TECHNICAL SPECIFICATION

REINFORCED CONCRETE STACKS

DEP 34.24.27.31-Gen.

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DESIGN AND ENGINEERING PRACTICE

USED BY

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APPENDICES

1. INTRODUCTION

This specification, which is a revision of an earlier publication of the same number dated December 1981, gives minimum requirements for the design and construction of reinforced concrete stacks and their foundations.

It shall be used in conjunction with DEP 34.00.01.30-Gen., 'Minimum requirements for structural design and engineering', and DEP 34.19.20.31-Gen., 'Reinforced concrete foundations and structures'.

It is intended for use in oil refineries, chemical plants, gas plants and, where applicable, in exploration, production and new ventures.

Unless otherwise authorized by SIPM, the distribution of this specification is confined to companies forming part of or managed by the Royal Dutch/Shell Group, and to contractors commissioned by them.

As a general rule the requirements of the national and/or local regulations shall be adhered to, but if these are less stringent than the requirements of this specification, the latter shall prevail.

Where regulations are more stringent than the requirements of this specification, the supplier and/or contractor shall inform the principal, who may negotiate with the authorities concerned, in order to obtain agreement to follow this specification as closely as possible.

As a basis for the design the designer/builder of the concrete stack will normally receive with the enquiry the basic information, e.g. on the quantity(ies), analysis(es) and temperature(s) of the flue gas(es), and possibly one or more instructional drawings, together with a covering requisition stating specific requirements.

All publications referred to in this specification are listed in Section 10: , the relevant standard drawing(s) in Section 11.

Where cross references are made, the number of the section or sub-section referred to is shown in brackets.

2. DEFINITIONS

For the purpose of this specification, the following definitions shall hold:

Shall and **Should** the word 'shall' is to be understood as mandatory and the word 'should' as strongly recommended to comply with the requirements of this specification.

The **Principal** is the party which initiates the project and ultimately pays for its design and construction.
The Principal will generally specify the technical requirements.
The Principal may also include an agent or consultant, authorized to act for the Principal.

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, construction and commissioning for the project.
The Principal may sometimes undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

3. SELECTION CRITERIA

3.1 GENERAL

Prior to the preparation of the detailed design, a comprehensive selection of one of the various types of stacks needs to be made.

In general, the configuration of a stack will be determined by its environmental, structural, chemical and physical, operational and maintenance aspects.

The shaft is the structural element, in which a (separate) lining is exposed to the discharged flue gases. The shaft dimensions will be determined depending on the required stack height, the quantity and velocity of flue gases and the method of construction. However, structural requirements or dimensions of the flue gas ducting may govern in this respect.

For the discharge of low level NO_x and SO_x containing flue gases, i.e. from gas fired equipment, the stack height can be reduced to below 80 m. This will allow the construction of simple steel stacks with an insulating concrete lining, and such stacks are attractive from both the capital cost and maintenance points of view.

However, this publication considers only the design and construction of reinforced concrete stacks with steel and/or brick linings.

3.2 DESIGN INFORMATION

The following information is required in order to make a proper selection for the detailed stack design :

- Required stack height.
- Analysis of fuel(s) to be used.
- The maximum and minimum quantities of flue gases to be discharged, expressed in kg/s.
- The maximum and minimum flue gas temperatures during normal operations, and their durations.
- The design temperature.
- The required maximum and minimum flue gas exit velocities.
- Specific structural requirements, e.g. earthquake resistance. - Subsoil investigations.
- Climatic conditions.

In addition the following further information, if applicable and available, should be considered: , it may even be governing:

- Local availability of construction materials, including lining, skilled labour and equipment.
- Future intentions to increase or decrease flue gas quantities.
- Shutdown and inspection requirements.
- Future intentions for the installation of air preheaters, gas scrubbers, etc., resulting in lower flue gas temperatures.

3.3 TYPES OF STACKS

3.3.1 Heat impact

Relative to heat impact, caused by the flue gas temperature on the stack, the following nomenclature is used :

- Cold stacks - where the temperature t < 100°C
- Medium hot stacks - where the temperature t = 100 to 300°C
- Hot stacks - where the temperature t > 300°C

3.3.2 Chemical load

The 'chemical load' to which stacks are exposed is mainly dependent on the relationship between flue gas composition and temperature range.

For petrochemical plants the SO_3 content in the flue gases is the most influencing factor concerning the consequential dewpoint corrosion.

Flue gases originating from natural gas-firing are not aggressive because the SO_3 content is negligible. However, the amount of water vapour in flue gases is relatively high and may cause moist conditions in flue ducts, brick linings and insulation.

In cold and in some medium-hot stacks, condensation will take place on the inside of the flue duct. In other medium hot and hot stacks condensation will take place in the lining or insulation. The amount of condensing SO_3 and its effects will then be dependent on the permeability and chemical resistance of the brick lining, insulation materials and protective layers respectively.

During start-up or taking a stack out of operation, condensation will progressively increase within the brick and in the duct lining. For this reason, stacks used for intermittent processes and stacks which are temporary out of service become subject to severe H_2SO_4 attack.

Therefore, where high concentrations of SO_3 or other aggressive flue gas components, e.g. HF or HCl, could be expected, the suitability of lining materials and additional protective measures shall be proven for each individual case.

The chemical load of gases containing SO_3 will vary with operating conditions as indicated below:

Low chemical load :

- natural gas-fired installations, in continuous operation
- hot stacks with t > 300°C, in continuous operation
- stacks subject to plant shutdowns with an average below 5 days/year.

Medium chemical load :

- stacks with t > 200°C, in continuous operation
- stacks subject to plant shutdowns with an average between 5-10 days/year.

High chemical load :

- stacks with t < 200°C
- stacks in intermittent operation independent of any flue gas temperature
- stacks subject to plant shutdowns with an average of more than 10 days/year.

NOTE : Local cooling below acid dewpoint temperature of parts of a stack may also cause chemical attack. Such spots are mainly at the top of the stack and at any points of major leakage through the lining.

3.3.3 Design options

Type A : Direct-lined concrete shaft. - Refer to the Arrangement Drawing, page 2 of

Appendix 2.

The inside of the concrete shaft is protected from condensing aggressive chemicals and overheating by a mastic layer applied directly to the concrete followed by a vapour-tight insulation layer, preferably of cellular glass, and a refractory or chemical resistant brick lining.

The brick lining, built up in sections to a maximum height of 15 m, is supported by corbels which are integrated with the shaft. The brick lining sections are allowed unrestrained expansion, in the radial direction by a 10 mm thick polystyrene layer between the cellular glass and the brickwork and also in the axial direction by overlapping the lining just above the corbel.

The rigidity and impermeability properties of the brick lining will be considerably improved by the use of bricks with tongue and groove joints, particularly in the case of earthquake requirements, or alternatively dowels can be fitted.

This type of stack is suitable for medium hot duties where the temperature t = 100 to 300°C, if the flue gases do not contain fluorine and to a minor extent, phosphate compositions.

Type B : With ventilated annular space between brick lining and concrete shaft. - Refer to page 10 of Appendix 2.

Ventilation of the annular space is achieved by air inlet holes in the shaft above grade level and with air outlets just below the top, fitted with louvres and wire mesh. Ring beams for supporting the lining sections shall be constructed such that the ventilated annular space will not be obstructed. Escaping flue gases entering the annular space will be discharged through the top openings, and therefore application of a protective layer to the inside of the concrete shaft, ring beams and consoles is required. Construction of the refractory brick lining is similar to that for Type A, but expansion movement in the axial direction only need be considered.

The temperature gradient over the brickwork should be limited to avoid cracking of the bricks and overheating of the annular space. This can be achieved by the application of insulation material over the brickwork, retained by means of glass fabric bands.

Where considerable variations of the flue gas temperature could occur a double brick lining, i.e. brick-insulation-- brick, may be applied.

This type of stack is suitable for t > 200°C and for all chemical loads.

Type C : With ventilated and accessible annular space between concrete shaft and one (or more) brick-lined flue(s).- Refer to page 20 of Appendix 2.

The brick lining is supported on platforms positioned to accommodate the brick lining in sections of 15 m maximum height. These platforms are independent of the shaft, being

supported by consoles integrated with the concrete shaft: , the platforms shall have sufficient openings for ventilation, and be covered with steel grating in accordance with Standard Drawing S 28.202. Provisions for ventilation in the shaft are similar to those for Type B. The temperature in the accessible annular space shall not be higher than ambient temperature by more than 15°C for moderate and 20°C for hot climates. This will allow inspection and repairs to be carried out during operation.

The insulation material, e.g. glass wool, mineral wool or diatomaceous blocks such as 'Moler bricks', should be installed during the brick lining of the flue(s). If glass wool or mineral wool is selected for the insulation, attachment to the brickwork may, for example, be by means of glass fabric bands.

The shaft has a top platform, see page 22 of Appendix 2, which supports an outer layer of curved bricks having acid-resistant joint fill or a stainless steel mantle. The top platform should be at a level of 4 m below the top part of the flue, to allow for inspection of the outside of the flue top during operation.

This type of stack is suitable for all temperature ranges, but if selected for use where t > 200°C with a high chemical load, then chemical-resistant brick lining materials shall be applied.

Type D : With ventilated and accessible annular space between the concrete shaft

and one (or more) steel flue(s). - Refer to page 27 of Appendix 2.

Steel-linings should preferably be supported from a position above the flue duct entry(ies), thus enabling the lining to expand upwards without restriction.

Depending on the stack height, a number of horizontal sliding supports spaced at distances apart of 40 times the flue diameter up to a maximum of 40 m are required. The highest sliding support should be installed approximately 2.0 m below the concrete top platform. For stack heights of more than 150 m additional supports should be installed to ensure gastight expansion joints.

The location of platforms, either steel with grating or of concrete, refer to Type C, is dependent on the desired location of the fixed and sliding supports, accessibility for maintenance and for the aircraft warning lights.

For the ventilation of the annular space, the fitting of insulation and the protective measures for the top platform, refer to Type C. Application of a protective layer on the inside of the shaft is not required.

The part of the steel flue(s) protruding out of the top platform is subject to a relatively more severe attack and it may be necessary to install a section of a more chemical-resistant alloy.

Carbon steel linings may be selected for use in temperature ranges up to 400 °C and for all chemical loads. If t < 100°C, rubber-lined steel or, in exceptional cases, plastic linings may be used. If t > 400°C the steel may be lined with refractory concrete.

NOTE : This refractory concrete will not achieve a ceramic bond, but will prevent the steel from overheating and corroding to a certain extent, because of the alkaline environment existing near the steel surface.

The Table of Appendix I summarizes the field of application, the relevant properties and experiences concerning the performance of the four types of stacks: , however, the indicated appraisals are based on general terms only, to provide guidance for initial selection.

The final selection shall always be made by a specialist, based on a thorough study of the information available, the requirements involved and specific local conditions.

4. MATERIALS

4.1 CONCRETE

For concrete material requirements, testing methods and procedures, refer to the relevant sections of DEP 34.19.20.31-Gen.

4.2 STEEL

Steel for structural use, i.e. platforms, ladders, etc., shall be mild steel in accordance with the requirements of ASTM A 283-C. Steel for supporting the flues shall meet the requirements of BS 4360 Grade 43A.

Steel plate for flues shall be in accordance with the requirements of ASTM A 285-C, with carbon content 0.23% max. for temperatures below 400 °C.

Stainless steel for top ladders and the outside top mantle of steel flues shall be to AISI-316 L.

Bolts for structural steel shall be high tensile bolts of grade 8.8.

Inserts and bolts for connection of externals (platforms, ladders, etc.) to the shaft shall be to AISI-316 L.

4.3 REFRACTORIES

4.3.1 Refractory bricks

Refractory bricks and shapes shall be of the 'medium duty' low porosity quality, in accordance with the requirements of DEP 44.24.90.31-Gen., 'Refractory bricks and shapes', with a modulus of rupture of 3.45 MPa minimum.

4.3.2 Refractory concrete

Insulating concrete to be applied near the connections of flue entries and the soot door to the brick lining shall be 'medium weight' (MESC 77.22.38.050.1) in accordance with the requirements of DEP 64.24.32.30-Gen., 'Insulating refractory concrete linings'.

The reinforcement bars used in the insulating concrete shall be to BS 4449 Grade 250, hot dip galvanized in accordance with the requirements of ASTM A123 or BS 729.

4.3.3 Cements

Sodium silicate, potassium silicate and silica cements shall be in accordance with the requirements of ASTM C466, and synthetic resin-based cements with ASTM C395, or equivalent specifications, see MESC 77.22.24.xxx.1.

4.4 CHEMICAL-RESISTANT BRICK LINING AND STACK BRICKWORK MATERIAL

Chemical-resistant bricks and tiles for lining systems, stack tops (supported by top platforms Type C) and the protection of top platforms Type C and D shall have a characteristic strength of 25 N/mm^2. For brickwork flues which will be subjected to high-chemical loads, refer to DEP 30.48.60.33-Gen., 'Requirements for acid resistant brick lining materials'.

4.5 INSULATION MATERIALS

4.5.1 Cellular glass

Cellular glass shall be Pittsburgh Corning Foamglass type T2 or equivalent with the following properties:

- chloride content : maximum 10 mg/kg
- pH : between 6-9

- compressive strength : 50 N/mm^2
- thermal conductivity : 0.05 W/m °C at 200 °C
- density : 125 kg/m^3 approx.

4.5.2 Mineral wool

Mineral wool blankets (MESC 85.62.28.236/264.1), shall be stitched on to 20 mm (3/4 inch) galvanized hexagonal wire mesh and comply with the following physical properties:

- chloride content : maximum 10 mg/kg
- pH : between 6-9
- density : approx. 80 kg/m^3.
- thermal conductivity : 0.036 W/m °C at 50 °C
  0.044 W/m °C at 100 °C
  0.052 W/m °C at 150 °C
  0.062 W/m °C at 200 °C.

Mineral wool slabs (MESC 85.62.08.010/060.1) shall meet the following requirements:

- chloride content : maximum 10 mg/kg
- pH : between 6-9
- density : approx. 80 kg/m^3
- thermal conductivity : 0.034 W/m °C at 50 °C
  0.040 W/m °C at 100 °C
  0.046 W/m °C at 150 °C
  0.056 W/m °C at 200 °C.

4.5.3 Glass wool

Glass wool blankets (MESC 85.62.28.xxx.1) shall be stitched on to 20mm ($^3/_4$ inch) galvanized hexagonal wire mesh and comply with the following requirements:

- chloride content : maximum 10 mg/kg
- pH : between 6-9
- density : approx. 55 kg/m^3
- thermal conductivity : 0.030 W/m °C at 50 °C
  0.036 W/m °C at 100 °C
  0.044 W/m °C at 150 °C
  0.053 W/m °C at 200 °C.

Glass wool slabs (MESC 85.62.08.xxx.1) shall meet the following requirements:

- chloride content : maximum 10 mg/kg
- pH : between 6-9
- density : 38 kg/m^3
- thermal conductivity : 0.030 W/m °C at 50 °C
  0.038 W/m °C at 100 °C
  0.048 W/m °C at 150 °C
  0.063 W/m °C at 200 °C.

4.5.4 Ceramic wool

For ropes in elongation details

- Heat resistance : up to 1260 °C
- Al_2O_3 content : between 45 and 52%
- pH : 6 and 9

4.6 TOP COVERS

4.6.1 Cast iron

The cast iron for top covers shall be in accordance with the requirements of ASTM A278 Class 30, in the untempered condition.

NOTE: The bolts connecting individual sections of the top cover shall be in accordance with the requirements of ASTM A307-Grade B.

4.6.2 Stainless steel

If covers of stainless steel are required, the steel and any connecting bolts shall be of type AISI 316L.

4.6.3 Ceramic cover

If a ceramic cover is required, the brickwork for such a cover shall be in accordance with DEP 30.48.60.33-Gen., 'Requirements for acid resistant brick lining materials'.

4.7 LEAD

The quality of the lead shall be type Pb 99 985 of DIN 1719 or ASTM B29 grade chemical lead, unless otherwise specified. Weight of lead slabs : 15 kg/m^2.

4.8 RUBBER LININGS

Refer to Section 2 of DEP 30.48.60.30-Gen., 'Requirements for rubber linings for process equipment, piping and concrete structures'.

4.9 PAINTS

Paint shall be obtained in accordance with the requirements of Sections 2 and 15 of DEP 30.48.00.31-Gen., 'Painting and coating of new construction projects'.

5. DESIGN

5.1 CONCRETE FOUNDATION AND SHAFT

5.1.1 Basic data

Soil investigation shall be carried out with reference to DEP 34.11.00.12-Gen., 'Geotechnical and foundation engineering'.

Design loads shall be in accordance with the requirements of DEP 34.00.01.30-Gen., 'Minimum requirements for structural design and engineering' but in addition, the effects of deflections, dynamic influences, loads due to erection and the installation of flue ducts respectively shall be incorporated, see also (5.4.3).

5.1.2 Stability ratio

The stability ratio shall not be less than 2 for the lowest weight condition (without lining) and the maximum wind load. For stability ratios less than 6, secondary order effects and stiffness of the foundation shall be taken into account.

5.1.3 Piling

Piling, if required, shall be designed in accordance with the requirements of DEP 34.11.00.12-Gen.*

5.1.4 Concrete design

The design of the reinforced concrete foundation and shaft shall comply with the requirements of DEP 34.19.20.31-Gen., 'Reinforced concrete foundations and structures'. Secondary moments resulting from horizontal deflections, including tolerances for deviations from the vertical, shall be taken into account and be based on non-linear elastic calculation with a 'short term stress-strain' curve.

5.1.5 Reinforcement of foundation and shaft

In addition to top and bottom reinforcement of the foundation slab, required for strength and to control crack width, 'cube reinforcement' shall be applied between the top and bottom reinforcement layers, consisting of bars at a maximum centre to centre distance of 600 mm.

The reinforcing bars for the shaft shall be pre-bent but without hooks. The length of the bars for the vertical reinforcement shall be adjusted to the erection method but shall not be longer than 6 m. For determination of the lap length, refer to DEP 34.19.20.31-Gen.: , lap positions shall be staggered.

Vertical reinforcement bars shall always be enclosed by horizontal bars.

5.1.6 Cover on bars

The concrete cover on the outer and inner bars shall be as indicated in DEP 34.19.20.31-Gen., relating to the expected chemical load and environmental ingress, but shall not be less than 40 mm.

5.1.7 Heat protection of concrete

The top surface of the foundation shall be adequately insulated and/or ventilated for protection against heat.

The stack lining shall provide adequate insulation in order to minimize thermal stresses. The maximum temperature of the concrete shall not exceed 80 °C.

For stacks Type A, the monolithic corbels for supporting the brick lining, shall be provided with sufficient vertical expansion joints in order to avoid excessive thermal stresses in the shaft.

For stacks Type C, the concrete platforms, which support the individual brick lining sections, shall themselves be supported on consoles which are connected to the inside of the shaft.

The concrete platforms and the consoles shall not be integrated.

The concrete top platform for stacks Type C and Type D may be integrated with the shaft.

5.1.8 Flue entries

The concrete shall be structured in such a way that stresses are effectively routed around the openings. The drawings shall indicate whether the reinforced concrete frames around the flue duct openings need to be fitted at the same time or after the shaft has been constructed.

5.1.9 Openings in shaft and lining

For stacks Type A and Type B, an opening in the shaft of suitable dimensions shall be left at the location of the soot door, designed to allow transportation of materials during construction, see page 2 and page 10 of Appendix 2.

For stacks Type C and Type D, provisions for the collection and removal of soot and condensation shall be made in the lowest part of the flue duct, see page 27 and 32 of Appendix 2. An entrance through the concrete shaft should both provide access to the annular space and ensure adequate supply of ventilation air.

5.1.10 Top platform (stacks Type C and D), see page 22 and 28 of Appendix 2.

The concrete top platform shall be designed with concrete curbs adjacent to the protruding flue with a stainless steel hatch. A concrete parapet, for personnel safety at a height of 110 cm above floor level, shall be constructed near the top of the concrete shaft.

The platform floor, the curbs and the inside of the parapet should be protected by means of chemical-resistant bricks and/or tiles laid in chemical-resistant cement, in accordance with the requirements of DEP 30.48.60.12-Gen., 'Design of chemical resistant linings for concrete structures'.

An appropriate slope shall be provided to discharge liquids via a drain hole to a vertical drain pipe of reinforced glass fibre epoxy resin inside the shaft, and subsequently taken on the outside of the stack to a neutralization pit or sewer system, see page 28 of Appendix 2.

5.2 FLUE LININGS

5.2.1 General

The selection of lining materials and method of construction is mainly based on both the expected thermal, chemical and mechanical load, see (3.3.1 up to and including 3.3.3).

In the temperature range below 200°C, acid-resistant brick linings may be applied instead of refractory bricks and carbon steel linings may be protected by means of coating systems or rubber linings. For design temperatures above 400°C steel linings shall be protected with insulating concrete.

The following requirements should ensure the proper functioning of flue linings:

- Unrestricted expansion of the lining shall be possible in both axial and radial directions.
- The appropriate insulation shall be installed.
- The draught in the flue shall be such that during normal operation, i.e. steady state, flue gases will not enter the annular space.
- Thermal stresses shall be computed on the basis of stationary heat flow and temporary extreme heat impact due to envisaged maloperations.

  NOTE: This applies for both radial and axial heat flow in the lower and upper section of the lining.

- Interactive forces between the shaft and the lining shall be avoided.

5.2.2 Brick lining

Brick linings are applied in Type A direct lined concrete shafts and in Type B and Type C stacks with ventilated and accessible annular space. The lining of the shafts shall be designed with reference to the 'Recommendations for the design of chimneys - Part B - The lining, by CICIND', and with the following requirements.

The height of brick lining sections should be limited to 15 m maximum. The stability of brick linings for flues shall be proved if:

- the height of a section (distance between two corbels or platforms) exceeds 20 m
- the slenderness ratio of the lining h/d > 10, where d is the smallest outside diameter
- the brick lining protrudes out of the top of the stack and is subject to wind forces.

The minimum thickness of brick linings should be based on the following table :

Minimum thickness in mm	
Inside diameter of the flue, in m	Shapes with tongue/groove all around
Up to 6	80
Up to 8	100
Up to 10	120

The type of brick to be installed should be determined on the basis of both chemical load and temperature influence. In the case of high-chemical load and temperatures below 200°C acid-resistant bricks shall be used, but if the temperature will exceed 200°C, refractory bricks are required. The dense quality of refractory bricks is applied in this temperature range in combination with a high-chemical load, in order to limit the amount of SO_3 condensation within the brick lining.

The application of bricks with tongue and groove joints, on four sides, improves the structural properties of bricklinings. In earthquake areas the application of dowels in the horizontal joints in addition to the tongue and groove joints should be considered.

The insulation material for stacks Type B and Type C should be installed on the outside of the brick lining during bricklaying. n general, the cement to be selected for the brickwork must have comparable mechanical, physical and chemical resistance properties with relation to the bricks.

The top section of the brickwork lining shall always consist of heat and acid-resistant refractory bricks in order to withstand the influences of both the weather and flue gases.

5.2.2.1 Cement mortar (for stacks Type A, Type B and Type C)

Simultaneously with the selection of an appropriate brick lining material, cement shall be selected on the basis of the applicable chemical and thermal loads as follows:

CEMENT TYPE

Service temperature °C	Degree of chemical load, see (3.3.2)		
	Low	Medium	High
150	1 or 2	1 or 2	1 or 2
150-300	2 or 3	2	2
300-900	2 or 3	2	2

1 - Synthetic resin-based cement see DEP 30.48.60.12-Gen.

2 - Sodium-free, potassium silicate see DEP 30.48.60.12-Gen. cement

3 - Aggregate on the basis of fire clay, aluminous cement

In the final selection of a particular brand or type of cement, the following criteria shall be satisfied :

- the mechanical properties of the cement after curing shall be compatible with those of the selected bricks. Therefore, the cements used for flue linings shall be of the chemical curing type, because the flue gas temperature will not be hot enough to achieve ceramic bonding
- the heat resistance shall satisfy the requirements originating from normal operations and an emergency situation (i.e. increased temperature for a short duration).

Due to the effects of weather on the top part of a brick lining, i.e. a distance downwards of approximately 3 times the inside diameter, cement which resists the impact of water and frequent temperature changes shall be applied for this part. Generally, aggregates based on fire-clay do not meet these requirements.

5.2.3 Steel linings

Steel linings are applied in stacks Type D. The operating conditions for the lining shall be thoroughly studied in the basic design stage, especially when more than one duct is connected to the flue.

Besides the top suspended arrangement for lining support and the application of expansion joints at appropriate elevations, the most commonly applied and recommended method is to support the steel lining just above the breechings, the upward expansion being accommodated by a weather-tight sealing of the steel lining where it passes through the top platform.

At relevant elevations, horizontal support of the lining to the shaft shall be provided by radial sliding supports, tangential cables or rods. Both methods shall permit an unrestrained vertical and radial expansion of the lining.

The steel flue duct parts below the support and the breeching(s), also being horizontally supported, shall have sufficient space for vertical expansion in the flue duct opening(s). Horizontal expansion will be provided by expansion joints between flue duct(s) and breeching(s), just outside the concrete shaft.

The material of construction for the lining (4.2) depends on the thermal and chemical load and it may need to be protected with coatings, rubber linings or insulating concrete, see (6.4.2), or by an allowance for internal corrosion (c_i) and external corrosion (c_e).

The minimum thickness of the lining, excluding corrosion allowance, shall be 6 mm.

The corrosion allowances indicated below are based on a design life of approximately 30 years, assuming that the flue gases contain SO_3, less than 0.1% of elementary chlorine or hydrogen chloride and less than 0.025% of hydrogen fluoride, and that the temperature of the surface in contact with the flue gases is below the acid dewpoint of the flue gas plus 20 °C for less than 200 operating hours.
All percentages are by weight and at 20 °C.

External corrosion allowance c_e

The external corrosion allowance depends on the type of construction material and/or the condition of the external surface of the lining as follows:

- painted (see DEP 30.48.00.31-Gen.) whether or not covered by insulation/cladding	Nil
- unprotected carbon steel	4 mm
- unprotected, weathering resistant material such as 'corten'or an equivalent	3 mm
- unprotected stainless steel	Nil

Internal corrosion allowance c_i

The internal corrosion allowance (in µm) for metal surfaces in contact with flue gases up to a maximum temperature of 400°C can be calculated using the following equation:

- $C_i = (220\ p + 720)$ µm, with a minimum of 2 mm

in which p is the SO_3 content (in mg/kg). If the SO_3 content is not known, it should be assumed to be 2% of the SO_2 content in the flue gas.

For flue gas temperatures below 90 °C and for a medium or high chemical load, a rubber lining shall be applied in accordance with the requirements of DEP 30.48.60.10-Gen. If flue gas temperatures exceed 400 °C, an insulating concrete shall be applied to the steel lining, anchored with V-studs. The type and thickness of insulating concrete and the material, dimensions and configuration of the V-studs will be dictated by the flue gas contaminants and temperatures. The application of a more heat-resistant alloy steel may be permitted, after consultation with the principal, taking into account the chemical load and mechanical properties.

The outside surface of the steel lining shall be 'shop painted' in accordance with Sub-section 6.3 of DEP 30.48.00.31-Gen.

Insulation material shall be applied to the steel lining, preferably prior to installation, on an appropriate anchor system welded to the lining.

Material selection for expansion joints or bellows shall be based on the relevant thermal and chemical load.

5.2.4 Calculations

Calculations for the following are required for both steel and brick linings :

- Flue gas velocities, draught and temperature drops at relevant heights (e.g. flue entry, corbel elevations, top).

  Flue gas exit velocities normally vary between 6 to 15 m/s. The design should preferably be based on 15 m/s: , however, if local regulations exist in this respect, they shall be adhered to.

  Nett draught is obtained from static draught minus the losses due to acceleration, friction and obstructions such as consoles.

  Except for occasional short periods, the design should ensure that positive pressure will not occur in the brickwork flues.

- Heat transfer shall be carried out on the basis of radial heat flow for both steady-state flue gas temperatures and those during an emergency situation restricted to a defined duration (3.2).

  Heat resistance and thermal stresses due to the resulting gradient shall be checked with material properties.

  The air temperature in the accessible annular space shall not be higher than the ambient temperature by more than 15 °C for moderate and 20 °C for hot climates. The gradient over the thickness of the concrete shaft in operating conditions shall not exceed 40 °C.

- The interactive forces between the reinforced concrete shaft and the brick or steel lining must be calculated for:

  - the dead load of the lining
  - restraint of relative movement between shaft and lining, caused by uniform and non-uniform thermal expansion
  - forces caused by seismic vibration of the shaft or the lining
  - forces caused by the movements of the shaft due to wind load.

- Earthquake loads, independent of any interaction effects between the shaft and the lining, due to the inertia of the lining itself.

- Stresses due to the dead load of the lining.

For steel linings only:

- Structural loads for the support structure of the flue lining(s) and for the consoles of the flue lining(s).

- Temporary construction parts required for erection of the steel lining, which are connected to the shaft and/or the lining respectively.

- Cone-cylinder discontinuities.

- Longitudinal stresses due to dead load, wind, earthquake and thermal loads:

  - Dead load

  The dead load shall be estimated on the basis of the weight of all permanent construction and fittings, insulation, dust loads, clinging ash, protective systems, whether paint, rubber lining or refractory concrete, and all other relevant loads.

  NOTE : Increased plate thickness due to specified corrosion allowance, refractory concrete or insulation shall be assumed to add load and moment, but not capacity.

- Wind

  Steel linings shall be designed for all loads and/or deflections due to wind loads acting on the concrete shaft and on the protruding top part of the stack lining. The response due to wind resonance shall be calculated.

- Earthquake

  To comply with earthquake requirements, the lining shall be designed for all loads and/or deflections originating from the concrete shaft and the stresses due to the inertia of the steel lining itself, if the distance apart of lateral supports so dictate.

- Thermal loads :

  Stresses due to both longitudinal and circumferential differential metal temperatures shall be calculated. In the case of two or more breechings containing flue gases with different temperatures, the designer should select from any conceivable operating mode the largest flue gas temperature differences. A minimum gas temperature differential of 14 °C is recommended for use in calculations even if all the gases enter the steel lining through one opening.

Steel linings shall be designed in accordance with the recommendations of the American Society of Civil Engineers for the 'Design and construction of steel chimney liners'. Stresses resulting from the combined loads shall comply with the safety factors given in this

publication.

5.2.5 Insulation

For heat transfer calculations, the temperature limitations of annular spaces and the inside of concrete shafts, see (5.2.4).

For a Type A direct-lined shaft, particularly if the chemical load is high owing to SO_3 concentration of flue gases and where dew point corrosion may be expected, a vapour-tight insulating material, such as cellular glass, shall be applied.

However, if there is evidence that the flue gases may contain fluorides, the application of cellular glass is not permitted. Neither shall it be exposed to temperatures above 400 °C.

Cellular glass should be applied to the shaft in blocks of a size which will achieve a satisfactory adjustment to the circular shape of the shaft and in two layers with staggered joints to give vapour tightness. The adhesives applied for both bed and radial joints are based on 'Colas' products* and the maximum allowable temperature for this adhesive is 125 °C. For a detailed installation procedure, see (6.2.2).

* COLAS PRODUCTS Ltd., of Slough, England, which is a Shell Group company.

A space of 10 mm should be left between the cellular glass insulation and the brickwork of the lining, to allow for expansion of the brick lining. For ease of construction this space may be filled with polystyrene sheets.

The insulation of both steel and brickwork linings with ventilated and also accessible annular spaces, i.e. for Type B, Type C and Type D stacks, shall be applied to the outside of the lining. Mineral or glass wool, in both blanket and slab form with the wire mesh to the outer side, are the most appropriate materials for this application. The fixing to the lining shall be carried out by lacing the wire mesh together at the joints and applying glass fabric bands.

For bricklinings, a sufficient number of bands shall be applied to securely hold the insulation to the brickwork. If steel linings are applied, anchor clips of material similar to that of the lining itself should be welded on to the outside of the lining.

For ease of construction, the installation of insulation blankets or slabs during erection/installation of the lining is recommended. The fixing of blankets or slabs should be such that no excessive heat losses will occur due to open radial joints or sagging in a later stage or from constrictions at the anchor clips or bands.

5.3 DRAINS (CONDENSATE DISCHARGE)

Stacks with a ventilated non accessible annular space shall be provided with drains to discharge condensate formed on the inside of the shaft.

In stacks where, owing to the thermal load, condensation of aggressive components of the flue gases is likely to occur, the bottom of the flue lining shall be constructed on a slope, thus enabling condensate to be discharged into an appropriate sewer system neutralization pit via a sealed pipe system such as a 'water channel', see page 8 of Appendix 2.

5.4 STEEL WORK

5.4.1 Cage ladders

Cage ladders shall be designed in accordance with page 41, 42 and 43 of Appendix 2. The internal ladders connecting the concrete and/or steel platforms in stacks Type C and Type D with ventilated accessible annular spaces shall also be ladders with safety cages.

5.4.2 Platforms

Rest and external platforms, for stacks Type A and Type B shall be designed in accordance with page 41 and 43 of Appendix 2. Rest platforms shall be integrated with the cage ladder structure at relevant elevations.

Circumferential platforms should be used, instead of one or more rest platforms when accessibility is required:

- for the connection, installation and maintenance of aviation warning lights
- to the provisions for flue gas detection and/or thermowells.

To allow inspection and maintenance of the outside of the concrete shaft when it is in service, a circumferential top platform shall be installed with integrated facilities for supporting 'sky-climber' and other loads.

Internal steel platforms around the steel flue duct(s) shall be designed in accordance with page 41 and 43 of Appendix 2. Provisions shall be made in the concrete shaft for inserts to allow installation and proper support of the beam structure.

5.4.3 Hoisting facilities

When circumferential platforms are fitted for reasons given in (5.4.2), the installation of a davit connected to the concrete shaft and reaching approximately 500 mm outside the handrail should be considered.

5.4.4 Inserts

Inserts for fixing steelwork platforms, cage ladders, davit, etc., shall be of type AISI 316L stainless steel, in accordance with the minimum requirements given on page 44 of Appendix 2.

The application of self-drilling anchor bolts is allowed for fixing the connections of lightning conductors: , however, brand and type shall be subject to approval by the principal.

5.4.5 Steelwork protection

For normal industrial environments all steelwork for ladders cage ladders, platforms, grating, davits, etc. shall be protected by means of hot-dip galvanizing in accordance with the requirements of ASTM A123 or BS 729.

The steelwork, inside stacks Type C and Type D for the supporting beam structures, cage ladders, platforms, etc. shall also be hot-dip galvanized to the above standards.

In marine and aggressive industrial environments all exposed steelwork for ladders, cage ladders, platforms, grating, davits, etc. shall be protected with the following paint system applied on top of the galvanizing, i.e. the 'Duplex system':

- clean the surface by an appropriate surface treatment
- apply an epoxy-based paint to a dry film thickness of 250 µm.

This system shall be applied in the workshop, after which due attention shall be paid to careful handling during transport and erection in order to avoid damage to the paint system. Accidental damage shall be made good by the contractor directly after erection of the steelwork.

The preparation and painting of steelwork shall be carried out in accordance with the

requirements given in the appropriate sections of DEP 30.48.00.31-Gen., 'Painting and coating for new construction projects'.

NOTE: The top 4 m of outside cage ladders should preferably be of type AISI 316 stainless steel.

5.5 TOP COVERS

5.5.1 Cast iron

The cast iron cover for capping the top of the stack shall be fabricated in sections, each section to weigh less than 100 kg. The segments shall be connected together with bolts and nuts of 20 mm diameter.

5.5.1.1 Protection of the cast iron cover

1. Workshop treatment

   The cast iron sections shall be given one priming coat of Bituproof No 3, applied by brush at the rate of 0.5 kg/m^2.

2. Site treatment

   - **Prior to installation**
     - touch up shop priming coat, if required
     - apply a further coat of Bituproof No 3 as above.
   - **After installation**
     - apply a coat of Bituproof No 7 by trowel at the rate of 3 kg/m^2
     - allow to dry for 24 hours
     - apply a second coat of Bituproof No 7, as above.

5.5.2 Stainless steel

Stainless steel covers for capping the top of the stack shall also be fabricated in at least four sections, each section to weigh less than 100 kg. The segments shall be connected together with bolts and nuts of 20 mm diameter.

5.5.3 Ceramic

The ceramic covering shall be constructed with tapered, heat and acid resistant refractory bricks in order to withstand the effects of both the weather and the flue gasses. For the selection of the type of cement for the joints, see (5.2.2.1)

5.6 INTERNAL LIGHTING

The annular space of stacks Type C and Type D shall have an electric lighting installation designed in accordance with the requirements of DEP 33.64.10.10-Gen.

5.7 ENGINEERING DOCUMENTS

Unless otherwise specified, the following engineering documents shall be submitted by the engineering contractor for the principal's approval:

5.7.1 Drawings

- General arrangement of the stack.
- Foundation of the stack.
- Piling plan (if applicable).
- Reinforcement of the stack foundation.
- Bar bending schedules for the foundation.
- Unfolded general arrangement of the shaft, indicating all inserts, etc. which are to be cast in.
- Reinforcement detail for the shaft.
- Reinforcement details for ring beams/consoles/platforms.
- Bar bending schedules for the shaft, including ring beams/consoles and platforms.
- General arrangement of cage ladders, platforms, hoist facilities, soot door, etc.
- Lightning conductor system and details (permanent and temporary).
- Cast-iron, stainless steel or ceramic capping.
- Electrical installation for warning lights.
- Details of steel or brick lining.
- Details of flue entry(ies).

5.7.2 Calculations

All calculations, required in accordance with (5.1) and (5.2) shall be submitted by the engineering contractor for the principals approval.

5.7.3 Miscellaneous

- Bills of quantities.
- Specification for construction.

6. CONSTRUCTION

6.1 FOUNDATION AND SHAFT

6.1.1 General

The reinforced concrete foundation and shaft shall be constructed in accordance with the requirements of DEP 34.19.20.31-Gen.

6.1.2 The shaft

The reinforced shaft should preferably be erected by means of the slip-form method. A continuous supply of concrete is required in order to keep the number of construction joints to the absolute minimum.

NOTE: The slip form method can be applied only for shaft diameters greater than 2.75 m.

Construction joints, if any, shall be carried out such that an optimal bond to the existing concrete will be achieved. Pouring of concrete and the subsequent compaction shall be carried out in layers of approximately 250 mm.

In order to prevent rotation of the slip-form, each pour should be carried out alternately clockwise and counter clock- wise respectively. The slip-form surfaces exposed to the concrete shall be made of steel or steel-lined wood.

When the slip-form is jacked up to a higher elevation, the subsequently exposed concrete of the shaft shall be trowelled with a steel trowel. In the case of surface impurities or other irregularities, repair/improvement shall be carried out directly, after the principal's approval.

In general, the use of curing compounds is considered to be beneficial: , however they shall be compatible with any paint or coating that may be applied later. The type, brand, and application procedure require the principal's prior approval.

A two-layer scaffold shall be used in order to progress the concreting, trowelling, repair, inspection and curing, etc. The vertical position and the rotation of the shaft shall be monitored continuously by means of optical plumblines from three locations, or by two laser beams.

6.1.3 Shaft tolerances

1) - Thickness

Negative deviations are not permitted. Positive deviations of up to 4%, to a maximum of 10 mm, are permitted.

2) - Out-of-vertical of shaft centre-line:

Deviations of up to 0.25%, to a maximum of 25 mm, are permitted.

3) - Elevations/locations of corbels, beams, platforms, inserts, etc.:
Deviations of plus or minus 10 mm are permitted.

4) - True circular sections:
The difference between the maximum and minimum inside diameters at any cross-section shall not exceed 1% of the nominal diameter at the cross-section under consideration.

5) - Miscellaneous:

Concrete cover	plus or minus 5 mm.
Location of reinforcing bars	plus or minus 5 mm.

6.2 INSULATION

6.2.1 Protective layer

Prior to the application of insulation and the brick lining for stacks Type A and Type B, a thorough inspection of the concrete surface shall be carried out, irregularities shall be properly repaired and air bubbles larger than 10mm shall be filled.

All dirt, oil, grease, loose particles and laitance shall then be removed by means of a hard brush and the inside of the shaft, consoles and if applicable, ring beams, shall be coated with a protective coating.

The coating shall be applied in layers as follows:

- 1st layer: prime by scrubbing well into the surface a solution of Bituproof No. 3*, diluted with an equal volume of clean cold water
- 2nd layer: apply a heavy brush coat of Bituproof No. 3*
- 3rd layer: apply by trowel a 3 mm wet thickness of Bituproof No.7*
- 4th layer: apply by trowel a 3 mm wet thickness of Bituproof No. 7*.

Allow each layer to dry between applications.

* Refer to (5.2.5).

6.2.2 Insulation of direct-lined shaft Type A

After application of the protective layer, the cellular glass insulation shall be applied as follows:

The cellular glass shall be installed in two layers with staggered joints, to achieve optimal vapour tightness. Bed joints as well as circumferential and radial joints shall be filled completely with the cement.

The cement for all joints shall consist of the following components mixed thoroughly:

- 1 part (by volume) sulphate-resistant cement
- 2 parts (by volume) Bituproof No. 3*
- 4 parts (by volume) clean, sharp silica sand
    - The sand shall be graded by passing through sieves to BS 410 as follows:
        - No. 36 90-100%
        - No. 72 60-100%
        - No. 100 20-40%.

As a preparation prior to application, the edges of all cellular glass slabs shall be dipped in Bituproof No. 3* diluted with one equal volume of clean cold water and allowed to dry.

* Refer to (5.2.5).

6.2.3 Insulation of the linings of ventilated accessible annular spaces for stacks Type B, Type C and Type D

The insulation of both brickwork and steel flue linings should be installed during the erection of these linings. For a steel lining, the insulation should be installed from the outside and be incorporated in the welding, painting and jacking/lifting cycle.

For the brick lining, the insulation should be applied to the outside of the lining during the bricklaying stage, and from the scaffolding erected inside the flue lining for the bricklaying.

Due attention shall be given to the proper fixing of insulation slabs or blankets to the flue lining. Open joints, sagging of insulation materials in a later stage or constrictions at the glass fabric bands shall be avoided to prevent heat losses. Mineral wool or glass wool blankets and semi-rigid slabs are the most commonly used insulation materials for application to the flue lining.

6.3 BRICK LININGS

During installation of the brick lining, the temperature in the stack shall be kept between 15 to 30 °C in order to achieve a proper curing of the applied cement. For dosing and mixing of silicate-based and synthetic-resin based cement, refer to Section 6.4 of DEP 30.48.60.23-Gen. This DEP should also be referred to for the installation of the brick lining.

The joints, both circumferential and axial, shall be carefully filled with cement in order to avoid any leakage between the flue duct and the annular space. The application of bricks with tongue and groove joints on four sides increases the stability of the brick lining and the gas tightness of the joints.

The flue gas side of the brickwork shall have a smooth surface: , therefore surplus cement shall be removed leaving the joints flush with the brick surface immediately after installing each particular brick. For brick-lined flue gas ducts with an inside diameter less than 4.0 m, special brick shapes shall be used.

For stacks Type A, a 10 mm gap can be maintained between the cellular glass insulation and the brick lining, by using polystyrene sheets to allow for free expansion of the brick lining.

Axial and circumferential joints shall be :

- 3 mm thick, if silicate-based cements are used
- 5 mm thick, if synthetic-resin based cements are used.

6.3.1 Brick lining tolerances

- Bricks: Shall be in accordance with the requirements of DEP 44.24.90.31-Gen., 'Refractory bricks and shapes'.
- True circular sections, i.e. the difference between the maximum and minimum inside diameters at any cross-section shall not exceed 2% of the nominal diameter at the cross - section under consideration.

6.3.2 Lead flashing

Where lead flashing is required for sealing purposes at corbels and ring beams, it shall be carefully formed to the correct shape against the inside of the shaft and the top of the ring beam. Jointing shall be carried out by soldering, with 40 mm laps.

6.4 STEEL LININGS

Depending on the diameter of the flue ducts involved, the prefabrication of steel-linings should be carried out in well equipped and covered workshops. If sections cannot be transported via public roads, they should be fabricated in a temporary workshop near the stack location.

Welding shall not be carried out when the surfaces of the parts to be welded are wet from rain, snow or ice or during periods of high winds.

The steel lining should be prefabricated in the longest possible sections that can be safely handled and transported to the inside of the shaft. The access to the bottom part of the concrete shaft shall therefore allow the hoisting/jacking and the erection procedure of the steel lining.

Holes in the plates for erection purposes are allowed provided that the smaller holes are later filled with weld metal and any larger openings filled with plate of the same specification. Any clips, jigs or lugs welded to the lining plates for erection purposes shall be removed without damaging the plates.

The welding of steel linings for concrete stacks shall be of good quality and if necessary shall comply with the appropriate national and/or local building regulations. If such regulations are not applicable or available, welding approval, testing and inspection shall be in accordance with the requirements of Standard Specification W-4-1/2/3.

Records of all data, tests and examinations relating to all welding procedures used during construction and erection shall be made available to the principal. The welding sequences should be arranged to avoid undue stresses and distortions due to welding. Vertical joints should be welded before horizontal joints and vertical joints shall be offset in adjacent shell courses by a minimum distance of five times the plate thickness, taking the thickest plate of the courses being welded.

The welding equipment used shall be adequately maintained to ensure its suitability for the weld procedures as applied. Care shall be taken to use the correct electrodes and welding gas where appropriate.

All parts being connected by welding shall be attached firmly to each other by bolting, clamping or other mechanical means until welding is complete. All plates should be formed to the specified curvature by rolling or pressing, and the specified curvature should extend to the end of the plate. When metal requires straightening, this should be accomplished by pressing or other non-injurious methods. Flame straightening by heating to a maximum of 700 °C is acceptable.

6.4.1 Steel lining tolerances

- True circular sections:

  The difference between the maximum and minimum inside diameter at any cross-section should not exceed 1% of the nominal diameter.

- Where an opening exists (breechings or manholes, etc.) the permissible difference in inside diameters may be increased by 2% of the width of the opening.

- Vertical misalignment :

  This misalignment shall not exceed 6 mm in any 3.00 m of height.

  Total out-of-vertical should not exceed 1% of the total height, but need not be more restrictive than the out-of-- vertical tolerance of the concrete shaft, see (6.1.3).

6.4.2 Protective coating for the steel lining

Protective measures to be taken for the inside of the steel flue lining are dependent on the thermal and chemical load. Carbon steel or specific steel alloys shall be applied on the basis of specialist advice. Protective measures to be applied in carbon steel flues are summarized in the following table.

	Degree of chemical load		
Operating temperature	Low	Medium	High
Below 100°C	Coating	Coating	Rubber lining, or Glass-fibre reinforced thermosetting membranes
100-200°C	Coating	Coating	Coating
200-400°C	None	None	None
Above 400°C	Refractory concrete	Refractory concrete	Acid resistant refractory concrete

Protective systems shall be in accordance with the requirements of the following publications:

- coating systems - DEP 30.48.00.31-Gen.
- rubber lining - DEP 30.48.60.10-Gen.
- refractory concrete - DEP 64.24.32.30-Gen.

If refractory concrete linings are applied, the steel substrate including anchors shall be painted, depending on the local temperatures, in accordance with the requirements of Sections 1 to 6 of DEP 30.48.00.31-Gen., 'Painting and coating for new construction projects'. The outside of flue ducts (insulation side) shall under all circumstances be painted in accordance with the above sections of the DEP. For corrosion allowance, see (5.2.3).

7. EXTERNAL STACK PROTECTION AND WARNING SYSTEMS

7.1 CONCRETE PROTECTION

Depending on the flue gas analysis, the outside of the concrete shaft will require protection against the effects of 'downwash', by the application of a paint or a paint and coating system.

For stacks Type A and Type B, a 400 µm thick high build 'EPIKOTE' paint to Shell Standard Colour No. 26 (silver grey) should be applied from the stack top downwards over a distance of 5 times the outside top diameter or a minimum of 15 m, whichever is the greater. In addition a 200 µm thick layer of 'EPIKOTE' resin-based coal tar paint shall be applied over a distance from the top downwards of 1.5 times the outside top diameter.

For stacks Type C and Type D, the concrete shaft and parapets shall be painted with high build 'silver grey EPIKOTE' paint as above, from the top of the shaft downwards to a distance of 5 times the outside diameter of the protruding flue duct or a minimum of 12 m.

The chemical-resistant tiling of the top platform shall be carried out in accordance with the requirements of DEP 30.48.60.22-Gen., 'Chemical resistant lining for concrete structures'.

A coating of the total concrete shaft should be considered if the aggressiveness of the environment and/or the porosity of the concrete warrant such protection.

NOTE: Certain types of curing compounds, applied on the shaft during construction, may provide an additional protection to the shaft for a period of several years.

Painting of concrete is generally allowed only after it has cured for 28 days and when the moisture content of the concrete does not exceed 4% by volume.

Prior to the painting of any part of the shaft the whole surface shall be inspected, irregularities shall be properly repaired and air bubbles larger than 10 mm shall be filled. The concrete shall then be lightly grit-blasted in order to remove curing compound, laitance and other foreign matter.

The mixing, application and curing times of the paints to be used shall be in strict accordance with the manufacturers instructions. Each coat of paint shall be applied in a different shade in order to keep a proper check on the progress and build-up of the specified system. All painting and coating shall be carried out in accordance with the requirements of Sections 3.5, 4 and 5 of DEP 30.48.00.31-Gen., 'Painting and coating for new construction projects'.

Aviation authorities in some countries may require day-time warning facilities in addition to warning lights. Such requirements may include the painting of a considerable part or even the total height of the stack, in which case the application of an appropriate protective coating in the required colours and pattern is recommended.

7.2 LIGHTNING CONDUCTOR

The final lightning conductor shall be constructed in accordance with the requirements of Part I, 'Electrical Safety' of the IP Model Code of Safe Practice in the Petroleum Industry. See also, pages 18, 25, 26 and 40 of Appendix 2. For inspection purposes, the connection strip of the lightning conductor shall be located near the cage ladder.

During construction, provisions shall be made for a temporary lightning conductor system. This temporary lightning system shall be built up by casting in additional 16 mm diameter, vertical and horizontal reinforcement bars of FEB 220 HW quality, which should be welded forming a cage connected to the reinforcement of piles or to earth rods.

7.3 AVIATION WARNING LIGHTS

If required by local civil and/or military aviation authorities, stacks shall be provided with aviation warning lights and day-time warning facilities, see (7.1) above. The warning lights shall be in accordance with the International Standards and Recommended Practices Aerodromes - Annex 14 to the Convention of International Civil Aviation. See also, pages 2, 10, 19, 20, 22, 27 and 36 of Appendix 2.

For stacks Type A and Type B, the warning lights should be connected to the railing of circumferential platforms or to the concrete shaft, approximately 1.5 m above these platforms.

For stacks Type C and Type D the warning lights should be located on the outside of the concrete shaft, in panels which are accessible for maintenance from the platform(s) inside the annular space.

7.4 THERMOCOUPLES

Thermocouples for temperature indication shall be provided in the top of the flue as well as in the flue gas channel, and in the annular space between the brickwork and the concrete shaft.

8. INSPECTION DURING CONSTRUCTION

8.1 GENERAL

Inspection is an integral part of the construction of the stack and its lining, and shall be carried out as the work progresses in accordance with the requirements given in Section 6 of this specification.

Prefabricated steel lining sections shall be inspected in accordance with the requirements of the following sub-section.

8.2 STEEL LINING FABRICATION

The workmanship during shop fabrication of steel lining sections shall be visually inspected to ensure that it is in accordance with accepted fabrication practices.

For inspection and acceptance requirements for both shop fabrication welds and field welds, refer to Standard Specification W-4-1/2/3, 'Welding and inspection requirements for equipment that is not covered by international standards and/or codes'.

9. OPERATIONAL START-UP, INSPECTION AND MAINTENANCE

9.1 START-UP

Stacks shall be brought into service very gradually by slowly increasing the temperature to the operating condition, to ensure that :

- moisture in the brick lining or insulating concrete will be slowly driven out
- sufficient draught will be achieved
- excessive tensile stresses and subsequent crack formation will be avoided.

The temperature shall, if possible, also be slowly reduced when taking a stack out of service.

For each individual stack a procedure showing the start-up and shutdown limitations shall be prepared, based on:

- the build-up of the stack lining
- the physical properties of the applied materials.

As a general procedure, the drying out as a result of heating the installation on first start-up should be acceptable.

However, if a separate drying out procedure is required then the following sequence can be applied:

- Increase the gas temperature inside the lining from ambient air to 100 °C over a period of 4 hours.
- Maintain the gas temperature inside the lining at 100 °C for 24 hours.
- Increase the gas temperature up to the final value with a gradient of 100 °C per hour.

If plant modifications are proposed which will influence the conditions in the stack, such as:

- higher/lower flue gas temperatures
- quenching of flue gases
- use of other fuels
- shutdown for very long period,

specialist advice should be sought concerning the consequences and the subsequent measures to be taken.

9.2 OPERATIONAL INSPECTION

After the stack has been taken into operation, each opportunity for internal and/or external inspection shall be utilized. A visual inspection of those parts of the shaft that can be seen from ground, platform and the cage ladder, and internally from the accessible annular space, should take place on a yearly basis.

The interval between comprehensive inspections of lining and shaft will depend on the chemical and thermal load and on the type of stack. A three year interval is recommended but, in practice, the opportunity for inspection will also depend on the shutdown cycle of the plant(s) using the stack: , however, the inspection interval shall not exceed five years. In many cases full external inspection and inspection in access spaces can be safely carried out during operation.

Inspection reports should indicate the potentially vulnerable parts of the stack, illustrated with relevant photographs and give recommendations concerning repair, modifications and maintenance to be carried out.

For stacks Type A and Type B, sections of the brick lining shall be removed from selected positions to allow inspection of insulation, corbels and ring beams, protective layer and the inside of the shaft.

In this respect, the availability of thermographic images taken prior to an inspection shutdown will facilitate the selection of suspect locations - 'hot spots'.

The following list indicates the main items which should be inspected :

Item	Criterion	Applicable to stacks Type			
		A	B	C	D
1. Outside shaft concrete/coatings	- chemical attack	A	B	C	D
	- crack formation	A	B	C	D
	- carbonation	A	B	C	D
2. Inside shaft concrete/protective layer	- chemical attack (dew point corrosion)	A	B		
	- crack formation	A	B	C	D
3. Corbels/ring beams	- overheating	A	B		
	- disbonding protective layer	A	B		

Item		Criterion	Applicable to stacks Type A	B	C	D
4.	Insulation:					
	a) cellular glass	- vapour tightness, joints	A			
		- disbonding from concrete	A			
		- cell structure	A			
	b) mineral and glass wool	- joints		B	C	
		- sagging		B	C	
		- deposits or condensation affecting insulating properties		B	C	
5.	Brick linings	- expansions	A	B	C	
		- quality/position ceramic ropes	A	B	C	
		- crack formation patterns	A	B	C	
		- joints (bond)	A	B	C	
		- spalling	A	B	C	
		- chemical attack	A	B	C	
		- overheating	A	B	C	
		- shape	A	B	C	
6.	Steel linings	- expansions				D
		- corrosion				D
		- shape (irregularities)				D
		- welds				D
7.	Steelwork : cage ladders, platforms, hoisting facilites	- connections: inserts, bolts	A	B	C	D
		- corrosion	A	B	C	D
8.	Chemical-resistant brick linings, top platform	- bricks, joints, bond			C	D
		- membrane			C	D
9.	Aviation warning lights	- connection	A	B	C	D
		- electrical install.	A	B	C	D
10.	Lightning conductor	- connection	A	B	C	D
		- effect	A	B	C	D
		- condition	A	B	C	D
11.	Miscellaneous: Drain systems,		A	B	C	D
	flue entries,		A	B		
	soot door,		A	B		
	capping		A	B	C	D

After a fire or an explosion, inside or outside of the stack, an earthquake or after very high winds, a stack inspection shall take place.

In the event of severe damage and/or conditions which may precipitate deterioration of one or more items, a specialist should review the situation on the basis of:

- flue gas temperatures and variations
- flue gas analysis
- analysis of contaminations in brickwork, cement and insulation
- compressive strength of the concrete
- carbonation concrete.

9.3 MAINTENANCE

Maintenance shall be carried out in accordance with the recommendations given in the inspection report and as follows:

Remedial work should be carried out as soon as is practical after inspection, or scheduled for the next shutdown. In many cases the external shaft will be safely accessible during operation for carrying out maintenance work.

To reduce the total maintenance costs during the lifetime of a stack, the following measures should be taken :

- Adherence to correct start-up and shutdown procedures in order to avoid excessive tensile stresses which will cause crack formation in brick lining materials.
- Regular inspection and the consequential maintenance.
- The use of fuels with low sulphur content.
- Maintenance of steady flue gas temperatures in accordance with the design assumptions.

  Overheating shall be avoided, as well as too low flue gas temperatures which will cause dew point corrosion of the lining and even the inside of the shaft.
- Avoid intermittent use or long periods when the stack is standing idle.

  In general, stacks subject to varying conditions or standing idle for a longer period will deteriorate faster than stacks in normal use. If a stack is expected to stand idle for a longer period, special precautions for preservation should be considered, such as:
- neutralizing or washing the surface of the flue lining
- maintaining a natural draught in the stack, which will remove condensate and thus reduce moisture absorption in brick linings
- increase the temperature in the flue gas duct to approximately 80°C just below the top by means of a low-pressure coil, booster heater, etc.

  NOTE: This expensive method is only feasible and applicable for relatively short shutdown periods
- application of a top cover in order to prevent ingress of rain and snow.

  Top covers which shall be capable of resisting high winds and should be easy to fit and remove, may be made of either timber, metal or tarpaulin (with a timber frame).

10. REFERENCES

In this manual, reference is made to the following publications.

Note : The latest issue of each publication shall be used together with any amendments/supplements/revisions to such publications.

It is particularly important that the effect of revisions to international, national or other standards shall be considered with DEPs, unless the standard referred to has been prescribed by date.

Painting and coating for new construction projects	DEP 30.48.00.31-Gen.
Design and installation of rubber-lined process equipment, piping and concrete structures	DEP 30.48.60.10-Gen.
Design of chemical-resistant linings for concrete structures	DEP 30.48.60.12-Gen.
Installation of chemical-resistant linings for concrete structures	DEP 30.48.60.22-Gen.
Installation of chemical-resistant brick linings for process equipment	DEP 30.48.60.23-Gen.
Requirements for rubber linings for process equipment, piping and concrete structures	DEP 30.48.60.30-Gen.
Requirements for chemical-resistant brick lining materials	DEP 30.48.60.33-Gen.
Electrical engineering guidelines	DEP 33.64.10.10-Gen.
Minimum requirements for structural design and engineering	DEP 34.00.01.30-Gen.
Geotechnical and Foundation Engineering	DEP 34.11.00.12-Gen.
Reinforced concrete foundations and structures	DEP 34.19.20.31-Gen.
Refractory bricks and shapes	DEP 44.24.90.31-Gen.
Insulating refractory concrete linings	DEP 64.24.32.30-Gen.
Welding and inspection requirements for equipment not covered by international standards and/or codes	Standard Specification - W-4-1/2/3

AMERICAN STANDARDS

Design and Construction of steel chimney liners	ASCE

Issued by:
The American Society of
Civil Engineers,
345 East 42nd Street,
New York, NY 10017

Specification for zinc (hot galvanized) coating on products fabricated from rolled, pressed and forged steel shapes, plates bars and strips.	ASTM A123
Specification for gray iron castings for pressure	ASTM A278

containing parts for temperatures up to 650 °F (345 °C)	
Specification for low and intermediate strength carbon steel plates, shapes and bars	ASTM A283
Specification for pressure vessel plates, carbon steel, low and intermediate tensile strength	ASTM A285
Specification for carbon steel externally threaded standard fasteners	ASTM A307
Specification for pig lead	ASTM B29
Specification for chemical resistant resin mortars	ASTM C395
Specification chemically setting silicate and silica chemical-resistant mortars	ASTM C466

Issued by:
American Society for Testing
and Materials, 1916 Race Street,
Philadelphia, PA 19103, USA

BRITISH STANDARDS

Specification for test sieves	BS 410
Hot dipped galvanized coatings on iron and steel articles	BS 729
Specification for weldable structural steels	BS 4360
Specification for hot rolled steel bars for the reinforcement of concrete	BS 4449

Issued by:
British Standards Institution,
2 Park Street,
London W1A 2BS, UK.

IP Model code of safe practice in the petroleum industry	Part I Electrical safety

Issued by
Institute of Petroleum
61 New Cavendish Street
London W1M AR, UK

GERMAN STANDARDS

Blei(lead)	DIN 1719

Issued by:
Beuth Verlag GmbH
Berggrafenstrasze 4 to 10,
1000 Berlin 30 W. Germany

INTERNATIONAL STANDARDS

Aerodromes	Annex 14 to the

Convention on
International Civil
Aviation

Issued by:
International Civil Aviation
Organisation
P.O. Box 400, Place de l'Aviation
Internationale,
1000 Sherbrooke Street West,
Montreal, Quebec, Canada H3A 2R2

Recommendations for the design of chimneys

Part B 'The lining'

Issued by:
Comité Internationale de Cheminées
Industrielles (CICIND),
136 North Street,
Brighton, BN1 1RG, U.K.

11. STANDARD DRAWINGS

In this specification, reference is made to the following standard drawing, the latest copy of which shall be used.

Platforms and ladders for concrete stack	S 28.202

12. APPENDICES

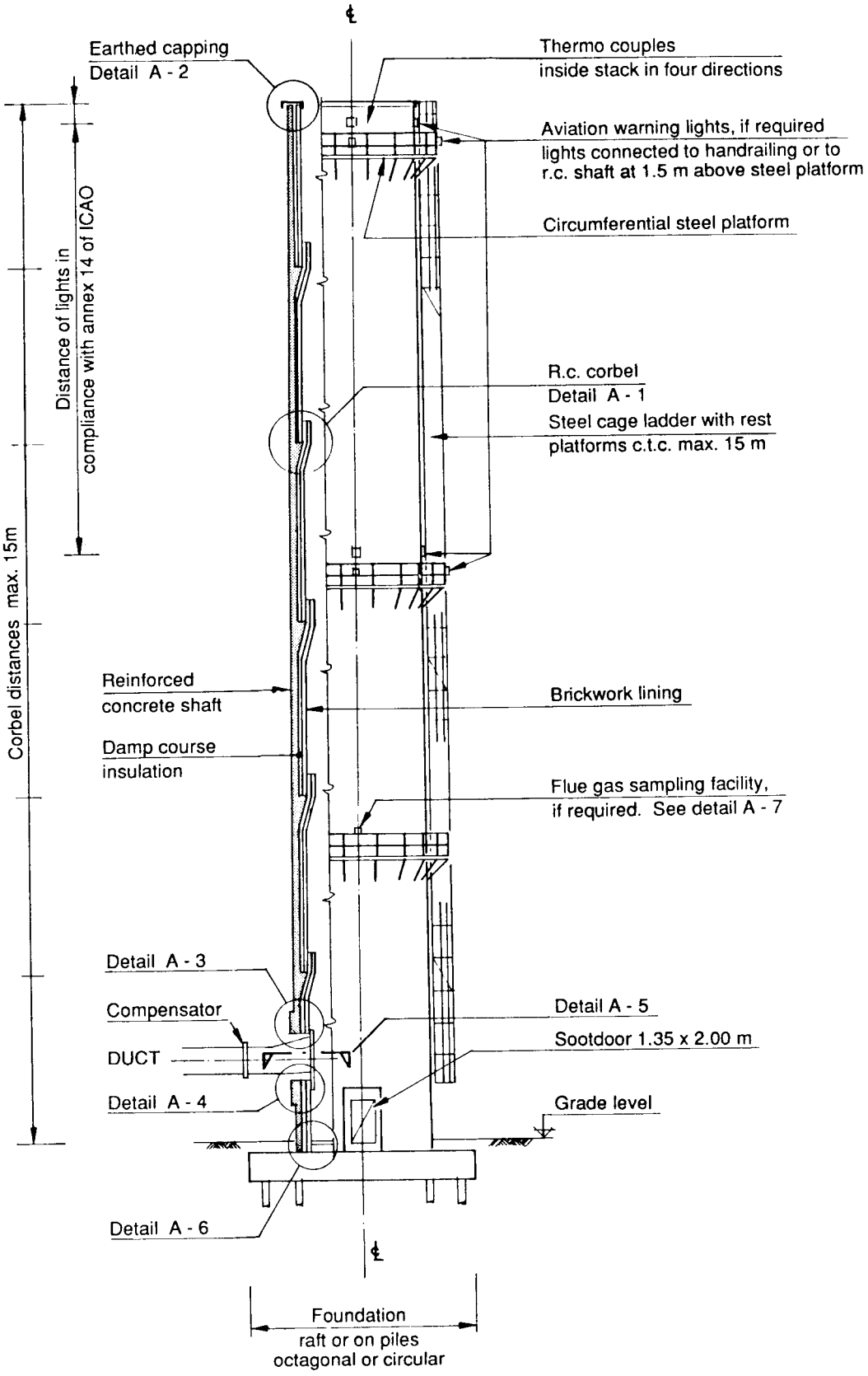
APPENDIX 1 TABLE 1 - SUMMARY OF APPLICATION, PROPERTIES AND EXPERIENCE WITH TYPE A B C AND D STACKS

Field of application properties / performance / Types of stacks	Temp. range t_1<100 °C t_2= 100-300 °C t_3>300 °C	Resistance to thermal shock	Protection by flue gas lining system against over-heating of the concrete shaft	Resistance of the inside of the shaft to chemical attack by flue gases	Limitation of height T = Techn. reasons E = Econ. reasons	Suitability for small diameter flues	Suitability for earthquakes design	Total dead weight by comparable heights	Resistance of concrete shaft due to down wash	Friction properties of flue gases to flue duet	Maintain-ability	Ease of insp/maint. during operation	Ease of insp/maint. during shutdown	Duration of construc-tion	Suitability for multi-flue purposes or extensions	String-ent start-up and shut-down proce-dures	Remarks
Type A Direct lined concrete shaft (Cellular glass insulation)	t_2 (1)	moderate	moderate	moderate	appr. 150 m' E	bad	good	unfavour-able	bad	moderate	moderate	bad	bad	bad	not suitable	yes	(1) If above acid dew point
Type B Ventilated annular space between brick lining and concrete shaft	t_2 (1) and t_3	moderate	bad	rather good	appr. 150 m' E	bad	moderate	unfavour-able	bad	moderate	moderate	bad	bad	moderate	not suitable	yes	(1) If above acid dew point
Type C Ventilated and accessible annular space between concrete shaft and one or more brick lined flues	t_1 (1) t_2 (1) and t_3	moderate	good	good	appr. 350 m' T	moderate	moderate	moderate	good	moderate	rather good	rather good	good	moderate	suitable	yes	(1) If above acid dew point chemical-resistant bricks shall be used
Type D Ventilated and accessible annular space between concrete shaft and one or more steel flues	t_1 (1) t_2 (1) and t_3 (2)	good	good	good	appr. 350 m' T	good	good	favourable	good	good to bad (3)	good	good	good	good	suitable	no brick lining	(1) Below acid dew point rubber lining of steel flues shall be consid-ered (2) t_3 >300°C refractory concrete lining (3) If refr. concrete applied

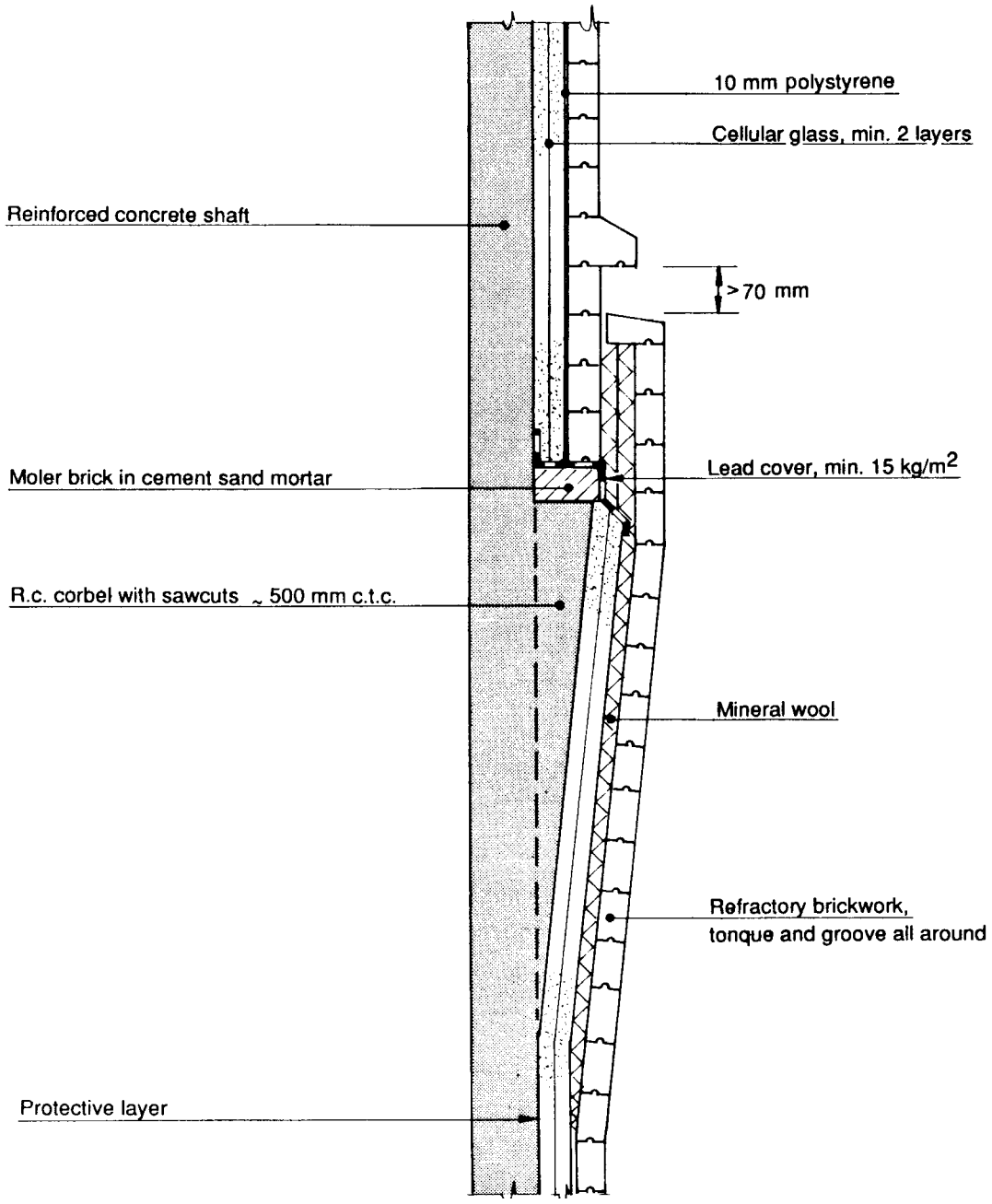
APPENDIX 2 TYPICAL ARRANGEMENT AND DETAIL DRAWINGS FOR STACKS TYPE A, B, C and D

	-	Detail D- 2	29
	-	Detail D- 3a	30
	-	Detail D- 3b	31
	-	Detail D- 4	32
	-	Detail D- 5	33
	-	Detail D- 6	34
	-	Detail D- 7	35
	-	Detail D- 8	36
	-	Detail D- 9	37
	-	Detail D-10	38
	-	Detail D-11	39
	-	Typical lightning protection system	40
ALL	-	Rest platform	41
TYPES	-	Ladder arrangement	42
OF	-	Circumferential platform	43
STACK	-	Inserts M20 and M12	44

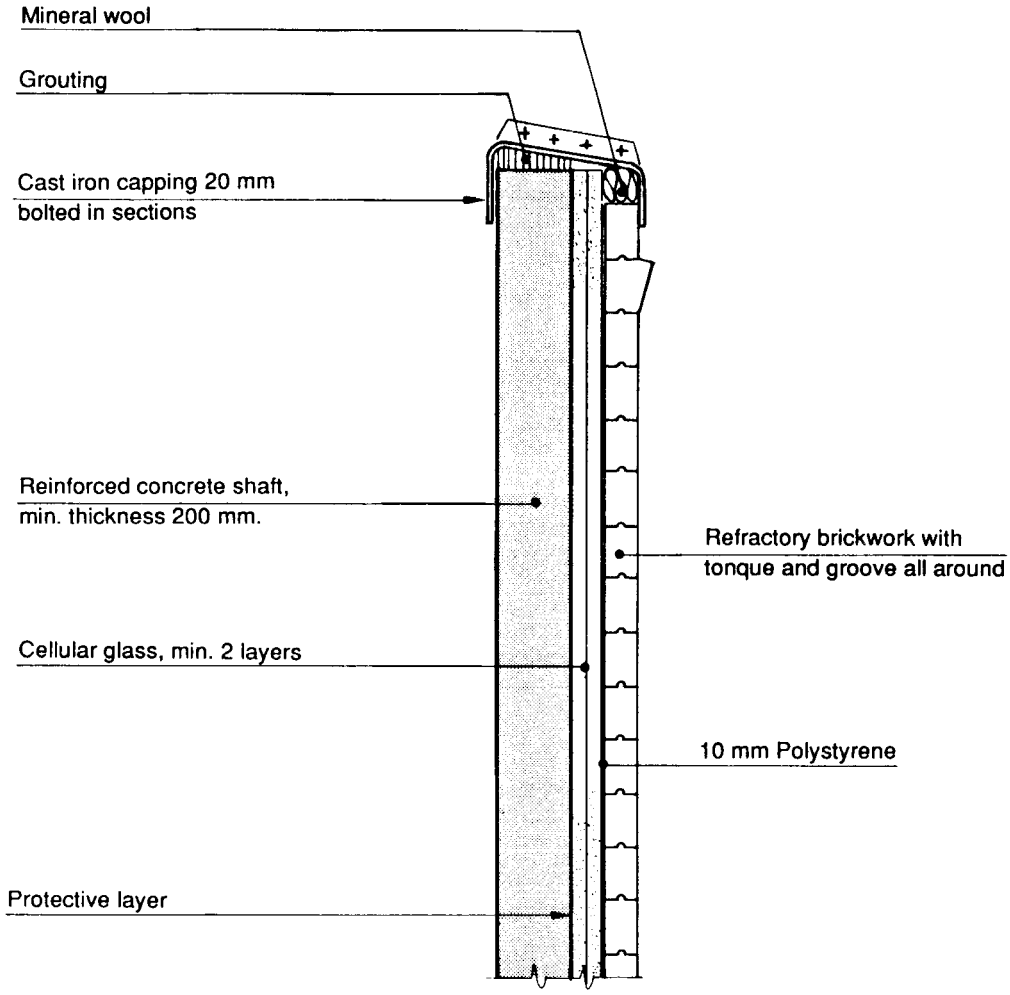
STACK TYPE A TYPICAL ARRANGEMENT


℄
Earthed capping
Detail A - 2
Thermo couples
inside stack in four directions
Aviation warning lights, if required
lights connected to handrailing or to
r.c. shaft at 1.5 m above steel platform
Circumferential steel platform
Distance of lights in
compliance with annex 14 of ICAO
R.c. corbel
Detail A - 1
Steel cage ladder with rest
platforms c.t.c. max. 15 m
Corbel distances max. 15m
Reinforced
concrete shaft
Brickwork lining
Damp course
insulation
Flue gas sampling facility,
if required. See detail A - 7
Detail A - 3
Compensator
Detail A - 5
Sootdoor 1.35 x 2.00 m
DUCT
Detail A - 4
Grade level
Detail A - 6
℄
Foundation
raft or on piles
octagonal or circular

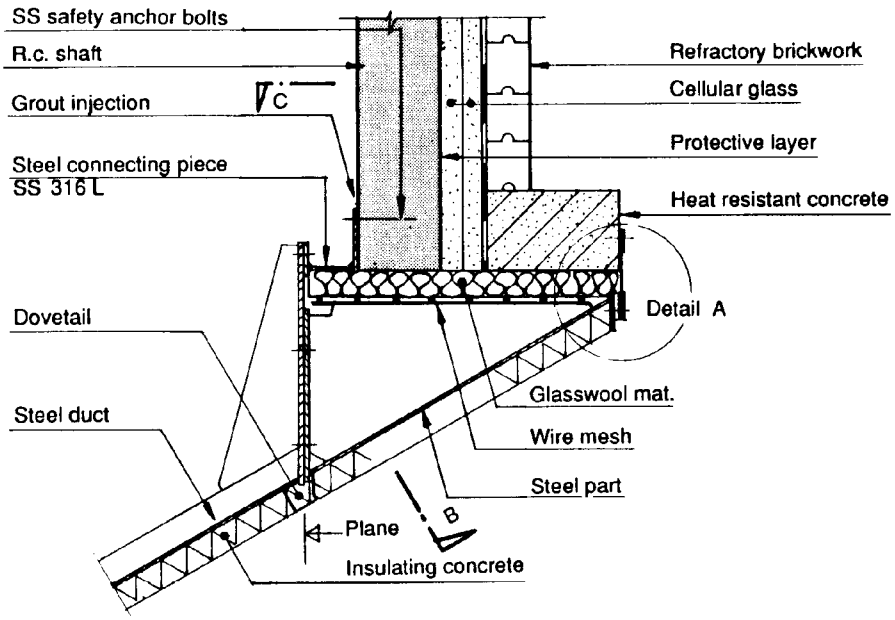
DETAIL A - 1

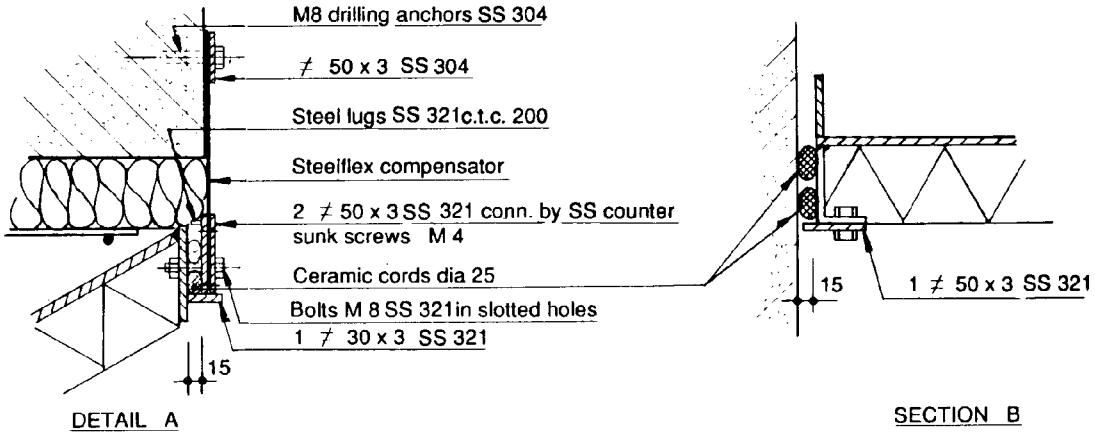

10 mm polystyrene
Cellular glass, min. 2 layers
Reinforced concrete shaft
>70 mm
Moler brick in cement sand mortar
Lead cover, min. 15 kg/m2
R.c. corbel with sawcuts ~ 500 mm c.t.c.
Mineral wool
Refractory brickwork,
tonque and groove all around
Protective layer

DETAIL A - 2


Mineral wool
Grouting
Cast iron capping 20 mm
bolted in sections
Reinforced concrete shaft,
min. thickness 200 mm.
Refractory brickwork with
tonque and groove all around
Cellular glass, min. 2 layers
10 mm Polystyrene
Protective layer

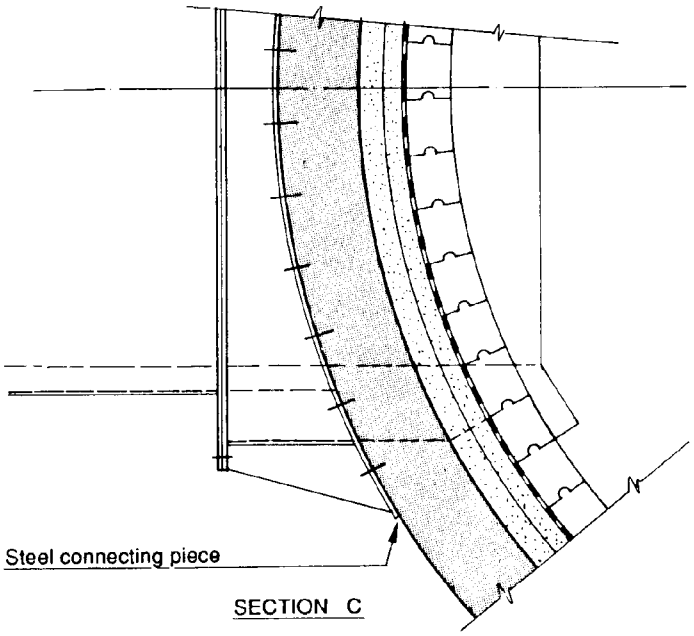
DETAIL A - 3





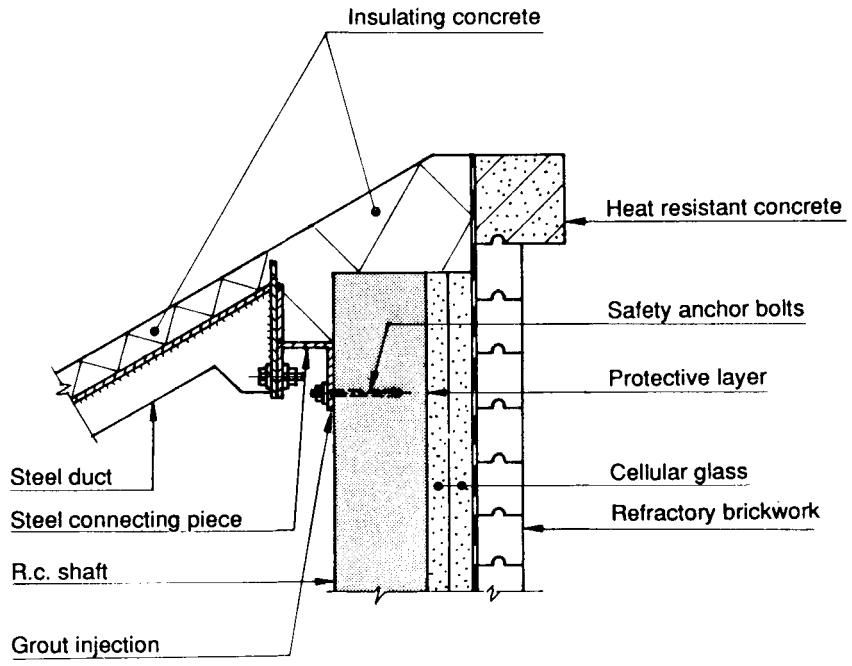
DETAIL A

SECTION B

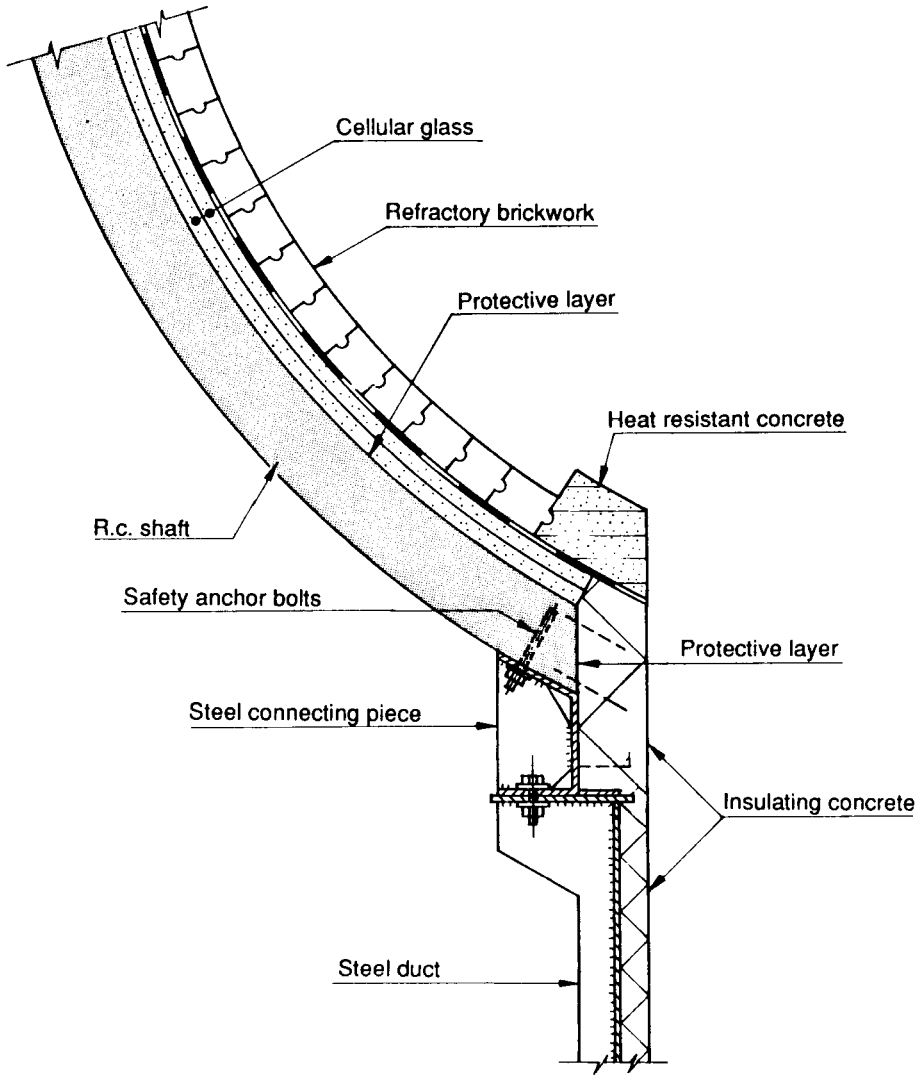


SECTION C

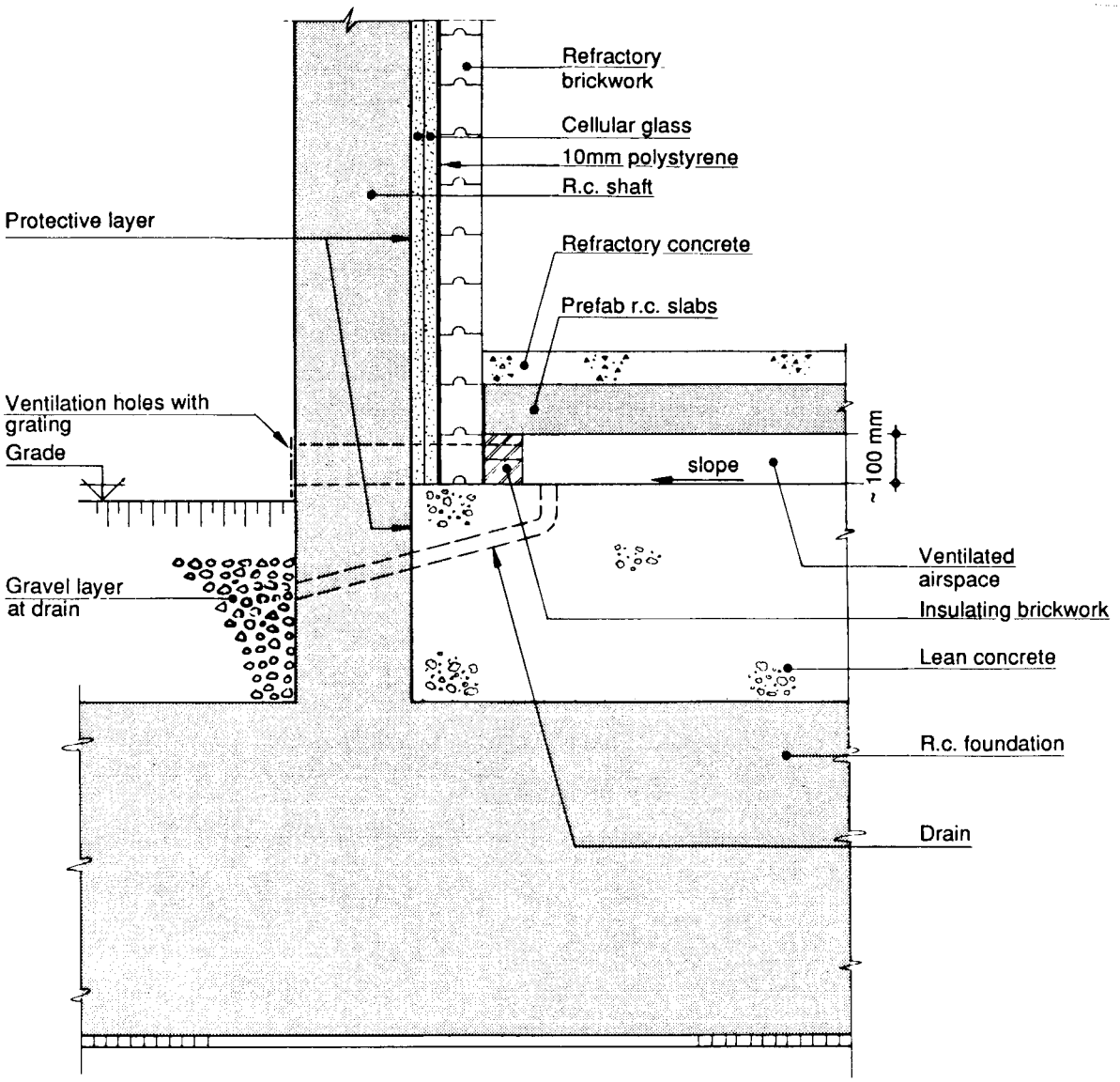
DETAIL A - 4


Insulating concrete
Heat resistant concrete
Safety anchor bolts
Protective layer
Cellular glass
Refractory brickwork
Steel duct
Steel connecting piece
R.c. shaft
Grout injection

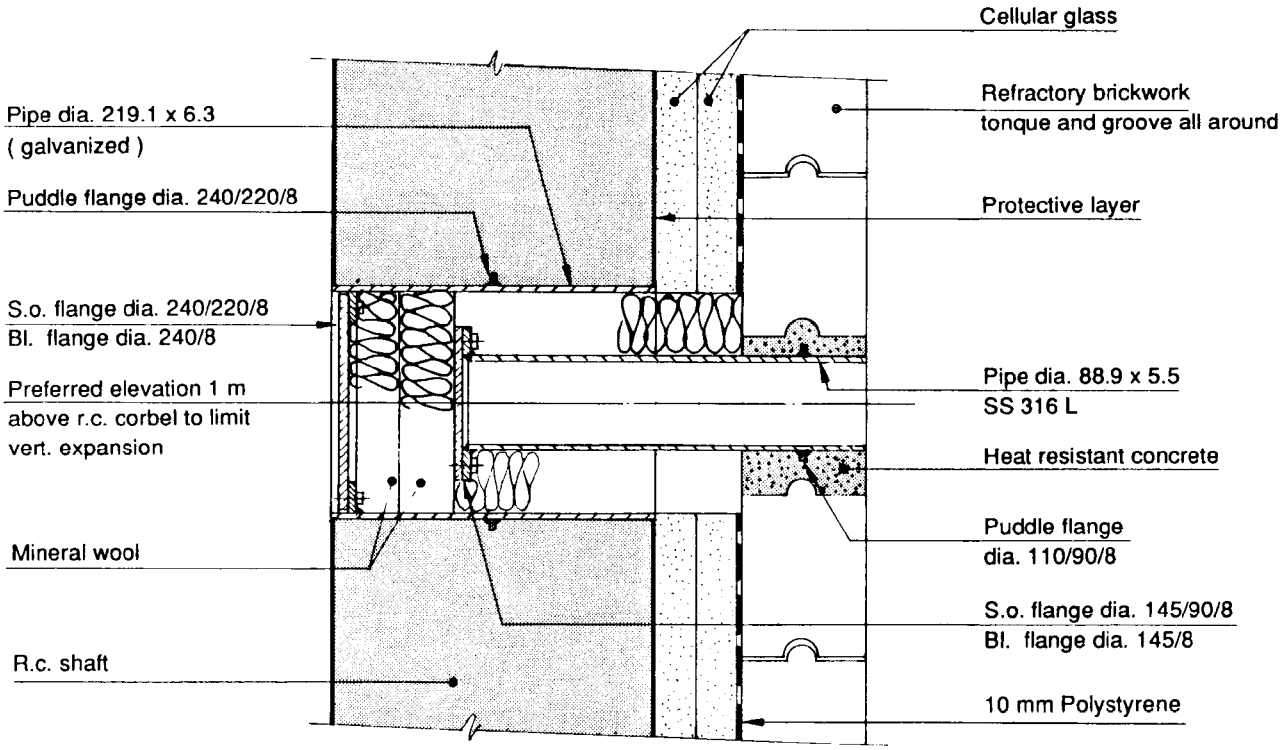
DETAIL A - 5


Cellular glass
Refractory brickwork
Protective layer
Heat resistant concrete
R.c. shaft
Safety anchor bolts
Protective layer
Steel connecting piece
Insulating concrete
Steel duct

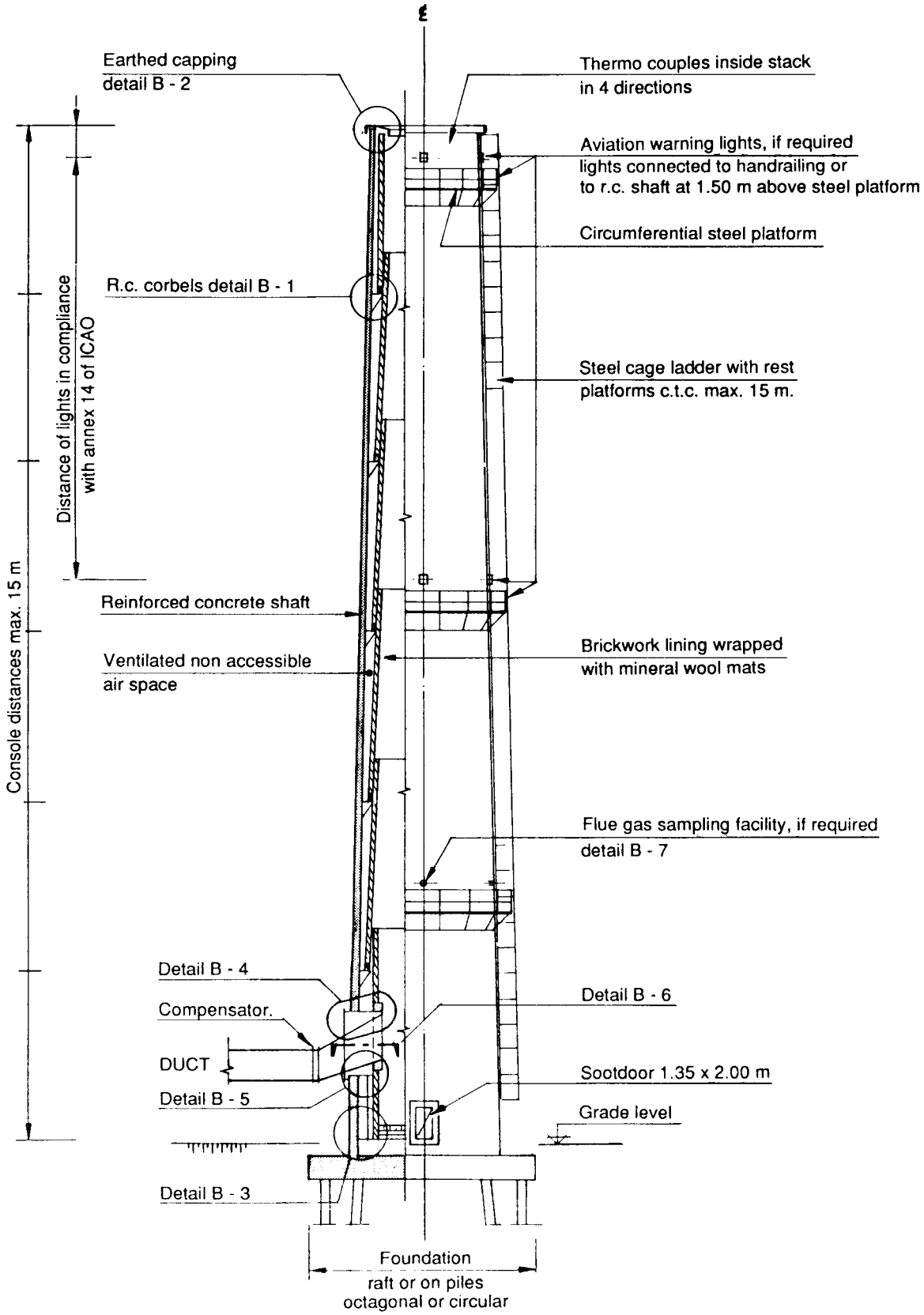
DETAIL A - 6


Refractory brickwork
Cellular glass
10mm polystyrene
R.c. shaft
Protective layer
Refractory concrete
Prefab r.c. slabs
Ventilation holes with grating
Grade
slope
~ 100 mm
Gravel layer at drain
Ventilated airspace
Insulating brickwork
Lean concrete
R.c. foundation
Drain

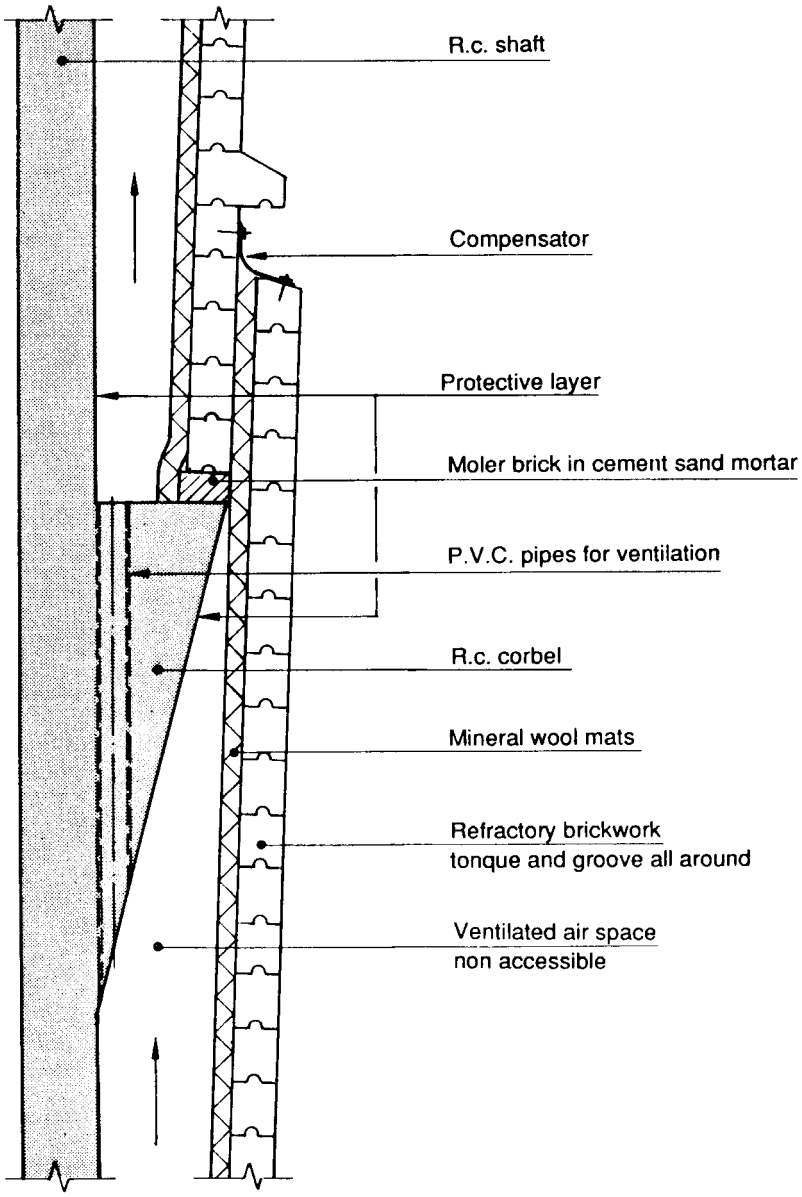
DETAIL A - 7


Cellular glass
Refractory brickwork
tonque and groove all around
Pipe dia. 219.1 x 6.3
(galvanized)
Puddle flange dia. 240/220/8
Protective layer
S.o. flange dia. 240/220/8
Bl. flange dia. 240/8
Pipe dia. 88.9 x 5.5
SS 316 L
Preferred elevation 1 m
above r.c. corbel to limit
vert. expansion
Heat resistant concrete
Puddle flange
dia. 110/90/8
Mineral wool
S.o. flange dia. 145/90/8
Bl. flange dia. 145/8
R.c. shaft
10 mm Polystyrene

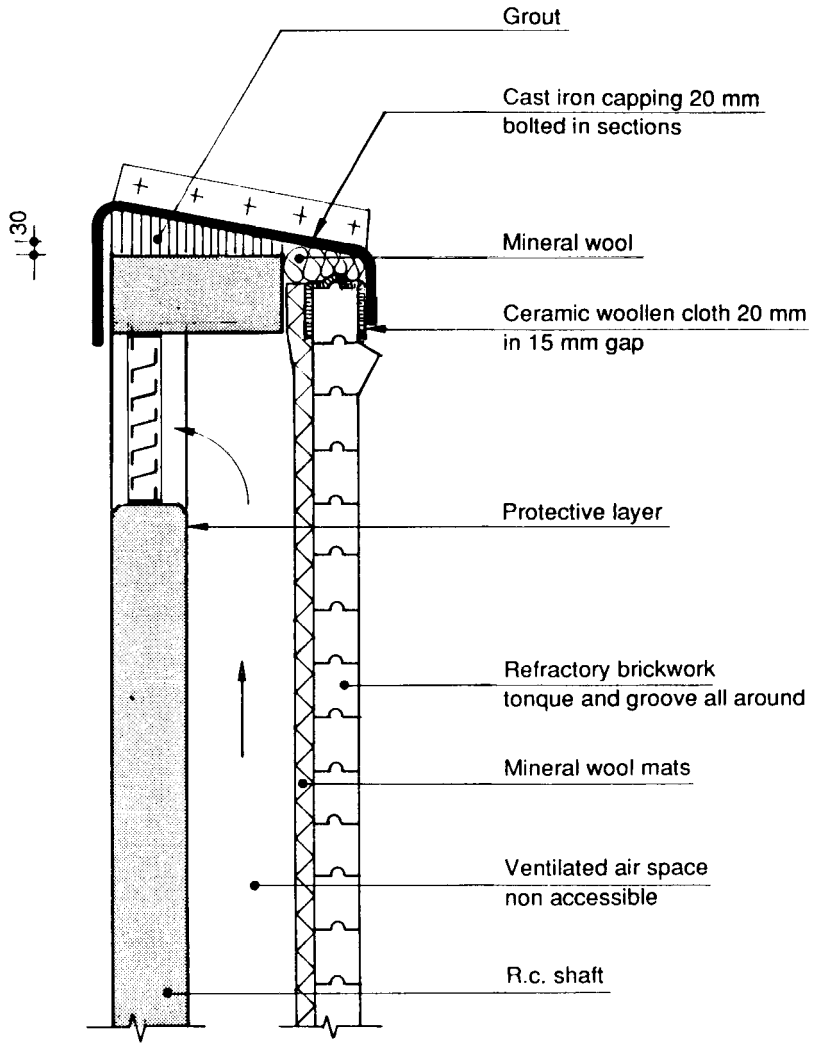
STACK TYPE - B TYPICAL ARRANGEMENT


Earthed capping
detail B - 2
Thermo couples inside stack
in 4 directions
Aviation warning lights, if required
lights connected to handrailing or
to r.c. shaft at 1.50 m above steel platform
Circumferential steel platform
R.c. corbels detail B - 1
Steel cage ladder with rest
platforms c.t.c. max. 15 m.
Distance of lights in compliance
with annex 14 of ICAO
Console distances max. 15 m
Reinforced concrete shaft
Ventilated non accessible
air space
Brickwork lining wrapped
with mineral wool mats
Flue gas sampling facility, if required
detail B - 7
Detail B - 4
Compensator.
DUCT
Detail B - 5
Detail B - 6
Sootdoor 1.35 x 2.00 m
Grade level
Detail B - 3
Foundation
raft or on piles
octagonal or circular

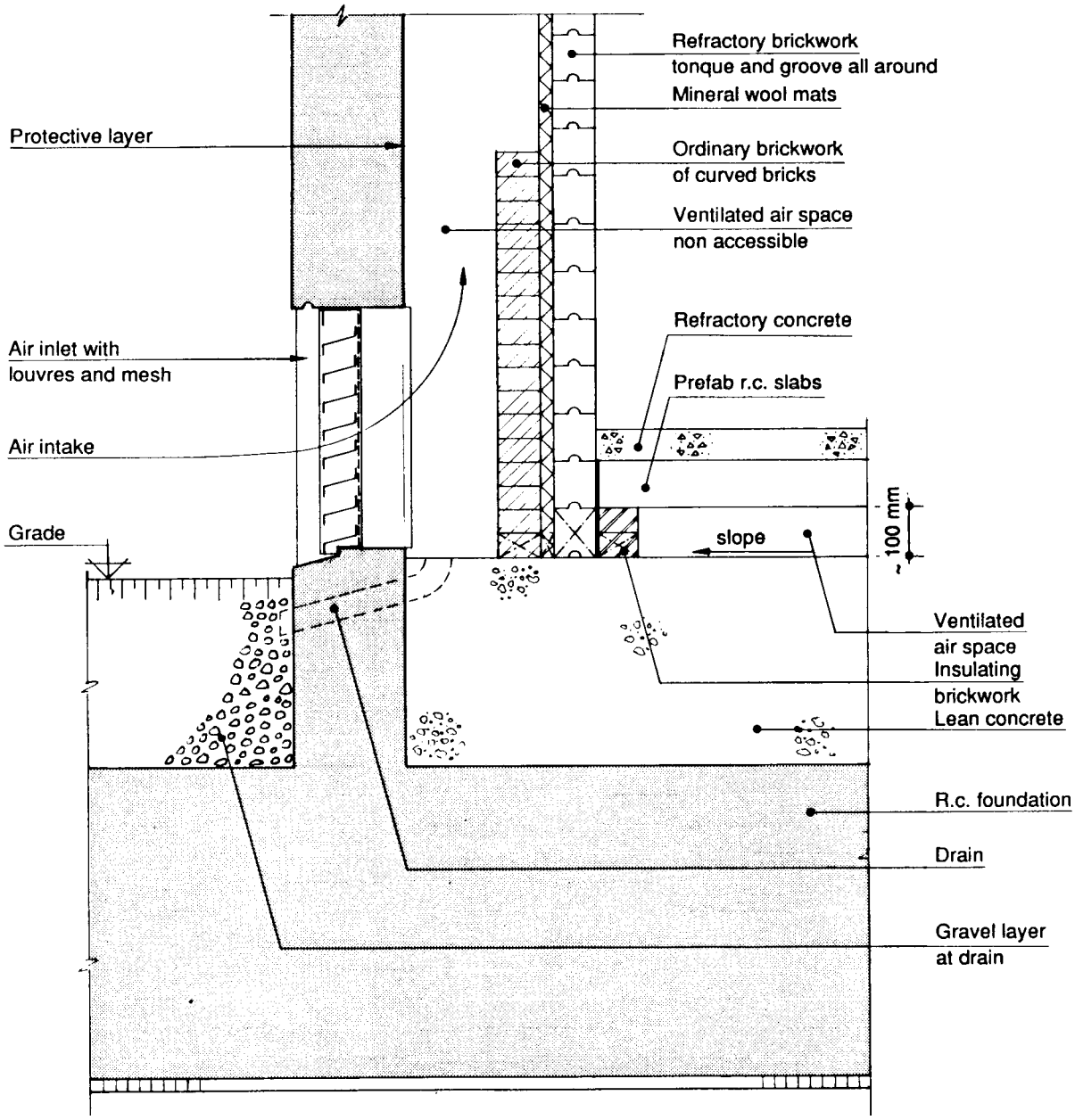
DETAIL B - 1


R.c. shaft
Compensator
Protective layer
Moler brick in cement sand mortar
P.V.C. pipes for ventilation
R.c. corbel
Mineral wool mats
Refractory brickwork
tonque and groove all around
Ventilated air space
non accessible

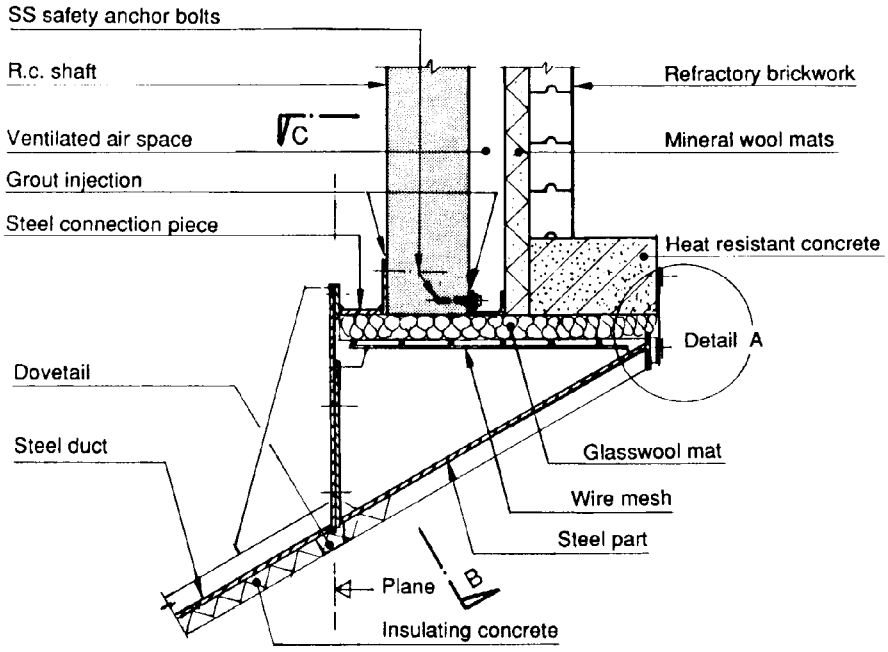
DETAIL B - 2

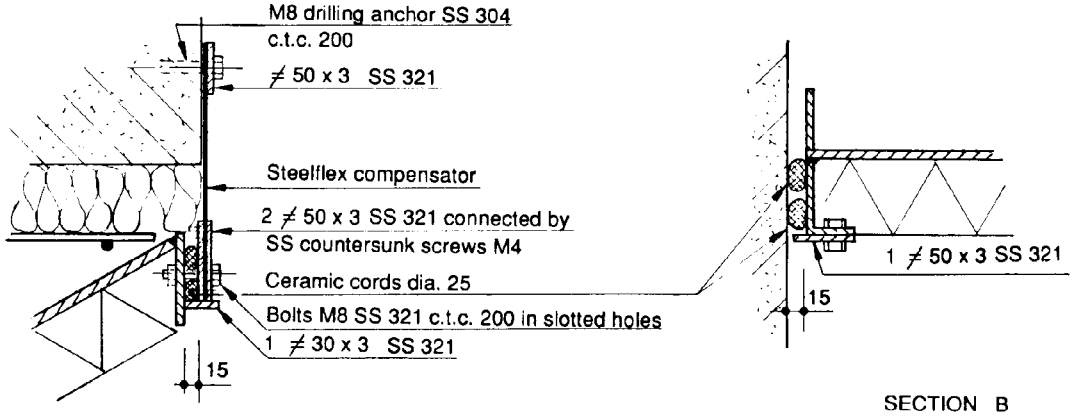

Grout
Cast iron capping 20 mm
bolted in sections
130
Mineral wool
Ceramic woollen cloth 20 mm
in 15 mm gap
Protective layer
Refractory brickwork
tonque and groove all around
Mineral wool mats
Ventilated air space
non accessible
R.c. shaft

DETAIL B - 3


Refractory brickwork
tonque and groove all around
Mineral wool mats
Protective layer
Ordinary brickwork
of curved bricks
Ventilated air space
non accessible
Refractory concrete
Air inlet with
louvres and mesh
Prefab r.c. slabs
Air intake
Grade
slope
~100 mm
Ventilated
air space
Insulating
brickwork
Lean concrete
R.c. foundation
Drain
Gravel layer
at drain

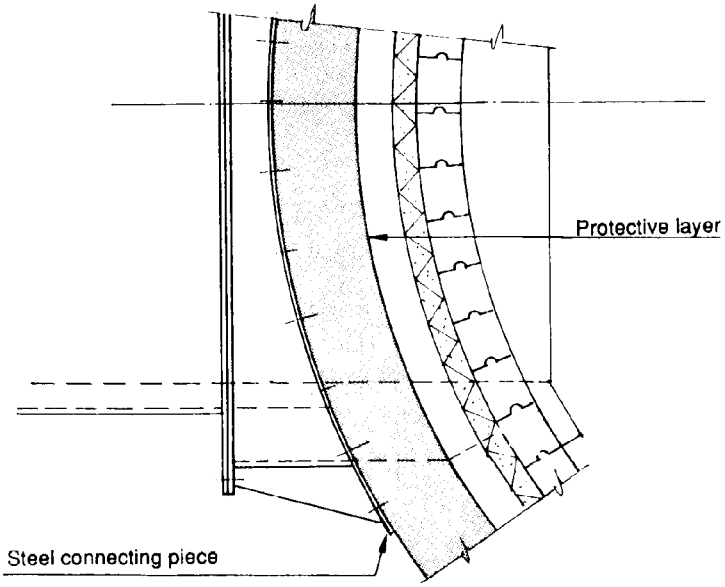
DETAIL B - 4





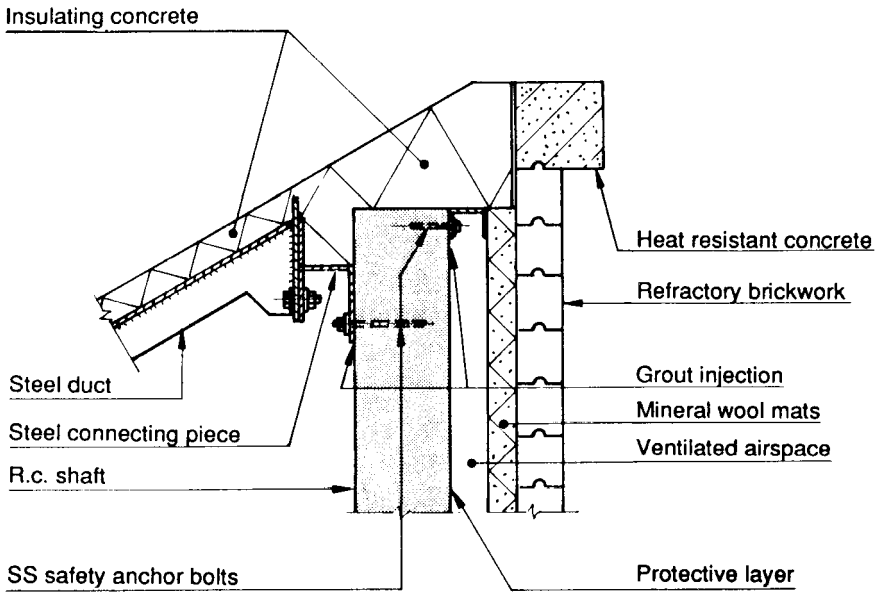
DETAIL A

SECTION B

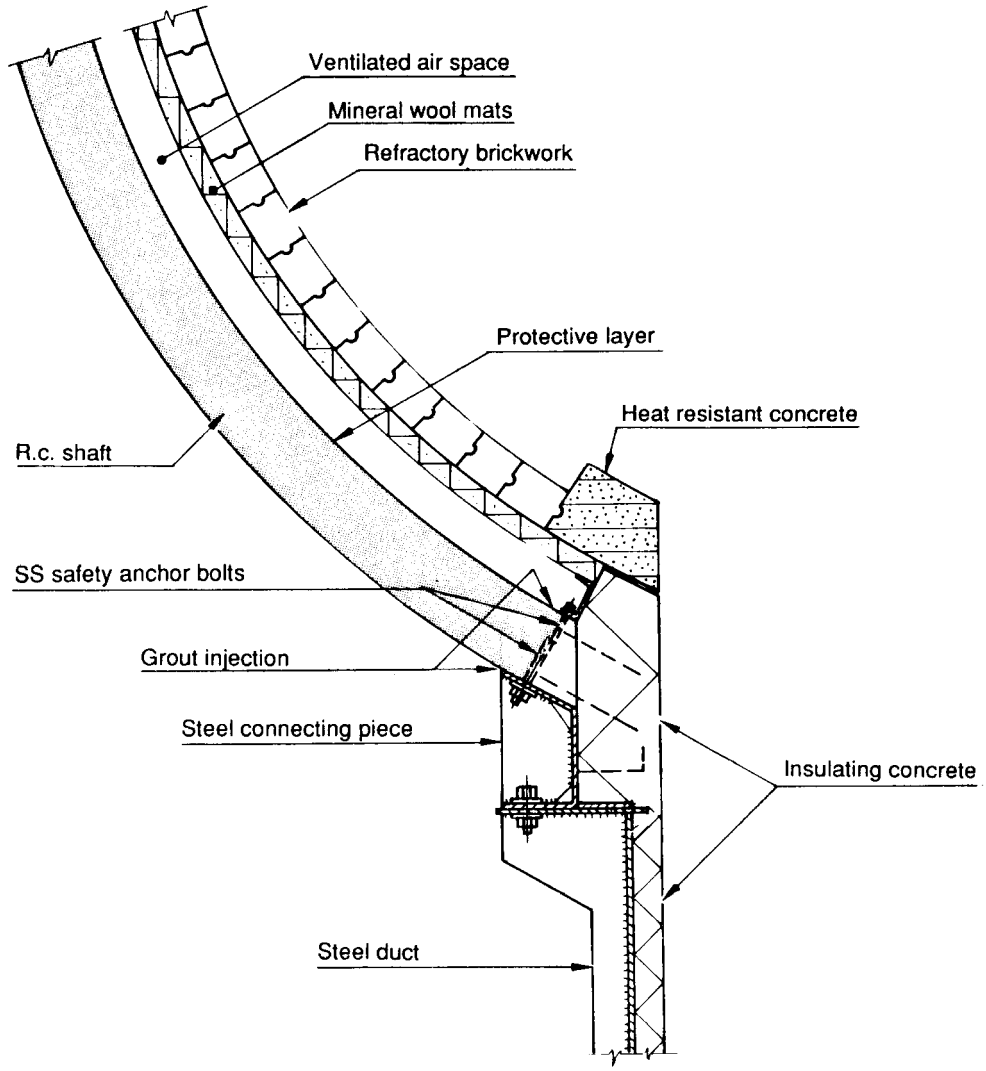


SECTION C

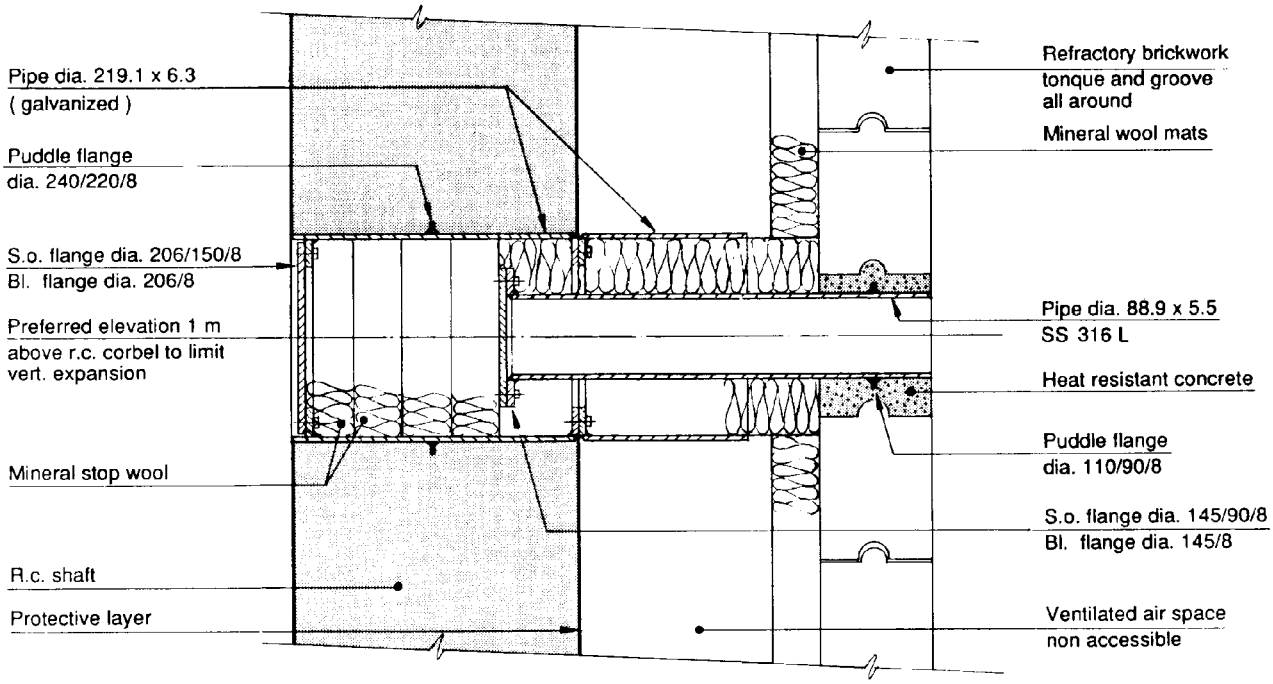
DETAIL B - 5


Insulating concrete
Heat resistant concrete
Refractory brickwork
Steel duct
Grout injection
Mineral wool mats
Steel connecting piece
Ventilated airspace
R.c. shaft
SS safety anchor bolts
Protective layer

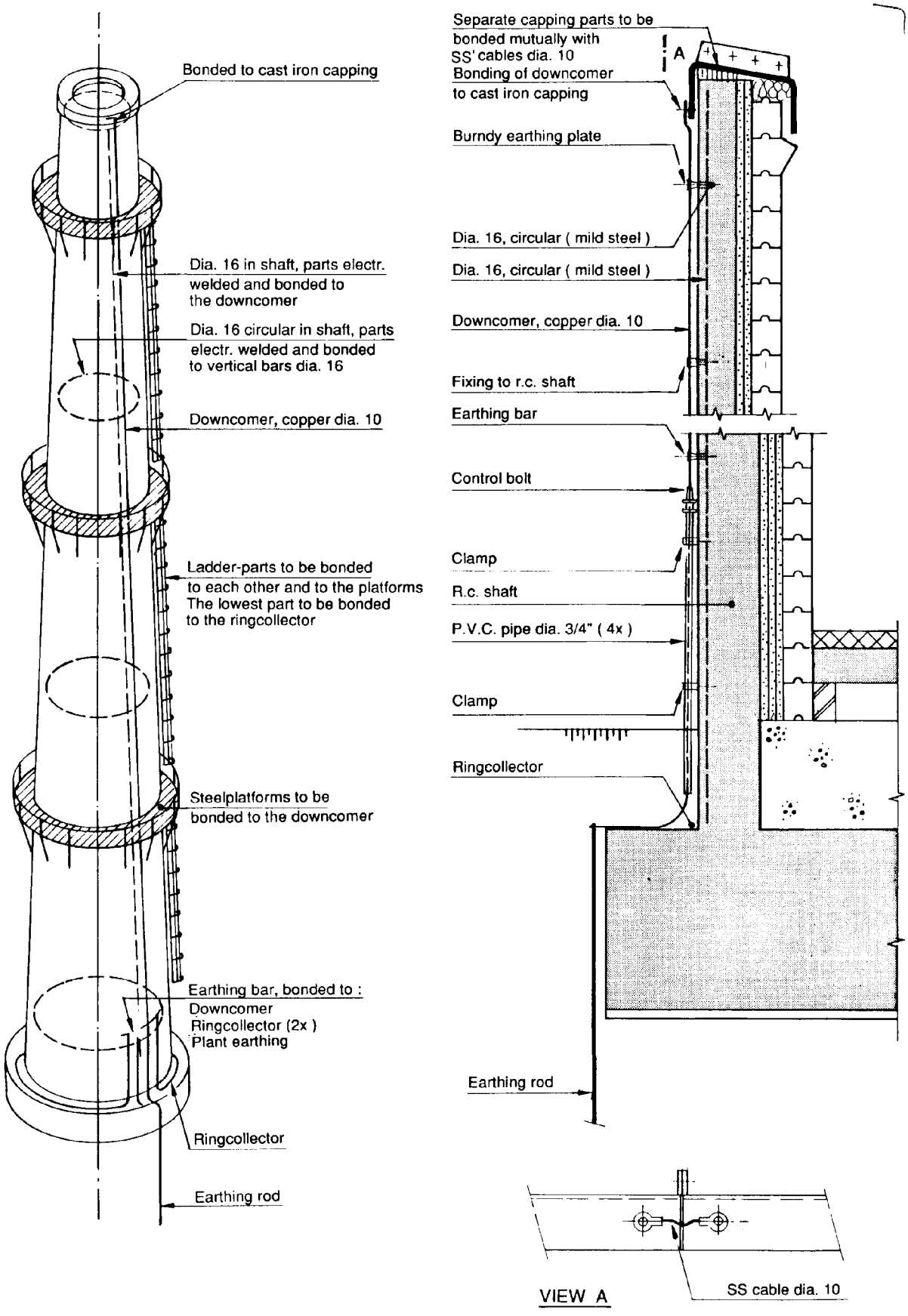
DETAIL B - 6


Ventilated air space
Mineral wool mats
Refractory brickwork
Protective layer
Heat resistant concrete
R.c. shaft
SS safety anchor bolts
Grout injection
Steel connecting piece
Insulating concrete
Steel duct

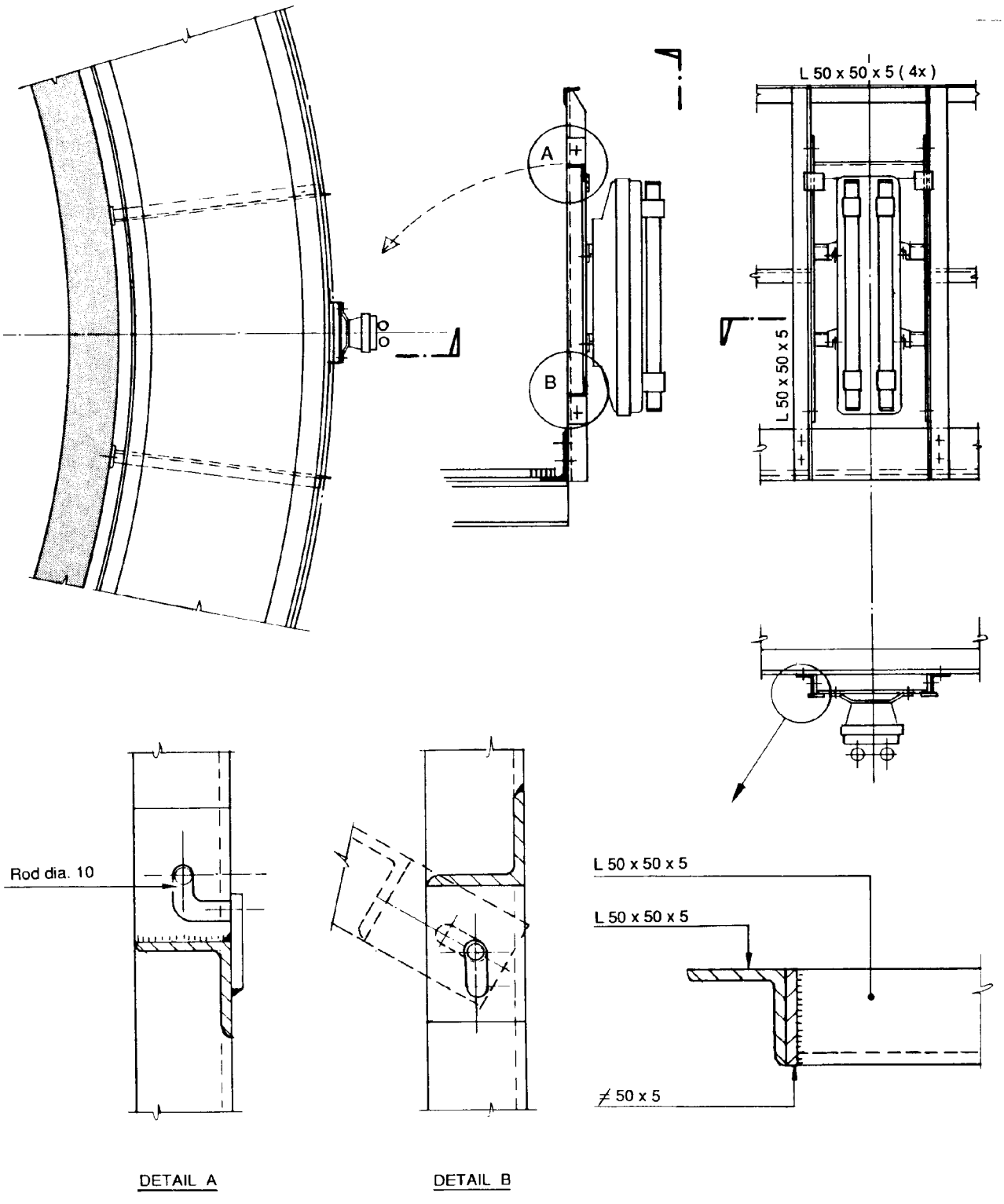
DETAIL B - 7


Pipe dia. 219.1 x 6.3
(galvanized)
Puddle flange
dia. 240/220/8
S.o. flange dia. 206/150/8
Bl. flange dia. 206/8
Preferred elevation 1 m
above r.c. corbel to limit
vert. expansion
Mineral stop wool
R.c. shaft
Protective layer
Refractory brickwork
tonque and groove
all around
Mineral wool mats
Pipe dia. 88.9 x 5.5
SS 316 L
Heat resistant concrete
Puddle flange
dia. 110/90/8
S.o. flange dia. 145/90/8
Bl. flange dia. 145/8
Ventilated air space
non accessible

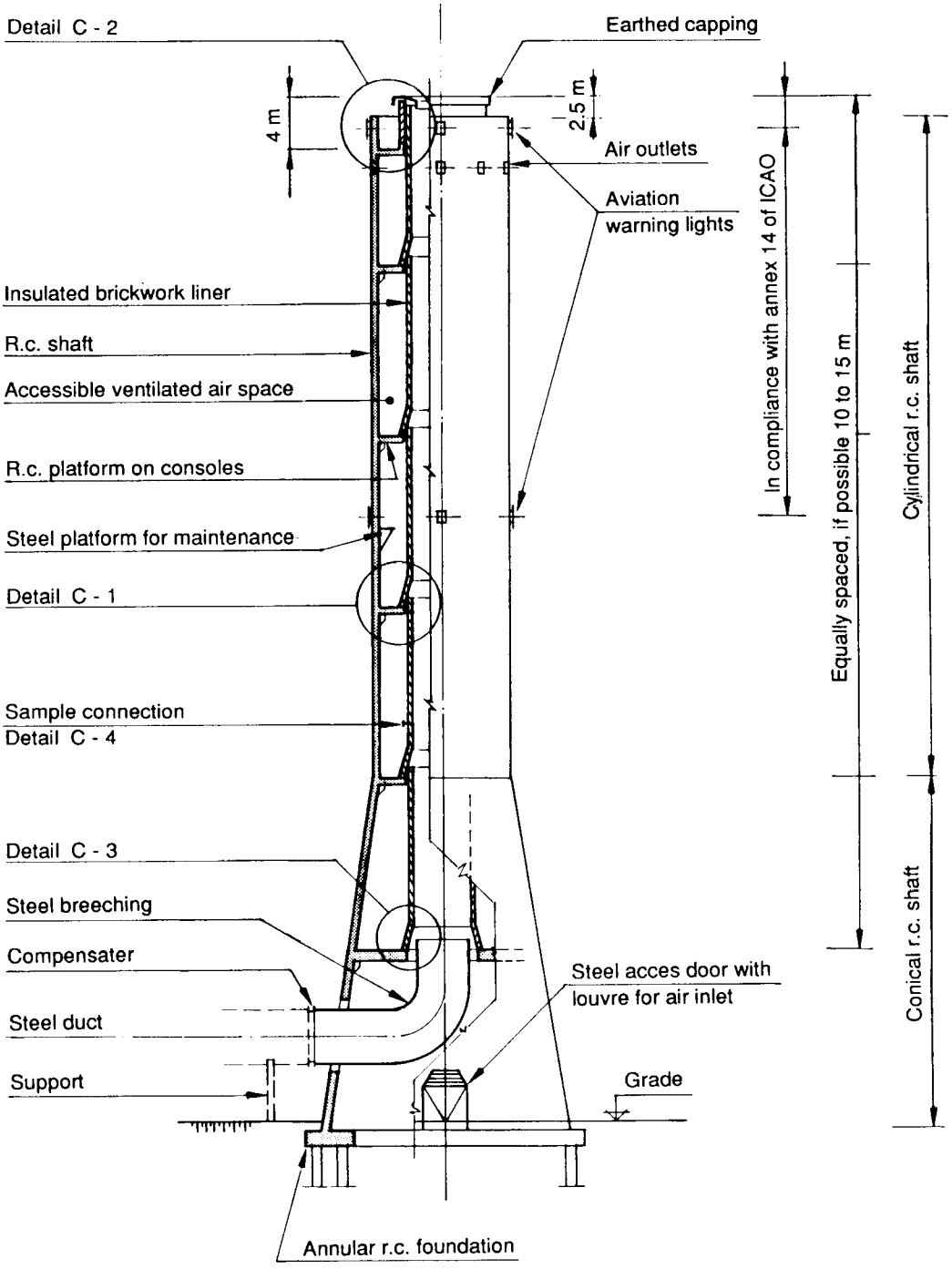
TYPICAL LIGHTNING PROTECTION SYSTEM (STACK TYPE A + B)


Bonded to cast iron capping
Dia. 16 in shaft, parts electr. welded and bonded to the downcomer
Dia. 16 circular in shaft, parts electr. welded and bonded to vertical bars dia. 16
Downcomer, copper dia. 10
Ladder-parts to be bonded to each other and to the platforms The lowest part to be bonded to the ringcollector
Steelplatforms to be bonded to the downcomer
Earthing bar, bonded to : Downcomer Ringcollector (2x) Plant earthing
Ringcollector
Earthing rod
Separate capping parts to be bonded mutually with SS' cables dia. 10
Bonding of downcomer to cast iron capping
Burndy earthing plate
Dia. 16, circular (mild steel)
Dia. 16, circular (mild steel)
Downcomer, copper dia. 10
Fixing to r.c. shaft
Earthing bar
Control bolt
Clamp
R.c. shaft
P.V.C. pipe dia. 3/4" (4x)
Clamp
Ringcollector
Earthing rod
A
VIEW A
SS cable dia. 10

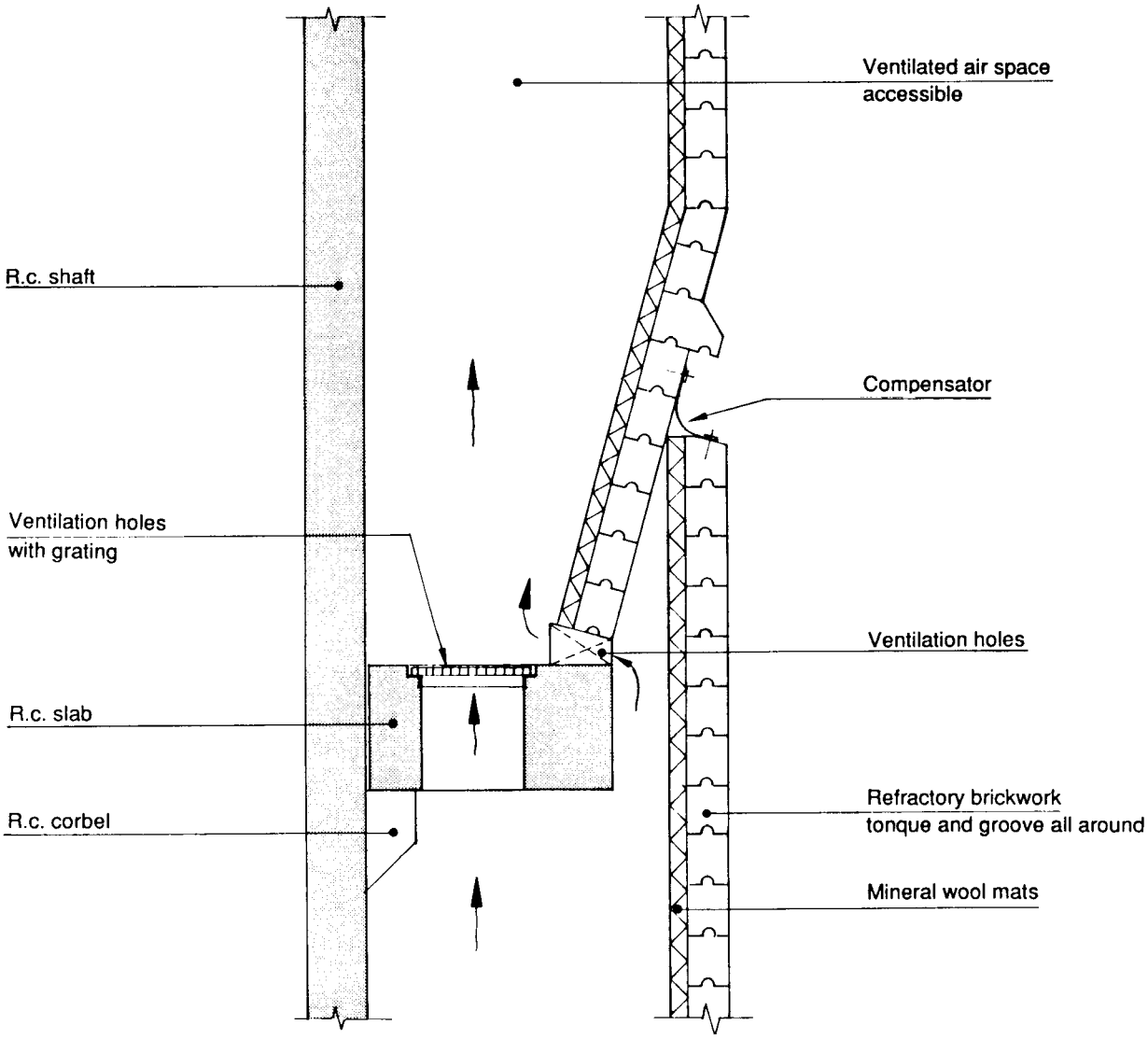
CONNECTION OF AVIATION WARNING LIGHTS (STACK TYPE A + B)


A
B
L 50 x 50 x 5 (4x)
L 50 x 50 x 5
Rod dia. 10
L 50 x 50 x 5
L 50 x 50 x 5
≠ 50 x 5
DETAIL A
DETAIL B

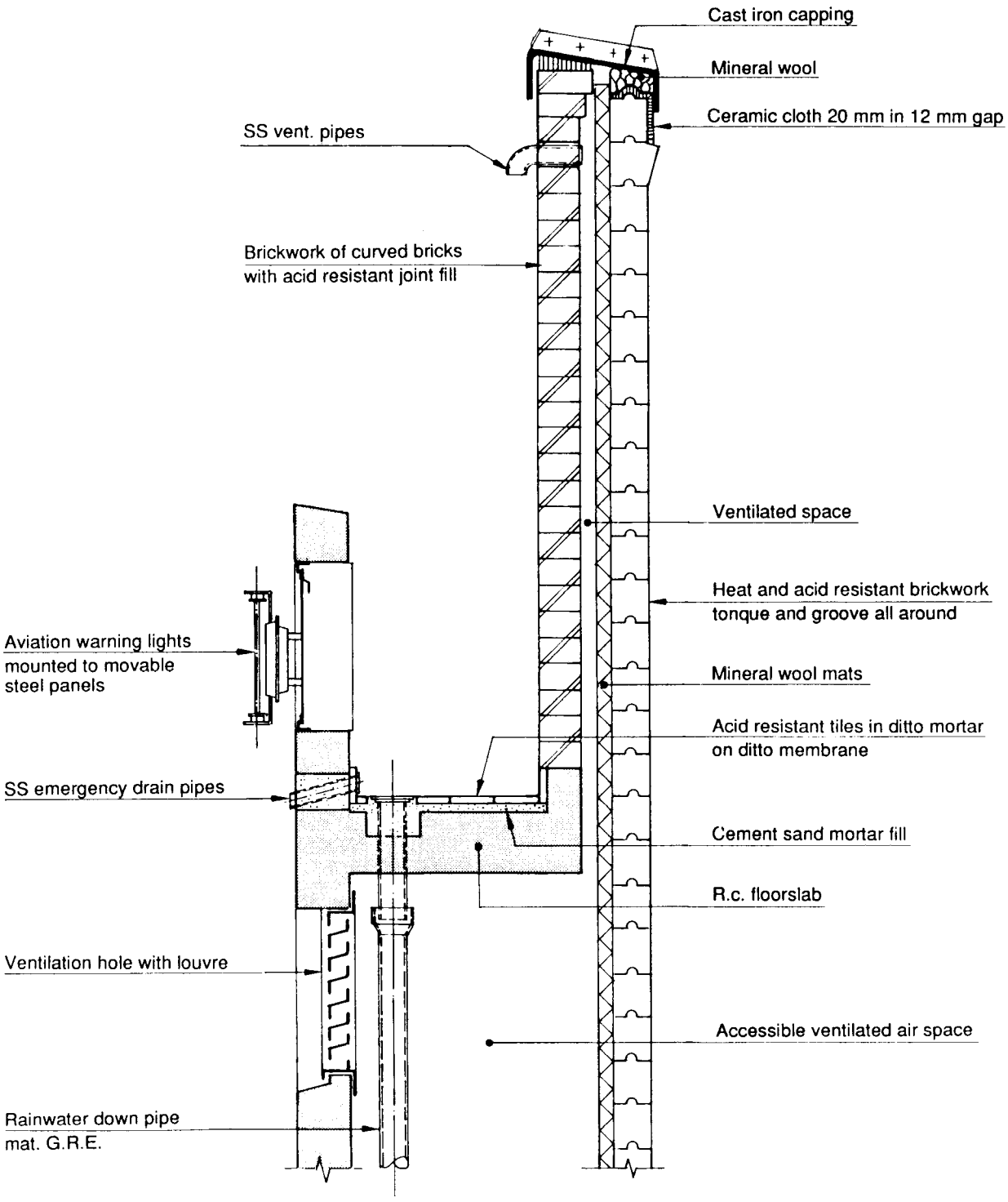
STACK TYPE - C TYPICAL ARRANGEMENT


Detail C - 2
Earthed capping
4 m
2.5 m
Air outlets
Aviation warning lights
In compliance with annex 14 of ICAO
Insulated brickwork liner
R.c. shaft
Accessible ventilated air space
R.c. platform on consoles
Steel platform for maintenance
Detail C - 1
Equally spaced, if possible 10 to 15 m
Cylindrical r.c. shaft
Sample connection
Detail C - 4
Detail C - 3
Steel breeching
Compensater
Steel acces door with louvre for air inlet
Steel duct
Support
Grade
Conical r.c. shaft
Annular r.c. foundation

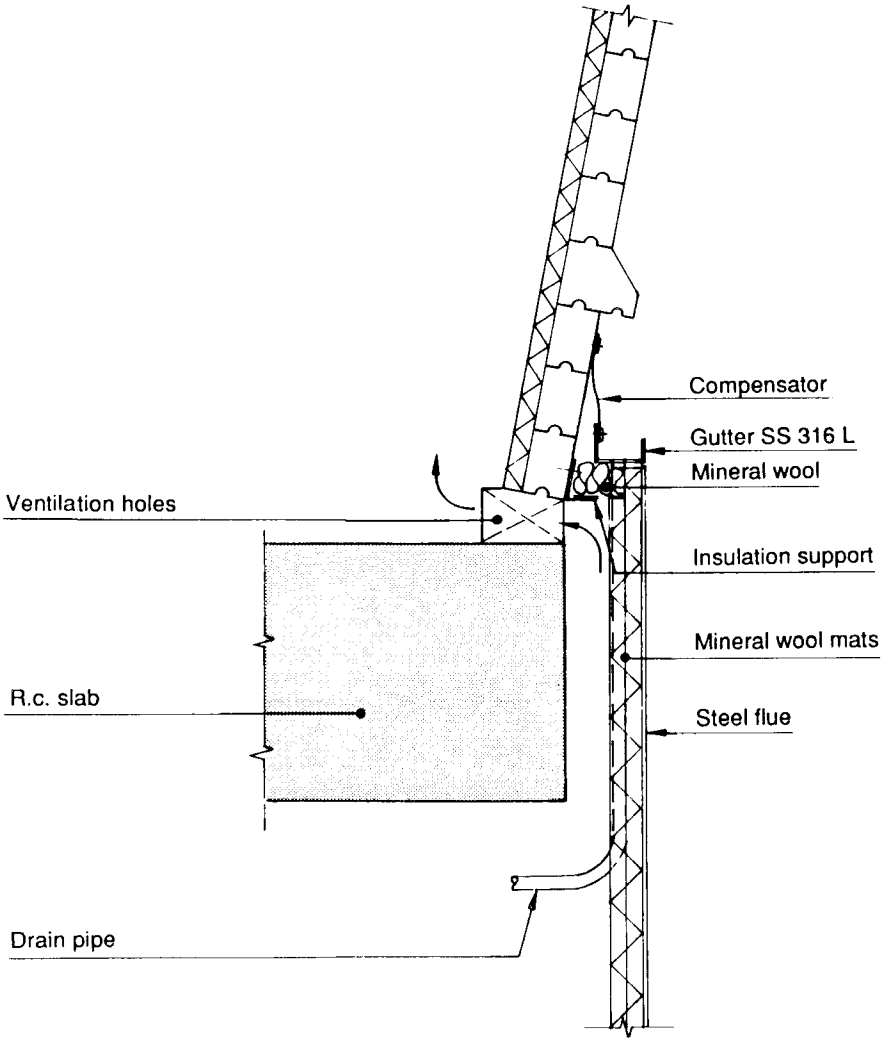
DETAIL C - 1


Ventilated air space
accessible
R.c. shaft
Compensator
Ventilation holes
with grating
Ventilation holes
R.c. slab
Refractory brickwork
tonque and groove all around
R.c. corbel
Mineral wool mats

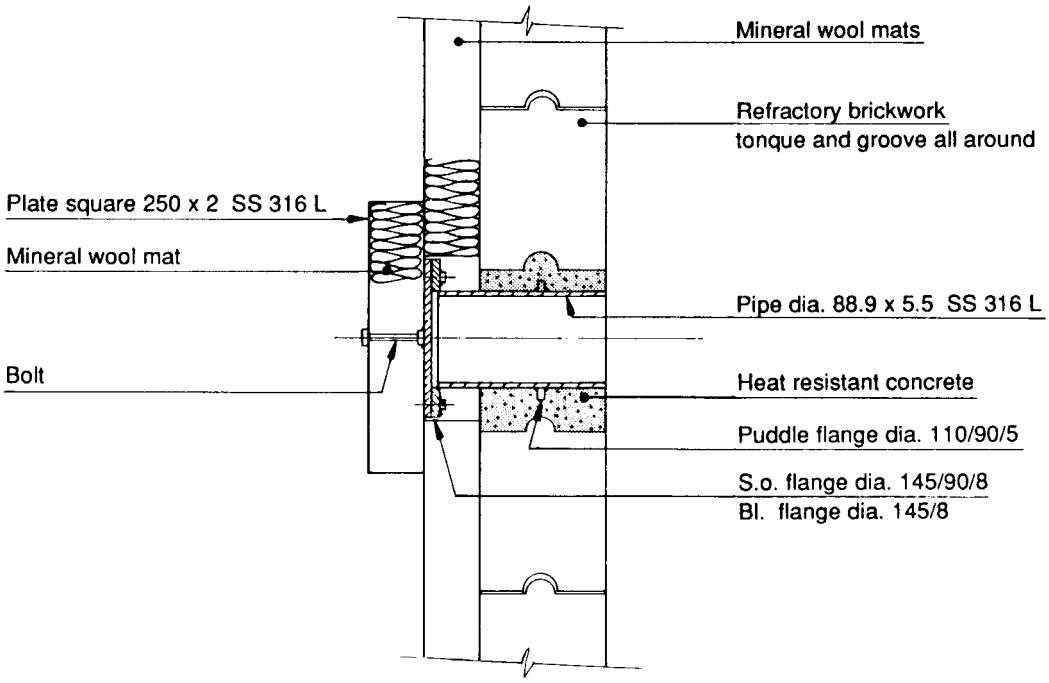
DETAIL C - 2


Cast iron capping
Mineral wool
Ceramic cloth 20 mm in 12 mm gap
SS vent. pipes
Brickwork of curved bricks
with acid resistant joint fill
Ventilated space
Heat and acid resistant brickwork
tonque and groove all around
Aviation warning lights
mounted to movable
steel panels
Mineral wool mats
Acid resistant tiles in ditto mortar
on ditto membrane
SS emergency drain pipes
Cement sand mortar fill
R.c. floorslab
Ventilation hole with louvre
Accessible ventilated air space
Rainwater down pipe
mat. G.R.E.

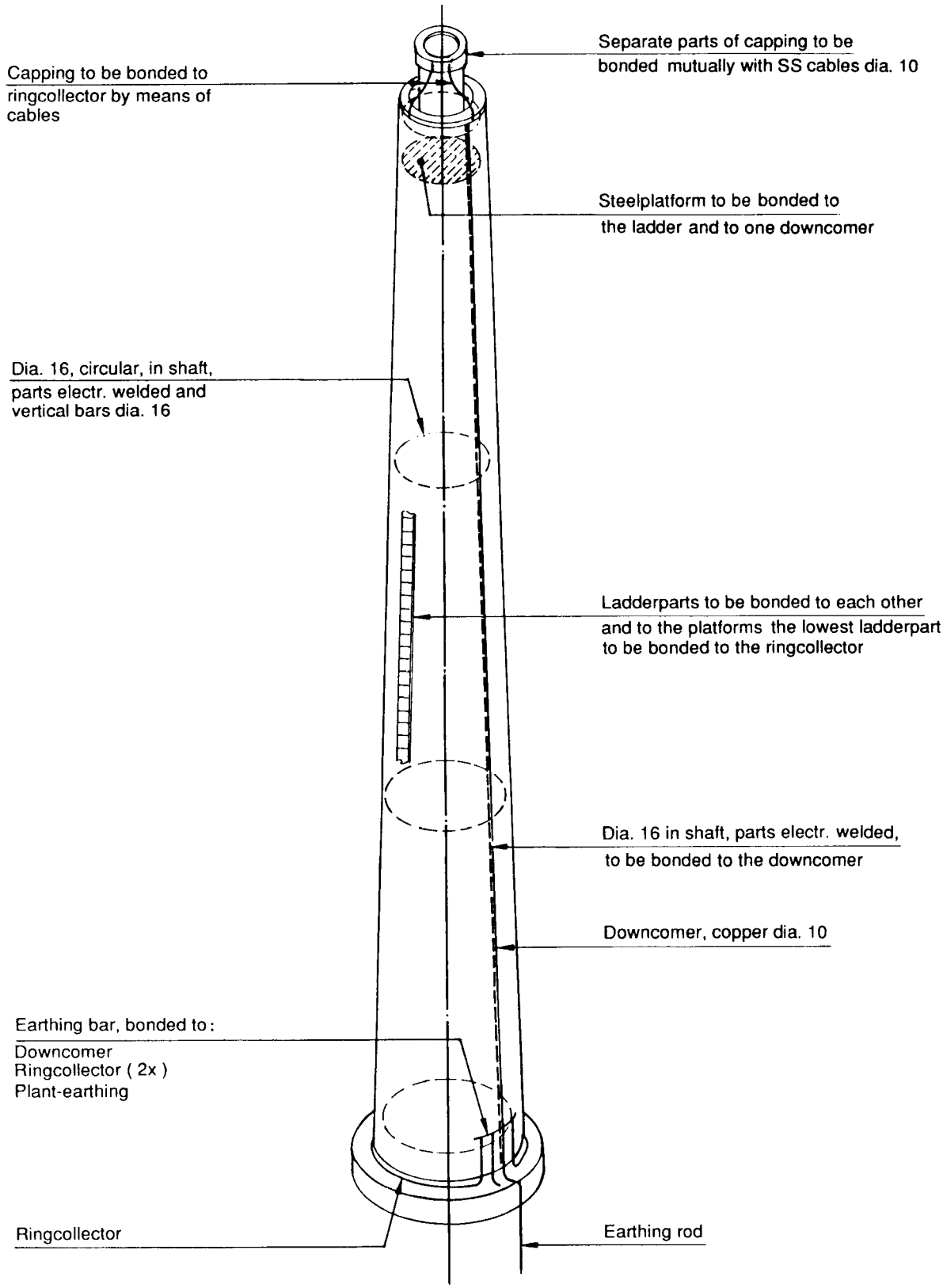
DETAIL C - 3


Compensator
Gutter SS 316 L
Mineral wool
Ventilation holes
Insulation support
Mineral wool mats
R.c. slab
Steel flue
Drain pipe

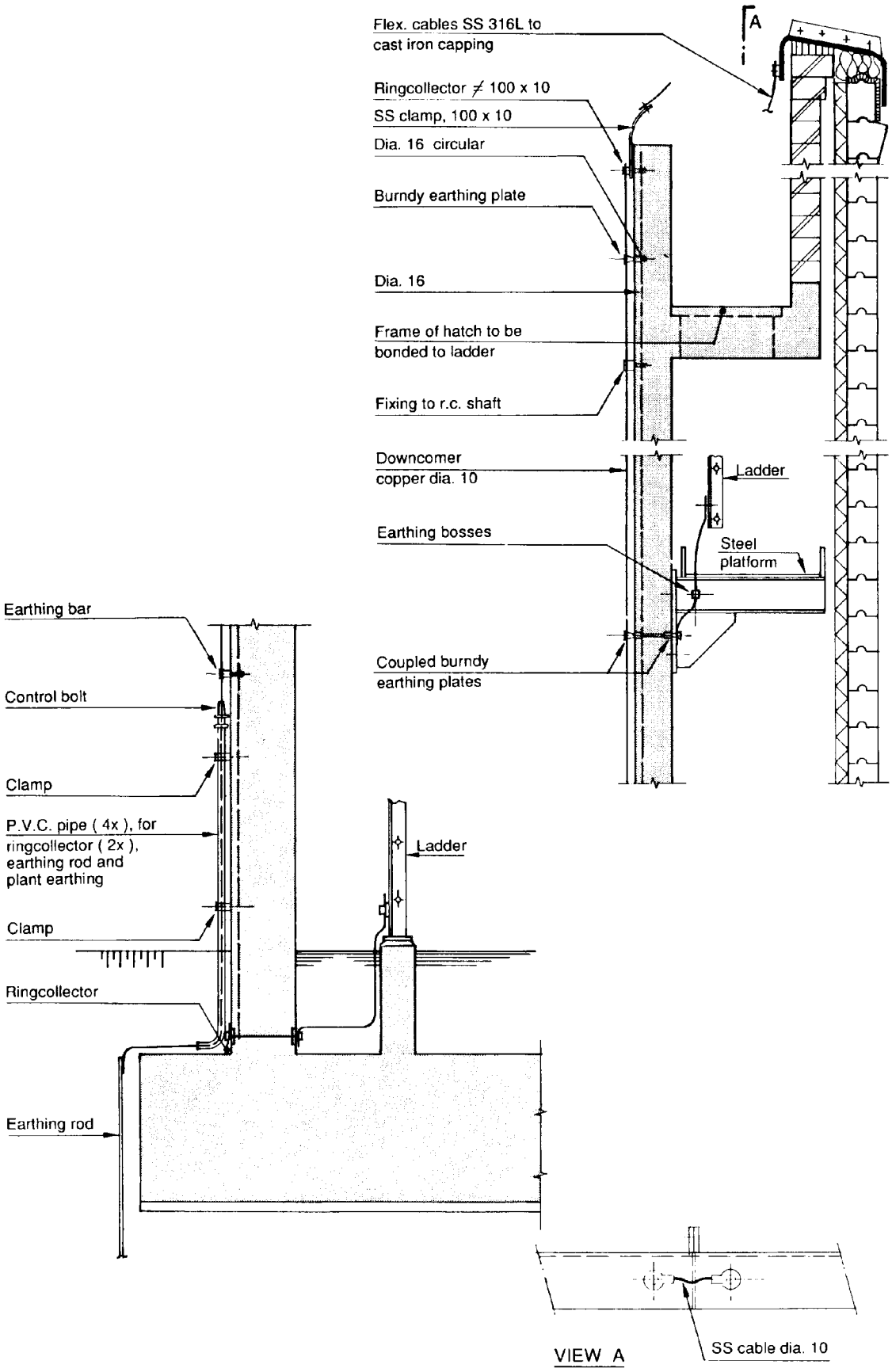
DETAIL C - 4


Mineral wool mats
Refractory brickwork
tonque and groove all around
Plate square 250 x 2 SS 316 L
Mineral wool mat
Pipe dia. 88.9 x 5.5 SS 316 L
Bolt
Heat resistant concrete
Puddle flange dia. 110/90/5
S.o. flange dia. 145/90/8
Bl. flange dia. 145/8

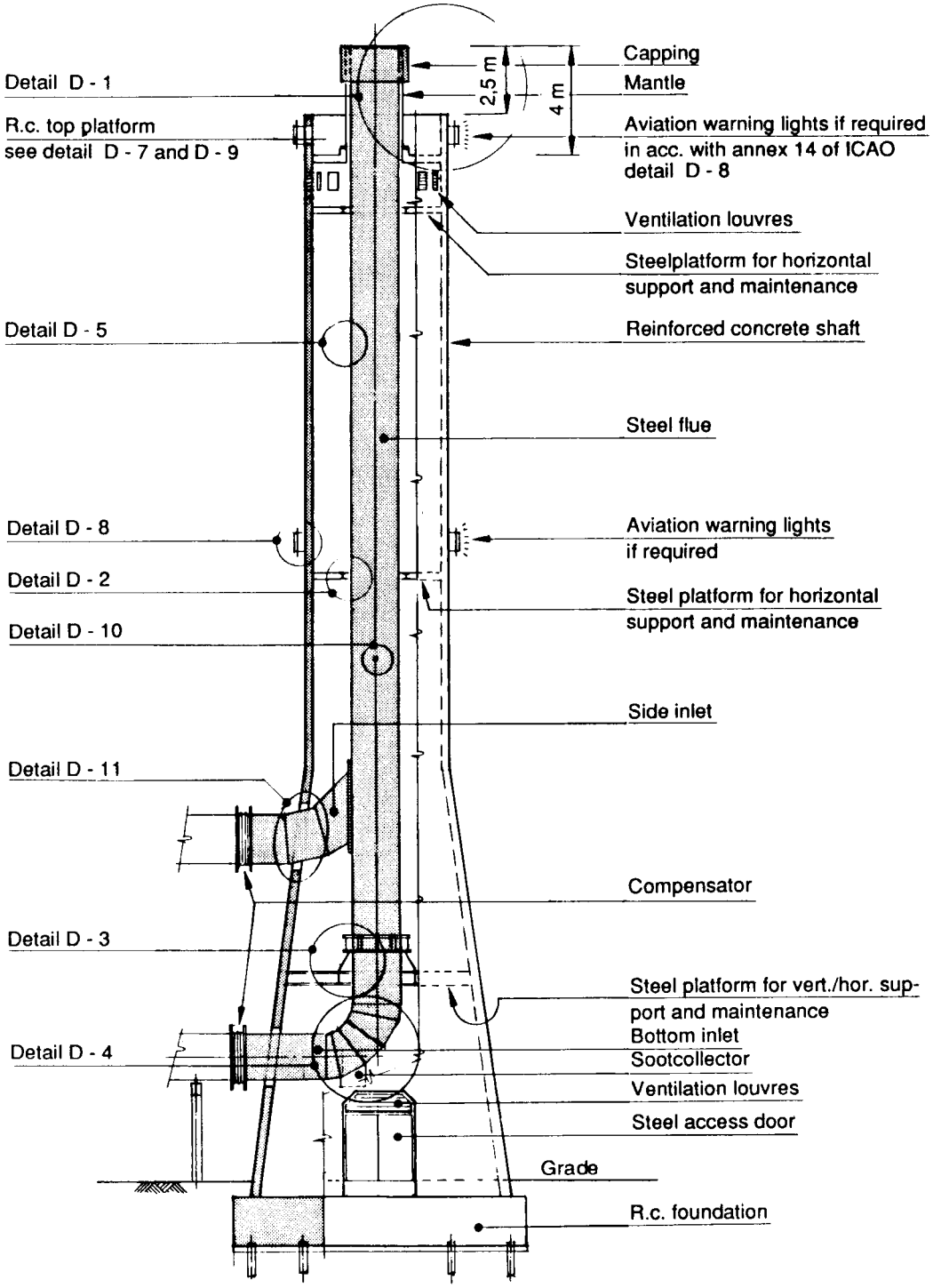
TYPICAL LIGHTNING PROTECTION SYSTEM (STACK TYPE C)


Separate parts of capping to be bonded mutually with SS cables dia. 10
Capping to be bonded to ringcollector by means of cables
Steelplatform to be bonded to the ladder and to one downcomer
Dia. 16, circular, in shaft, parts electr. welded and vertical bars dia. 16
Ladderparts to be bonded to each other and to the platforms the lowest ladderpart to be bonded to the ringcollector
Dia. 16 in shaft, parts electr. welded, to be bonded to the downcomer
Downcomer, copper dia. 10
Earthing bar, bonded to:
Downcomer
Ringcollector (2x)
Plant-earthing
Ringcollector
Earthing rod

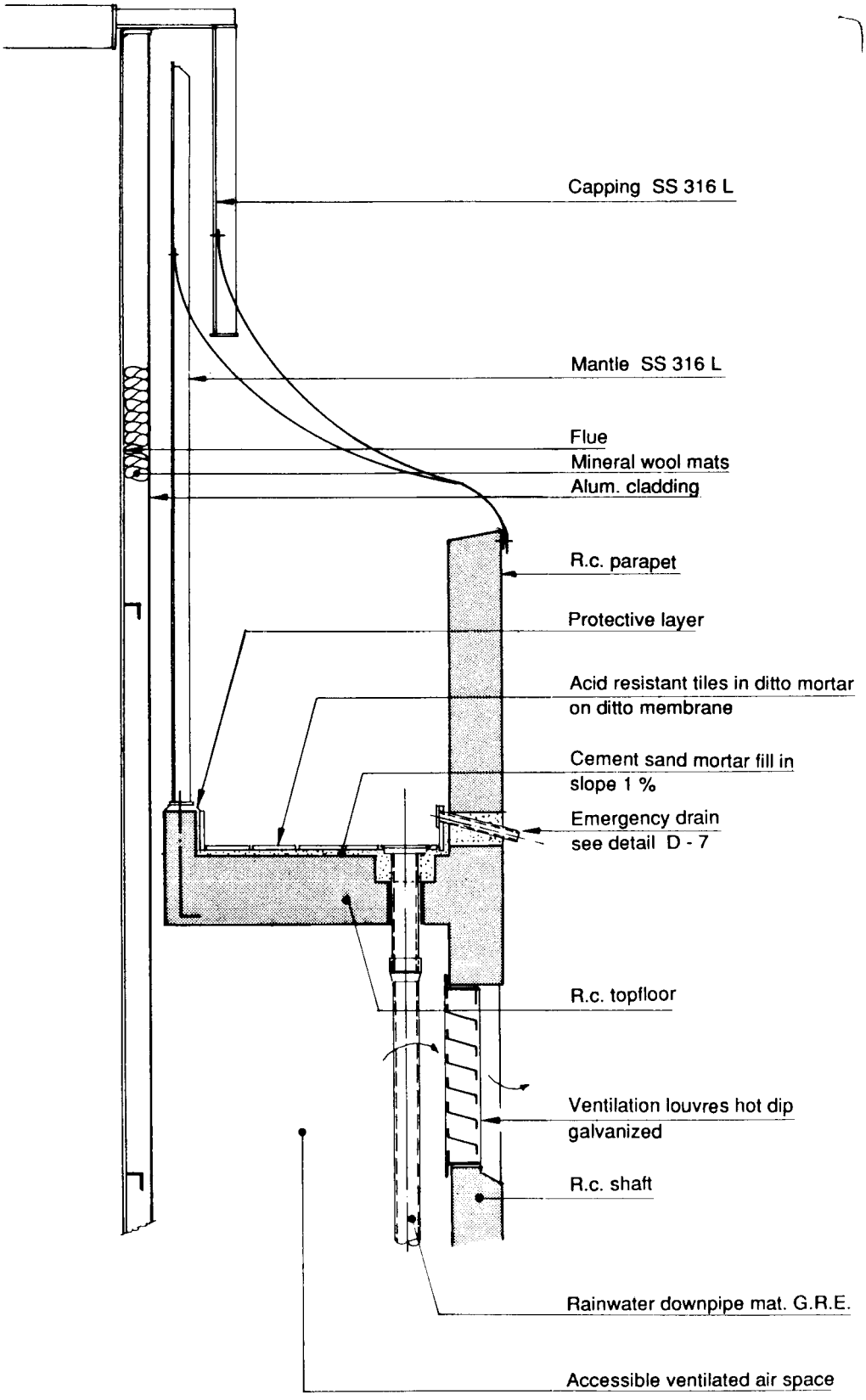
TYPICAL LIGHTNING PROTECTION SYSTEM TOP - AND BASE DATAIL (STACK TYPE C)


Flex. cables SS 316L to cast iron capping
A
Ringcollector ≠ 100 x 10
SS clamp, 100 x 10
Dia. 16 circular
Burndy earthing plate
Dia. 16
Frame of hatch to be bonded to ladder
Fixing to r.c. shaft
Downcomer copper dia. 10
Ladder
Earthing bosses
Steel platform
Earthing bar
Coupled burndy earthing plates
Control bolt
Clamp
P.V.C. pipe (4x), for ringcollector (2x), earthing rod and plant earthing
Ladder
Clamp
Ringcollector
Earthing rod
SS cable dia. 10
VIEW A

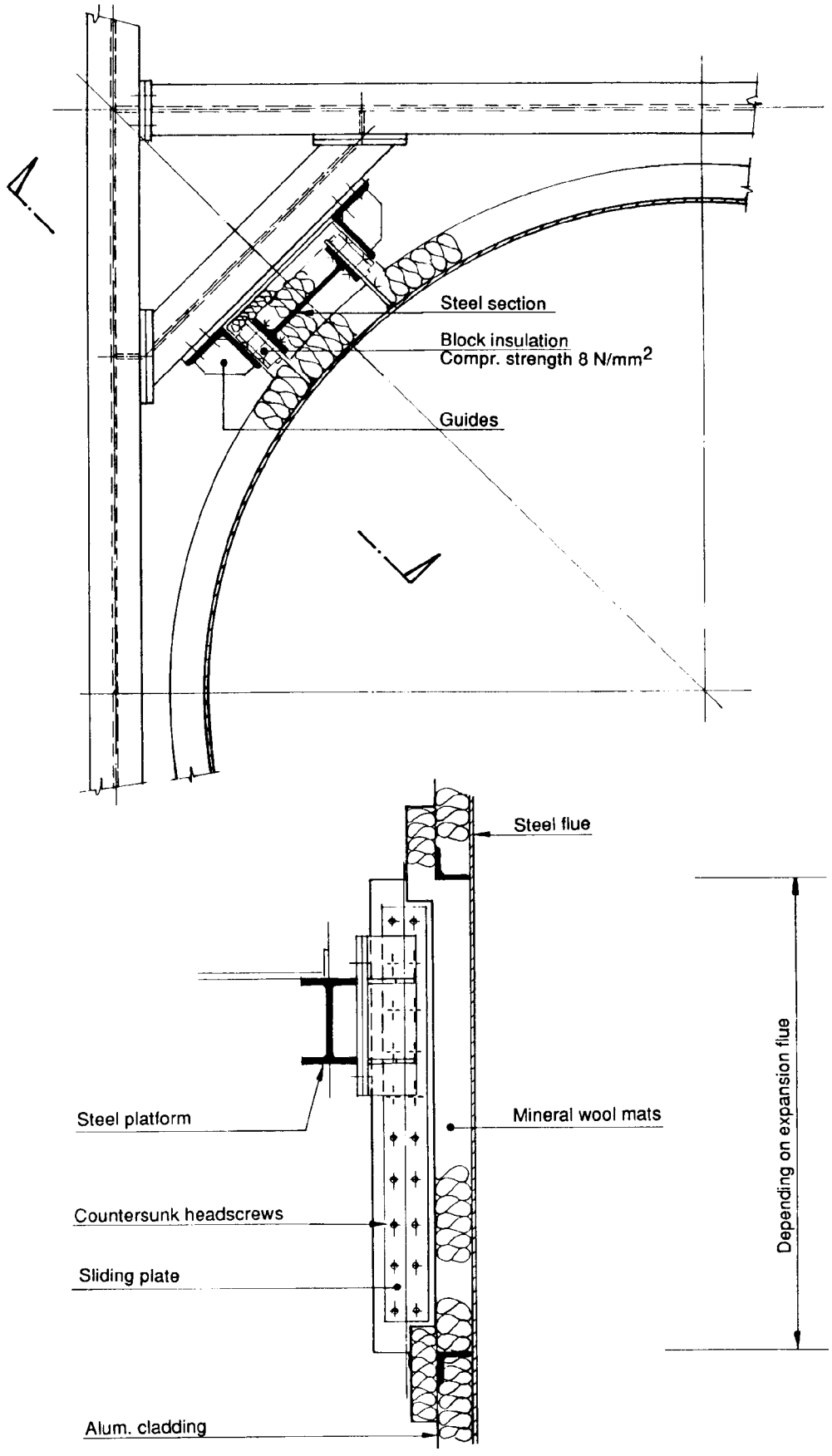
STACK TYPE D - TYPICAL ARRANGEMENT


Detail D - 1
R.c. top platform
see detail D - 7 and D - 9
Detail D - 5
Detail D - 8
Detail D - 2
Detail D - 10
Detail D - 11
Detail D - 3
Detail D - 4
2,5 m
4 m
Capping
Mantle
Aviation warning lights if required
in acc. with annex 14 of ICAO
detail D - 8
Ventilation louvres
Steelplatform for horizontal
support and maintenance
Reinforced concrete shaft
Steel flue
Aviation warning lights
if required
Steel platform for horizontal
support and maintenance
Side inlet
Compensator
Steel platform for vert./hor. sup-
port and maintenance
Bottom inlet
Sootcollector
Ventilation louvres
Steel access door
Grade
R.c. foundation

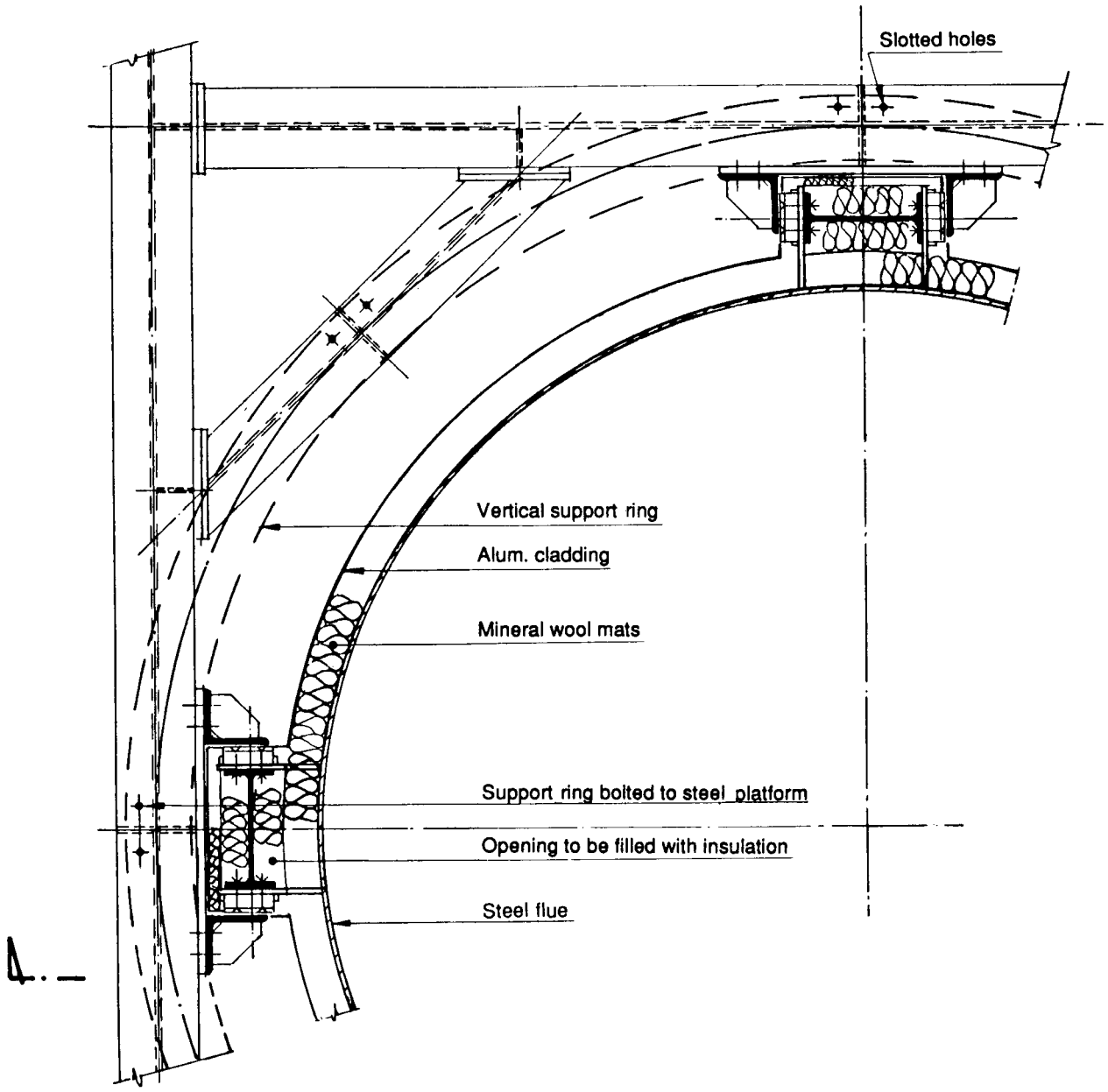
DETAIL D - 1


Capping SS 316 L
Mantle SS 316 L
Flue
Mineral wool mats
Alum. cladding
R.c. parapet
Protective layer
Acid resistant tiles in ditto mortar
on ditto membrane
Cement sand mortar fill in
slope 1 %
Emergency drain
see detail D - 7
R.c. topfloor
Ventilation louvres hot dip
galvanized
R.c. shaft
Rainwater downpipe mat. G.R.E.
Accessible ventilated air space

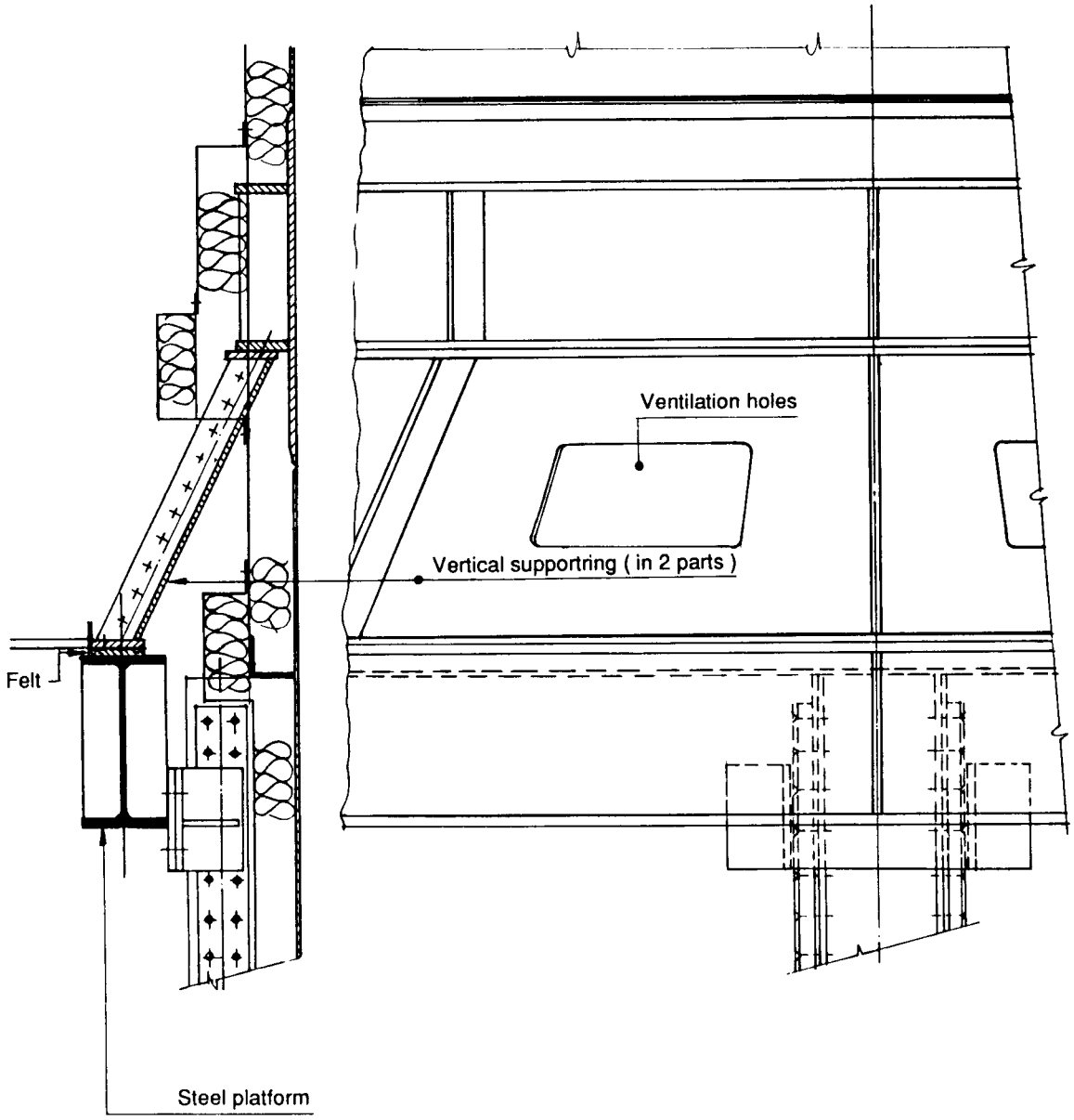
DETAIL D - 2


Steel section
Block insulation
Compr. strength 8 N/mm2
Guides
Steel flue
Steel platform
Mineral wool mats
Countersunk headscrews
Sliding plate
Alum. cladding
Depending on expansion flue

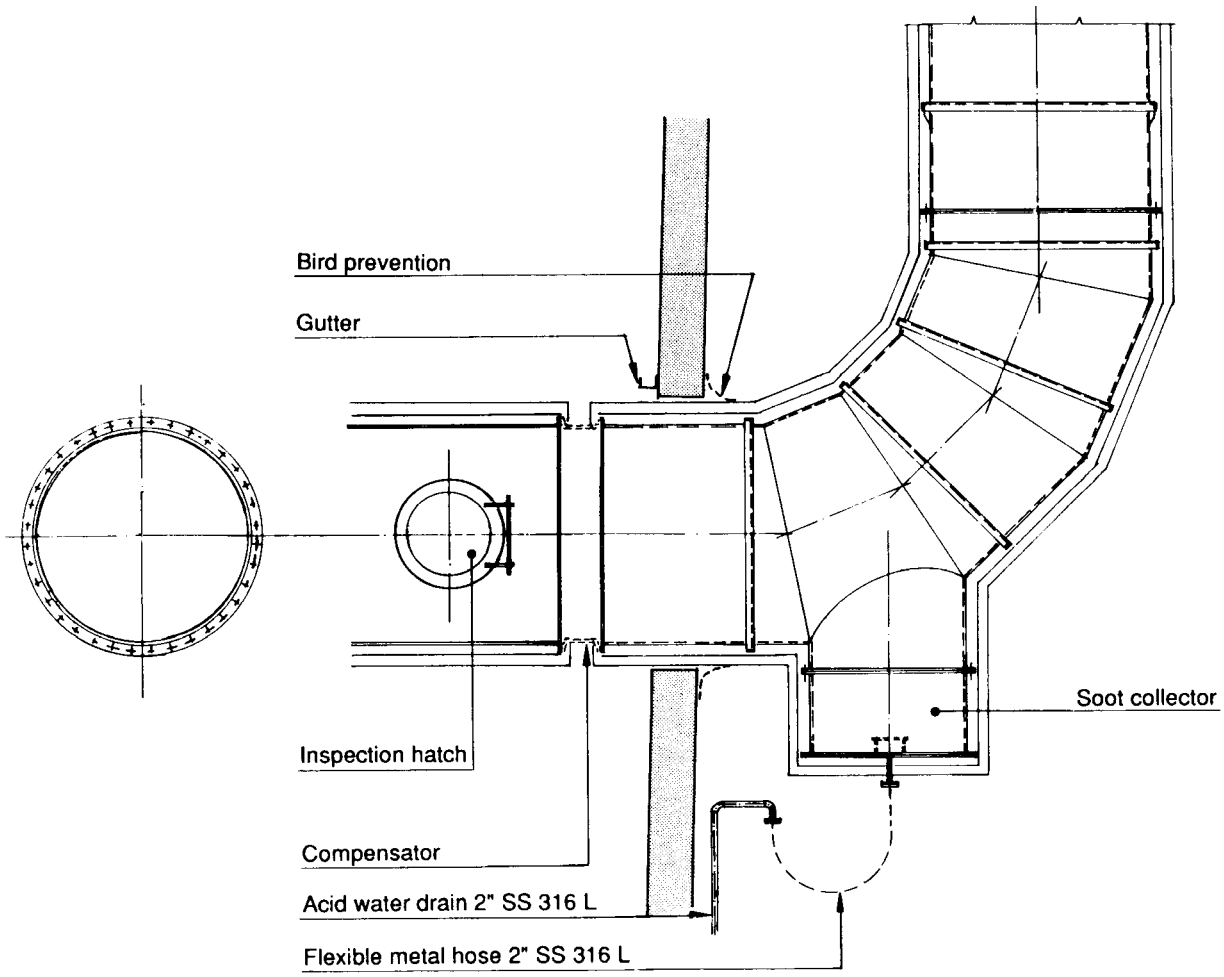
DETAIL D - 3a


Slotted holes
Vertical support ring
Alum. cladding
Mineral wool mats
Support ring bolted to steel platform
Opening to be filled with insulation
Steel flue

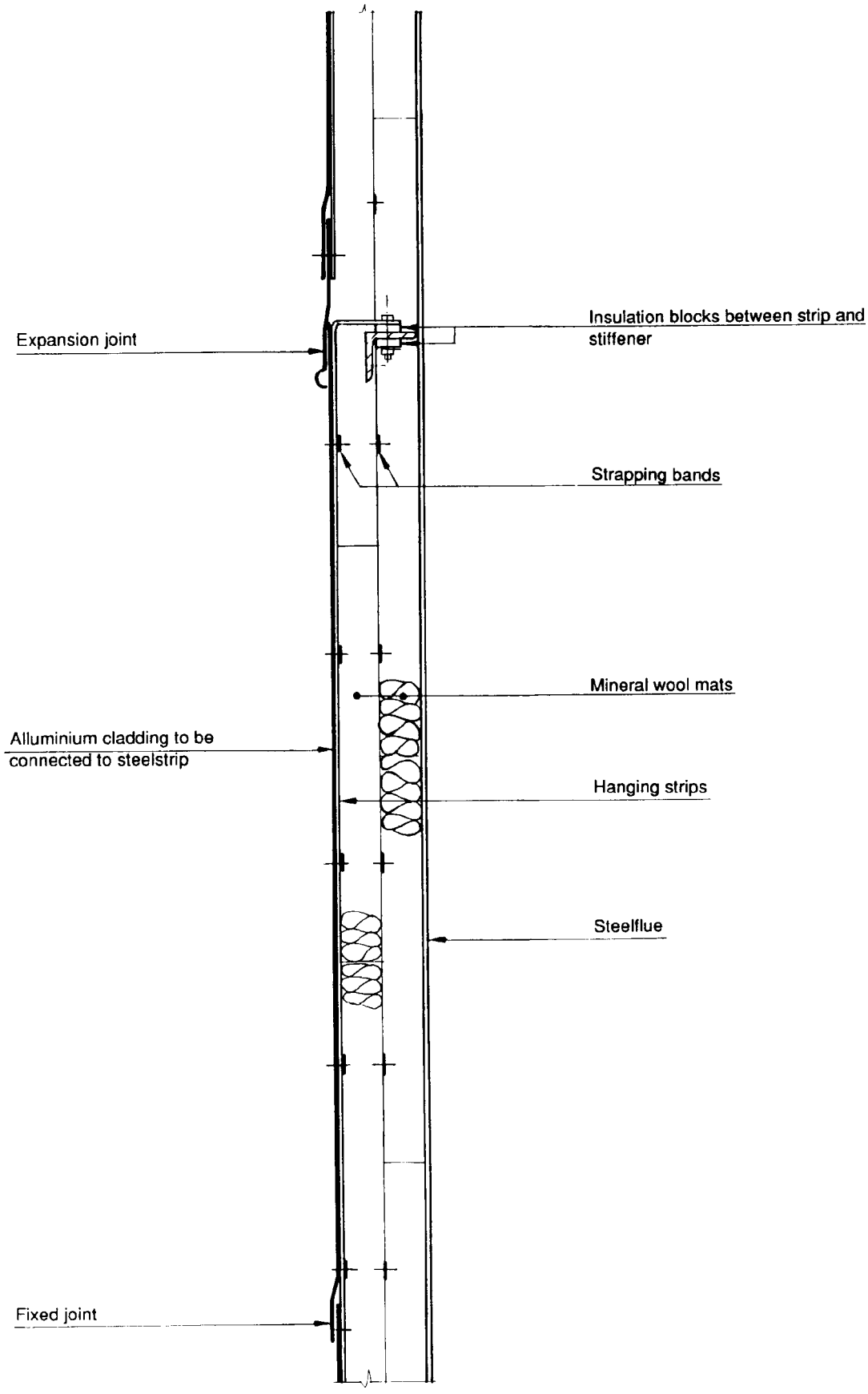
DETAIL D - 3b


Ventilation holes
Vertical supportring (in 2 parts)
Felt
Steel platform

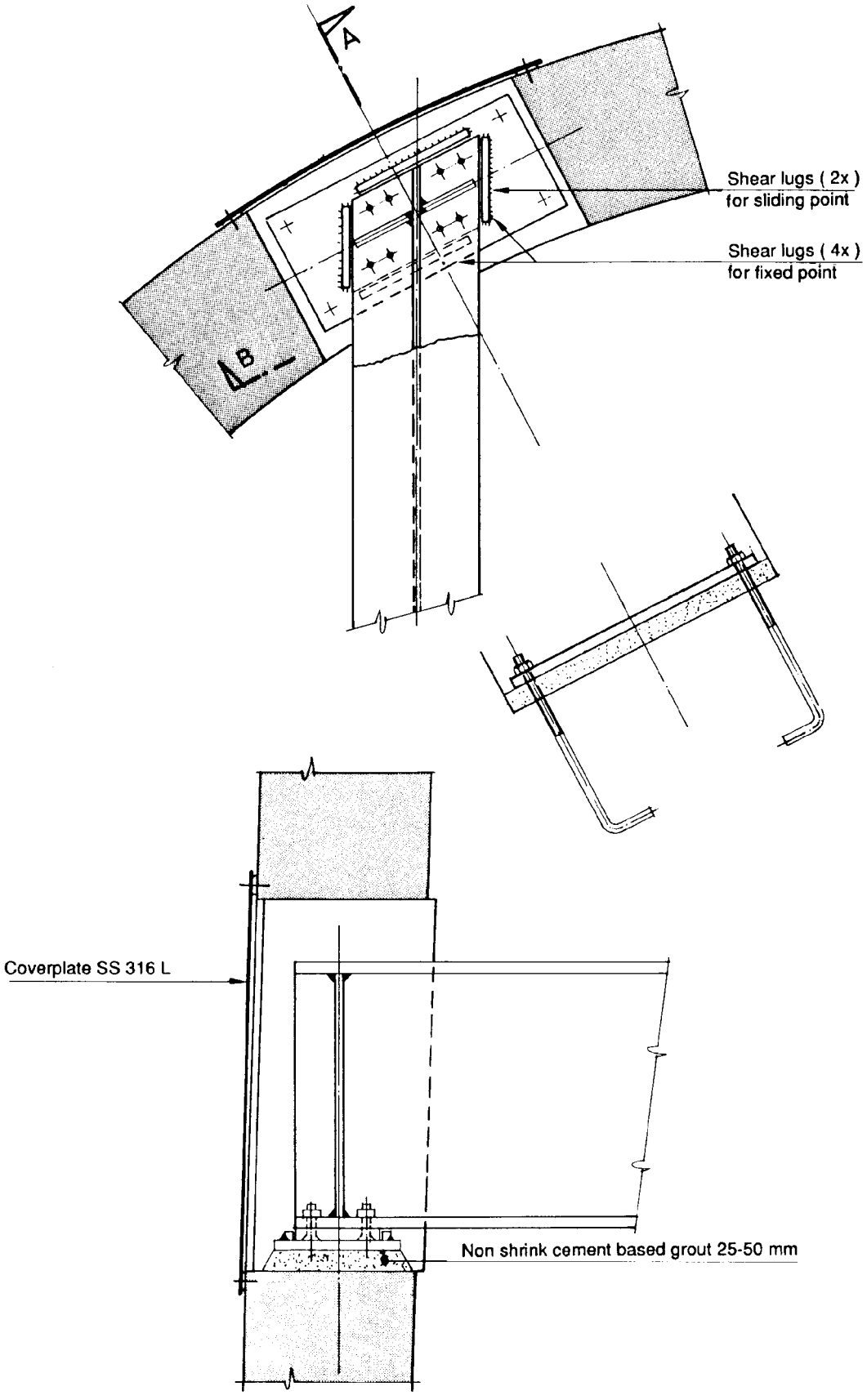
DETAIL D - 4


Bird prevention
Gutter
Soot collector
Inspection hatch
Compensator
Acid water drain 2" SS 316 L
Flexible metal hose 2" SS 316 L

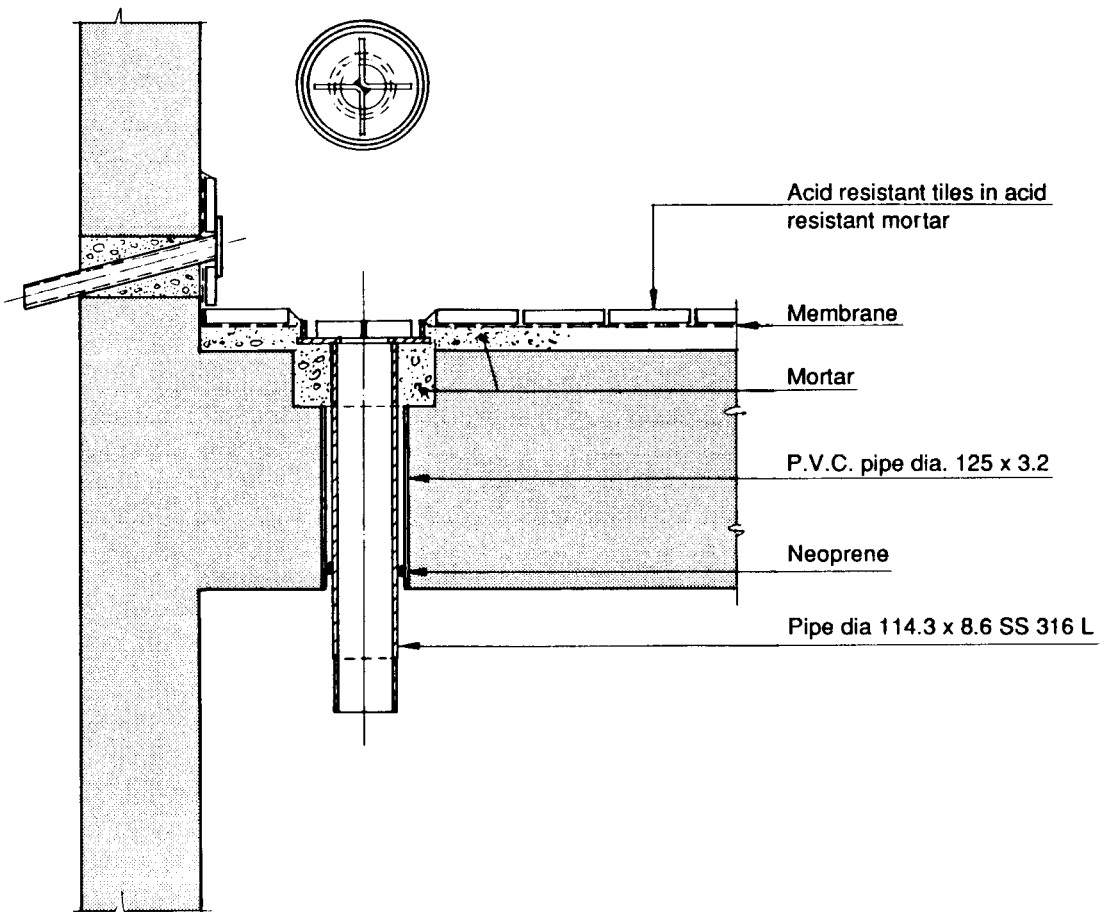
DETAIL D - 5


Insulation blocks between strip and stiffener
Expansion joint
Strapping bands
Mineral wool mats
Alluminium cladding to be connected to steelstrip
Hanging strips
Steelflue
Fixed joint

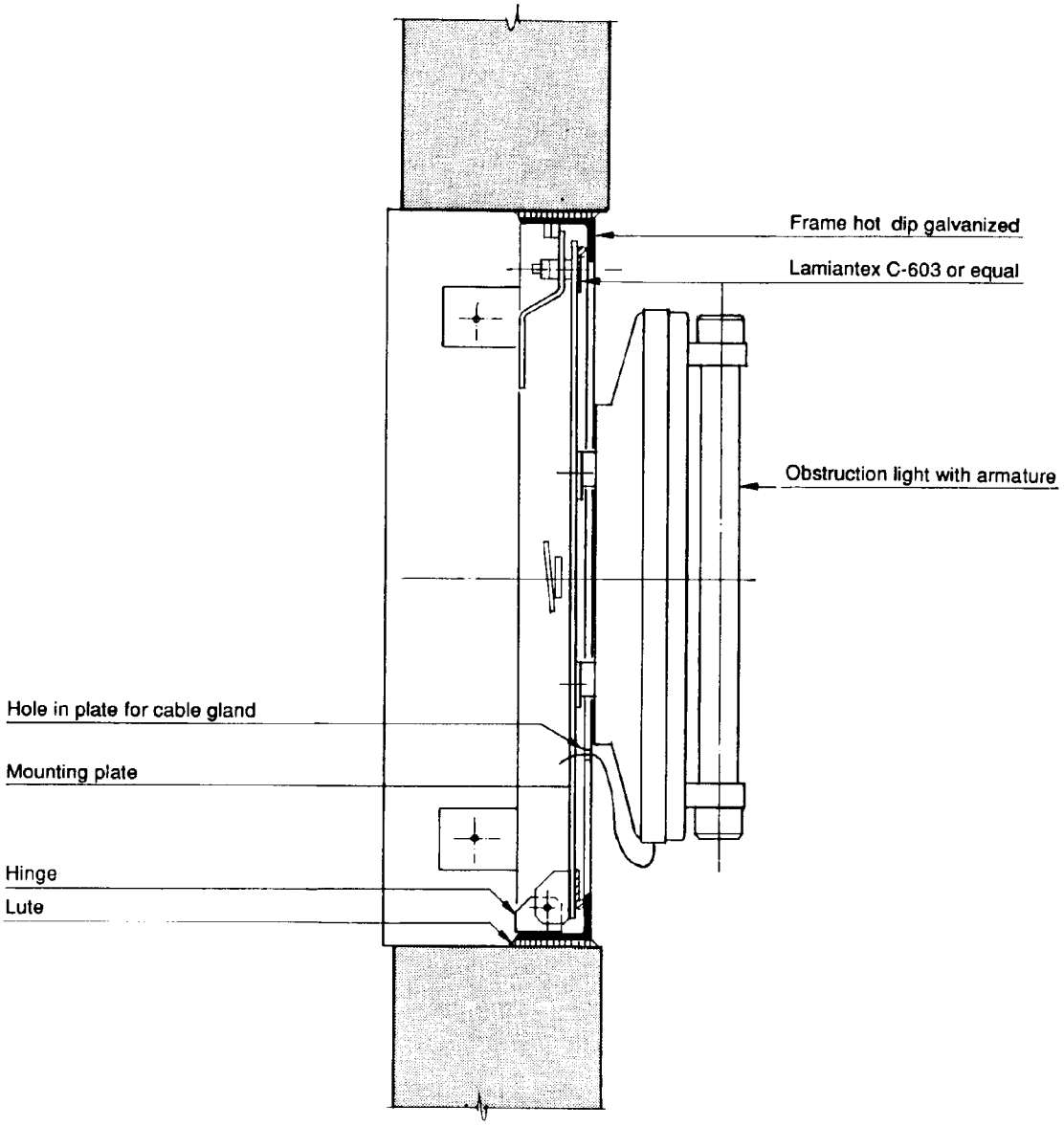
DETAIL D - 6

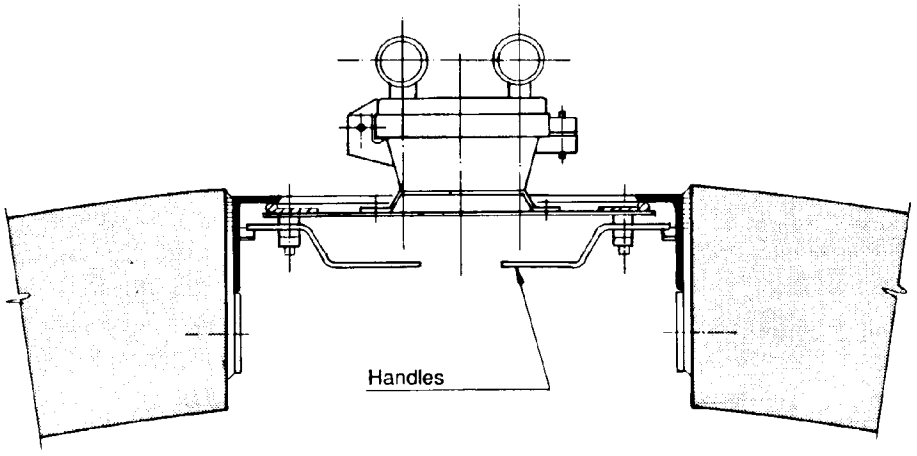

A
B
Shear lugs (2x)
for sliding point
Shear lugs (4x)
for fixed point
Coverplate SS 316 L
Non shrink cement based grout 25-50 mm

DETAIL D - 7

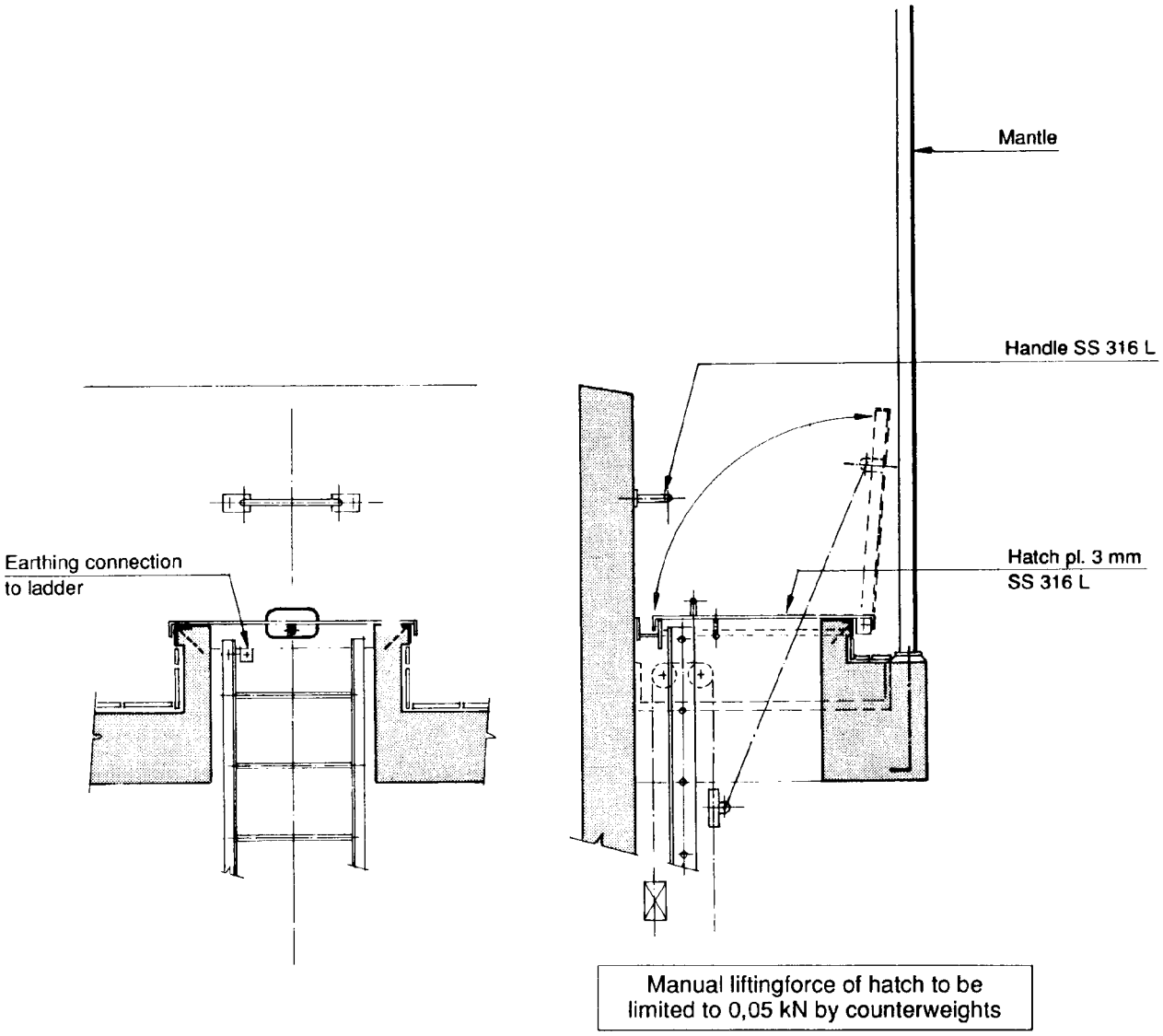

Acid resistant tiles in acid resistant mortar
Membrane
Mortar
P.V.C. pipe dia. 125 x 3.2
Neoprene
Pipe dia 114.3 x 8.6 SS 316 L

DETAIL D - 8

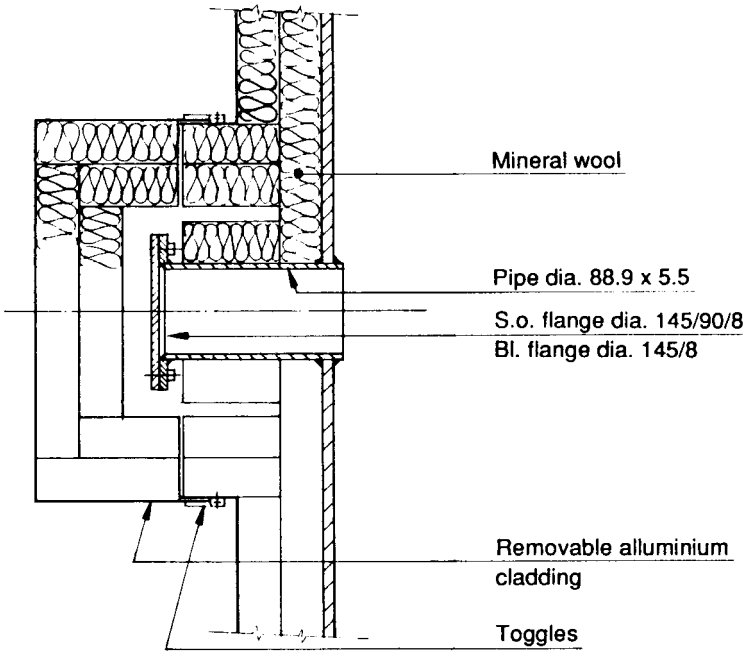

Frame hot dip galvanized
Lamiantex C-603 or equal
Obstruction light with armature
Hole in plate for cable gland
Mounting plate
Hinge
Lute


Handles

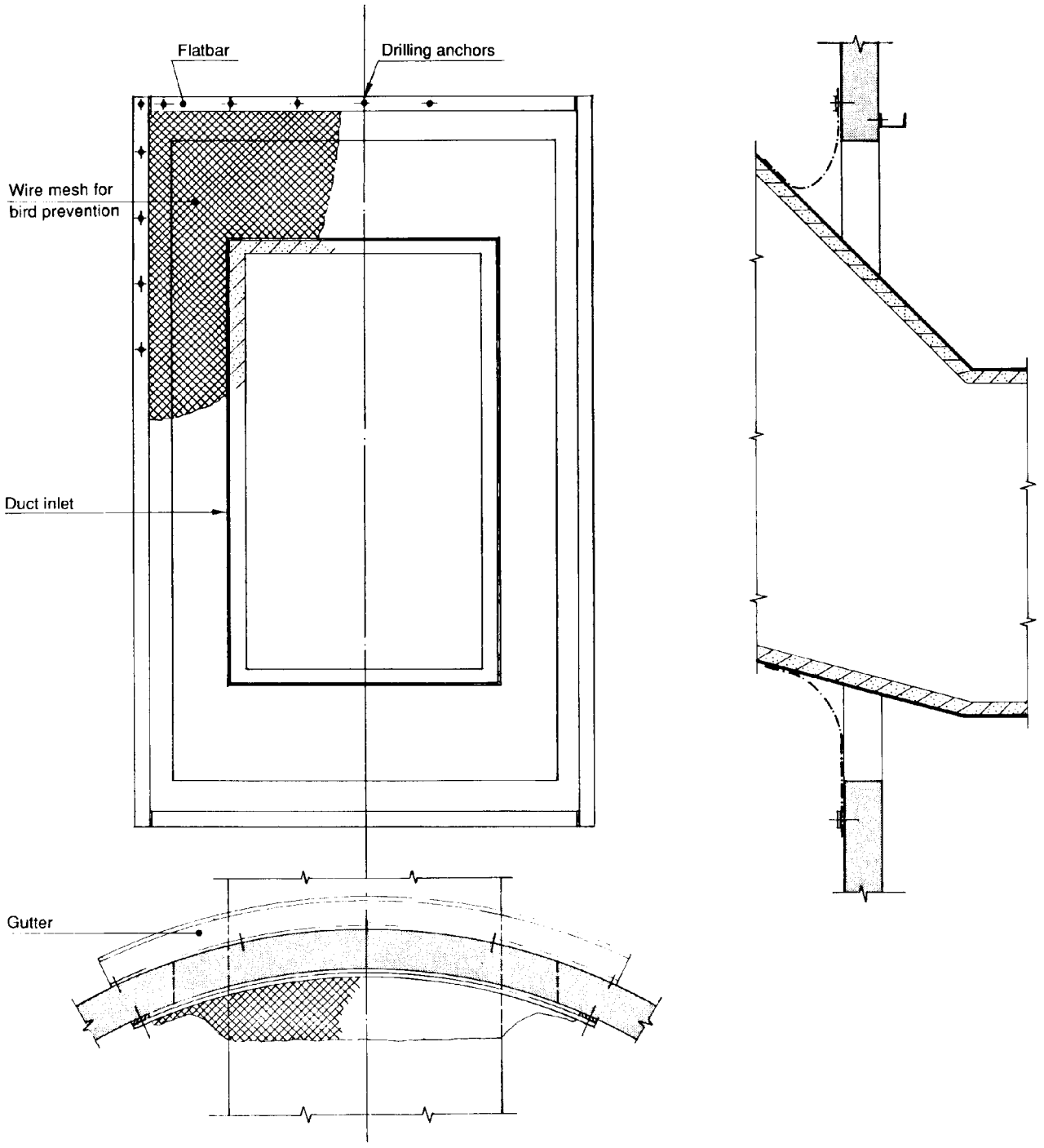
DETAIL D - 9


Mantle
Handle SS 316 L
Hatch pl. 3 mm
SS 316 L
Earthing connection
to ladder
Manual liftingforce of hatch to be
limited to 0,05 kN by counterweights

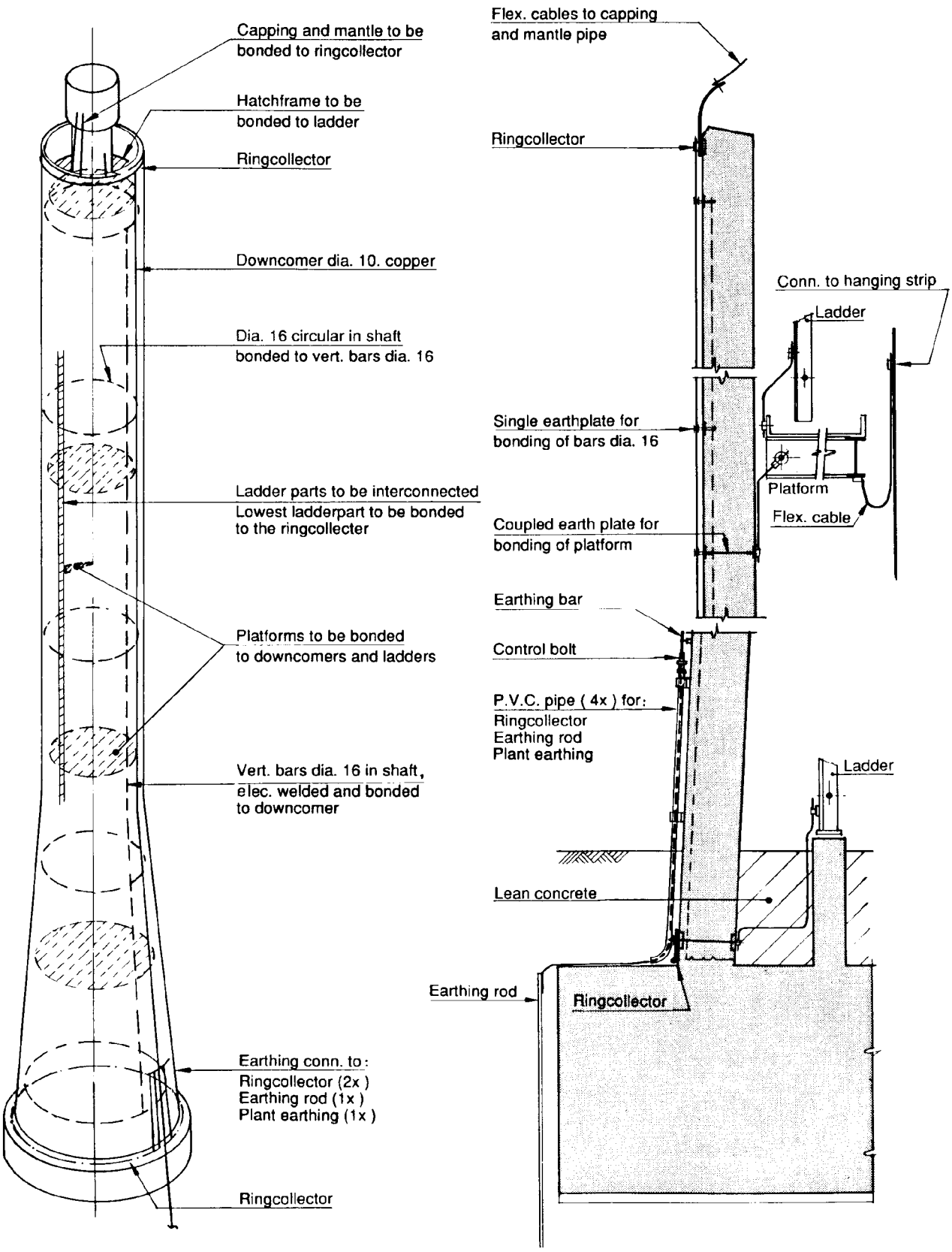
DETAIL D - 10


Mineral wool
Pipe dia. 88.9 x 5.5
S.o. flange dia. 145/90/8
Bl. flange dia. 145/8
Removable alluminium
cladding
Toggles

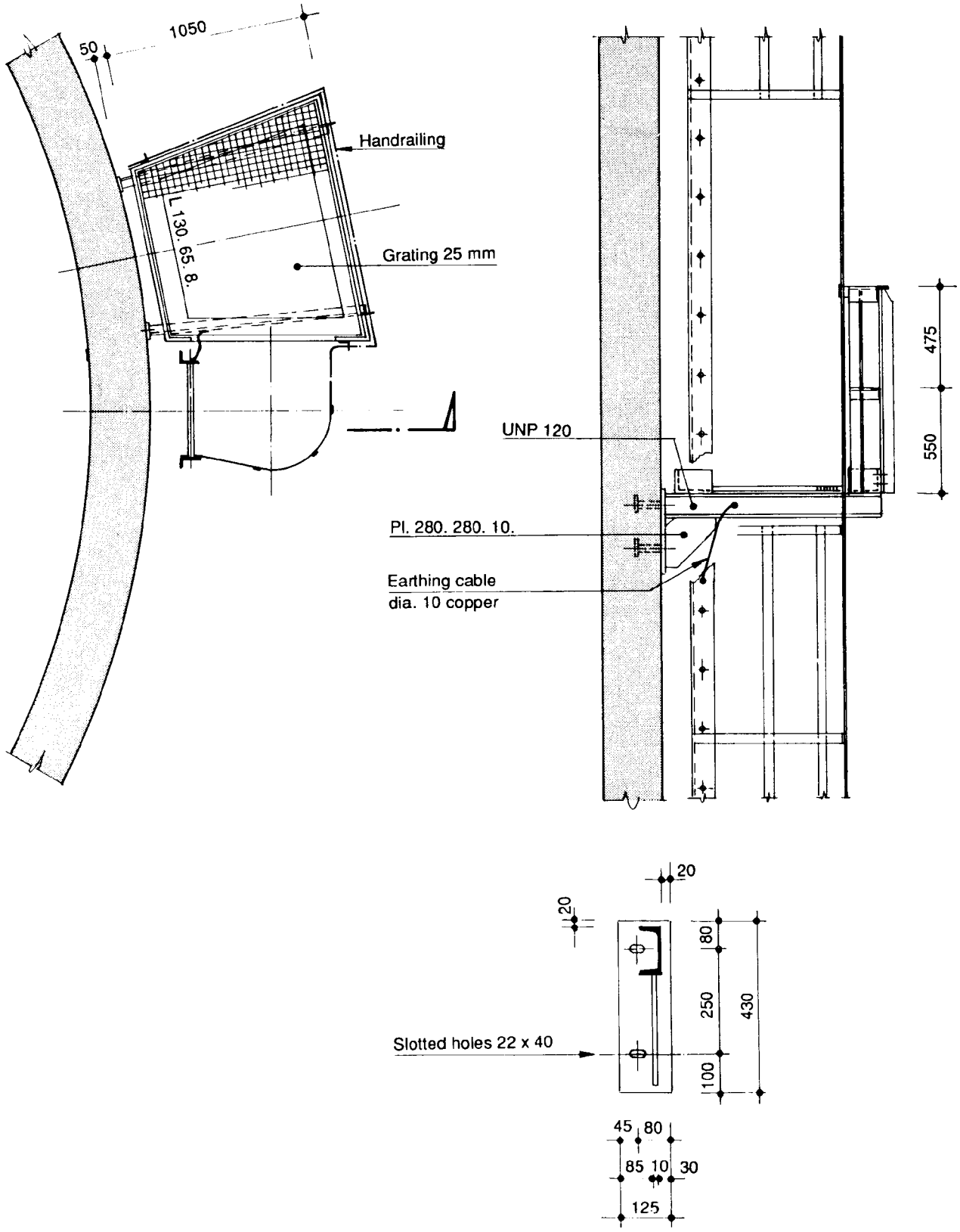
DETAIL D - 11


Flatbar
Drilling anchors
Wire mesh for bird prevention
Duct inlet
Gutter

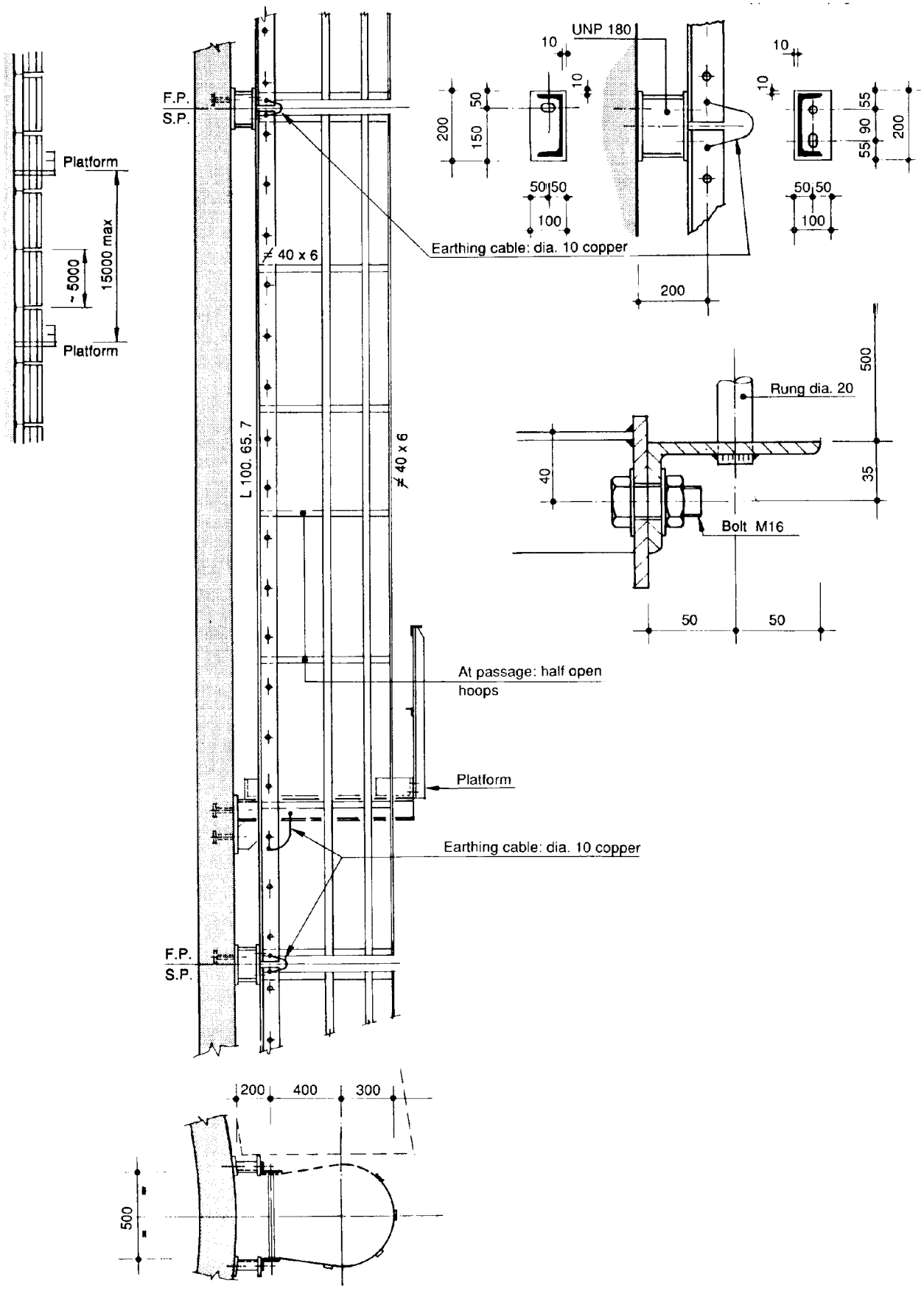
TYPICAL LIGHTNING PROTECTION SYSTEM (STACK TYPE D)


Capping and mantle to be bonded to ringcollector
Hatchframe to be bonded to ladder
Ringcollector
Downcomer dia. 10. copper
Dia. 16 circular in shaft bonded to vert. bars dia. 16
Ladder parts to be interconnected
Lowest ladderpart to be bonded to the ringcollecter
Platforms to be bonded to downcomers and ladders
Vert. bars dia. 16 in shaft, elec. welded and bonded to downcomer
Earthing conn. to:
Ringcollector (2x)
Earthing rod (1x)
Plant earthing (1x)
Ringcollector
Flex. cables to capping and mantle pipe
Ringcollector
Conn. to hanging strip
Ladder
Single earthplate for bonding of bars dia. 16
Platform
Flex. cable
Coupled earth plate for bonding of platform
Earthing bar
Control bolt
P.V.C. pipe (4x) for:
Ringcollector
Earthing rod
Plant earthing
Ladder
Lean concrete
Earthing rod
Ringcollector

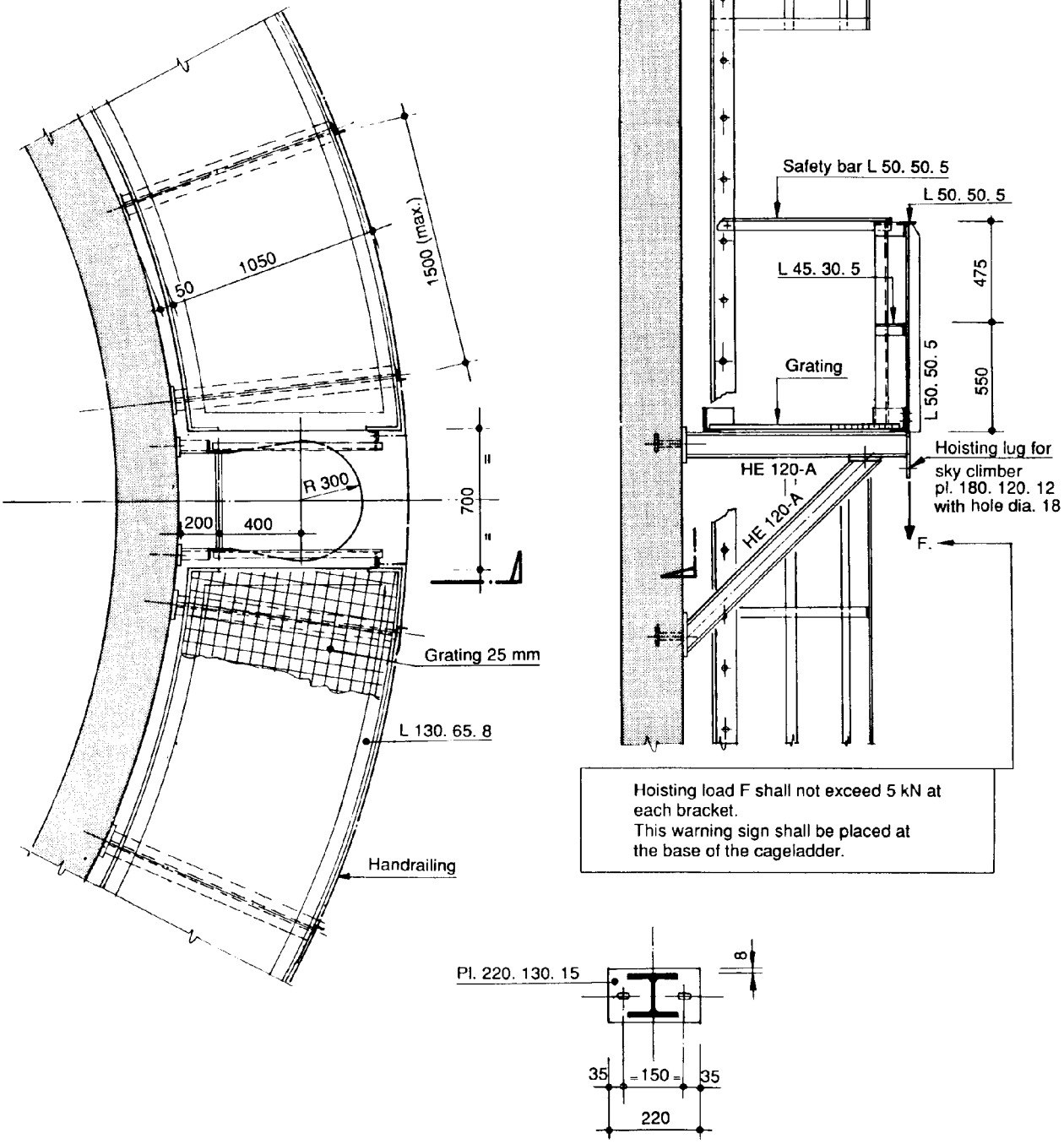
RESTPLATFORM FOR ALL STACK TYPES


50
1050
Handrailing
L 130. 65. 8.
Grating 25 mm
UNP 120
Pl. 280. 280. 10.
Earthing cable
dia. 10 copper
475
550
20
20
80
250
430
100
Slotted holes 22 x 40
45
80
85
10
30
125

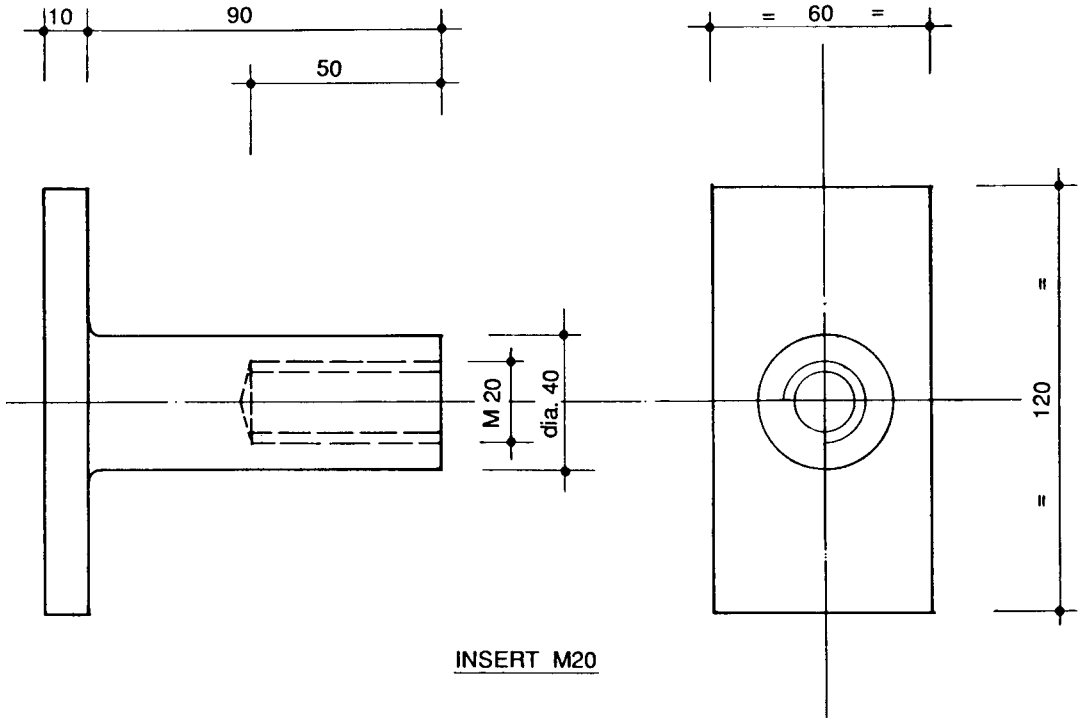
LADDER ARRANGEMENT FOR ALL STACK TYPES


Platform
15000 max
~ 5000
Platform
F.P.
S.P.
≠ 40 x 6
L 100. 65. 7
≠ 40 x 6
UNP 180
10
10
10
10
200
150
50
50 50
100
55
90
55
200
50 50
100
Earthing cable: dia. 10 copper
200
500
Rung dia. 20
40
35
Bolt M16
50
50
At passage: half open hoops
Platform
Earthing cable: dia. 10 copper
F.P.
S.P.
200
400
300
500

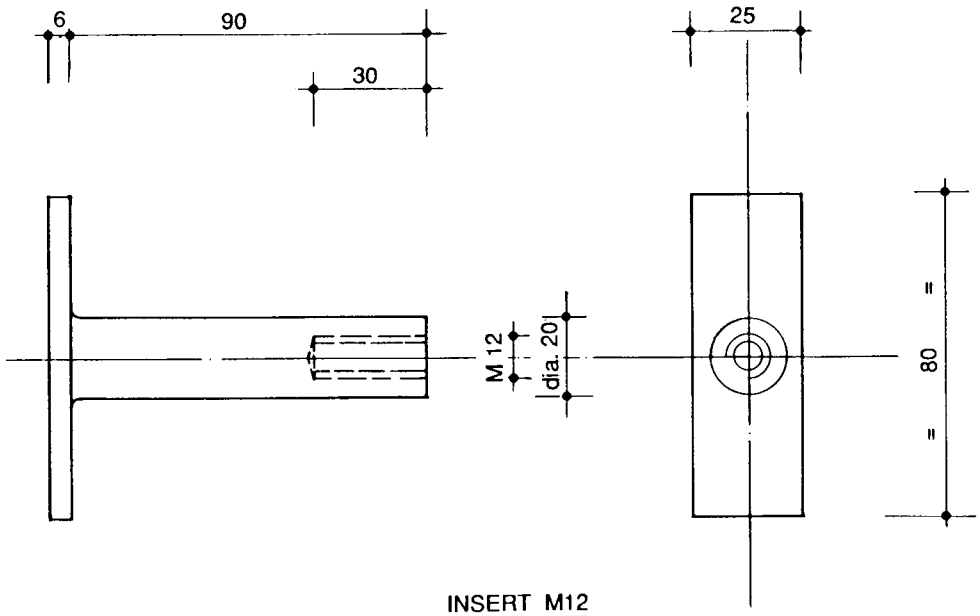
CIRCUMFERENTIAL PLATFORM FOR ALL STACK TYPES


1500 (max.)
1050
50
R 300
200
400
700
Grating 25 mm
L 130. 65. 8
Handrailing
Safety bar L 50. 50. 5
L 50. 50. 5
L 45. 30. 5
Grating
L 50. 50. 5
475
550
Hoisting lug for
sky climber
pl. 180. 120. 12
with hole dia. 18
HE 120-A
HE 120-A
F.
Hoisting load F shall not exceed 5 kN at each bracket.
This warning sign shall be placed at the base of the cageladder.
Pl. 220. 130. 15
8
35
150
35
220

INSERTS M20 AND M12 FOR ALL STACK TYPES



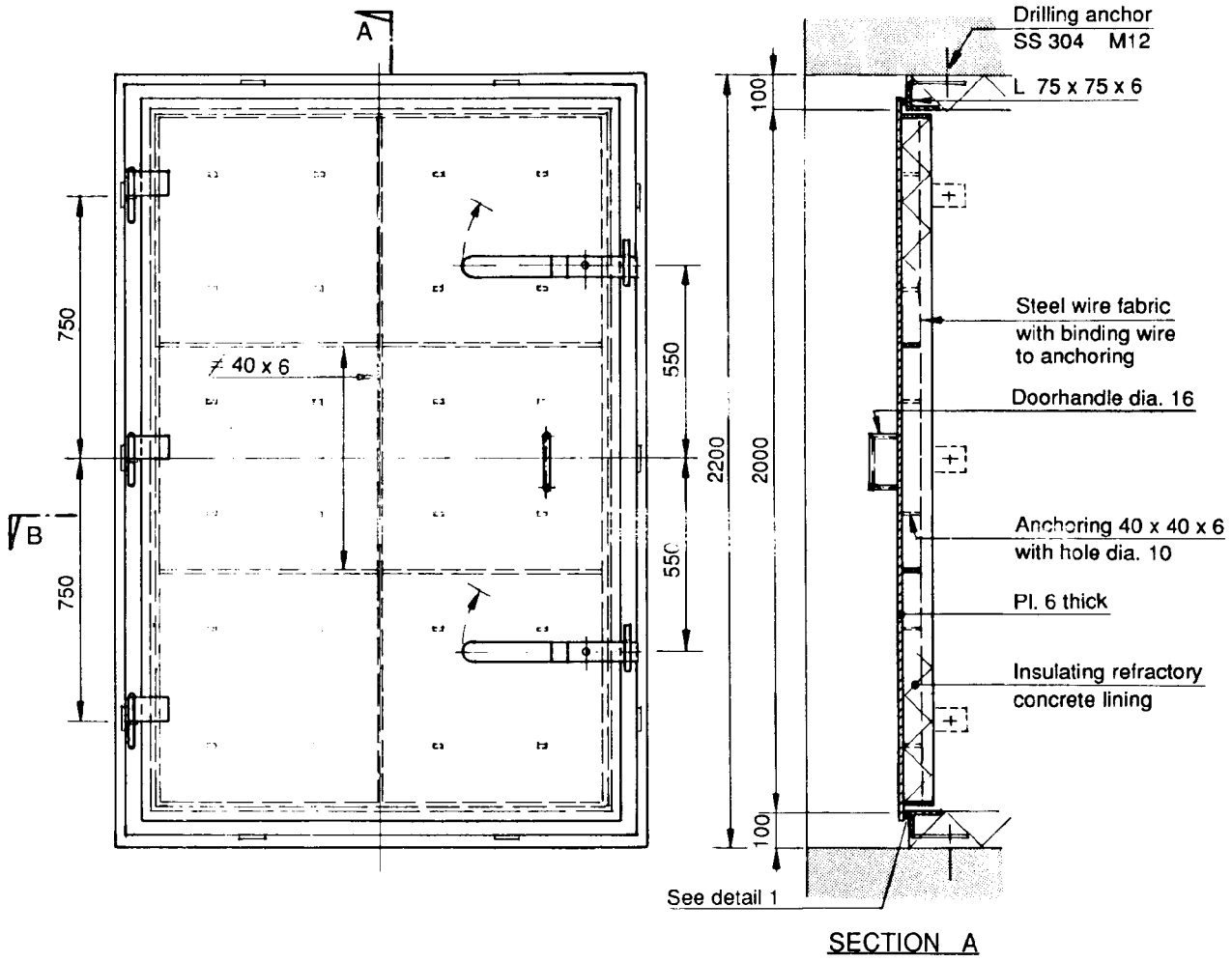
INSERT M20



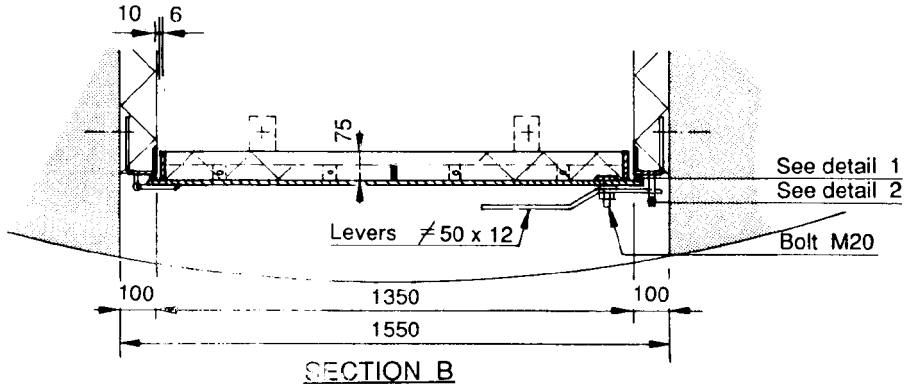
INSERT M12

Mat. : SS 316L AISI

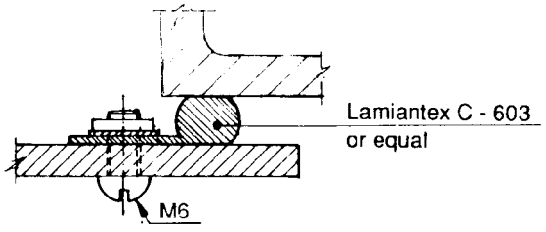
SOOT DOOR FOR STACK TYPES A AND B



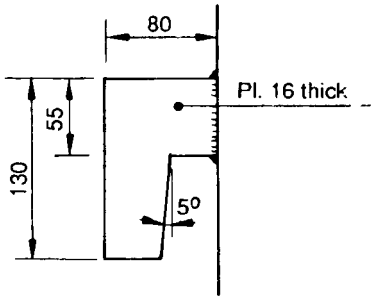
SECTION A



SECTION B



DETAIL 1



DETAIL 2