ENGINEERING, CONSTRUCTION

AND

MATERIALS STANDARD

FOR

CHIMNEYS AND STACKS

CONTENTS :

APPENDICES:

1. SCOPE

In this Standard, chimneys and stacks are generally divided into two categories, i.e.:

a) Chimneys for Domestic Use.
b) Chimneys for Industrial Use, which consist of reinforced concrete or masonry chimneys and steel stacks.

2. REFERENCES

In this Standard the following standards and publications are referred to an to the extent specified form a part of this Standard:

BSI   (BRITISH STANDARDS INSTITUTION)

BS 4076: 1989	"Specification for Steel Chimneys"
BS 5854: 1980	"Flues and Flue Structures in Buildings"

DIN   (DEUTSCHES INSTITUT FÜR NORMUNG E.V.)

DIN 1056: 1984	"Solid Construction, Free-Standing Chimneys"
DIN 1057: 1985	"Building Materials for Free-Standing Chimneys"

ACI   (AMERICAN CONCRETE INSTITUTE)

ACI 307: 1988	"Specification for the Design and Construction of Reinforced Concrete Chimneys"

PBO   (PLAN AND BUDGET ORGANIZATION)

Publication No. 92: 1984	"Architectural Details for Masonry Buildings"

IPS   (IRANIAN PETROLEUM STANDARDS)

E-CE-120	"Foundations"
E-CE-200	"Concrete Structures"
E-CE-210	"Steel Structures"
E-CE-500	"Loads"
M-CE-105	"Building Materials"
M-CE-165	"Materials for Concrete, Mortars and Admixtures"
E-TP-100	"Paints"
C-TP-101	"Surface Preparation"
C-TP-102	"Painting"
E-TP-350	"Linings"
C-TP-352	"Lining Application"

3. UNITS

This Standard is based on International System of Units (SI), except where otherwise specified.

4. CHIMNEYS FOR DOMESTIC USE

For general information about design criteria, materials and method of construction of domestic chimneys reference is made to IPS-D-CE-213 (2 sheets) based on PBO Publication No. 92: 1984.

5. CHIMNEYS FOR INDUSTRIAL USE

5.1 Free Standing Chimneys (Reinforced Concrete and Masonry)

5.1.1 General

This Clause of the Standard applies to solid construction, free standing chimneys designed and constructed in accordance with DIN 1056: 1984, which includes provisions for lining and their effect on the stresses set up in the concrete shell due to temperature.

5.1.1.1 A chimney shall be considered as free-standing if one of the following two conditions is fulfilled:

> **a)** its load bearing structure does not form part of another structure;
> **b)** its load bearing structure shall be able to sustain horizontal loads.

5.1.1.2 As concrete or masonry chimneys are not usually utilized in Oil Industries' Installations, therefore besides giving reference to authentic standards, the following design requirements are also to be considered:

5.1.2 Design loads

The following factors shall be taken into account in the design of free standing chimneys:

> - self weight;
> - imposed loads;
> - wind load;
> - designed underpressure and overpressure;
> - thermal effects;
> - deviation of the structure from plumb;
> - load conditions during construction;
> - seismic action.

5.1.2.1 For detailed discussion of the above factors reference is made to DIN 1056: 1984, Clause 7 and IPS-E-CE-500, "Loads", and whichever is more stringent for a particular case shall be adopted.

5.1.2.2 Clause 9 of DIN 1056: 1984 shall apply for the design requirements of the shaft, lining, openings in the shaft, the foundations of reinforced concrete/masonry chimneys and loadbearing fittings in the shaft..

5.2 Steel Stacks

5.2.1 General

This Clause of the Standard covers requirements governing the structural design, selection of material, fabrication and inspection of steel stacks, with or without linings, and their supports. It also relates to the application of lining or cladding to such stacks, where required.

The principles described in this Clause apply generally to stacks varying widely in height, shape, purpose and design. The design of stacks other than circular cross section is not included in this Clause.

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

5.2.2 Stack shells

5.2.2.1 Loading

The determination of dead load, wind load and other loads shall be in accordance with the recommendations of IPS-E-CE-500, and BSI-CP 3: Chapter V: Part 2: Wind loads, 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 250 fixed to a chimney shall be determined in accordance with the recommendations of BSI-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 [1]

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, i.e.:

$$\text{add} \quad \frac{(B_H - C_H)(80 - h)}{70}$$

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.

Note:

1) For factor S_2 refer to Appendix B Table B.1.

d) Oscillation

To prevent across-wind oscillations the stability of the stack should be checked against the criteria of Appendix B of BS 4076: 1989. If these criteria are exceeded, perform one of the following.

1) Provide an aerodynamic stabilizer. It is recommended that helical strakes or guys are used. Strakes should have three rails, projecting between 0.1 and 0.12 times the diameter of the stack, wound, equally spaced, around the perimeter of the shell at a pitch of about five times the diameter of the stack. The strakes should extend for the upper third of the stack height. The drag force coefficient shall be calculated over the projected area of circular cross section enclosing the stabilizer ribs. This coefficient shall be taken as 1.2.

2) Provide additional structural damping to ensure that the stability criteria of Appendix B of BS 4076: 1989 are met. This can be provided by tuned mass or impact dampers or by resilient materials at the main supports.

Note:

Oscillation of guyed, stayed, bracketed, pairs or groups of stacks is outside the scope of this Standard. However, guys, stays or brackets should be adequate to eliminate appreciable increase of stress due to movement.

5.2.2.2 Materials

a) Plates and Sections

Steel plates used in the construction of stacks coming within the scope of this Standard shall comply with the requirements for grade 43A of BS 4360: 1986. In any case, compliance with the requirements of IPS-E-CE-2I0 and IPS-M-CE-105 is mandatory.

b) Bolts and Nuts

- Carbon steel

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

- 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: 1986.

- 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.

c) Guy Ropes and Fittings

Guy ropes shall comply with the requirements of BS 302: Part 3. 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 3032, BS 3551 and BS 5281). Guy ropes with hemp cores shall not be used.

d) 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.

e) Other Remarks

- Alloys requiring postweld heat treatment shall not be used.

- Castable refractory shall be medium weight insulating type per ASTM C 401 with a minimum dry installed density of 12 kN/m³.

- Wire fabric shall be electric welded 50 × 50 mm mesh to 100 × 100 mm mesh fabric. The wire size shall be from 2.3 to 3.2 mm diameter and shall be ungalvanized.

5.2.2.3 Design

5.2.2.3.1 General

The use of structural steel for the shell and other components of steel stacks shall be in accordance with the requirements of the relevant clauses of IPS-E-CE-210.

The recommendations in IPS-E-CE-210 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.

5.2.2.3.2 Minimum thickness of steel

5.2.2.3.2.1 Stack shell

The minimum thickness of the structural shell, in single or multiple shell constructions, shall be the calculated thickness obtained from stress and deflection considerations plus the corrosion allowance but shall not be less than 6.0 mm, nor less than 1/500 of the outside diameter of the stack at the same height. Ovalling shall be considered, see B.4 of BS 4076: 1984.

5.2.2.3.2.2 Stack liner

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

Note:

Plastic liners are not covered by this Standard.

5.2.2.3.2.3 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.

The minimum thickness of (see 5.2.2.2.a) 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.

5.2.2.3.2.4 Flanges

The minimum thickness of jointing flanges shall be 6.0 mm.

5.2.2.3.3 Allowable stresses

5.2.2.3.3.1 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. For carbon steel the appropriate value for K_t from Table 1 shall be used to multiply the allowable stresses specified in BS 449 or the compressive stress from the equation in 5.2.2.3.3.3. The expected temperature of the steel components shall not be allowed to exceed 480°C. The values in Table 1 may be ad-

justed proportionately between the nearest tabulated values. If other qualities of steel are used, appropriate allowances for temperature and buckling shall be made according to the properties of the steel employed.

TABLE 1 - TEMPERATURE COEFFICIENT K_t

Temperature °C	-30 [1] to 315	370	425	480 [2]
K_t	1.0	0.9	0.7	0.5

Note:

1 and 2 see A.8 and A.9 of Appendix A respectively.

5.2.2.3.3.2 Effective height of chimney shell

For the purpose of 5.2.2.3.3.3, the effective height shall be taken from Fig. 1.

5.2.2.3.3.3 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 5.2.2.3.3.1) and calculated with the corrosion allowance deducted from the thickness, t.

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

Where:

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

if

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

and

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

if

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

Where:

t	is the corroded 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 Fig. 1).

5.2.2.3.3.4 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 will cause the axial load to
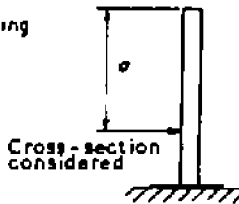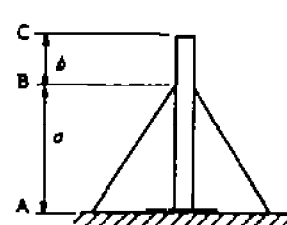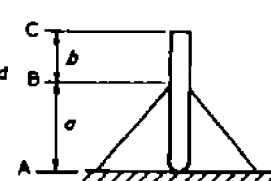
become eccentric; the moment so produced shall be determined, added to that from the wind load and any other live or dead load and used to calculate the combined stresses, which shall not exceed those specified in 5.2.2.3.3.3. This procedure is necessary only if the total axial load produces stresses greater than 1/3 of the bending stresses due to wind.

5.2.2.3.3.5 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 5.2.2.2.c), 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.

5.2.2.3.3.6 Stresses due to wind forces

Except for those stresses described in 5.2.2.3.3.3 the allowable stresses given in this Standard 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.

EFFECTIVE HEIGHT OF STACK SHELL
Fig. 1

5.2.2.4 Corrosion

5.2.2.4.1 General

A stack 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 stack is unused for protracted periods.

5.2.2.4.2 External corrosion

The amount of corrosion which takes place on the exterior of a stack shell (see Table 2) shall be taken as:

a) none, if the stack 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.

5.2.2.4.3 Internal corrosion

The corrosion of the internal surface of a stack 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 stack if condensation takes place. If the inner surface of the stack, 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 stack is being heated to above the acid dew point. This amount of corrosion shall be taken as, ′average′ in Table 2.

TABLE 2 - CORROSION ALLOWANCES

CONDITIONS (MATERIALS/DEGREE OF CORROSION)	CORROSION ALLOWANCE IN (mm)	
External C_e	for 10 years	for 20 years
All painted steel	nil	nil
Carbon steel protected by insulation/cladding	nil	nil
Unprotected carbon steel	1.5	3.0
Unprotected weathering steel or similar	1.0	2.0
Unprotected stainless steel	nil	nil
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
Exception (e.g. unprotected oil-fired)	Not recommended	Not recommended

5.2.2.4.4 Temperature control

To maintain the temperature of the inner surface of the stack above the acid dew point it is necessary to minimize the heat loss; this can be achieved by fitting suitable cladding or insulation.

5.2.2.4.5 Allowance for corrosion

a) 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.

b) Corrosion allowance with respect to the expected temperature of stack metal shall be provided according to Table 3.

TABLE 3 - CORROSION ALLOWANCES WITH RESPECT TO STACK METAL TEMPERATURE

STACK METAL TEMPERATURE	CORROSION ALLOWANCE	
	Ferritic Steel	Austenitic Stainless Steel
345°C and above	3 mm	None
Below 345°C: Lined Unlined	1.5 mm 3 mm	

5.2.2.5 Erection tolerance

The departure of the stack from the vertical on erection shall not exceed 25 mm or 1/1000 of the height, whichever is the greater, at any point.

5.2.2.6 Fixing of guys

5.2.2.6.1 Position

Guys shall be positioned sufficiently below the outlet of the stack to avoid the corrosive action of the emergent combustion products. A minimum distance shall be 3 meters.

There shall be a minimum of three guy ropes to each set; guys shall be positioned radially in plan and the angle between any adjacent pair of guys shall not exceed 130°.

The guy ropes shall not exceed an angle of 60° to the horizontal.

5.2.2.6.2 Erection tension

The tension in the guys after erection shall be not less than 15% nor more than 30% of the calculated maximum tension due to the wind.

5.2.3 Supporting structures

5.2.3.1 General

Structures supporting stacks shall be constructed of steel, concrete, brick or other suitable materials specified in IPS-M-CE-165 and IPS-M-CE-105, and in accordance with construction standards IPS-C-CE-200 and IPS-C-CE-210.

5.2.3.2 Stability

For every part of the structure where wind load stresses are reduced by the dead load carried, and where this is taken into account, a calculation shall be made to show that the stress imposed by 1.6 times the total of wind load plus any stress-increasing imposed loads, less 0.9 times the minimum dead load excluding any stress-reducing imposed loads, will not exceed 1.8 times the allowable stress specified in IPS-E-CE-200 for the material.

5.2.3.3 Foundations

The foundation shall be designed in accordance with the recommendations of IPS-E-CE-120 and the following criteria:

a) The entire footing area shall be in compression for the design overturning moment for stacks over 30 m high bearing on cohesionless soil and for stacks over 90 m high bearing on any type soil.

b) Concrete foundation shall not be directly exposed to hot flue gases. Sufficient insulation, vents and drains, shall be provided to control concrete temperatures and minimize corrosion.

c) The permissible load on the concrete foundation for steel stacks shall not exceed:

4 N/mm² on concrete with sand-cement grout.
8 N/mm² on concrete with non-shrink ready mixed grout.

d) Reinforced concrete foundations shall comply with IPS-E-CE-120 and IPS-E-CE-200.

e) Piling, if required, shall be in accordance with IPS-E-CE-130.

5.2.4 Stack linings

5.2.4.1 General

Linings for steel stack may be required for one or more of the following purposes:

a) to protect the stack shell from heat;
b) to act as a protective covering, thus reducing corrosion;
c) to maintain the temperature of the flue gases.

5.2.4.2 Materials

a) Firebricks

These are made in radial form to suit the stack dimensions; firebricks having an alumina content between 28% and 32% are satisfactory for the majority of applications. These bricks are set in mortar made from ground fire clay or in a suitable fire cement.

This type of lining fulfills requirement (b) and partly fulfills requirement (a) in 5.2.4.1, up to a temperature of about 1200°C, but its high density makes it of little use in respect of requirement (c). Its strength and hard surface would give protection to the steel from abrasion when this has to be considered.

Bricks shall have the following properties:

Thermal conductivity:	about	1.25 W/(m.K)
Bulk density:	not less than	2000 kg/m³
Cold crushing strength:	not less than	14 N/mm²
Coefficient of expansion:	up to	3.3×10^{-6} /K

For chimneys taking gases from certain process or incinerator equipment at temperatures in excess of 1200°C, a brick with a higher alumina content is needed and linings for such special duties need individual detailed consideration.

b) Solid grade diatomaceous bricks

These can be made to suit the diameter of the stack and in thickness (generally between 76 mm and 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 addition of Portland or higher alumina cement, according to the gas temperature, or in mortar supplied by the brick manufacturers.

Conditions likely to lead to loss of strength of high alumina cement are known and shall be avoided where it would be significant.

This class of lining would cover requirements (a) and (c) and depending upon the type of gas, requirement (b) in 5.2.4.1 within the temperature range 150°C to 800°C.

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

Bricks shall have the following properties:

Thermal conductivity:	not greater than	0.23 W/(m.K)
Bulk density:	not less than	700 kg/m³
Cold crushing strength:	not less than	4.6 N/mm²
Coefficient of linear expansion:		$2.0 \pm 0.1 \times 10^{-6}$ /K
Modulus of rupture:		0.90 N/mm²

c) Acid resisting bricks

These are used when the flue gases are highly acidic or are at temperatures at or below 150°C (i.e. in the neighborhood of the 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 (b) in 5.2.4.1 in circumstances of low flue gas temperature.

It is practicable to use highly vitrified clay bricks or vitrified firebricks resistant to temperatures up to 540°C and 1100°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.

d) 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.

This class of lining has a relatively low coefficient of expansion (see BS 4207) and would cover requirements (a) and (c) and, depending upon the type of gas, requirement (b) in 5.2.4.1 in the temperature range 150°C to 870°C.

e) 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 fulfills similar requirements (see BS 4207).

f) Sand and cement mixtures

These are suitable for linings constructed by the ′gunning′ process, more generally for use in the low temperature range (see BS 4207).

g) 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.

5.2.4.3 Design and construction

5.2.4.3.1 General

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

5.2.4.3.2 Thermal expansion

The thermal expansion of the lining shall be provided for in 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 pliable, non-combustible filling.

5.2.4.3.3 Brickwork

Shaped bricks shall be used for stacks up to 4 m in internal diameter, or when necessary to meet the service requirements, and the general contour of the brickwork shall correspond with the curvature of the stack 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 a brickwork lining shall be not less than 114 mm thick nominal (see note) and shall be taken to the top of the stack unless operating conditions are such that lining of the whole stack is not required.

Note:

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

5.2.4.3.4 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. Arrangements for replacement of linings will often be necessary and the design shall facilitate this.

5.2.4.3.5 Refractory and insulating concrete lining

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

Castable linings shall be secured to the stack shell by a suitable anchorage. Such anchorage may consist of steel fabric, concentric with the shell, fixed by supports welded to the shell at approximately 600 mm centers, or of mushroom or Y-shaped studs at about 450 mm centers.

The lining shall provide not less than 25 mm of cover to all mesh and studs. The lining may be applied with the stack shell in a horizontal position, the latter being rotated during forming, if desired, to avoid the use of shuttering.

If linings are applied by the ′gunning′ process they shall be secured in a manner similar to that described for castable linings and shall be cured after application as recommended by the Manufacturer.

5.2.5 Exterior insulation

5.2.5.1 General

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

Externally insulated stacks shall be provided with a metal jacket insulation covering. The amount of insulation required to maintain the temperature of flue gases above the acid dew point depends upon:

    a) the effectiveness of the insulation;
    b) the velocity of the flue gases;
    c) the inlet temperature of the flue gases.

A number of insulation methods may be used which fall basically into the following four types:

    a) aluminum cladding;
    b) mineral wool insulation;
    c) double skin stack;
    d) multi-flue stack.

For further information about the said methods refer to BS 4076: 1989, Clause 7.

5.2.6 Protective treatment

For the following protective treatments reference is made to the Clause 8 of BS 4076: 1989 and relevant BS or Iranian Petroleum Standards:.

    a) Surface preparation prior to protective treatment: (refer to IPS-C-TP-101).

    b) Painting of interior surfaces of unlined, lined, multi-flue stack shells with heat resistant paint; (refer to IPS-E-TP-100 and IPS-C-TP-102).

    c) Monolithic lining of interior surfaces of stacks shall be done with refractory cement; (refer to IPS-E-TP-350 and IPS-C-TP-352).

    d) Painting of exterior surfaces of exposed steel shells, shells with external cladding and multi-flue stack framework; (refer to IPS-E-TP-100 and IPS-C-TP-102).

    e) For general information about external cladding refer to IPS-E-TP-350 (Appendix A).

    f) Metal spraying, including surface preparation and methods of application and sealing of coatings; (refer to BS 2569).

5.2.7 Inspection of stacks

5.2.7.1 Stacks should be inspected by a competent person and the first inspection should be about one year after erection.

5.2.7.2 Uninsulated and unlined steel stacks should be examined preferably annually, and the thickness of the shell determined by either ultrasonic thickness testing or by drill testing.

5.2.7.3 At the same time, any decorative or other surface finish on the exterior of the stacks should be examined. The internal surface of large diameter steel stacks may also be inspected, preferably by close examination from a bosun's chair or similar means of support.

5.2.7.4 Flanges should be inspected to see if there is a build-up of rust between them, as the pressure of rust build-up can overload the bolts in tension. In bolted connections particular attention should be given to the condition of the bolts. Selected bolts in critical areas should be removed and replaced by new bolts. The removed bolts should be inspected and tested as necessary. Should the examined bolts still be serviceable no further action is to be taken. However, if any bolts are unserviceable further investigation will be necessary.

5.2.7.5 For lined and insulated stacks carry out an examination as above at three-yearly intervals subsequent to the first examination. Lined stacks should also be inspected internally by close examination from a bosun's chair, or similar means of support, to ascertain that the lining is still in serviceable condition and fulfilling its tasks.

5.2.7.6 Where loose fill is used for insulation this should be inspected at 3-monthly intervals in the first twelve months and then annually. The level of loose fill should be checked and, if necessary, topped up.

5.2.7.7 Guy wire and fittings, where present, should be examined for security and tension and, if necessary, be cleaned and greased.

5.2.7.8 A detailed report should be submitted after each inspection describing any recommended maintenance. The date of inspection shall be marked on the information plate.

APPENDICES

APPENDIX A
RECOMMENDATIONS FOR THE USE OF STAINLESS AND OTHER STEELS

A.1 Stainless and alloy steels are occasionally used in the fabrication of steel stacks when the gases are of an extremely aggressive nature or are at a temperature higher than 480°C.

A.2 The use of the correct grade of stainless steel can increase the life of the stacks over and above the life expectancy of mild steel. Although it is difficult to predict the increase in life, in general, stainless steel of the correct grade should at least double the expected life of a stacks.

A.3 From experience it has been found that of the stainless steels in the 18/8 grade, the one which has the most resistance to corrosion caused by flue gases is 316S16, as specified in BS 1449: Parts 2: 1975. An almost identical grade is 316S12.

A.4 It should be noted that stainless steel is normally supplied in its mill finish condition which is a matt light gray color and is not supplied in a polished ′mirror′ finish. If a mirror finish is required, the cost of polishing is high.

A.5 Because of the high cost of stainless steel, it is normally only used in positions where maximum corrosion attacks can be anticipated, e.g. the top section of a stack or liner.

A.6 In cases of very severe corrosive attack, consideration should be given to the use of the high nickel and chromium content alloys. These are very resistant to acid attack but are considerably more costly than stainless steel.

A.7 It has been found from experience that the low copper alloy steels have a considerably greater resistance to atmospheric corrosion than mild steel, but their resistance to acid attack resulting from the condensation of flue gases is about the same as that of mild steel.

A.8 For stacks that will be subject to ambient air temperature below -10°C for long periods, it is recommended that low temperature alloy steels be used. The properties of these steels can be ascertained from the Steel Manufacturer.

A.9 For anticipated metal temperatures above 480°C in unlined stacks it is necessary to use an alloy steel. The steel manufacturer's advice should be sought regarding service temperature; consideration should also be given to the allowable stress at service temperature.

APPENDIX B
TABLE B.1 - GROUND ROUGHNESS, BUILDING SIZE AND HEIGHT ABOVE GROUND, FACTOR S_2

H	1) Open country with no obstructions			2) Open country with scattered wind breaks			3) Country with many windbreaks; small towns; outskirts of large cities			4) Surface with large and frequent obstructions, e.g. city centers		
	CLASS			**CLASS**			**CLASS**			**CLASS**		
	A	B	C	A	B	C	A	B	C	A	B	C
3 or less	0.83	0.78	0.73	0.72	0.67	0.63	0.64	0.60	0.55	0.56	0.52	0.47
5	0.88	0.83	0.78	0.79	0.74	0.70	0.70	0.65	0.60	0.60	0.55	0.50
10	1.00	0.95	0.90	0.93	0.88	0.83	0.78	0.74	0.69	0.67	0.62	0.58
15	1.03	0.99	0.94	1.00	0.95	0.91	0.88	0.83	0.78	0.74	0.69	0.64
20	1.06	1.01	0.96	1.03	0.98	0.94	0.95	0.90	0.85	0.79	0.75	0.70
30	1.09	1.05	1.00	1.07	1.03	0.98	1.01	0.97	0.92	0.90	0.85	0.79
40	1.12	1.08	1.03	1.10	1.06	1.01	1.05	1.01	0.96	0.97	0.93	0.89
50	1.14	1.10	1.06	1.12	1.08	1.04	1.08	1.04	1.00	1.02	0.98	0.94
60	1.15	1.12	1.08	1.14	1.10	1.06	1.10	1.06	1.02	1.05	1.02	0.98
80	1.18	1.15	1.11	1.17	1.13	1.09	1.13	1.10	1.06	1.10	1.07	1.03
100	1.20	1.17	1.13	1.19	1.16	1.12	1.16	1.12	1.09	1.13	1.10	1.07
120	1.22	1.19	1.15	1.21	1.18	1.14	1.18	1.15	1.11	1.15	1.13	1.10
140	1.24	1.20	1.17	1.22	1.19	1.16	1.20	1.17	1.13	1.17	1.15	1.12
160	1.25	1.22	1.19	1.24	1.21	1.18	1.21	1.18	1.15	1.19	1.17	1.14
180	1.26	1.23	1.20	1.25	1.22	1.19	1.23	1.20	1.17	1.20	1.19	1.16
200	1.27	1.24	1.21	1.26	1.24	1.21	1.24	1.21	1.18	1.22	1.21	1.18