones, shall be taken as 0.6.

Wind force on ladders constructed in accordance with BS 4211 fixed to a chimney shall be determined in accordance with the recommendations of CP 3: Chapter V: Part 2 and added to the force on the chimney calculated in accordance with the requirements of this standard.

(b) Factor S_3 . The factor S_3 in CP 3: Chapter V: Part 2: 1972 shall be taken as not less than 1.0.

(c) Factor S_2 . For chimneys over 80 m in height, the factor S_2 shall be taken from the class C column. For those chimneys between 10 m and 80 m the class C factor shall be increased by the difference between class B and class C at the appropriate level, multiplied by 80 minus the chimney height, and divided by 70,

$$\text{i.e. add } \frac{(B_H - C_H)(80 - h)}{70}$$

where

B_H is the factor for class B at the appropriate level above ground

C_H is the factor for class C at the appropriate level above ground

h is the actual height of chimney (in m)

For chimneys less than 10 m high the values in the class B column shall be used.

(d) Oscillation. To allow for oscillation, one of the following procedures shall be adopted.

(1) Chimneys fitted with aerodynamic stabilizers shall be designed for a force coefficient of 1.2 on the part fitted with stabilizers*. The latter shall be measured as the projected area of circular cross section enclosing the stabilizing ribs. For other types of stabilizing devices see B.3.6.

(2) Self-supporting chimneys not fitted with aerodynamic stabilizers or tensioned guys shall be so designed that stabilizers or guys can be fitted quickly and without difficulty later, if required, i.e. allowance for wind force on the stabilizers or the loads on the guys shall be made as specified in 4.1(d)(1).

(3) Chimneys may be designed in accordance with appendix B to provide for increase of loading for dynamic effect and, if necessary, for the fitting of stabilizers. If stabilizers are necessary, the design of the chimney shall be in accordance with 4.1(d)(1).

(e) Deflection. The deflection at the top of the chimney produced by the design wind load, calculated as acting on the circular cross section, in the case of designs according to 4.1(d)(1) or 4.1(d)(2) shall not be greater than $h/200$. This requirement does not include the wind force on stabilizers, nor does it apply to chimneys designed in accordance with the formulae in B.3.2. and B.3.3.

* For instance, helical strakes of three rails having a projection of 0.1 to 0.12 times the diameter of the chimney, wound, equally spaced, round the perimeter of the shell at a pitch of about five times the diameter of the chimney for not less than the upper one-third of it.

(f) *Guyed, stayed, bracketed or groups of chimneys.* Oscillation of guyed, stayed, bracketed, pairs or groups of stacks is outside the scope of this standard except to require that guys, stays or brackets shall be adequate to eliminate appreciable increase of stress due to movement.

4.2 Materials

4.2.1 *Plates and sections.* Steel plates used in the construction of chimneys coming within the scope of this British Standard shall comply with the requirements for grade 43A of BS 4360: 1972. Alternatively, suitable stainless or alloy steels may be used in special circumstances (see appendix C) but the thicknesses shall otherwise comply with the requirements of this specification. Supporting steelwork and ancillary fittings shall comply with the requirements of BS 4 or BS 4848 for dimensions and with not less than grade 43A or 50B in BS 4360: 1972 for quality.

4.2.2 Bolts and nuts

4.2.2.1 *Mild steel.* All mild steel bolts and nuts shall have a tensile strength of not less than 400 N/mm² and a minimum elongation of 17 %, as defined in BS 4190: 1967 and BS 4395: Part 1: 1969.

4.2.2.2 *High tensile steel: structural quality.* The material used for the manufacture of high tensile steel bolts, nuts and washers, for which permissible stresses are given in BS 449, shall have a minimum tensile strength of 580 N/mm² and other mechanical properties appropriate to grade 50B of BS 4360: 1972.

4.2.2.3 *Friction grip bolts.* Friction grip bolts, nuts and washers shall comply with the requirements of BS 4395: Part 1, and shall be used in accordance with the requirements of BS 4604: Part 1.

4.2.3 *Guy ropes and fittings.* Guy ropes shall comply with the requirements of BS 365. Fittings for guys shall be galvanized and shall comply with the requirements of the relevant British Standards (e.g. BS 462, BS 463, BS 464, BS 825 and BS 5281). Guy ropes with hemp cores shall not be used.

4.2.4 *Access fittings.* Access fittings shall comply with the requirements of BS 3678. The attachment of permanent ladders to steel chimneys is not recommended but, if required, they shall comply with the requirements of BS 4211.

4.3 Design and construction

4.3.1 *General.* The use of structural steel for the shell and other components of steel chimneys shall be in accordance with the requirements of the relevant clauses of BS 449.

The recommendations in BS 449 regarding the following matters shall, however, be superseded by the requirements of this standard:

- (a) minimum thickness;
- (b) allowable deflection;
- (c) allowable compressive stress in circular shells due to direct force and bending moment;
- (d) allowance for corrosion;
- (e) allowance for temperature;
- (f) stresses due to wind.

All members, including guys, if any, shall be taken into account in design calculations, except

that the weight of the flue lining shall be included in the dead load, but its strength shall be excluded from the calculations for bending and stiffness.

4.3.2 Minimum thickness of steel

4.3.2.1 *Chimney shell.* The minimum thickness of the load-bearing chimney shell, in single or multiple shell constructions, shall be the calculated thickness obtained from stress and deflection considerations plus the corrosion allowance (see 4.3.4.5), but shall not be less than 6.0 mm, nor less than 1/500 of the outside diameter of the chimney at the same height.

4.3.2.2 *Chimney liner.* The minimum thickness of the steel liner in a double skin or multi-flue construction shall be the calculated thickness obtained from stress considerations plus the corrosion allowance, but shall be not less than 6.0 mm.

4.3.2.3 *Supporting steelwork.* The minimum thickness for hot rolled sections used for external construction exposed to the weather shall be 8.0 mm, and for constructions not so exposed and ancillary steelwork, 6.0 mm (see BS 449). These provisions do not apply to the webs of British Standard (see 4.2.1) rolled steel sections, or to packings.

The minimum thickness of British Standard (see 4.2.1) hollow sections sealed at the ends, used for external construction exposed to the weather or other corrosive influences shall be 4.0 mm, and for constructions not so exposed, 3.0 mm.

4.3.2.4 *Angle flanges.* The minimum thickness of jointing angles to chimney flanges shall be 6.0 mm.

4.3.3 Allowable stresses

4.3.3.1 *General.* Allowable working stresses shall be calculated to take account of the most adverse temperature to which the member or part may reasonably be expected to be exposed and shall be obtained by multiplying the allowable stresses specified in BS 449 or the compressive stresses from the equation in 4.3.3.3 by the appropriate temperature coefficient, K_t , from table 1. The expected temperature of the steel components shall not be allowed to exceed 480 °C. The values in table 1 may be adjusted proportionately between the nearest tabulated values.

TABLE 1. TEMPERATURE COEFFICIENT, K_t

Temperature °C	-30* to 315	370	425	480†
K_t	1.0	0.9	0.7	0.5

* See (C.8) of appendix C.

† See (C.9) of appendix C.

4.3.3.2 *Effective height of chimney shell.* For the purposes of 4.3.3.3, the effective height shall be taken from figure 1.

4.3.3.3 *Compressive stress in the shell.* To control buckling, the compressive stress caused by the combination of extreme fibre stress due to bending and direct load shall not exceed the following, reduced further, if necessary, for temperature (see 4.3.3.1) and calculated with the corrosion allowance deducted.

BS 4076: 1978

Compressive stress = $115 \times A \times B$ (N/mm²)

where $A = \frac{1}{0.84 + \left(0.019 \frac{h_e}{D}\right)^2}$ if $\frac{h_e}{D} > 21$;

if $\frac{h_e}{D} < 21$, $A = 1$

and $B = 270 \frac{t}{D} \left(1 - 67 \frac{t}{D}\right)$ if $\frac{D}{t} > 130$;

if $\frac{D}{t} < 130$, $B = 1$

where t is the thickness of plate at the level considered (in m)

D is the mean diameter at the level considered (in m)

h_e is the effective height for consideration of buckling (in m) (see figure 1).

4.3.3.4 Deflection stresses. If the chimney carries a vertical load other than its own weight, due, for example, to the reaction of guys, a heavy lining or an imposed load, so that an appreciable compressive stress results, deflection due to wind may cause the axial load to become eccentric; the moment so produced shall be determined, added to that from the wind load and any other live or dead load and used to calculate the combined stresses, which shall not exceed those specified in 4.3.3.3. This procedure is necessary only if the total axial load produces stresses greater than 1/3 of the bending stresses due to wind.

4.3.3.5 Safety factor of guy ropes and fittings. A minimum factor of safety of 3 shall be used; i.e. designed breaking load $\geq 3 \times$ maximum calculated load. Because of the large variety of fittings (see 4.2.3), great care shall be taken in the selection of these items, to ensure that the minimum factor of safety is provided by all components of the supporting systems.

4.3.3.6 Stresses due to wind forces. Except for stresses caused by factors described in 4.3.3.3 and those for chimneys designed in accordance with 4.1(d)(3), the allowable stresses given in this specification may be exceeded by 25 % in cases where an increase in stress is solely due to wind forces. The steel thickness, however, shall not be less than that needed if the wind stresses were neglected.

4.3.4 Corrosion

4.3.4.1 General. A chimney shell is subject to attack by corrosion both internally and externally. The corrosion of the exterior surface is caused by atmospheric attack; this is normally minimal compared with the attack which takes place on the inner surface due to the corrosive effect of the flue gases or if the chimney is unused for protracted periods.

4.3.4.2 External corrosion. The amount of corrosion which takes place on the exterior of a chimney shell (see table 2) shall be taken as:

(a) none, if the chimney is fitted with weatherproof insulation or cladding;

(b) none, if the exterior is maintained at regular intervals and prevented from rusting; regular painting with a suitable paint is an effective treatment;

(c) above average, if it is unprotected by painting or other exterior anti-corrosive treatment.

4.3.4.3 Internal corrosion. The corrosion of the internal surface of a chimney is a direct result of the corrosive effect of the flue gases which it carries. If the flue gases are of a non-corrosive nature, no corrosion allowance is required. Flue gases attack the interior surfaces of a chimney if condensation takes place. If the inner surface of the chimney, which is in contact with the flue gases, is allowed to fall below the acid dew point of the gases (for normal boiler flue gases this may be taken as 132 °C) condensation takes place and acid attack results. If the inner surface of the chimney is kept above the acid dew point of the gases which it is carrying, internal attack will take place only whilst the inner surface of the chimney is being heated to above the acid dew point. This amount of corrosion shall be taken as 'average' in table 2.

4.3.4.4 Temperature control. To maintain the temperature of the inner surface of the chimney above the acid dew point it is necessary to minimize the heat loss; this can be achieved by fitting suitable cladding or insulation (see clause 7).

4.3.4.5 Allowance for corrosion. The total allowance for corrosion shall be the sum of the external (C_e) and internal (C_i) allowances given in table 2. This total allowance shall be added to the thickness of shell obtained from the calculation of the stresses and deflection. Internal flanges shall have corrosion allowance C_i , and the external flanges corrosion allowance C_e on all exposed surfaces.

TABLE 2. CORROSION ALLOWANCES

Degree of corrosion expected	Design life	
	10 years	20 years
	mm	mm
None (i.e. paint, insulation, cladding or similar protection)	Nil	Nil
Above average (i.e. unprotected)	1.5	3.0
Internal C_i		
None (e.g. non-corrosive flue gases or the structural shells of multiple chimneys)	Nil	Nil
Average (e.g. lined, insulated or natural gas-fired)	1.5	3.0
Above average (e.g. unprotected coal-fired)	3.0	5.0
Exceptional (e.g. unprotected oil-fired)	Not recommended	Not recommended

4.3.5 Allowances for large apertures in shell. The allowable stresses apply to the shell plates after due allowance for rivets and bolt holes. Where large apertures are cut in the shell plates, as for inlets or inspection panels, a structural analysis of the stresses shall be made and compensating material provided, as required, to ensure that the stresses specified in the standard are not exceeded. Apertures in the shell