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*भारतीय मानक*

# इस्पात की चिमनी के डिजाइन और निर्माण — रीति संहिता

भाग 1 पत्रिका पक्ष

*(पहला पुनरीक्षण)*

*Indian Standard*

# DESIGN AND CONSTRUCTION OF STEEL CHIMNEY — CODE OF PRACTICE

**PART 1 MECHANICAL ASPECT**

*( First Revision )*

(Incorporating Amendment No. 1)

UDC 697.8 [669.14] : 006.76



**B U R E A U O F I N D I A N S T A N D A R D S**
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## FOREWORD

This Indian Standard (Part 1) (First Revision) was adopted by the Bureau of Indian Standards on 20 April 1989, after the draft finalized by the Structural Engineering Sectional Committee had been approved by the Structural and Metals Division Council.

This standard was first published in 1971. On suggestions by practising engineers and representatives of various organizations in the country, the Sectional Committee decided to bifurcate the standard in two parts, separating structural aspects from the mechanical aspects as follows:

Part 1 Mechanical aspects, and

Part 2 Structural aspects.

The present practice of design of steel chimney recognizes the influence of aerodynamic shadow on the height of chimney and this aspect has been taken into account in this revision in addition to the consideration of regulations on atmospheric pollution.

Design and construction of chimneys has become specialized field with scope for the further research and modifications. Therefore, attempt has been made in this standard (Part 1) to cover only the basic requirements. The designer should use his discretion in the use of research data available.

Appendix G of the earlier version of the standard had dealt with the calculation of dispersion in atmosphere of emission of dust and sulphur dioxide from power and steam generating chimneys only. In this standard (Part 1) a more generalized approach for the determination of height of chimneys in relation to concentration of pollutants has been included keeping in view an acceptable air quality standard at the ground level.

In the preparation of this standard, considerable assistance has been derived from BS 4076 : 1978 'Specification for steel chimneys', covered by the British Standards Institution, UK.

This edition 2.1 incorporates Amendment No. 1 (October 1997). Side bar indicates modification of the text as the result of incorporation of the amendment.

*Indian Standard*

# DESIGN AND CONSTRUCTION OF STEEL CHIMNEY — CODE OF PRACTICE

## PART 1 MECHANICAL ASPECT

*( First Revision )*

## 1 SCOPE

**1.1** This standard (Part 1) covers design, construction, maintenance and inspection of mechanical aspects of steel chimneys. The mechanical aspects include lining, draft calculations, considerations of dispersion of pollutants and ash disposal.

## 2 REFERENCES

**2.1** The following Indian Standards are necessary adjuncts to this standard:

| *IS No.* | *Title* |
|---|---|
| IS 6 : 1983 | Specification for the moderate heat duty fireclay refractories, group 'A' ( *fourth revision* ) |
| IS 8 : 1983 | Specification for high heat duty fireclay refractories, group 'B' ( *fourth revision* ) |
| IS 460 (Part 1) : 1985 | Specification for test sieves: Part 1 Wire cloth test sieves ( *third revision* ) |
| IS 460 (Part 2) : 1985 | Specification for test sieves: Part 2 Perforated plate test sieves ( *third revision* ) |
| IS 2042 : 1972 | Specification for insulating bricks ( *first revision* ) |
| IS 4041 : 1987 | Glossary of terms relating to refractory materials ( *first revision* ) |
| IS 8829 : 1978 | Guidelines for micrometeorological techniques in air pollution studies |

## 3 STATUTORY PROVISIONS

**3.1** Compliance with this code does not relieve any one from the responsibility of observing provisions as may have been promulgated by any statutory bodies and/or observing provincial building by-laws and the civil aviation requirements pertaining to such structures.

## 4 TERMINOLOGY

**4.0** For the purpose of this standard terminology as defined in **4.1** to **4.21** shall apply. For definitions not covered in this part, a reference shall be made to Part 2 of the standard.

**4.1 Actual Draft**

The suction produced at the base of a chimney minus the drop in draft due to frictional resistance in flue gas passages.

**4.2 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.

**4.3 Boiler Efficiency**

The ratio of heat used in the boiler to the available heat.

**4.4 Boiler-Mounted Chimney**

A chimney supported by a boiler and its foundation.

**4.5 Draft Loss**

Drop in static pressure of gas between two points in a system.

**4.6 Efflux Velocity**

The speed of discharge of gases from the top of the chimney.

**4.7 Flux Gas Temperature**

Temperature of flue gas at the chimney outlet.

**4.8 Forced Draft**

System which maintains the products of combustion, when flown to or through it, at a pressure above atmospheric.

**4.9 Ground Level Concentration**

Concentration of air pollutant in mg/m$^3$ in the breathing zone.

**4.10 Height of Chimney**

It is the distance between the centre line of the incoming flue stream to the top of the chimney. However the height of chimney for atmospheric dispersion modelling shall be taken as the distance between the ground level and the chimney's top.

**4.11 Horizontal Top Plate**

A Horizontal cast iron plate fitted to the top of the structural shell covering the area between it and the liners.

**4.12 Induced Draft**

System which maintains the products of combustion, when flown to or through it, at a progressively increasing sub-atmospheric pressure.

**4.13 Mass Rate of Emission**

Emission of pollutants from a chimney in terms of mass per unit of time.

**4.14 Natural Draft**

Draft created in the boiler unit due to chimney only.

**4.15 Nominal Chimney Diameter**

Internal diameter at the topmost opening of the steel shell.

**4.16 Output Efficiency**

Ratio of energy equivalent of draft per kg of gases produced by artificial draft to the energy equivalent per kg of gases of the additional heat carried away by the flue gas due to natural draft.

**4.17 Plume**

The trajectory of the movement of gases discharged from a chimney.

**4.18 Refractory Work**

All terms relating to refractory work shall be in accordance with IS 4041 : 1987.

**4.19 Sloping Cap Plate**

A sloping cast iron plate fitted to the top of the structural shells covering the area between it and the liners and incorporating cravats through which the liners protrude.

**4.20 Theoretical Draft**

The suction that would be produced at the base of a chimney with no flue losses.

**4.21 Turn Down Ratio of Boiler**

Ratio of fuel firing at maximum and minimum loads.

## SECTION 1 DESIGN

## 5 GENERAL CONSIDERATIONS

### 5.1 Classification of Chimneys

On the basis of types of construction of the shaft, the chimneys are classified into two types, namely, self-supporting and guyed. The chimney may be lined either over the entire or part height depending upon the temperature and/or aggressiveness of the flue gases. The inlet for the flue gases may be below or above the ground level.

### 5.2 Selection of Chimney

**5.2.1** In the selection of chimneys, advantages and disadvantages of steel chimneys *versus* chimneys with other construction material, such as reinforced cement concrete/masonry should be considered with reference to overall economy. Some of the important advantages and disadvantages of chimneys of different materials of construction are as follows:

a) Steel chimneys are ideally suited for process work where a short heat up period and low thermal capacity are required whereas it encourages acid condensation and corrosion hence smutting and reduction in the life of chimney;

b) Guyed steel chimneys are better suited where the supporting capability of the soil is low whereas it involves regular maintenance of guy wires anchor points and other fittings in addition to difficulty in finding suitable anchor points of guys at ground;

c) Reinforced cement concrete chimneys are more expensive than other forms of construction up to about 45 m height but above this, they are very competitive. Above 65 m height, they are more readily acceptable because of their flexibility of shape and flue layouts, in addition to the absence of any limitation on size; and

d) Brick chimneys are suitable in clay industries for use with intermittent kiln firing and with very high exhaust gas temperatures. They are cheaper for smaller heights but require regular attention and, therefore, involve higher maintenance cost.

**5.2.2** Some of the important factors to be considered in choosing the chimney are as follows:

a) Characteristics of the equipment for which the chimney is designed, including number of units, type, etc, taking into account future expansion of units if the proposed chimney is to cater for these units also;

b) Type of fuel used;

c) In the case of boilers, surface area, output efficiency, draft required, etc;

d) Mode of operation;

e) Temperature of the flue gas before entering the chimney and its likely variation;

f) Composition of the flue gas, its specific weight, quantity of dust data about the aggressiveness of the gases. These factors decide the type of lining;

g) Local statutory regulations relating to height, dispersion of pollutants, provision for earthing, aviation warning lamp, health, etc, and

h) The mode of erection of chimney.

### 5.3 Basic Dimensions

**5.3.1** The basic dimensions of the chimney, namely, the height and clear diameter or cross-sectional area of individual flues or in multiflues stacks depend upon the following information:

a) Draft required by the plant;

b) Efficiency of the source generating flue gases;

c) Fuel adopted (provisions in boiler design to fire any inferior grade fuel in future shall also be considered);

d) Excess air requirement;

e) Site data (ambient air temperature, barometric pressure);

f) Flue gas temperature;

g) Flue gas velocity;

h) Proposed type of construction of the chimney;

j) Natural or mechanical draft;

k) Length of horizontal flue run; and

m) Turn-down ratio.

**5.3.2** The basic dimensions of steel chimney from consideration of strength and stability shall satisfy the relevant provisions of Part 2 of this standard.

**5.3.3** As a guideline, the nominal dimensions of steel chimney are given in Table 1.

**Table 1 Recommended Height to Diameter Ratio of Steel Chimney**

| Nominal Diameter of Chimney cm | | Height of Steel Shaft m | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Unlined | Lined | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 70 | 80 | 90 | 100 | 110 |
| 50 | | × | | | | | | | | | | | | | | |
| 60 | | × | | | | | | | | | | | | | | |
| 80 | 50 | × | | | | | | | | | | | | | | |
| 100 | 60 | | × | | | | | | | | | | | | | |
| 120 | 80 | | × | × | | | | | | | | | | | | |
| 140 | 100 | | | × | × | | | | | | | | | | | |
| 160 | 120 | | | | × | × | × | × | | | | | | | | |
| 180 | 140 | | | | × | × | × | × | × | | | | | | | |
| 200 | 160 | | | | × | | | | × | × | × | | | | | |
| 220 | 180 | | | | | | | | | × | × | | | | | |
| 240 | 200 | | | | | | | | | | × | × | | | | |
| 280 | 240 | | | | | | | | | | | × | × | | | |
| 315 | 275 | | | | | | | | | | | | × | × | | |
| 355 | 315 | | | | | | | | | | | | | × | × | |
| 400 | 360 | | | | | | | | | | | | | | × | × |
| 450 | 410 | | | | | | | | | | | | | | | × |

NOTE — 'X' denotes more commonly used dimensions.

**5.3.4** The clear diameter of the chimney is the nominal diameter of the shell if the chimney is unlined or partially lined. For fully lined chimney, the clear diameter of the chimney will be the clear diameter of the lining at the top. The fully lined chimneys shall have a minimum clear diameter of 500 mm. If, for technological reasons, it is necessary to have a smaller diameter, the top opening shall be reduced by constructing the passage locally.

**5.3.5** The chimney shall be at least 5 m taller than the tallest building in a surrounding area of 150 m radius unless other regulations do not necessitate a taller chimney ( *see also* **7** ).

## 6. CALCULATIONS

**6.1** The draft losses in combustion chamber will vary depending on the actual design and this may be worked out based on aerodynamic calculations. Hence, the draft losses at the exit flange of the combustion chamber or the boiler should be provided by the customer, for it will not be possible to standardize draft losses for various types of combustion chambers, boiler capacities, etc. The total loss will be the sum of the losses at the exit flange of the boiler and the losses in precipitators and the connecting ducts, in case of coal fired boilers and the loss at the exit flange of the boilers plus the losses in the connection ducts in case of oil and gas fired boilers. These losses plus the loss in the chimney shall be considered along with the draft available on account of forced or induced draft systems while fixing up the height. The losses across the precipitators will also have to be given by the customer.

### 6.2 Inside Diameter of the Chimney

The inside diameter of the chimney in m is calculated as follows:

$$D = \sqrt{\frac{4Q}{\pi V_{02}}}$$

where

$Q$ = quantity of the gas in $m^3$/sec, and

$V_{02}$ = velocity of the flue gas at exit point of chimney in m/sec.

However, the diameter shall be so chosen that the velocity will not exceed, under any circumstances, 30 m/sec.

The optimum range of velocity may be taken as 15 to 20 m/sec.

### 6.3 Draft Losses

The following draft losses shall be considered:

a) Draft losses through the chimney $d_e$ in mm of water column may be calculated as:

$$d_e = \frac{4\,fHV^2}{2\,gD}.\,\rho g$$

b) Draft losses through the ducts $d_d$ in mm of water column may be calculated as:

$$d_d = \frac{4\,flV^2_1}{2\,gD_1}.\,\rho g$$

c) Draft losses in bends $d_b$ in mm of water column may be calculated as:

$$d_b = \frac{K_1V^2}{2g}.\,\rho g$$

d) Draft losses due to sudden change of sections $d_s$ in mm of water will depend upon the degree of sharpness, form of section and the ratio of area of the section after and before the change. Also, if the change in section is gradual, that is, if enlargement or contraction is gradual, the loss will depend on the included angle. It may be calculated as follows:

1) $d_s = \frac{K_2{V_2}^2}{2g}.\,\rho g$ when the change of section is abrupt, and

2) $d_s = \frac{K_3K_2{V_2}^2}{2g}.\,\rho g$ when the change of section is gradual.

e) Draft loss due to kinetic energy at the exit:

$$d_k = \frac{V^2}{2g}.\,\rho g$$

**6.3.1** Legends used in the above formulae are explained as under:

$d_e$, $d_d$, $d_b$, $d_s$, and $d_k$ = draft losses as explained above, in mm of water column;

$f$ = fanning friction factor;

$H$ = height of the chimney in m;

$l$ = Length of the duct in m;

$D$ = diameter of the chimney in m;

= shaft diameter in case of cylindrical chimney and average diameter in case of conical chimney of smaller height;

$D_1$ = diameter of the duct in m, if circular in cross-section; or $\frac{2AB}{A+B}$ if rectangular in cross sect on with $A$ and $B$ as dimensions;

$V$ = velocity of gas in m/sec;

$V_1$ = velocity of gas in the flue duct in m/sec;

$V_2$ = velocity of gas in m/sec after the change in section;

$K_1$ = coefficient of friction as obtained from Fig. 1;

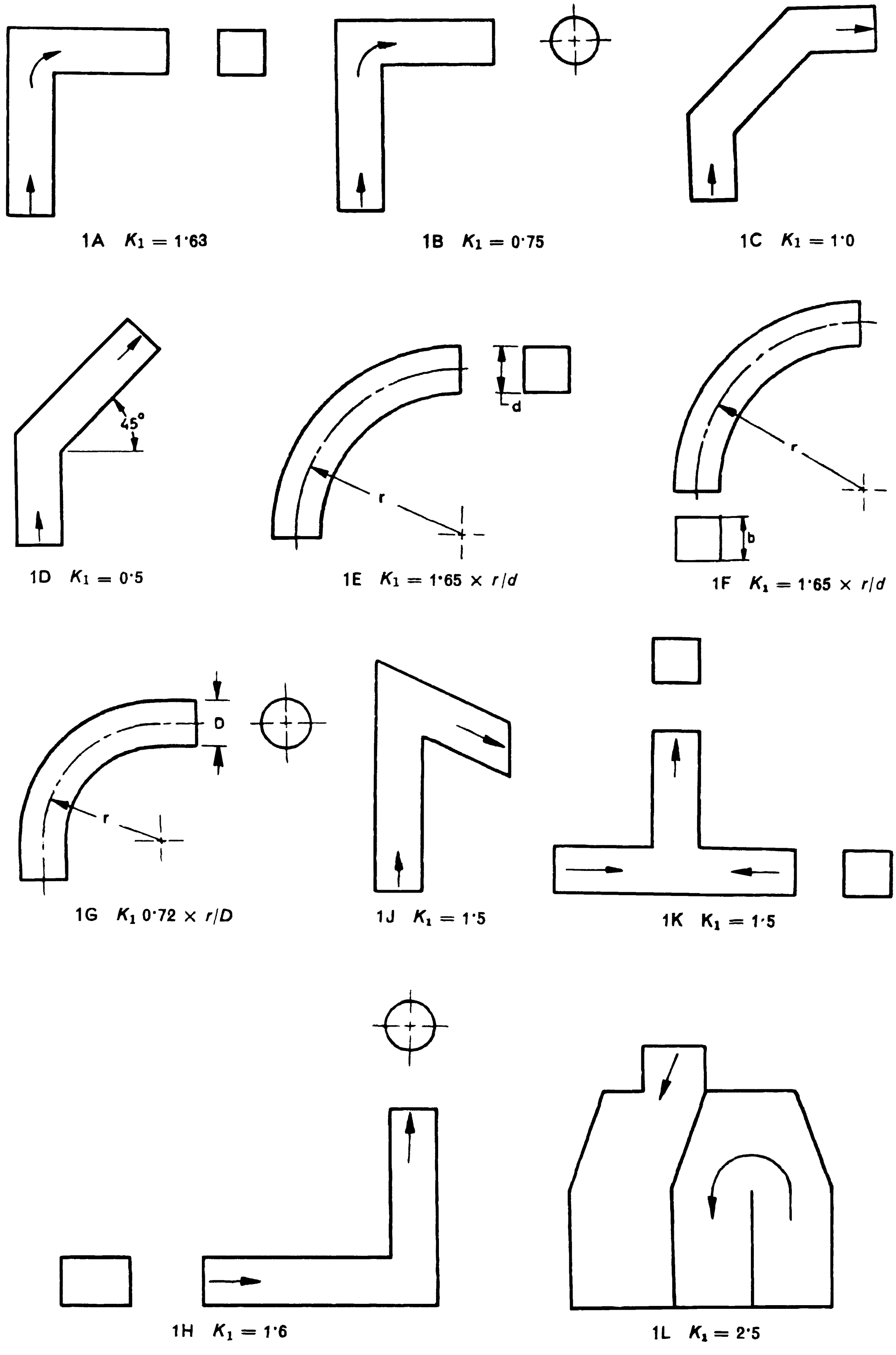



FIG. 1 COEFFICIENT OF FRICTION ( $K_1$ ) IN BENDS

$K_2$ = coefficient of friction due to sudden change in section as obtained from Fig. 2;

$K_3$ = factor for gradual change in section as obtained from Fig. 3;

$g$ = acceleration due to gravity in m/s$^2$; and

$\rho g$ = average density of fuel gas within the chimney, in ducts, in bends or at the exit; as appropriate in kg/m$^3$.

**6.4** The draft induced by the chimney, $d_a$ in mm of water column is:

$d_a = H(\rho a - \rho g)$

where

$\rho a$ = density of air at ambient temperature and pressure in kg/m$^3$, and

$\rho g$ = density of gas at average temperature and pressure within chimney in kg/m$^3$.

**6.5** The draft available in the chimney as calculated in **6.4** should take care of all the draft losses as calculated in **6.3** (adjusted for the usage of forced draft and induced draft fans). The height and diameter of the chimney should be so chosen as to obtain the necessary draft and the necessary exit velocity.

## 7 DETERMINATION OF HEIGHT OF CHIMNEY

**7.1** The height of chimney chosen shall satisfy the requirement given in **6.5**.

**7.2** The influence of aerodynamic shadow on the height of the chimney shall be assessed in accordance with Annex A.

**7.3** While deciding the actual height of the chimney, consideration of dispersion of pollutants on the height of chimney as covered in IS 8829 : 1978 shall be taken. In the absence of availability of sufficient data regarding meteorological techniques in air pollution study, method as given in Annex B shall be taken into account. This Annex also covers recommended height of stacks for process gases from pollution consideration for iron and steel industries in particular.

**7.4** The final adoptable height of the chimney shall be based on all the factors covered in **7.1** and **7.3**.

# SECTION 2 LINING AND INSULATION

## 8 CHIMNEY LINING

### 8.1 General

Lining for steel chimney may be required for one or more of the following purposes:

a) To protect the chimney shell from heat,

b) To act as a protective covering thus reducing corrosion, and

c) To maintain the temperature of the flue gases.

### 8.2 Materials

**8.2.1** *Firebricks*

These are made in radial form to suit the chimney dimensions. Firebricks having an alumina content between 28 and 32 percent are satisfactory for the majority of applications. These bricks are set in mortar made from ground fireclay or in a suitable fire cement.

This type of lining fulfils requirement **8.1**(b) and to a certain extent requirements **8.1**(a) up to a temperature of about 1 200°C but its high density makes it of little use in respect of requirement **8.1**(c). Its strength and hard surface would give protection to the steel from abrasion when this has to be considered.

Suitable bricks shall have the following properties:

| | |
|---|---|
| a) Thermal conductivity | : About 1.25 W/(mK) |
| b) Bulk density | : Not less than 2 000 kg/m$^3$ |
| c) Cold crushing strength | : Not less than 14 N/mm$^2$ |
| d) Coefficient of expansion | : Up to $3.3 \times 10^{-6}$/°K |
| e) Aluminium oxide ($Al_2O_3$) | : 30 percent, *Min* |
| f) Acid solubility | : 2.0 percent, *Max* |
| g) Spalling resistance | : 15 cycles, *Min* |
| h) Approximate porosity | : 20 percent, *Max* |
| j) Refractoriness under load (R.U.L) | : 1 300°C, *Min* |
| k) Warpage | : 1 mm, *Max* |
| m) Size tolerance | : ± 1.5 percent |

**8.2.1.1** Mortar for fireclay bricks (hard fired), mixed with blast furnace slag cement in the ratio 80 : 20, should have the following properties:

| | |
|---|---|
| a) Aluminium oxide ($Al_2O_3$) | 20 percent, *Min* |

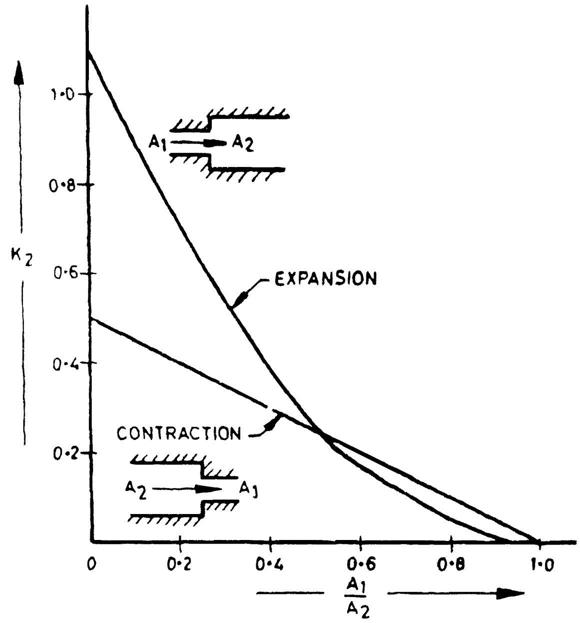



FIG. 2 COEFFICIENT OF FRICTION ( $K_2$ ) DUE TO SUDDEN CHANGE IN SECTION

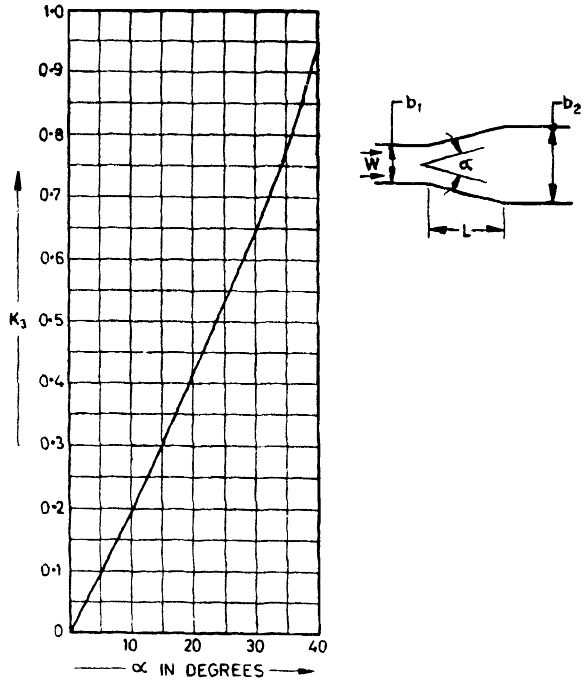



FIG. 3 COEFFICIENT OF FRICTION ( $K_3$ ) DUE TO GRADUAL CHANGE IN SECTION

| | |
|---|---|
| b) Ferric oxide ($Fe_2O_3$) | 2.5 percent, *Max* |
| c) Pyrometric cone equivalent, Standard cone No. (ASTM) | 28, *Min* |
| d) Dry shrinkage | 2.5 percent, *Max* at 110°C |
| e) Fired shrinkage | 2.5 percent, *Max* at 1 250°C/2 hr |
| f) Grading | 0 to 1 mm<br>—95 percent, *Min* passing 1 mm sieve<br>—50 percent, *Min* passing 0.09 mm sieve |
| g) Workability | Good |

**8.2.1.2** Blast furnace slag cement should have the following chemical composition:

a) $SiO_2$ : 25 to 26 percent

b) $Al_2O_3$ : 12 to 14 percent

c) $Fe_2O_3$ : 2.0 percent, *Max*

d) CaO : 48 to 50 percent

**8.2.1.3** In case the chimney has to discharge gases from processes or incinerators at a temperature higher than 1 200°C, special duty lining has to be used as given in IS 6 : 1983 and IS 8 : 1983.

**8.2.2** *Insulation Refractory Bricks*

These bricks are used for achieving all the three functions of the insulation. These bricks are available in three grades suitable to temperatures 850, 1 250 and 1 500°C. These bricks shall conform to IS 2042 : 1972. The application is similar to that of firebricks. Insulating bricks shall, however, fulfil the following properties.

| | | *Service Temperature* | |
|---|---|---|---|
| | | 1 200°C | 1 050°C |
| a) $Al_2O_3$ | : | 30 to 33 percent | — |
| b) Porosity, percent | : | 60, *Min* | 72, *Min* |
| c) Cold crushing strength, $N/mm^2$ | : | 3.5, *Min* | 0.8, *Min* |
| d) Bulk density, $kg/m^3$, | : | 1 000, *Max* | 630 to 735 |
| e) Thermal conductivity, w/(mk) | : | 0.31 at hot face temp of 600°C | 0.2 at 360°C mean temp |
| f) Size tolerance | : | ± 2% or ± 2 mm | ± 2% or ± 2 mm |

Light weight insulating bricks shall have the following properties:

| | | Service Temperature | |
|---|---|---|---|
| | | 1 200°C *Min* | 1 050°C *Min* |
| a) $Al_2O_3$ | : | 28 percent, *Min* | — |
| b) $Fe_2O_3$ | : | 2.5 percent, *Max* | — |
| c) Pyrometric cone equivalent Standard cone (ASTM) No. | : | 29, *Min* | — |
| d) Dry shrinkage (%) | : | 3, *Max* at 110°C | — |
| e) Fired shrinkage (%) | : | 3.5, *Max* at $\frac{1200°C}{2\ h}$ | 3, *Max* (dry and fired) |
| f) Grading, mm | : | 0 to 1 (95% passing 0.5 mm sieve) | 0 to 1 (95% passing 0.5 mm sieve) |
| g) Workability | : | Good | Good |

**8.2.3** *Solid Grade Distomaceous ( Molar ) Bricks*

The bricks are made to suit the diameter of chimney and in suitable thickness (generally, between 76 to 114 mm) to suit the degree of insulation required. This type of brick is set in mortar made from the brick material ground to powder form with the addition of Portland or high alumina cement, according to the brick manufacturers.

This class of lining would cover requirements in **8.1** (a) and (c) and depending upon the type of gas, requirement in **8.1** (b) within the temperature range 150 to 800°C.

When dry, this material has low coefficient of expansion and is resistant to temperature changes. Being highly water-absorbant, these bricks should be stored in dry surroundings; brick linings should be dried out slowly and preferably, maintained at an elevated temperature thereafter.

Suitable bricks shall have the following properties:

| | | |
|---|---|---|
| a) Thermal conductivity | : | Not greater than 0.23 W/(mk); |
| b) Bulk density | : | Not less than 700 kg/m$^3$, |
| c) Cold crushing strength | : | Not less than 4.6 N/mm$^2$, |
| d) Coefficient of linear expansion | : | $2.0 \pm 0.1 \times 10^{-6}$/K, and |
| e) Modulus of rupture | : | 0.90 N/mm$^2$ |

**8.2.4** *Acid Resisting Bricks*

These bricks are used when the flue gases are highly acidic or are at temperature at or below 150°C (that is in the neighbourhood of dew point). They are set in an acid resisting cement and, as the object is to present an impervious lining, severe fluctuations of temperature should be avoided, otherwise the rigidity of the lining may cause it to fracture and become less efficient. It follows that this class of brick is suitable for requirement in **8.1** (b) in circumstances for low flue gas temperature.

It is practicable to use highly vitrified clay bricks or vitrified firebricks, resistant to temperature up to 540°C and 1 100°C, respectively.

The acid resisting bricks and cement should be chosen specifically to resist the acids known or expected to be present in the flue gases.

Suitable bricks shall have the following properties:

| | *Type 1* | *Type 2* |
|---|---|---|
| a) Spalling resistance (cycle) | — | 2 *Min* |
| b) Cold crushing strength, N/mm$^2$ | 50 *Min* | 25 *Min* |
| c) Water absorption, percent | 2 to 4 | 8 *Max* |
| d) Acid resistance | 99 *Min* | 96 *Min* |
| e) Bulk density, kg/m$^3$ | 2 200 *Min* | 2 400 to 2 500 |
| f) Size tolerance, percent | ± 2 | ± 2 or ± 2 mm |

**8.2.4.1** Mortar for acid proof bricks should have the following properties:

| | | |
|---|---|---|
| a) $Al_2O_3$ | : | 10 percent |
| b) Fineness | : | All passing through 1 mm sieve conforming to IS 460 (Part 1 or Part 2) : 1985 |

c) Firing shrinkage : 2 percent *Max*, at 1 300°C

d) Acid solubility : 1.5 *Max*

**8.2.5** *Solid Grade Diatomaceous Concrete*

The aggregate for solid grade diatomaceous concrete is of the same materials as the bricks mentioned above, in appropriate gradings, and is mixed with high alumina cement. The concrete can be precast in shapes as required, cast *in situ* or placed by the 'gunning' process. The thickness of the monolithic lining shall, in no case, be less than 50 mm. A minimum cover of 25 mm shall be provided to anchorages where corrosive conditions exist.

This class of lining has a relatively low coefficient of expansion and would cover requirements of **8.1** (a) and (c) and, depending upon the type of gas, requirement of **8.1** (b) in the temperature range 150 to 870°C.

**8.2.6** *Refractory Concrete*

A refractory concrete lining may be formed *in situ* or applied by the 'gunning' process. In use, it is similar to a firebrick lining and fulfils similar requirements.

**8.2.7** *Sand and Cement Mixtures*

These are suitable for linings constructed by the gunning process, more generally for use in the low temperature range.

**8.2.8** *Other Materials*

Other lining materials may be required for use in special circumstances and these shall be applied in accordance with the manufacturer's specification.

**8.3 Design and Construction**

**8.3.1** *General*

The interior surface of the steel shell shall be clean and shall be free from loose rust and scale, for example by wire brushing, immediately before applying the lining.

**8.3.2** *Thermal Expansion*

The thermal expansion of the lining shall be provided for, in the design. Refractory and acid resistant linings shall be divided into sections; a suitable height of section is 6 m. Each section of the lining shall be supported by an internal steel ring securely attached to the chimney shell. A space for expansion shall be left above the top of each section so that it remains clear of the ring above. The expansion space shall be filled with refractory fibre, mineral wool or other pliable, non-combustible filling.

The thermal expansion of solid grade diatomaceous earth bricks or of concrete made from similar material, being low, section heights may be greater, and for small chimneys, a lining of these materials may be taken almost to the top of the shell without dividing it into sections. Due consideration should be given to the reheat shrinkage of these materials.

The upper portion of such a lining is subject to damage by weather and it should, therefore, terminate at a distance below the top approximately equal to the diameter of the shell, the lining being completed with an engineering brick or dense firebrick, jointed with a suitable mortar. It is recommended that the top surface of the lining should be suitably protected from the weather.

**8.3.3** *Brickwork*

Shaped bricks shall be used for chimneys up to 4 m in internal diameter, or when necessary to meet the service requirements, and the general contour of the brick work shall correspond with the curvature of the chimney shell. Joints shall be properly filled and shall be as thin as possible. Mortar shall not be placed between the bricks and the steel shell and there shall be no cavity between them and the shell.

Normally the nominal thickness of the brick-work shall be not less than 114 mm ( *see* Note ) and shall be taken to the top of chimney unless operating conditions are such that the lining of the whole chimney is not required.

NOTE — Brick linings not less than 76 mm thick are permissible for chimneys not more than 760 mm in internal diameter, by agreement between the parties concerned.

**8.3.4** *Supporting Rings*

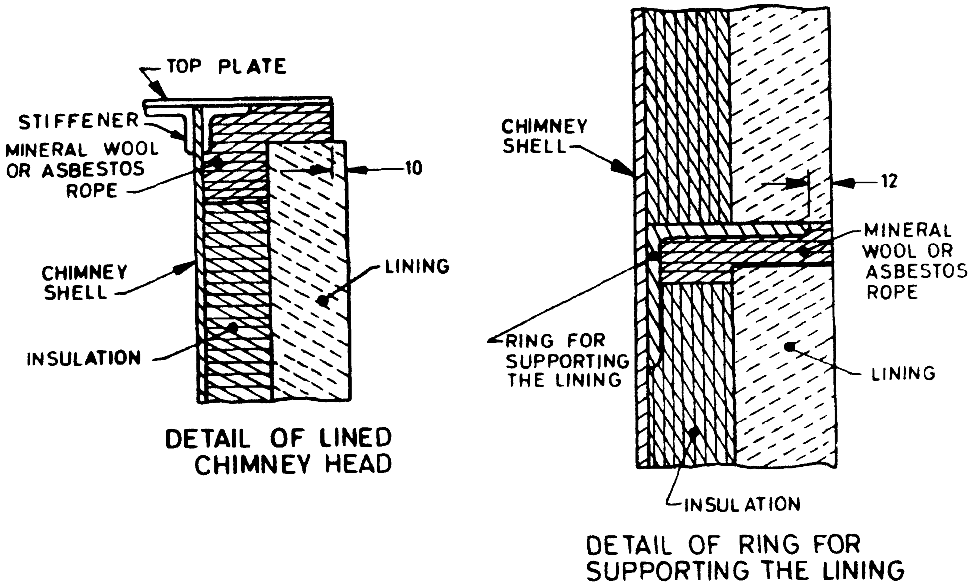
Where supporting rings are used, the first course of brick above each ring shall project at least 10 mm, so as to protect the ring and allow any condensate to fall clear of the lining below. The steel ring shall extend inward from the shell so as to reach at least 0.6 times the thickness of the lining. A typical arrangement of providing top plate and top stiffener is shown in Fig. 4.

**8.3.5** *Openings*

Openings for flue and access doors into the chimney lining shall be properly formed with arches or suitable supports to soffits. Thresholds, heads and jambs shall be suitably insulated to prevent deterioration.

**8.3.6** *Lining Support*

Where linings are not fixed against the shell, the supports shall be designed not only to allow for relative movements due to temperature




All dimensions in millimetres.

FIG. 4 A TYPICAL ARRANGEMENT OF PROVIDING TOP PLATE AND STIFFENER

changes but to secure the lining safely against forces due to oscillation and deflection of the structure so as to prevent damage to either lining or structure. Arrangement for replacement of linings will often be necessary and the design shall facilitate this.

**8.3.7** *Conical Base Sections*

In chimneys having a conical base section, the lining should not be less than 229 mm thick, as far as is practicable; the internal diameter will normally be equal to that of the lining above. The space between the lining and the steel shell shall be filled with:

a) brickwork; or

b) lean concrete (between 8 to 10 : 1) using a heat stable aggregate, such as brick rubble, or

c) a suitable combination of (a) and (b) above.

**8.3.8** *Refractory and Insulating Concrete Lining*

It is not generally practicable to line chimneys of less than 1 m shell diameter with brick-work or gunned linings after erection; in such cases, castable refractory mixes of various compositions may be used.

Castable linings shall be secured to the chimney shell by a suitable anchorage. Such anchorage may consist of steel mesh, concentric with the shell, fixed by supports welded to the shell at approximately 600 mm centres, or mushrooms of *Y*-shaped studs at about 450 mm centres. The lining shall provide not less than 25 mm of cover to all mesh and studs.

The lining may be applied with the chimney shell in a horizontal position, the latter being rotated during forming, if desired to avoid the use of shuttering.

**8.3.9** *Guniting*

Guniting shall be done commencing from the bottom and progressing upwards. It shall also be ensured that this is done in narrow strips so that in one operation the lining is complete to that width. The height of each band depends on the diameter of chimney, the thickness of the insulation and the materials used, so that initial setting does not start before the strips are completed.

At the end of the day's work, all incomplete lining shall be removed with the trowel and left square to the chimney and at the level where the full thickness of the insulation exists. Studs of 3.15 mm diameter and length equal to half the thickness of guniting should be spot welded to the inside surface of the steel chimney at 500 mm distance, staggered both ways, on to which welded wire fabric of mesh 150 mm square shall be welded, acting as reinforcement for guniting.

## 9 EXTERIOR INSULATION

### 9.1 General

In order to minimize loss of heat from a chimney and to maintain the temperature of the steel shell above the acid dew point level, external insulation may be fitted.

The amount of insulation required to maintain the temperature of flue gases above the acid dew point depends upon:

a) the effectiveness of insulation,

b) the velocity of the flue gases, and

c) the inlet temperature of the flue gases.

For wind load calculations, the chimney diameter *D* shall be taken over all the external cladding. For section modulus, *D* shall be measured over the steel shell.

It has been found from observation and calculations that the effectiveness of insulation is as shown in Table 2. It is essential that the grade of insulation selected is suitable to maintain the temperature of the inner surface of the chimney above the acid dew point under normal operating conditions.

The velocity of the flue gases shall be as high as practicable to ensure their rapid passage through the length of the chimney. Ideally, the velocity should not fall below 4.5 m/s when under light load but a lower velocity is sometimes unavoidable. If the velocity of the gases is too low, they will not completely fill the bore at the top of the chimney, cold air will enter on the windward side, descend the chimney for some distance and thus cool the surface of the chimney to below acid dew point. This effect is known as 'cold air inversion' and may be overcome by fitting a top core to the chimney. Gas velocities above about 35 m/s may create problems due to acoustic effects but these are outside the scope of this standard. It should be noted that, however effective the insulation may be, if the flue gas entry temperature is too low, condensation and acidic corrosion will take place.

A number of insulation methods may be used which fall basically into the four types described in **9.2** to **9.5**.

**9.2 Aluminium Cladding**

Aluminium cladding (sheet steel or other forms of cladding may be suitable in some cases) is an effective form of insulation because of its high thermal reflectivity, and it shall be applied as stated below:

a) The exterior of the steel shell shall be treated as described in **13** of Part 2 of this standard using a good quality heat resistant aluminium point.

b) The cladding shall consist of aluminium sheet not less than 1.6 mm thick with symmetrical flange covers made in halves from aluminium sheets which shall also be not less than 1.6 mm thick.

**Table 2 Heat Loss Values '*U*' for Insulation Materials**

( *Clause* 9.1 )

| Type of Insulation | Thickness mm | Overall Average *U* Values W/ ($m^2$ K) |
|---|---|---|
| Aluminium | 6, air gap | 3.4 to 4.5 |
| Aluminium | 18, air gap | 2.6 to 4.0 |
| Mineral wool | 25 | 2.3 |
| Mineral wool | 50 | 1.15 |
| Mineral wool | 75 | 0.7 |
| Mineral wool | 100 | 0.5 |
| Expanded mineral | 50 | 1.15 |
| Expanded mineral | 75 | 0.7 |
| Expanded mineral | 100 | 0.5 |
| Expanded mineral | 150 | 0.35 |

c) The claddings shall be made in strakes, using a number of equal plates per strake. All seams shall be connected by aluminium alloy rivets at not more than 100 mm centres. Vertical seams of each strake shall be set at the mid point of the strake beneath.

d) The cladding shall be fitted with its internal face 6 mm away from the external face of the chimney shell, or as near as possible to clear rivet heads in the steel shell, this distance being maintained by continuous circumferential spacers of 6 mm thick asbestos tape coincident with the horizontal joints of the aluminium. The asbestos tape shall be cemented into position by means of sodium silicate or other suitable adhesive. The ends of the horizontal rivets in the aluminium sheets serve to retain the asbestos tape in position after erection. The circumferential asbestos spacers divide the 6 mm air space between the steel and the aluminium into sections not more than 1.5 m apart, thus reducing convection heat losses.

e) When the length of the sections of shell between flanges is not a whole multiple of the strake width, only one make-up strake per section of chimney shall be used.

f) All projections shall be clad. Cleaning doors and other points where access is required shall be 'boxed in' with removable aluminium panels.

g) The cladding shall be sealed to prevent ingress of moisture.

h) Each upper strake of aluminium shall lap over the lower strake by a minimum of 25 mm. The vertical seams similarly shall have a minimum lap of 25 mm.

j) To permit the examination of steel shell of the chimney without removing the cladding, 150 mm square openings, located at carefully selected points and covered by removable weatherproof panels approximately 230 mm square, shall be provided. Suitable positions are:

   i) Diametrically opposite to any inlet, and

   ii) Approximately 1.25 m from the top of the chimney.

k) After erection, the cladding may be degreased and painted with a clear lacquer.

m) The aluminium cladding may be applied on site either before or after the chimney is erected, or at the manufacturer's works. If the aluminium is applied at works or on site before erection, great care shall be taken not to damage the aluminium sheets. If a sheet becomes damaged, it shall be removed and replaced with a new sheet. Riveting a patch of aluminium over the damaged area is not acceptable.

n) Great care shall be taken to ensure that dissimilar metals do not come into contact with each other. If it is essential in the design that two dissimilar metals have to be connected, a suitable non-conductive and water impervious film or agent shall be placed between them.

**9.3 Mineral Wool Insulation**

Wrapping the steel shell with a suitable grade of mineral wool fibre insulation material of sufficient thickness provides more effective insulation than aluminium cladding with the usual 6 mm air gap. Thicknesses of over 50 mm are applied in two separate layers, the outer layer being fitted so that the vertical and the horizontal joints are staggered from the joints of the inner layer.

If the angle joining the flange of the chimney section projects past the outer face of the mineral wool, it shall be wrapped with an additional layer of mineral wool of the same thickness for at least 75 mm on each side of the flange joint. As mineral wool has to be protected from the weather, a convenient way of doing this is to cover it with an aluminium cladding as described in **9.2** but omitting the air gap. The mineral wool mattress shall be arranged and fixed so that it does not slip.

**9.4 Double Skin Chimney**

The space between the outer shell and the liner of a double skin chimney can be filled with mineral wool, expanded mineral, or other suitable insulator. Unless a special heat resisting steel is used for the liner, the temperature limitation of Table 3 of Part 2 of the standard applies. It is essential that there shall be no metal to metal contact between the liner and the outer shell, otherwise 'cold spots' occur on the liner, thus reducing local areas to below the acid dew point level and facilitating acidic condensation and corrosion.

It shall be so arranged that insulating filling cannot subside or settle to cause uninsulated areas.

**9.5 Multi-Flue Chimney**

**9.5.1** The multi-flue chimney is an effective method of maintaining the velocity of the flue gases at various operating levels and of providing adequate insulation.

**9.5.2** The liners in a multi-flue chimney may be contained in a structural shell of steel, brick, or reinforced concrete, in a shaft within the structure of a building or in an open load bearing frame built from steel sections or reinforced concrete. Normally, each liner is connected to one combustion unit so that the optimum gas velocity can be achieved in all operating conditions.

**9.5.3** The temperature of the inner surface of the liner can be maintained either by wrapping the exterior of the liner with a mineral wool mattress or by filling the space between the liners and the structural shell with an expanded mineral, or both.

**9.5.4** When a granular material is used as an insulant, it is essential that a gate valve be provided for its removal and that a notice be affixed adjacent to the gate valve warning of the dangers of operation by unauthorized personnel.

**9.5.5** If liners are supported by an open structural frame, it is essential that they are adequately insulated and protected from the weather. Suitable methods are outlined in **9.2** and **9.3**.

**10 ASH DISPOSAL**

**10.1** Typical arrangements for the disposal of ash in chimney have been dealt with in Annex C.

# ANNEX A

( *Clauses* 7.2 *and* 7.3 )

## INFLUENCE OF AERODYNAMIC SHADOW ON HEIGHT OF CHIMNEY

### A-1 FACTORS INFLUENCING HEIGHT OF CHIMNEY

**A-1.1** The height of the chimney shall not be less than the height of the zone of turbulent air layers formed due to uneven heights of buildings near the chimney. For the purpose of calculation of the minimum height of chimney for keeping its plume above the turbulent zone, the following procedure shall be adopted:

a) The types of surrounding building structures along the direction of wind may be divided into two groups:

1) *Narrow Building*, where $B \leq 2.5\ H_B$; and
2) *Wide Building*, where $B > 2.5\ H_B$.

where

$B$ = width in metres of the building in the downwind direction, and

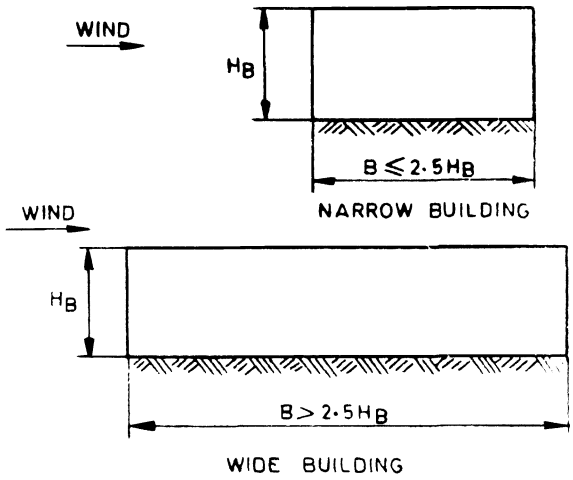
$H_B$ = height in metres of the building.

b) The relative orientation of buildings along direction of wind may be divided into four groups:

1) *Independent Narrow Building* ( *Type 1* ) — A narrow building in the downward direction of which there is no other building or obstruction up to a distance of 6 $H_B$.
2) *Independent Wide Building* ( *Type 2* ) — A wide building in the downward direction of which there is no other building or obstruction up to a distance of 4 $H_B$.
3) *Narrow Building Behind Another Building or Obstruction* ( *Type 3* ) — A narrow building in the downward direction of which there is another building or obstruction at a distance $X$ such that $H_B < X < 10\ H_B$.
4) *Wide Building Behind Another Building or Obstruction* ( *Type 4* ) — A wide building in the downward direction of which there is another building or obstruction at a distance $X$ such that $H_B < X \leq 8\ H_B$.

where

$X$ = distance in m at which another building or obstruction is located.




$B$ = Width of building in metres

$H_B$ = Height of building in metres

NARROW AND WIDE BUILDINGS STRUCTURE

### A-2 AERODYNAMIC SHADOW

**A-2.1** This is the zone downwind of the chimney in which any release of pollutant may be entrapped into the eddies. These are illustrated in Fig. 5.

**A-2.2** Height of aerodynamic shadow is obtained as follows:

1) For Type 1 $H_s = 0.36\ B + 2.5\ H_B$
2) For Type 2 $H_s = 0.36\ B + 1.7\ H_B$
3) For Types 3 and 4 $H_s = 0.36\ ( B + X ) + H_o$

where

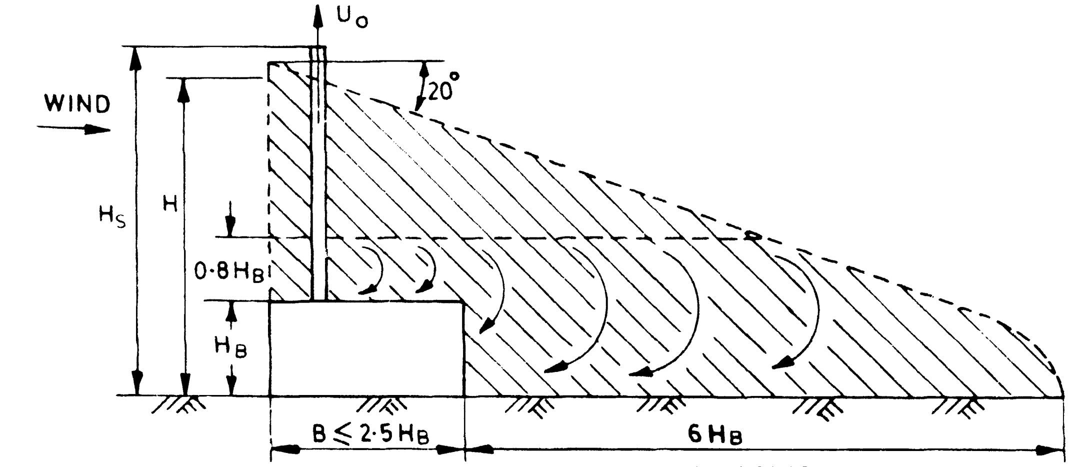
$H_s$ = height in metres of aerodynamic shadow; and

$H_o$ = height in metres of obstruction or building in downwind direction.

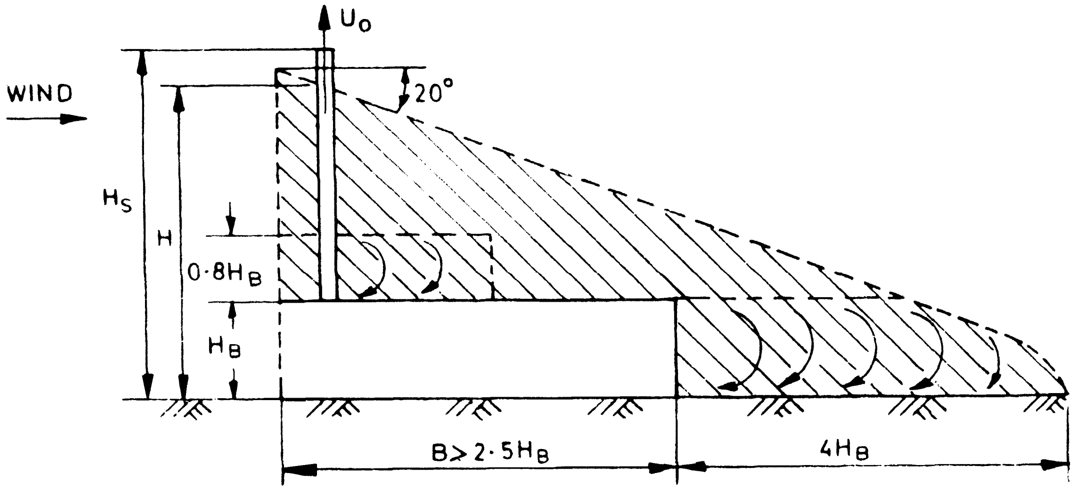
**A-3** Design height $H$ of chimney shall be greater than $H_s$ for all the types calculated above.

where

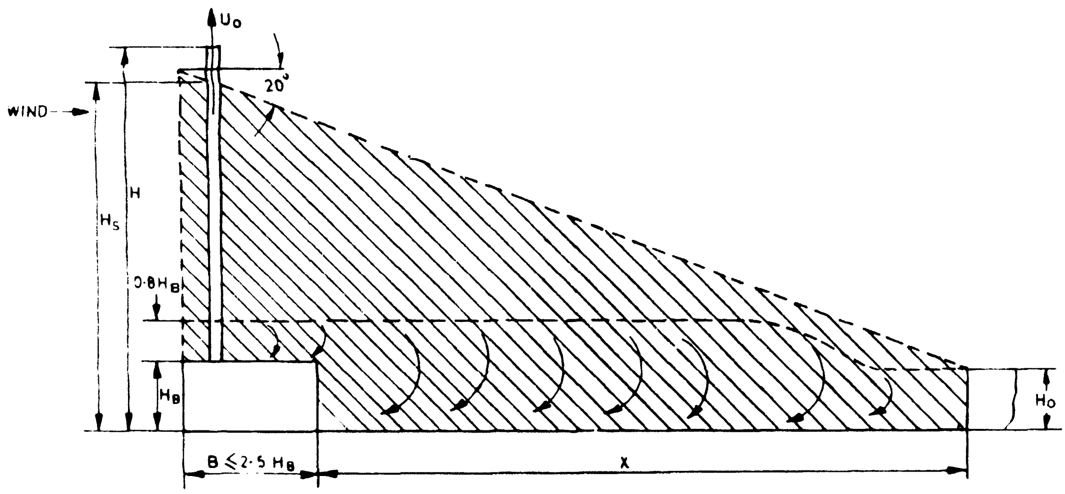
$H$ = Calculated height in m of the chimney.




5A TYPE 1 INDEPENDENT NARROW BUILDING
$H \nless H_S = 0.36B + 2.5H_B$

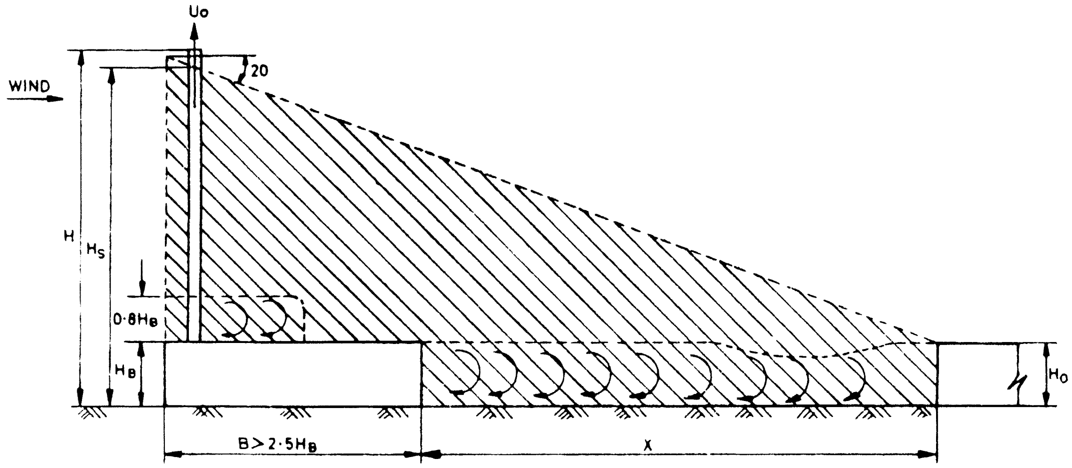



5B TYPE 2 INDEPENDENT WIDE BUILDING
$H \nless H_S = 0.36B + 1.7H_B$




5C TYPE 3 NARROW BUILDING BEHIND ANOTHER BUILDING $H \nless H_S = 0.36(B + X) + H_o$

FIG. 5 RELATIVE ORIENTATION OF BUILDINGS ALONG DIRECTION OF WIND ( *Continued* )




$B$ — width of building in the downwind direction, m
$H_B$ — height of building where the stack is installed, m
$H$ — calculated height of chimney, m
$H_S$ — height of aerodynamic shadow, m
$X$ — distance at which another building or obstruction is located, m
$H_o$ — height of obstruction or building in downwind direction, m
$U_o$ — ejection velocity through stack, m/s

FIG. 5 RELATIVE ORIENTATION OF BUILDINGS ALONG DIRECTION OF WIND

# ANNEX B

( *Clause* 7.3 )

## CONSIDERATION OF DISPERSION OF POLLUTANTS ON THE HEIGHT OF CHIMNEY

### B-1 HEIGHT OF STACK

**B-1.1** Tall stacks are necessary to disperse pollutants into the atmosphere in order to maintain an acceptable air quality standard at the ground level. Height of stack is a function of various factors, for example, mass rate of emission, efflux velocity, temperature of effluent, topographical conditions, meterological conditions of the area where stack is located and lastly, the air quality standards that must be maintained. Based on these parameters, assuming a relatively flat terrain and temperature of effluent equal to the atmospheric temperature, the height of the stack is determined from the following formula:

$$H = \left[ \frac{AMFD}{8\,CV} \right]^{\frac{3}{4}}$$

where

$H$ = calculated height of stack in m

$A$ = coefficient of temperature gradient of atmosphere responsible for horizontal and vertical mixing of plume
( For tropical zone $A$ = 280, and for semi-tropical zone $A$ = 240 ),

$M$ = estimated mass rate of emission of pollutant in g/s,

$F$ = dimensionless coefficient of rate of precipitation
(For gases, $F$ = 1, and
for dust $F$ = 2 if efficiency of dust catching is above 90 percent
2.5 if efficiency of dust catching is 75 to 90 percent
3.0 if efficiency of dust catching is below 75 percent),

$C$ = maximum permissible ground level concentration of pollutant in mg/m$^3$ standard temperature and pressure (stp) (may be taken as 0.5 mg/m$^3$ unless otherwise specified in relevant health standards),

$V$ = Estimated volume rates of emission of total flue gases, m$^3$/sec, and

$D$ = diameter of stack at the exit of the Chimney in m.

**B-1.2** Recommended height of stacks from the consideration of pollution of iron and steel plant units is given in Table 3.

**B-1.3** Recommended minimum efflux velocities are given in Table 4.

**Table 3 Recommended Standard Height of Stacks (for Process Gases) from the Consideration of Pollution for Iron and Steel Plant Units**

( *Clause* B-1.2 )

| Sl No. | Unit | Height (m) | Remarks |
|---|---|---|---|
| 1 | Sintering plant | 100 to 150 | Depending on $SO_2$ loading of exhaust gas |
| 2 | Blast furnace — stoves | 60 to 70 | Check calculations for unburnt carbon monoxide, if any |
| 3 | Steel melting shop: | | |
| | a) Converter, oxygen blown | 100 | |
| | b) Open hearth, oxygen blown | 100 | |
| | c) Electric arc furnace | 30 | Discharge point is kept at least 3 to 4 m higher than the highest point of the roof |
| 4 | Rolling mill: | | |
| | a) Scarfing machine | | Discharge point is kept at least 3 to 4 m higher than the highest point of roof. For pickling with hydrochloric or sulphuric acid, the efficiency of cleaning shall be not less than 95 percent (applies to a to f) |
| | b) Soaking pit | 60 to 70 | |
| | c) Reheating furnace | 35 | |
| | d) Bell annealing furnace | 45 | |
| | e) Continuous pickling line | 40 | |
| | f) Hot dip galvanizing line | 45 | |
| 5 | Rotary kilns: | | |
| | a) For line | 60 to 80 | |
| | b) For dolomite | 60 to 80 | |
| 6 | Coke oven | 100 | For discharging combustion products of battey. |
| 7 | Thermal power plant | 120 to 180 | For coal fired boiler, fly ash is the main hazard. Height may be checked with $SO_2$ loading of gas also. |

**Table 4 Recommended Minimum Efflux Velocities from Air Pollution Point of View**

( *Clause* B-1.3 )

| Sl No. | System | Velocity m/s |
|---|---|---|
| 1 | Natural draft system | 6 |
| 2 | Forced draft system: | |
| | a) Chimneys up to 20 m height | 6 |
| | b) Chimneys from 20 to 45 m height | 9 |
| | c) Chimneys over 45 m height | 12 |
| 3 | Induced draft system | 7.5 |
| 4 | Other waste gases and exhaust of industrial ventilation system | 15 |
| 5 | Thermal power plants | 25 |

NOTE — Use of any weather cowl on the top of stack which restricts the vertical motion of plume is not recommended. If it is absolutely essential to restrict entry of rain water into dust system, special weather cowls which will restrict the entry of rain water but allow the gases to move vertically upwards with the recommended efflux velocity may be permitted.

**B-2 Limitations of the Formula**

**B-2.1** The formula is applicable only in cases of tall stacks, the plume from which is free from interference with the air currents produced by nearby tall buildings.

**B-2.2** The formula assumes only a single source of air pollution. Where several stacks are located close to each other, the value of $H$ obtained from the formula has to be increased such that the total ground level concentration at a place from all the stacks for any particular pollutant does not exceed the air quality standards.

**B-2.3** The formula assumes the temperature of the gases to be equal to the atmospheric temperature. The resultant height of stack is slightly on the higher side.

**B-2.4** The maximum concentration as calculated above is reached at a distance $X$ m from the chimney, approximately given by $X = 20\ H$ where $H$ is the height of the chimney in m above the ground level.

## ANNEX C

( *Clause* 10.1 )

## ASH DISPOSAL

### C-1 GENERAL

**C-1.1** In any coal fired boiler, a particular percentage of ash which escapes along with the flue gas will be precipitated due to change in the direction of flue, at the bottom of the chimney. This will require periodical disposal depending upon the quantity of ash. For small boilers, quantity will be very small and this will not require elaborate arrangements while for medium and high capacity boilers, the quantity will be considerable and will require separate arrangements for disposing the ash.

### C-2 ASH DISPOSAL SYSTEMS

**C-2.1** In case of bigger boilers where the quantity is more, a separate arrangement has to be provided and usually this will be a hopper at the bottom of the chimney and just below breach openings left for flue connection. The typical arrangement of this is indicated in Fig. 6.

**C-2.2** In the case of small boilers, the ash may be disposed of by providing a hopper on the foundation itself as indicated in Fig. 7.

**C-2.2.1** This consists of a hopper with a gate at the bottom which when a particular weight or volume of ash is collected, will automatically open and discharge the ash into the pit at the bottom. This ash can be disposed of by mechanical, pneumatic or hydraulic systems, depending on the system adopted for the disposal of the ash from the combustion chamber.

**C-2.2.2** In the case of the mechanical system, a conveyor will be provided in the pit so that the ash can be removed and loaded in the trucks outside.

**C-2.2.3** In the pneumatic system, ash will be removed by ejector or sucking by compressed air and discharged into the main ash disposal system.

**C-2.2.4** In the case of hydraulic system, enough quantity of water will flush the ash into the main ash disposal system.

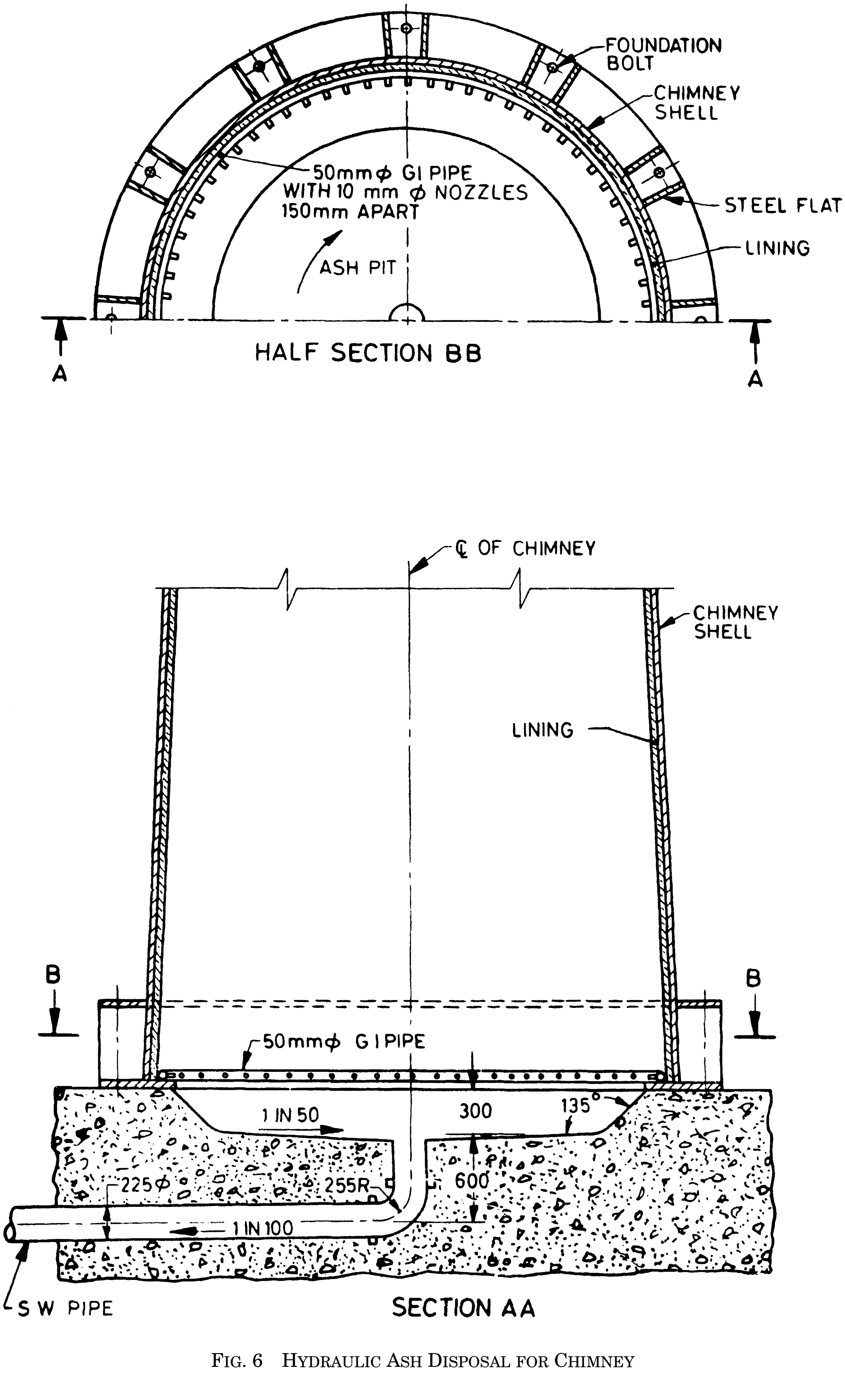



FIG. 6 HYDRAULIC ASH DISPOSAL FOR CHIMNEY

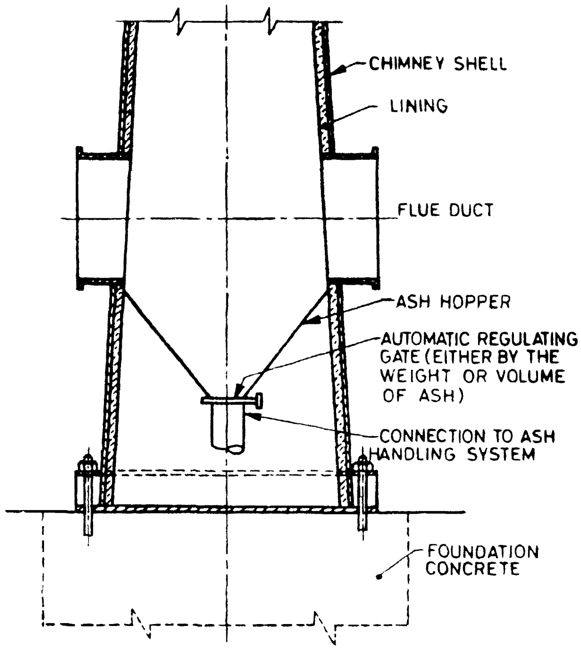



FIG. 7 ASH REMOVAL SYSTEM FOR CHIMNEY

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