MANUAL

REFRACTORY BRICKS AND SHAPES

DEP 44.24.90.31-Gen.

October 1994
(DEP Circular 18/95 has been incorporated)

DESIGN AND ENGINEERING PRACTICE

USED BY

COMPANIES OF THE ROYAL DUTCH/SHELL GROUP

PREFACE

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APPENDICES

1. INTRODUCTION

1.1 SCOPE

This DEP, which is a revision of the DEP of the same number dated December 1982, covers the design, supply and installation of insulating, dense, special composite and acid-resistant refractory bricks and special (pre-formed) shapes.

This revision includes integration of the technical developments since the last revision and a change in format from a Technical Specification to a Manual. The intention of the change of format is to provide in one document the recommended engineering practice supported with guidance and explanations.

Refractory bricks and shapes are often used in combination with monolithic refractory materials of similar compositions. For these monolithic refractory applications, reference is made to DEP 64.24.32.30-Gen. and DEP 30.48.60.34-Gen., which should be read in conjunction with this DEP.

Non-refractory acid-resistant bricks and tiles are excluded from the scope of this DEP, but are covered by DEP 30.48.60.33-Gen.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIPM, the distribution of this document is confined to companies forming part of or managed by the Royal Dutch/Shell Group, and to Contractors nominated by them (i.e. the distribution code is "C", as defined in DEP 00.00.05.05-Gen.).

This DEP is intended for use in oil refineries, chemical plants, gas plants, supply/marketing installations and exploration and production facilities.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this document which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned with the object of obtaining agreement to follow this document as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

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

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, authorised to act for the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

The **Applicator** is the party which applies the refractory linings specified by the Contractor.

The term **bricks** includes both bricks and special shapes.

The term **refractory** materials/products/linings includes dense, insulating, acid-resisant and/or special composite refractory materials.

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets. Other documents referenced by this DEP are listed in (9).

2. USE AND CLASSIFICATIONS OF SHAPED REFRACTORY MATERIALS

2.1 USE OF SHAPED REFRACTORY MATERIALS

The design and application of refractory linings is required to protect equipment (such as radiant and convection sections of furnaces including burners, waste heat boilers, flue ducts and fluidised bed installations) from process conditions.

Refractory linings are used to:

- enclose a space in which processes take place at high temperatures, giving protection to the steel enclosure and the environment. Examples: furnaces, kilns, (fluid bed) incinerators, waste heat boilers, ducts, steel stacks.
- be placed in installations in which solids or gases are processed at high temperatures. Examples: reactors, strippers, regenerators.

Refractory materials need to have:

- resistance to high temperatures and temperature fluctuations;
- chemical/mechanical resistance against those substances which come in contact with the refractory material, e.g. gases, slag, etc.;
- sufficient mechanical strength to be part of the construction of the installation and to withstand loads during maintenance operations.

The specifications to obtain satisfactory service from refractory materials depend strongly on the location(s) where they are to be used. A substantial investment in refractory products designed to handle high temperatures and destructive operations can be lost by inadequate design or careless construction/installation.

All shaped (insulating, dense, special composite or acid-resistant) refractory materials are classified in terms of the chemical and mineralogical nature of the main constituents according to ISO 1109, as follows:

high alumina products	(Group HA),
fireclay and low fireclay products	(Group FC and LF),
siliceous and silica products	(Group SS and SL).

NOTE: Siliceous and silica products are rarely used in refinery equipment.

2.2 CLASSIFICATIONS OF SHAPED REFRACTORY MATERIALS

Refractory bricks are divided into four sub-groups:

2.2.1 Shaped insulating refractory materials

Insulating refractory materials are manufactured from base refractory materials, fired and with a total porosity of at least 45% determined in accordance with ISO 5016.

NOTE: This definition stems from the fact that thermal insulating products all have a low thermal conductivity and a small thermal capacity, properties which are related to the total porosity of the product. The bulk density, which for a given product is directly linked with porosity, can therefore be chosen as a criterion for classification.

2.2.2 Dense shaped refractory materials

Dense refractory materials are manufactured from base refractory materials with a total porosity of less than 45% and with a pyrometric cone equivalent (P.C.E.) of at least 1500 °C. The main constituents are alumina silicates.

In the manufacturing process the method of bonding and the process of shaping the materials define to a great extent the ultimate properties of refractory bricks and shapes. A distinction may therefore be drawn between, plastic, semi-dry and dry formed products.

2.2.3 Special compositions

Special compositions are mainly manufactured from refractory base materials other than the alumina silicate group, i.e. basic compositions (magnesia), silicon carbide and zirconium silicate used for special applications.

2.2.4 Acid-resistant refractory materials

Acid-resistant materials are manufactured from refractory base materials and comply with the classification criteria of refractory products defined in ISO 1109.

The classification is based on ISO 10080, with respect to resistance against sulphuric acid and apparent porosity of the refractory material.

3. QUALITY ASSURANCE/QUALITY CONTROL

The required properties of the refractory bricks are specified in Appendix 1.

Sampling and testing requirements are specified in Appendix 2.

The application of refractory linings involves several distinct steps from design to installation. Lack of quality control in any of these steps could lead to complete failure of the lining. It is therefore of vital importance for a quality control procedure to be established for each refractory lining application, covering all aspects from refractory material selection up to and including final inspection of the installed lining.

This principle quality control procedural aspects which should be covered as a minimum, are as follows:

Base material selection	Clearly specified requirements
Manufacturing of materials	Inspection, testing
Design	Design requirements to enable a sound refractory lining
Refractory shipment and storage	Requirements, inspection, certification
Installation/application	Requirements, inspection, Applicator's procedure Qualification of equipment and crew
Completed lining	Inspection
Lining repairs	Methods, requirements, inspection

The Contractor shall set up an appropriate quality control programme addressing at least all steps described above.

The Contractor shall provide refractory suppliers and Applicators with sufficiently detailed specifications for each of their specific activities. In particular the demarcation of responsibilities and the smooth handover between parties involved should be duly covered in the quality assurance programme.

Lining details shall be included on drawings. They may also be provided by equipment suppliers. Any conflicting requirements shall be investigated by the Contractor and referred to the Principal for resolution before bidding or proceeding with the refractory work.

The properties and their applications shall be tested in accordance with ISO or equivalent standards. All refractory materials shall be tested by a recognised laboratory, experienced in testing of refractory materials.

For appropriate testing standards, refer to DEP 64.24.32.30-Gen., Table 3-1.

4. DESIGN

4.1 DESIGN PARAMETERS

All expected operating conditions shall be reflected in the refractory design. The design of linings shall also take into consideration the construction and maintenance aspects.

Linings can be single or multi-layered, depending on the operating temperatures. Maximum allowable surface temperatures of refractories may, for instance, necessitate the use of a hot face layer backed up by an insulating layer (multiple lining). Thicknesses of linings are determined by strength, method of application and insulation properties. Attention shall be paid to proper detailing of joints to compensate for thermal expansion and drying shrinkage.

Table 5-1 of DEP 64.24.32.30-Gen. gives a summary of the relation between operating/lining design conditions and refractory characteristics, which should be used as guidance in lining design.

4.2 TYPES OF LINING

The types of refractory lining described below provide a common basis for identification.

- Single layer linings, consisting of dense or insulating refractory bricks;
- Multi-layer linings (commonly 2 or 3 layers), consisting of layers of dense and/or insulating refractory bricks.

The design should normally be such that the outer wall temperature is between 60-80 °C, as specified by the Principal. If sulphur-containing fuels are used for firing, the Contractor shall verify whether or not there is a risk of dew point corrosion, in which case a wall temperature above 150 °C is required. In such cases, the Contractor shall submit relevant calculations to the Principal.

Walls, arches, hearths and other equipment parts should be designed and constructed to ensure structural stability at both ambient and at high temperature operation. Proven material properties and anchorage systems shall be used in the design and determination of lining thickness and stresses.

A similar selection process may be followed as that given for guidance in Table 5-2 of DEP 64.24.32.30-Gen.

Bricked constructions should be designed and built with dimensions as internationally accepted standard bricks and shapes, such as ISO 5019, in order to improve availability, independence from manufacturers, cost-reduction and ease of maintenance.

Depending on the design of brick constructions, bricks are laid in walls, hearths and arches in so-called 'bonds', i.e. tightening the construction by combination of header-and-stretchers courses and staggered cross joints.

Bonds improve the strength and stability of the constructions and depend on:

- thickness of the walls,
- allowable permeability through the joints,
- operating conditions,
- pre-designed ease of maintenance.

To reduce permeability through (mortar) joints, bricks designed with tongue-and-groove should be used.

The choice of mortar used for joining the bricks together shall be in accordance with the same design and operational conditions as are valid for the refractory bricks, and it shall be applied in full and consistent thin layers.

4.3 SELECTION OF SHAPED REFRACTORY MATERIALS

The abbreviations used in this section are:

CF	ceramic fibre
CFM	ceramic fibre modular (system)
FC	fireclay
HA	high alumina
HT	high temperature
IFB	insulating fibre brick
LF	low fireclay
LMV	Lyunet multiple vortex
LN	low NOx
MW	medium weight
P_2O_5	di phosphate pentoxyde
SHIB	semi-high intensity burner
SiC	silicon carbide

4.3.1 Burners

The selection of refractory bricks used in burners is divided in two main groups:

- oil fired or dual fired burners;
- gas fired burners.

Burners are normally designed for long operational service with low maintenance. The refractory lining of oil fired or dual fired burners consists of bricks of pre-formed shapes, or occasionally precast and prefired (low cement) castables or plastic refractory materials.

The refractory lining of gas fired burners consists either of bricks, precast or prefired castables, plastic refractory, or prefired, vacuum-formed modules of ceramic fibres.

Dependent on the type of fuel used, common grades of refractory bricks for burners are shown in Table 4-1:

Table 4-1 Refractory bricks for burners

Type	Gas fired burners	Oil fired or dual fired burners
Lyunet cup SHIB, cup & throat LN cup	Group HA58-HA65, Sillimanite/Andalusite based or Group HA70, Mullite based (for SHIB mainly)	Same as for gas fired or Group FC45, Low-iron, P_2O_5 impregnated, for moderate temperature applications or SiC-(Oxy) Nitride bonded bricks + Group HA70, Mullite based, backup, for high temperature and very heavy fuel applications
LMV-combustor	Group HA58-HA65, Sillimanite/Andalusite based	SiC-(Oxy)-Nitride bonded bricks, or Group HA70, Mullite based, P_2O_5 impregnated
LMV-combustor (SRU units)	Group HA75 + Group 150-L IFB backup	n. a.
Radiant wall	Group HA58-HA65, Sillimanite/Andalusite based, or HT vacuum formed ceramic fibres, prefired	n. a.
Commercial	Manufacturers recommendation	

4.3.2 Furnaces

The lining of furnaces may consist of bricks, cast or gunned refractories. In view of the operational conditions and the possible presence of slag, vapours or other contaminating agents, only a brief summary is given in Table 4-2:

Table 4-2 Refractory for furnaces

Gas fired furnaces		Oil fired furnaces
Walls:	HT vacuum formed ceramic fibres, prefired. or Group 125 insulating firebricks with Rockwool or CF board backup.	Same as for gas fired. Same as for gas fired, but with CF board backup only.
Roofs:	Same as for walls	Same as for gas fired, but Group FC30 refractory bricks around uptakes.
Floors:	Group 125 insulating firebricks. or Group 130 castables, with Group FC30 refractory bricks protection layer	Same as for gas fired.
Hot ducts:	Same as for walls, but with CFM systems with IFB paths	Same as for gas fired, but Group FC30 refractory bricks around uptakes and areas susceptible to erosion.

4.3.3 Sulphur Recovery Units (SRUs)

Amended per Circular 18/95

Because SRUs may differ in layout and type, only a general summary is given in Table 4-3:

Table 4-3 Refractory for Sulphur Recovery Units

Equipment	Refractory lining
Main reaction chamber:	
burner	Same as for LMV (table 4-1).
reaction chamber	minimum Group HA55 refractory bricks, with Group 140 IFB. or minimum FC45 with CF board (optional).
baffle wall	minimum Group HA70, Mullite-based bricks (special creep resistant).
tube sheet	minimum MW 175-1.4-L, bubbled alumina castable. or putty mix Group 175 with HA95 ceramic ferrules.
Primary line burner:	
burner	Same as for LMV (table 4-1), temperature up to 1800 °C.
body	minimum Group FC35 refractory bricks, with Group 125 IFB
Secondary line burner:	
burner	Same as for LMV (table 4-1), temperature up to 1800 °C
body	minimum Group FC35 refractory bricks
Incinerators:	Same as for main reaction chamber (burner temperature up to 1800 °C).
Reactors:	Group FC35 refractory bricks.
Hot ducts:	Same as for connecting primary or secondary line burner.
Flue gas ducts:	None (but with outside lagging or weather protection). or Group LF25 refractory bricks.

5. SUPPLY

5.1 MANUFACTURE OF REFRACTORY MATERIALS

Refractory materials shall comply with the materials specification in (Appendix 1). Sampling and testing shall be in accordance with (Appendix 2).

5.2 REFRACTORY SHIPMENT AND STORAGE

All bricks shall be carefully unloaded and stacked by hand on the job site. Any items that are damaged, broken, chipped or cracked during handling, or no longer conform to the specification, shall be removed from the job and replaced with satisfactory bricks.

6. TRANSPORT OF BRICK-LINED EQUIPMENT

To prevent possible cracking, deformation and disbonding caused by shock or vibration, the equipment should not be transported or handled after brick lining.

If transport and handling of brick-lined equipment or parts thereof, e.g. smaller vessels, pipe sections, ducting, etc., cannot be avoided, the design and execution shall be submitted to the Principal for review and approval.

The equipment shall be completely cured and prestressed before handling. Rigging shall be such that flexure and distortion do not impact on the integrity of the lining.

In the case of unforeseen moving of equipment, stiffening rings or structures shall be applied. However, welding on equipment with an incorporated, non-metallic liner, i.e. membrane or coating, should be avoided.

7. INSTALLATION OF REFRACTORY BRICK CONSTRUCTIONS

7.1 GENERAL

Only Applicators experienced in refractory work shall be employed for the installation of refractory linings.

Before installation a thorough inspection shall be carried out of the condition and cleanliness of the surface to be lined. The bricks shall also be clean. Sufficient ventilation shall be provided during the application of chemical containing materials (mortars).

Proper scaffolding shall be provided and overhead work shall only be executed with appropriate equipment and prior approval from the Principal.

All walls shall be built up regularly, not leaving any part more than 1 metre lower than another, unless special circumstances render this impracticable. Any walls left at different levels shall be stepped and sufficiently supported to avoid sagging in any direction. The courses shall be properly levelled, perpends kept, quoins, jambs and other angles plumbed as the job proceeds.

7.2 TEMPERATURE CONTROL DURING INSTALLATION

To avoid temperature and humidity changes during installation, bricks and tiles should be stored near the job under the temperature conditions given below for approximately 48 hours before using.

The temperature of equipment that will be bricked-lined should be maintained between 5 °C and 25 °C. Lower and higher temperatures will influence the correct curing of the mortar.

At temperatures below 5 °C the equipment should be heated, preferably electrically by hot air. This heating should avoid uncontrolled moisture development and create an unoppressive environment for the labour force.

If the equipment to be lined is at a temperature above 25 °C, the mortar shall be mixed in small quantities in some other location and kept between 15 °C and 20 °C before use. Temperatures which are too high shorten the 'pot-life' of the mortar.

7.3 BRICKED CONSTRUCTIONS

All brickwork shall be set out and built to the required dimensions as shown on the drawings.

Generally, an appropriate mortar is used to level courses and to provide smooth bedding of the bricks. The thickness shall be consistent, as thin as possible, and be specified 1 to 4 mm thick. The mortar thickness selected depends strongly on the brick quality, the dimensional tolerances due to manufacturing, the type of mortar used, the desired resistance against gas permeability and slag penetration and the thermo-mechanical stress applied under operating conditions.

Standard bricks and shapes can be laid in four different ways in order to obtain a proper, strong and stable construction; combinations of all four ways (known as 'bonds') are used during installation (see Figure 1).

Notwithstanding the shape of the standard bricks, whether or not they are rectangular tapered or radially shaped, the same bonds should be used for construction of walls, hearths, arches, and other flat, cylindrical or curved constructions.

A summary of standard brick shapes, with their given names, is shown in Figure 2.

In this manner a minimum number of shapes has to be ordered and stocked for maintenance, whilst reducing the need for special shaped (non-standard) brick sizes.

7.4 ANCHORS

Bricked constructions shall be stable and robust. Anchor systems are used to assure sufficient stability.

In general these systems consist of dedicated and specially designed refractory anchor blocks, attached to the shell or other support constructions by means of steel anchors.

The properties of ceramic anchor blocks shall be at least equal to the highest properties of the refractory materials they support, i.e. mainly at the hot face. Because of their special nature, they usually exceed those required thermal and mechanical properties.

Anchor systems are generally placed in square or staggered pitches, with dimensions as summarised in Table 7-1. The Contractor shall state the exact dimensions in the design drawings, supported by calculations.

Table 7-1 Anchor spacing

Construction	Anchor spacing
Roof	≤ 450 mm
Wall:	
vertical	≤ 500 mm
horizontal	≤ 1000 mm
Floor	only in special cases

8. INSPECTION, MAINTENANCE AND START-UP

8.1 INSPECTION

The equipment shall be inspected by experienced personnel to be approved by the Principal. Equipment to be assembled from parts shall be checked for correct assembly before installation of the lining. Brick-lined equipment shall be inspected at regular intervals, observing any local regulations. The inspection may be restricted to visual observations with consideration of the following:

- General condition of the brick lining,
- Colour of the bricks,
- Regular shape of the brick lining:
  disbonding of bed joints could cause irregularities,
- Expansion joints;
  cleanliness and presence of loose particles,
- Cracks;
  deformation of equipment due to lack of or improper pretreatment can cause irregularities,
- Spalling;
  generally distributed spalling could result from incorrect composition and porosity characteristics of the bricks or too severe operational conditions, e.g. frequent temperature or pressure changes. Local spalling could result from direct impact by liquid or vapour jets causing rapid temperature changes, impact and the effect of boiling on the interface level
- Level and condition of cement in the joints;
  pollution, erosion, dissolving or washing out, e.g. (for silica-based cements) by steam, water or chemical attack,
- Lining in and around nozzles and manholes;
  if design, location, material selection, installation, special treatment and operation are correctly done only minor repairs should be expected,
- If disbonding and spalling of bricks are noticed;
  this should be further investigated by careful hammer testing.

If visual inspection or hammer testing reveals defects, e.g. leakages, disbonding, cracks (other than normally expected, e.g. due to shrinkage), missing bricks, severe spalling, material reduction or open joints, a further thorough examination is necessary. This may require locally opening up the brick lining, dependent on the severity of the damage.

A specialist's advice based on visual inspection, hammer testing and further examination, including laboratory analysis, shall then decide whether the damage could be the result of material selection, materials supplied, design of equipment and/or lining, specifications, protection of materials during storage and installation, curing and heating or operation.

There may be other considerations, such as local conditions, findings in inspection or operating reports, etc., that may help the specialist to decide on the type and extent of any repairs that may be required.

8.2 MAINTENANCE

Brick linings shall be carefully maintained, inspected and serviced in accordance with the requirements given in the design requirement.

To avoid mechanical damage, special protective provisions shall be made for clean-out, scaffolding and brick lining repair activities. Nozzles and manholes shall be opened only when required for access or to provide the appropriate working climate. For the execution of local repairs, the remaining lining shall be properly supported if bricks have to be removed. Shocks and vibrations to the surrounding brick lining shall be avoided.

Even minor defects of brick linings should be consistently repaired to prevent spread of defects to deeper layers of the brick. This includes the replacement of dissolved or washed out cement from joints. Scraping to sound material and subsequent filling with fresh cement is sufficient when the damage is not too deep. When the wastage approaches 75% of the thickness of the top (hot face) brick layer of the lining, the affected area of this layer shall be completely removed and replaced in order to restore the integrity of the lining.

To repair a leak, disbonding, wide cracks, fall-out of bricks or severe spalling, all the affected material shall be removed as far as required to allow replacement of brick linings and to ensure complete and proper bonding to the remaining brick lining.

All surfaces of the brick lining shall be thoroughly cleaned before any replacement work commences. The adhesion between cement and wet or dirty bricks will be significantly lower than with clean dry bricks. The original brick configuration shall be maintained on replacement.

Welding on the outside of brick-lined equipment should be avoided. If welding is unavoidable, the brick lining shall be locally removed up to a minimum distance of 250 mm from the weld. After welding, cleaning and drying, proper replacement of the brick lining shall follow as previously described.

Wash coating with mortar shall not be used to fill up surface defects in refractory brick or lining. Such closure of the hair cracks and/or openings of joints, due to reversible thermal expansion, will inevitably cause more damage during subsequent operation.

8.3 START-UP AND OPERATION

Brick-lined equipment shall only be operated after:
- complete curing of the mortar, and
- release and approval after inspection (6.1).

The equipment shall be brought into service very gently by slowly increasing the temperature up to the operation condition. A holding period for 4 - 8 hours at 100 - 150 °C should be employed to evaporate collected water in repairs and to stabilise and allow checking of operational settings. The same careful handling is required when the equipment is taken out of operation. Temperature stresses caused by inexpert handling could destroy the brick lining completely and should not exceed 100 °C/hr.

Accurately written dry-out/heat-up schedules and operating instructions shall be established, in close co-operation between the Principal and the Manufacturer. Critical limitations of temperature during start-up and/or operations shall be supplied to the operator.

Brick-lined equipment standing idle should be protected against frost, especially for those cases where moisture can accumulate in the lining.

9. REFERENCES

In this DEP reference is made to the following publications:

NOTE: Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendment/supplements/revisions thereto.

SHELL STANDARDS

Index to DEP publications and standard specifications	DEP 00.00.05.05-Gen.
Chemical-resistant (ceramic) lining materials	DEP 30.48.60.33-Gen.
Erosion resistant refractory linings	DEP 30.48.60.34-Gen.
Insulating and dense refractory concrete linings	DEP 64.24.32.30-Gen.

INTERNATIONAL STANDARDS

Refractory products; Classification of dense shaped refractory products	ISO 1109
Shaped insulating refractory products; Classification	ISO 2245
Shaped insulating refractory products; Determination of bulk density and true porosity	ISO 5016
Dense shaped refractory products; Determination of bulk density, apparent porosity and true porosity	ISO 5017
Refractory bricks; Dimensions	ISO 5019
Shaped refractory products; Sampling and acceptance testing	ISO 5022
Dense shaped refractory products; Determination of resistance to sulfuric acid	ISO 8890
Refractory products; Classification of dense, shaped acid-resisting products	ISO 10080
Refractory products Measurement of dimensions and external defects of refractory bricks	ISO/DIS 12678

Issued by:
International Organisation for Standardisation
1, Rue du Varembé
CH-1211 Geneva
Switzerland.

GERMAN STANDARDS

Ceramic refractory materials; fireclay bricks for general industrial applications (type A bricks up to 45% Al_2O_3)	SEW 917

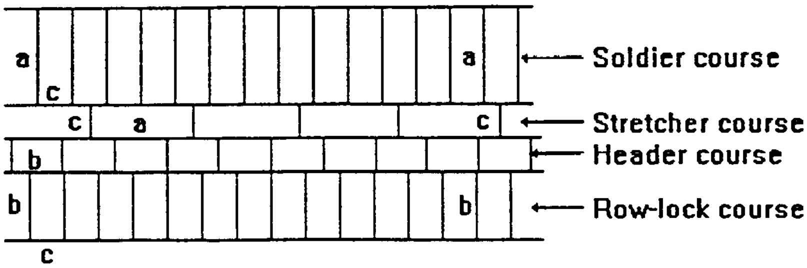
Issued by:
Verein Deutscher Eisenhütteleute
Verlag Stahleisen GmbH

Postfach 105164
D-40042 Düsseldorf
Germany.

FIGURES

FIGURE 1 Types and names of courses

Defintion of courses:

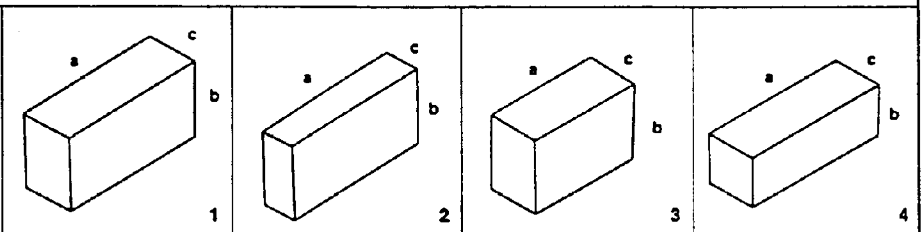
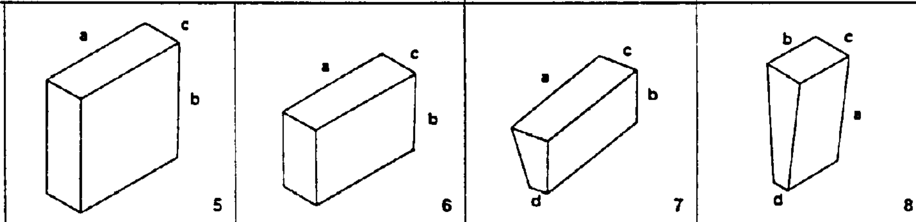
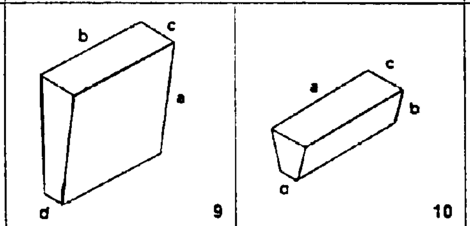
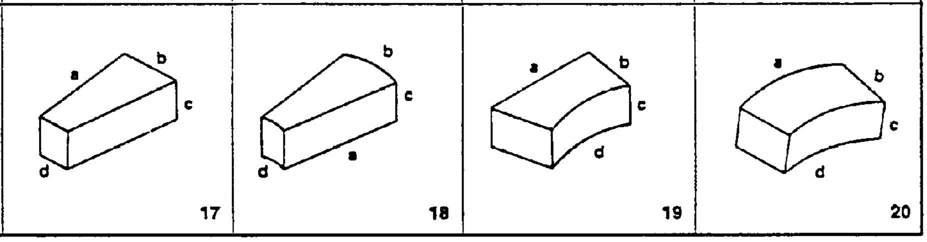


a = length

b = width

c = height

FIGURE 2 Types and names of brick shapes

No. NAME	
1 SQUARE STRAIGHT 2 SPLIT SCONE 3 CROPPED HEADER THREE QUARTER BRICK 4 PUP SOAP CLOSER	
5 DOUBLE STANDARD 6 BROADBACK SQUARE 7 SIDE ARCH ARCH 8 END ARCH WEDGE	
9 DOUBLE ARCH 10 SIDE ARCH PUP	
17 TAPERED HEADER KEY CROWN CUPOLA 18 CIRCULAR HEADER CIRCLE KEY 19 FLATBACK 20 CIRCULAR STRETCHER CIRCLE BRICK	

a = length

b = width

c = height

d = taper

APPENDIX 1 SPECIFICATION FOR SHAPED REFRACTORY MATERIALS

1. APPLICATION

This appendix specifies the properties required for insulating and dense refractory bricks and shapes which are used in heaters, ducts and stacks, vessels or other equipment to be internally protected from process conditions.

Acid-resistant refractory, as well as bricks and shapes made of special composites, are also specified in this appendix.

2. SCOPE

Installation or repair of refractory linings can normally be executed with standard manufactured refractory materials. Their properties shall meet the requirements of the Manufacturer's data-sheet.

There are a number of special applications where standard specifications do not cover the specific requirements. Examples are: Fluidised Catalytic Cracker (FCC) Units (regenerator and reaction section), calciners (rotating), fluidised bed combustors, combustion chambers in Sulphur Recovery Units (SRUs), burner parts, etc. In these cases, one or more properties have to be specified more accurately with reference to constructional or operational conditions.

3. DOCUMENTATION

3.1 APPLICABLE STANDARDS

Refractory bricks should be tested in accordance with the standards shown in Table 3-1 of DEP 64.24.32.30-Gen. They shall meet the requirements and properties as specified in the purchasing documents.

The Contractor shall submit to the Principal the Manufacturer's certificates for all refractory materials supplied.

Certificates shall attest that the refractory bricks comply with the sampling and testing requirements as specified in (Appendix 2).

Test certificates for each batch of bricks supplied shall include the following information:

- name of the manufacturer,
- name of the material*,
- dates of manufacture and testing*,
- batch, serial or fabrication number*,
- indent or order number*
- result of tests.

NOTE: *this data shall also be identified on the package.

The Contractor shall supply the Principal with full information about appropriate mortars which shall be used in compliance with the refractory bricks.

4. SPECIFICATION OF SHAPED REFRACTORY MATERIALS

4.1 CLASSIFICATION OF SHAPED INSULATING REFRACTORY MATERIALS

This classification is based on ISO 2245. The criteria for classification are as follows:

- the temperature at which the material does not show any permanent linear change (PLC) in dimension of more than 2% after 12 hours.
- the bulk density, rounded off to two decimal places.

Table 1 Classification of shaped insulating refractory materials.

Amended per Circular 18/95

GROUP	Temperature (°C) at which the PLC is no more than 2% after 12 hours	If the Bulk Density (g/cm^3) is below the following limits, the products belong to **Class L**
75	750	0.40
80	800	0.50
85	850	0.55
90	900	0.60
95	950	0.65
100	1000	0.65
105	1050	0.65
110	1100	0.70
115	1150	0.70
120	1200	0.70
125	1250	0.75
130	1300	0.80
135	1350	0.85
140	1400	0.90
150	1500	0.95
160	1600	1.15
170	1700	1.35
180	1800	1.60

NOTES:

1. If the bulk density of the considered product is lower than the appropriate limit given in the above table, the product belongs to **Class L** and shall be designated according to the following example:
   Group 135 material with bulk density of 0.6 g/cm^3 is classified as 135-0.6-L.

2. If the bulk density of the considered product is equal to or higher than the appropriate limit given in the above table, the product does not belong to **Class L** and shall be designated according to the following example:
   Group 135 material with bulk density of 1.0 g/cm^3 is classified as 135-1.0.

4.2 CLASSIFICATION OF SHAPED DENSE REFRACTORY MATERIALS

The table gives a summary of commonly used grades in the Shell Group.

Table 2 Classification of shaped dense refractory materials and property values (use being made of SEW 917).

Designation		Chemical Composition				Physical Properties					
Old	International Group	Al_2O_3 %	Fe_2O_3 max. %	MgO/CaO %	Na_2O/K_2O max. %	Bulk Density g/cm^3	Apparent Porosity %	CCS ambient N/mm^2	RUL minimum t_a °C	RUL minimum $t_{0.5}$ °C	Thermal expansion %
	HA75	> 75	1.0	-	0.6	2.60	≤ 22	≥ 50	1650	1550	0.8 to 0.6 at 1000 °C
	HA65	65 - 75	1.5		0.8	2.55	≤ 21	≥ 50	1650	1550	
M	HA55	55 - 65	1.5	0.3	0.8	2.45	≤ 19	≥ 60	1600	1520	
	HA45	45 - < 50	2.0		1.3	2.25	≤ 19	≥ 40	1450	1370	
A	FC40	40 - < 45	≤ 2.5		< 2.5	2.10	≤ 21	≥ 25	1420	1340	
	FC40 li		1.2				≤ 19	≥ 35	1500	1420	
B	FC35	35 - < 40	≤ 2.5	Approx 0.5 to 1.0	< 3.0	2.05	≤ 20	≥ 25	1380	1300	
C	FC30	30 - < 35	≤ 3.0		< 3.0	2.05	≤ 20	≥ 25	1350	1250	
	FC30 li		1.8			2.20	≤ 16	≥ 35	1400	1320	
	LF10	10 - < 30	≤ 3.0		< 3.0	2.05	≤ 19	≥ 30	1320	1220	

CCS = Cold Crushing Strength
RUL = Refractoriness Under Load
HA = High alumina
FC = Fireclay
LF = Low alumina Fireclay
li = low iron quality

4.3 CLASSIFICATION OF SHAPED SPECIAL COMPOSITIONS

Special compositions are mainly manufactured from refractory base materials, other than the alumina silicate group, i.e. basic compositions (magnesia), silicon carbide, zirconium silicate used for special applications.

Only limited use is made of these refractory products in the Shell Group. However, there is a growing demand and further development is expected.

Because of the speciality of the singular materials, no further classification will be given regarding main constituents and probably location for use. In case of possible use, these products should be considered in close co-operation with the Manufacturer to confirm suitability for the intended application.

Basic products:	little use in the petrochemical Industry
Special products, based on:	
carbon	(Acid resistant refractory linings)
graphite	(Acid resistant refractory linings)
zirconium silicate & zirconia	(Special thermal shock resistant linings)
silicon carbide carbides borides	(High temperature and thermal shock resistant linings) (Erosion and thermal shock resistant linings)
Products based on pure oxides.	

4.4 CLASSIFICATION OF SHAPED ACID-RESISTANT REFRACTORY MATERIALS

This classification is based on ISO 10080. The products are sub-divided on the basis of resistance to sulphuric acid and apparent porosity.

4.4.1 Resistance to sulphuric acid

- The acid resistance is determined by a test carried out in accordance with ISO 8890.
- Three groups are distinguished on the basis of loss of mass:

Group 1: toss of mass less than or equal to 2%,
Group 2: Loss of mass above 2% but less than or equal to 4%,
Group 3: Loss of mass above 4% but less than 7%.

4.4.2 Apparent porosity.

- The apparent porosity is determined by a test carried out in accordance with ISO 5017.
- In each group (4.4.1) two sub-groups are distinguished on the basis of apparent porosity:

Sub-group A: apparent porosity less than or equal to 15%,
Sub-group B: apparent porosity greater than 15%.

4.4.3 Designation of acid-resistant refractory materials

Shaped acid-resistant refractory materials are designated by a combination of their resistance to sulphuric acid (4.4.1) and their apparent porosity (4.4.2).

Example: Designation 1A has a loss in mass of less than or equal to 2% and an apparent porosity less than or equal to 15%.

APPENDIX 2 SPECIFICATION FOR SAMPLING AND TESTING OF SHAPED REFRACTORY MATERIALS

1. INTRODUCTION

This appendix specifies the testing and acceptance criteria for shaped refractory materials.

The data resulting from regular tests will develop into a distribution pattern which will facilitate future assessment of the material properties. The specific properties to be considered will depend on the field of application or on the operating factors on the basis of which the refractory material is chosen.

2. DOCUMENTATION

Refractory bricks shall comply with the sampling and testing requirements as specified and be inspected by:

- investigation of physical and chemical properties,
- checking of dimensions,
- visual inspection for manufacturing defects,
- investigation of packing and transport procedures/measures.

The investigations should be performed at the manufacturer's location prior to shipment, possibly witnessed by the Purchaser.

3. SAMPLING AND DIMENSIONAL INSPECTION OF SHAPED MATERIALS

3.1 SAMPLING FOR TESTING

In the relevant test methods a minimum number of test specimens for execution is normally specified; otherwise they shall be agreed between parties.

Since verification of the properties of refractory materials call mainly for destructive test methods, the testing shall be based on standard sampling plans.

3.1.1 Investigation of physical and chemical properties

Properties should be related to the envisaged conditions of use as far as possible (e.g. porosity is related to thermal conductivity). Considerable benefits can be achieved, both in terms of economy and availability, by making optimum use of standardised qualities and sizes.

Selection should be made of properties which can be checked by simple and inexpensive tests, so that the necessary number of measurements can be made. Thus it is important to distinguish:

- the essential properties which should be subject to strict control tests by statistical methods,
- supplementary properties whose values will be given as information.

3.2 INSPECTION OF DIMENSIONS

Dimensional inspection is based on sampling at random from pallets, batches or the like, chosen within a purchase order, with the objective of checking the dimensions, the amount of warpage or taper of the manufactured products.

Routine measurement and inspection of dimensions, warpage, taper and radius shall be performed in accordance with ISO/DIS 12678 Part 1.

3.2.1 Sampling size

Under normal circumstances, if no particular agreement is established between parties for delivery of standard and common special shapes the sample size shall be chosen from the Table 1, severity class D. Class C shall apply when specified by the Principal.

Table 1 Sequential sampling plan for inspection.

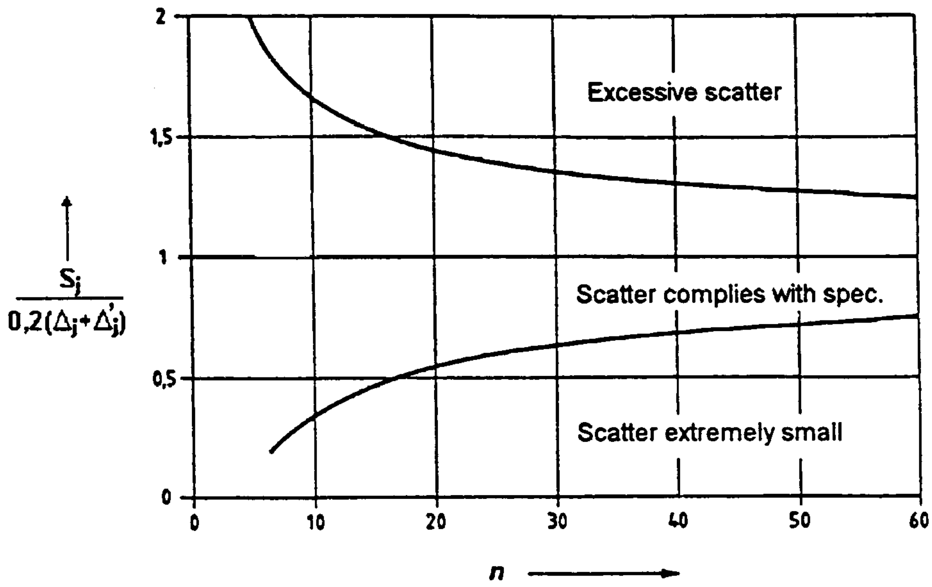
Severity class of acceptance	Sample sequence	Number of bricks to be inspected in sample	Accumulated number of inspected bricks	Number of defective bricks: accept lot if c ≤	Number of defective bricks: reject lot if c >
C (AQL 4 %)	1	38	38	0	5
	2	15	53	1	6
	3	16	69	2	7
	4	15	84	3	8
	5	16	100	4	9
	etc.				
D (AQL 6.5%)	1	22	22	0	5
	2	10	32	1	6
	3	9	41	2	7
	4	10	51	3	8
	5	9	60	4	9
	etc.				

NOTE: Terminology and statistical symbols:
AQL = Acceptable Quality Level
c = Number of defective bricks per sample

For each dimension, the observations are ordered in the form of a frequency table. If any measured value is found outside the tolerance limits, the lot should be judged for dispersion, i.e. whether there is excessive or very small scatter beyond the limits of tolerance. If the scatter is very small this normally indicates a systematic deviation (Figures 3a and 3b).

If the dispersion complies with the limits of tolerance according to the figures below and the rejected bricks do not exceed the next number in the last column above, one further sample in accordance with the table can be added to the previous one. The procedure shall be repeated once more. If the lot fails again, it shall be rejected.

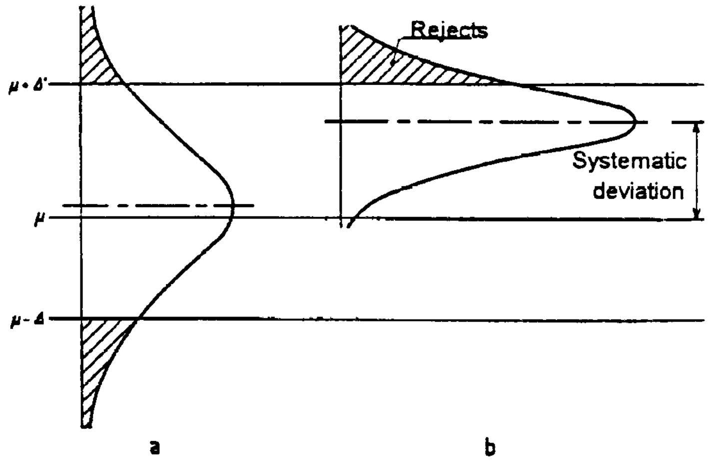
Figure 3a Inspection of brick dimensions, judgement of the dispersion



S = calculated standard deviation of sample

Δ = allowed minus and plus tolerance

Figure 3b a) Mean value practically correct, but excessive scatter
b) Small dispersion, but systematic size deviation



3.2.2 Inspection of dimensions

The Purchaser should indicate the dimension to be taken into consideration. In general, only one dimension is really important, rarely two. More dimensions should be identified by a special agreement between the Manufacturer and the Purchaser.

A special agreement is required for pieces where the weight is greater than 35 kg and the length greater than 500 mm. (In case of silica products, greater than 25 kg and 400 mm).

3.2.3 Values of dimensional tolerances

All the numerical values of tolerances given in Table 2 are based on an AQL of 6.5%. When the value for tolerance expressed as a percentage becomes less than the value expressed in mm, the latter shall be used.

Table 2 Dimensional tolerances

Type of product (as per ISO 1109)		**Tolerance +/-** lesser of %	**mm**
1. Silica products:		1.5	2
2. Silicious, fireclay, low and high alumina products:			
2.1 Plastic pressed	dimension < 100 mm		2
	dimension ≥ 100 mm	2	
2.2 Semi-dry pressed	dimension < 150 mm		1.5
	dimension ≥ 150 mm	1.5	
2.3 Dry pressed	dimension < 200 mm		1.5
	dimension ≥ 200 mm	0.75	
3. Insulating products:			
3.1 Unrectified:			
3.1.1 Plastic body		2.5	3
3.1.2 Dry pressed		1.5	2
3.2 Rectified			1

NOTE: These tolerances are rounded off to the nearest millimetre, recognising the fact that the tools used to measure on site do not generally give greater precision.

3.2.4 Warpage

Where warpage is inspected, it should be checked against an AQL of 6.5%. The maximum number of pieces which may have a warpage greater than the tolerance is given in Table 1.

The limiting value of warpage shall be determined across the diagonal.

These limits of tolerance are:

for plastic pressed (2.1 in Table 2)	1.5%
for dry or semi-dry pressed products (2.2 and 2.3 in Table 2) and unrectified insulating products (3.1 in Table 2)	diagonal ≤ 350 mm 2 mm diagonal > 350 mm 3 mm
Rectified insulating products (3.2 in Table 2)	Zero warpage allowed

NOTE: Warpage is checked by means of a steel straight edge having a minimum length of:
500 mm for diagonal length of ≤ 350 mm
800 mm for diagonal length of > 350 mm

3.2.5 Taper

Where the taper is inspected, it should be checked against an AQL of 6.5%. For each type of product given in the Table 2 and independent of the tolerances mentioned therein, the allowable deviation on the difference between the inner and outer face shall not exceed the following:

- for a radial height ≤ 250 mm: +/- 1 mm
- for a radial height > 250 mm: +/- 2 mm

The inner and outer face shall be measured with the aid of a tape measure so that the difference can be calculated. The measurements shall be rounded to the nearest mm.

NOTE: Certain manufacturing methods require a small taper on the products (draw from mould). This small taper does not constitute a parameter of dimensional control.

3.2.6 Radius

A radius of 5 mm is permissible on all inside edges of special shapes. All other edges shall be sharp and true. To inspect the overall dimensions of sets of bricks, whether circular or otherwise (such as burner throats), pre-assembly by the Manufacturer may be required. In this case the overall dimensions shall be checked. When assembled, the shapes shall have no mortar joints greater than 3 mm.

3.3 INSPECTION OF MANUFACTURING DEFECTS

The Purchaser should indicate which of the defects should be taken into consideration for inspection purposes.

Routine measurement of corner and edge flaws as well as other surface flaws shall be in accordance with ISO/DIS 12678-Part 2.

3.3.1 General

The following description applies to fireclay, high alumina and silica bricks, standard shapes and special shapes commonly used in refractory linings. The subsequent requirements for the appearance of the bricks shall not be taken as representative for the average quality of a lot, but as the definition of an acceptability limit for testing attributively.

After samples have been taken from the lots according to Table 1, each brick in a sample shall be visually inspected on the characteristics given below.

3.3.2 Description of the characteristics

Laminations and texture:

The bricks shall be free of laminations. A hammer test, using a 100 gram hammer with a wooden handle, shall be used to check for the presence of laminations. If the hammer test reveals the suspicion of laminations, the bricks shall be rejected (however, a sample may be cut to confirm the validity of the hammer test).

The bricks shall be free of grain segregation at corners and edges and shall have external evidence of a strong, well bonded and uniform texture, developed in a proper firing process.

There shall be no signs of local vitrification or presence of extraneous particulate matter.

Surface flaws:

Any roughness caused by difference in expansion of the mixture components is not considered a flaw.

The acceptance criteria for surface flaws are given below, and are summarised in Table 4. For some flaws, different criteria apply for the working face and the buried faces. A working face is defined as a face visible from the inside of the furnace or other equipment in which the brick will be installed; all other brick faces are to be considered buried.

A brick shall contain no more than five flaws (craters, edge flaws, corner flaws and cracks), even if the dimensions of the individual flaws are within the stated acceptance criteria.

If surface defects can be corrected by chipping or grinding, the Manufacturer may do so. Brick surfaces shall be even and free from adhering material.

Craters:

Craters are usually the result of melt phenomena, caused by iron oxide or lime. Iron oxide stains shall be tested with a hammer to determine the presence of craters.

No face shall contain a crater having dimension d, h or D greater than 6, 3 or 6 mm respectively. Furthermore, the working face shall not contain more than two craters of any size.

Cracks:

Surface crazing which, when representative bricks are cut, exhibits penetration of less than 2 mm shall not be considered as cracks.

Individual cracks less than 10 mm in length are acceptable. Individual cracks longer than 60 mm in length shall be rejected. Cracks between 10 and 60 mm in length shall be subject to the approval of the Principal and their rejection should depend on the severity of the application.

Corner damage:

The working face shall have no any corner damage in which dimension a, b or c is greater than 5 mm. A buried face shall have no corner damage in which dimension a, b or c is greater than 20 mm.

Edge damage:

The working face of a brick shall have no edge damage in which dimension e, f or h is greater than 5 mm. A buried face shall have no edge damage in which dimension e, f or g is greater than 20, 20 or 30 mm respectively. There shall be no fins at edges.

Table 4 Acceptance criteria for surface flaws

Amended per Circular 18/95

TYPE OF FLAW	MAXIMUM PERMITTED DIMENSION (mm) OF A SINGLE FLAW (see figures 4 to 7)																	
	WORKING FACE									BURIED FACE								
	a	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**D**	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**D**
Corner	5	5	5							20	20	20						
Edge					5	5	5							20	20	30		
Crater				6				3	6				6				3	6
Crack length	10 (60 with Principal's approval)																	

NOTE: If the brick passes the above criteria, it shall still be rejected if there are more than five flaws of any size.

Amended per Circular 18/95

Figure 4 Typical corner defect

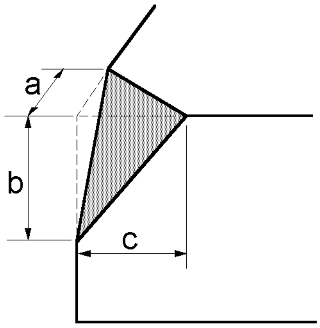


Figure 5 Typical edge defect

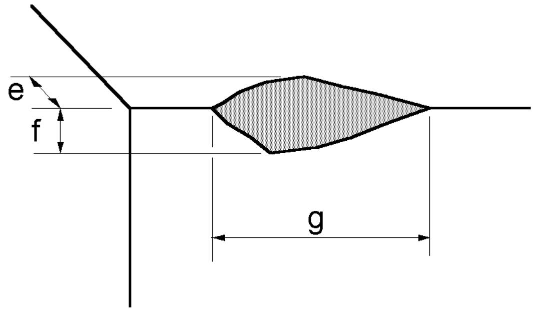


Figure 6 Typical cracks

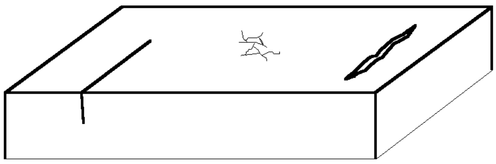


Figure 7 Measuring crater dimensions