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Guidance on Industry Standard for Refractory Installation

GIS 72-002

BP GROUP
ENGINEERING TECHNICAL PRACTICES

Foreword

This is the first issue of Engineering Technical Practice (ETP) BP GIS 72-002. This Guidance on Industry Standard (GIS) is based on parts of heritage documents from the merged BP companies as follows:

British Petroleum (Pre-1999)

RP 15-1-1 Internal Insulating and Refractory Lining Rev 4 June 1996

Amoco

A NM-REF-00-C Non-metallic Materials Refractory Installation Specification. July 1997

A NM-REF-00-G Non-metallic Materials Refractory Guide July 1997

ARCO

Engineering STD 110-D97 Refractory Linings August, 1997

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1. Scope

This GIS provides guidance on industry standard for the installation, inspection, repair, and testing of refractory lining systems for equipment operating above 540°C (1 000°F).

2. Normative references

The following normative documents contain requirements that, through reference in this text, constitute requirements of this technical practice. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this technical practice are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies.

BP

GIS 72-001	Guidance on Industry Standard for Procurement of Refractory (including Material Performance Requirements).
GIS 72-003	Guidance on Industry Standard for Refractory Dry-out.
GIS 72-004	Guidance on Industry Standard for Refractory Inspection.
GIS 72-102	Guidance on Industry Standard for Vee Anchoring Systems.
GIS 72-103	Guidance on Industry Standard for Hex-Mesh Anchoring Details.
GIS 72-105	Guidance on Industry Standard for Refractory Construction Details.
GIS 72-106	Guidance on Industry Standard for Independent Anchor Systems - Hex Cells, S-Bars & Curl Anchors.
GIS 72-107	Guidance on Industry Standard for SRU Thermal Reactor Refractory Lining Details
GIS 72-108	Guidance on Industry Standard for Miscellaneous Refractory Construction Details.
GIS 72-109	Guidance on Industry Standard for Catalytic Reformer Refractory Details - Cold Wall Vessel Design

American Society of Mechanical Engineers (ASME)

ASME BPVC Section IX Welding and Brazing Qualifications

Steel Structures Painting Council (SSPC)

SSPC SP 6	Surface Preparation Specification No. 6, Commercial Blast Cleaning
SSPC SP 7	Surface Preparation Specification No. 7, Brush-Off Blast Cleaning
SSPC SP 10	Surface Preparation Specification No. 10, Near White Blast Cleaning
SSPC Vis 1	Surface Appearance

3. Terms and definitions

For the purposes of this GIS, the following terms and definitions apply:

Alkaline Earth Silicate (AES) Wool

The AES Wool is a family of fibrous products that possess high temperature exposure limits that features low bio persistence. This family of products was developed to provide a ceramic fibre that is soluble in body fluids of the lung. This fibre material has been thoroughly tested and does not require



the hazard label common with Refractory Ceramic Fibres. Thermal Ceramics produces a product called Superwool and Unifrax produces a product called Insulfrax.

Anchor

Metallic or refractory device that retains the refractory or insulation to the shell of vessels or piping.

BP's Engineer

BP's appointed engineer

Castables

Castable is a general term for a mixture of heat-resistant aggregates and heat resistant binder. The binder is typically a hydraulic Calcium Aluminate cement that produce the bonding necessary for physical property development. However, low cement and no cement castables are available that utilizes a non cementitious matrix that is capable of developing the desired physical properties. A castable is mixed with water and rammed, cast, cast vibrated, pumped or gunited. The combination of refractory grain and bonding agent (cement or sintering aids) develops the designed physical or chemical properties after the addition of water.

Casting

The process of placing wet mixed refractory concrete by pouring, pumping, rodding or with internal (submergible) vibrators. Mineral Wool & Diatomaceous Block Insulation – These blocks are commonly used to backup brick linings, RCF linings and castable linings. Mineral wool (or slag wool) exhibits significant deterioration above recommended temperature limits. Diatomaceous silica blocks exhibit greater physical stability than mineral wool and are comparable in most applications. The diatomaceous blocks are also heavier (density) than mineral wool blocks with slightly higher thermal conductivity.

Coking

A coking environment is common to the converter of all Fluid Catalytic Cracking Units. Hydrocarbons saturate the refractory and form coke at all available sites within the refractory. The coking of refractory changes all physical properties of a refractory as a function of coke content. Some property changes enhance lining performance, while others have a negative influence that must be addressed in design.

Contractor

A company or business that agrees to furnish materials or perform specified services at a specified price and/or rate to the BP.

Curing

Process of bond formation in newly installed monolithic refractory. For hydraulic bonded castables, this occurs at room temperature is facilitated by an excess of water being present to react with the cement component. For phosphate bonded (chemically bonded) plastic refractories, heating to 260°C to 370°C (500°F to 700°F) is required to form the bond. For phosphate bonded castables, curing is primary at room temperature, but fully matures when heated to 425°C (800°F).

Dense Firebrick

Bricks with densities over 2 000 kg/m³ (125 lb/ft³) are normally used as hot face refractory lining systems. Thermal conductivities are typically high and normally require IFB or castables as back-up to meet heat flow (flux) requirements. Dense firebricks are used in applications where ceramic bonding, hot load strength and chemical stability are important.



Dry-out

The initial heating of a newly installed castable lining in which heating rates and hold times are controlled to safely remove retained water (mechanical and chemically bonded water) without explosively spalling and to form a well distributed network of shrinkage cracks in the lining.

Erosion Resistant Lining

Single layer of erosion-resistant castable/plastic refractory retained in hexmesh or independent anchoring system that has a tested erosion loss of less than 12 cc. Erosion resistant linings are utilized in areas where erosion will compromise vessel walls or pressure boundaries.

Extreme Erosion Resistant Lining

Single layer of erosion resistant castable/plastic refractory retained in hexmesh or independent anchoring system that has a tested erosion loss of less than 7 cc. Extreme erosion resistant linings are utilized in areas where severe erosion is present and will compromise vessel wall or pressure boundaries.

Gunning

The application of monolithic refractories by means of air placement (pneumatic) guns.

Heat Curing

Process of heating used to develop bonding in refractories such as phosphate bonded plastic refractories. With these refractories, heat curing is concurrent with dryout, but not necessarily interchangeable with use of the term, as dryout refers only to the elimination of retained water within the lining system.

Inspector

A BP or BP appointed inspector.

Insulating Firebrick (IFB)

Insulating Firebrick (IFB) is a class of lightweight bricks having relatively low thermal conductivity and is used as insulating back-up linings for dense refractory brick linings systems. IFB are also used as primary (hot face) linings for fired heaters/furnaces and primary reforming furnaces where lining integrity and insulation value are both important.

Low-Cement/No-Cement Castables

Low-cement and no-cement castables are specially formulated castables that utilize sintering aids to promote physical property development. These castables develop unique and enhanced physical and chemical properties but have limited applications. Limitations and attributes of such castables should be fully understood before they are specified or approved.

Manufacturer

The recipient of a direct purchase order for materials and/or equipment. In this context, a direct order is one issued to manufacturer by a contractor or BP. An indirect order is one issued to a manufacturer by a vendor (recipient of a direct order) for materials, fabricated components, or subassemblies.

Mineral Wool & Diatomaceous Block Insulation

These blocks are commonly used to backup brick linings, RCF linings and castable linings. Mineral wool (or slag wool) exhibits significant deterioration above recommended temperature limits. Diatomaceous silica blocks exhibit greater physical stability than mineral wool and are comparable in most applications. The diatomaceous blocks are also heavier (density) than mineral wool blocks with slightly higher thermal conductivity.



Organic Fibres

The use of polypropylene fibres in castable products is designed to enhance to escape of moisture during the initial heating of cast or gunited linings. The organic fibres disappear at low temperatures ($<150^{\circ}\text{C}$ (300°F)) and provide capillaries for moisture in the form of steam to escape and prevent the build-up of steam pressures that cause explosive spalling.

Phosphate Bonded Castables

A family of refractory castables that utilize an aluminium phosphate to bond aggregate. The aluminium phosphate binder is designed to provide excellent strength and erosion resistance.

Plastic Refractory

Plastic refractory is a composition of aggregate and plasticizers tempered with water and extruded. Extruding develops a level of workability, permitting ramming with pneumatic tools to form a monolithic structure. Plastic refractory mixes are prepared at a manufacturer's facility, extruded into columns, sliced and packaged into 25 – 45 kg (55 – 100 lbs) cartons. Quality of plastic refractory lining is dependent upon the manufacturer's quality control program and the skill of the applicator that produces a fully consolidated lining. The installer affects lining quality but not material quality. Guniting of plastic refractory is possible, but has limited applications that require approval by BP.

Pneumatic Ramming

A refractory placement technique whereby materials with plastic like consistencies are rammed into an anchoring system with pneumatic rammers to form a refractory lining free of voids. Materials are purchased in a premixed state, ready for placement, or purchased in bags and mixed with the desired liquid to produce a plastic consistency that easily rams to form the desired lining. The rammers pound the materials into place to achieve a homogeneous mass that exhibits the desired physical properties.

Purchaser

The party placing a direct purchase order. The purchaser is the BP's designated representative.

Refractory Ceramic Fibre

Refractory Ceramic Fibres are man-made fibres composed primarily of alumina and silica. Additives, such as chromium oxide and zirconium oxide develop enhanced physical properties. Fibres are produced by spinning and blowing molten alumina-silica compositions, forming 2,5 to 3,5 micron diameter fibres. RCF exhibits excellent thermal conductivity (insulating value). RCF is classified as Class 2E carcinogen and certain restrictions apply to its use. Consult plant and/or corporate HSE departments for information regarding use of RCF. Application forms include bulk, blanket, paper, modules, rope and vacuum-formed shapes.

Refractory Classifications

Lightweight Refractory Class - materials having an installed fired density of 800 to $1\,070\text{ kg/m}^3$ (50 to 67 lb/ft^3).

Medium Weight Refractory Class – materials having an installed fired density of 1 090 to $1\,440\text{ kg/m}^3$ (68 to 90 lb/ft^3).

Moderate Density Refractory Class – materials having an installed fired density of 1 460 to $1\,920\text{ kg/m}^3$ (91 to 120 lb/ft^3).

Heavy Weight Refractory Class – materials having an installed fired density of 1 940 to $2\,400\text{ kg/m}^3$ (121 to 150 lb/ft^3).

Dense Refractory Class – materials having an installed fired density of greater than $2\,400\text{ kg/m}^3$ (150 lb/ft^3).



Self Levelling Castable

Castables with and without cement binders that are designed to exhibit flow characteristics (rheology) that promote levelling of the properly mixed products, which eliminated the need for external or internal vibration.

Stainless Steel Fibres

Additive to refractory castables and/or plastic refractories that improve lining integrity and assist in crack distribution.

Third Party Inspector

Inspector(s) contracted directly with BP to represent BP in matters related to compliance with pertinent specification, procedures, QA/QC audits and industry standards related to specific projects.

Third Party Testing Laboratory

Testing laboratory that is not affiliated with the manufacturer of refractory or the contractor.

Vibration Casting

Castable installation technique whereby refractory is mixed with minimal water contents and placed into a formed enclosure with the aid of externally mounted vibrators, which causes the refractory to become fluid-like and thereby flows and consolidates into the desired shape of the formed enclosure. The refractory is specifically designed for cast vibrating and exhibits thixotropic properties that allow for very low water contents in the mixed refractory.

Wet Gunning

An installation procedure developed to install refractory castable without adding water at the gunite nozzle as is common with "dry" gunning. The castable products are mixed with recommended quantities of water, hydraulically transported to the wet gunning nozzle and propelled onto the vessel shell with compressed air. There are additions of water at the nozzle; however, accelerators are injected into the refractory along with the placement air to provide additional stability to the lining mass.

TYPE OF REFRACTORY LININGS

Refractory linings are generally designed (engineered) to provide specific protection of various operating systems or environmental conditions. Heat conservation should be optimized within limits of sound refractory design. Refractory linings should be selected based on the most important physical property necessary for optimum, cost effective performance. Cost of materials and installation are important components of refractory systems and should be evaluated together to ensure cost effectiveness. Refractory technology constantly changes and new improved products are regularly introduced. Limited experimentation is encouraged; however, coordination with the company refractory specialist is necessary to reduce potential for poor performance and to communicate results throughout BP. Properly engineered refractory systems provide the best performance.

Single Layer Wear-Resistant Lining

This type of lining consists of dense refractory, generally 25 mm to 50 mm (1 in to 2 in) thick, anchored with hex mesh grating or independent anchoring systems designed for wear resistant linings. When independent anchoring systems such as S-Bars, Hex Cells, Curl Anchors and K-Bars are used, refractory should contain stainless steel fibres. These linings should be considered as having limited insulating value and designer must consider heat transfer (heat flux) in design of the equipment. Application of single layer wear-resistant linings is generally accomplished with pneumatic ramming guns. Other procedures must be approved by BP.



One-Shot Linings

One-shot linings are single layer linings over 50 mm (2 in) thick installed with a pneumatic gun. The installation technique is referred to as Guniting.

One-shot linings are generally lightweight or medium weight insulating refractories; however, moderate and severe erosion resistant products are included in this classification in limited applications.

Anchors for one-shot linings should be footed double hook or footed wavy Vee anchors that conform to GIS 72-102, Figures 1 & 2.

Straight bottom double hook or wavy Vee anchors may be used with approval of BP. When using straight bottom anchors, installer shall develop an installation technique to weld anchors without undercutting base or Tyne.

Cast Linings

Casting is performed with castables that have sufficient rheology (flow characteristics) to consolidate into a monolithic mass with minimum external assistance (vibration, rodding, etc>). Vibration, when required, shall be minimized to avoid segregation of castable components and is typically performed with an internal vibration device such as a "pencil vibration", also known as submergible vibrators.

Cast Vibrated Linings

Cast vibrated linings are linings installed with rigorous vibration. These linings are typically dense and provide protection from abrasive or erosive mediums and posses excellent strength, but generally exhibit high thermal conductivity ($> 1,0 \cdot W/m^2K$ ($7,0 \text{ BTU} \cdot \text{in/hr} \cdot \text{ft}^2 \cdot ^\circ F$)).

Cast vibration of castables promotes optimum compaction and consolidation of castables with minimum water content. Physical properties are maximized in this installation technique leading to superior service for most applications.

Cast vibrated linings are limited to shop installations unless otherwise approved by BP.

Designer and installer shall consider the effect of vibration on attachments or components being lined. Cracking of welds due to fatigue is possible and procedures must reconcile this eventuality and provide assurances that nozzles and other attachments are not affected by the rigorous vibration.

Dual Layer Insulating and Wear-Resistant Linings

The dual layer insulating and wear-resistant lining is a layer of lightweight refractory protected on the surface by a layer of dense refractory. Dense layer of refractory shall contain proportional concentrations of stainless steel fibres and shall be a minimum of 75 mm (3 in) thick, unless the hot face lining is anchored with hexmesh grating. Anchoring systems must comply with requirements in GIS 72-102, Figures 4 & 5.

Refractory Ceramic Fibre Linings

Ceramic fibre provides thermally efficient, lightweight linings for areas where erosion or mechanical abuse is absent. Refractory linings weights may be reduced by a factor of 10 to 12. RCF and Soluble fibres are available to meet specific HSE requirements. Ceramic fibre lining systems are extremely permeable and when corrosive gases are present in the operating environment, an approved coating is required to protect the metal shell from corrosion.

Brick Linings

Brick linings are constructed of individual brick shapes and are used primarily in areas where ceramic bonded products are necessary to withstand environmental and mechanical condition of the equipment. Reliability of brick linings is highly dependent on the skill of the bricklayer (installer) and



is more complicated than monolithic construction techniques. Engineering details of lining design are also important and engineered drawings are required for approval prior to installing brick linings.

4. Symbols and abbreviations

For the purpose of this GIS, the following symbols and abbreviations apply:

CCS	Cold Crushing Strength
MOR	Modulus of Rupture
PLC	Permanent Linear Change
cc	cubic centimetre (associated with abrasion loss)
FCCU	Fluid Catalytic Cracking Unit
FCU	Fluid Cracking Unit
SSPC	Steel Structure Painting Council

5. Documentation

- a. All material properties shall be tested to EN or ASTM Standards. Testing standards shall be submitted for review during bidding. Any deviations shall be approved by BP.
- b. Compliance Data sheets showing gunned physical properties shall be developed by Refractory Manufacturers & BP and supplied for all products to be pneumatically applied.
- c. Written Installation Procedures approved by BP
- d. Weld Procedures for attachment of Anchors, approved by BP
- e. Dryout Procedures and sketches with thermocouple locations and burner positioning for newly installed refractory linings, where appropriate.
- f. The following information shall be supplied for approval by BP in the bid:
 1. Refractory materials proposed by installer.
 2. Steel fibre reinforcement
 3. Shipping and handling procedures for all refractory and or refractory lined equipment and component parts for approval by BP.
- g. Final Records

Final records include a copy of all installation records, a listing of all samples taken w/installer and pertinent data and Areas repaired.

6. General

- a. Refractory linings and lining design shall comply with GP 72-00
- b. Materials for refractory lining shall be obtained in accordance with GIS 72-001 and the appropriate compliance data.
- c. Material selection shall be based on physical property requirements listed in GIS 72-001.
- d. Agreement on pre-shipment testing acceptance/rejection requirements shall be obtained from material manufacturer and BP prior to purchase of selected material.



- e. Pre-shipment testing of refractory materials, which is required for all refractory orders, is defined in GIS 72-001 section 6.3. When packaging for castables/gunite mixes differs from conventional packing ((25 kg (55 lb) bags)), consult with the corporate refractory specialist or consultant for proper pre-shipment test requirements.
- f. WRITTEN APPLICATION PROCEDURES: The refractory contractor shall provide a written application procedure to BP and receive approval for the procedure prior to starting installation of Refractory Procedure shall include:
 - 1. Equipment requirements and back-up contingencies.
 - 2. Cleaning requirements and cleaning frequency for mix equipment.
 - 3. Mixing and handling methods.
 - 4. Details of application including:
 - a) Method of measuring thickness
 - b) Method of trimming in gunning applications
 - c) Location of gunite machine relative to work area
 - d) Equipment set-up
 - e) Method to deal with inclement weather
 - f) Water source and pressure
 - g) Air source and pressure
 - h) Communication requirements among crew
 - i) Crew Organization Chart
 - 5. Curing and drying procedures.
 - 6. Material Testing Requirements.
 - a) Pre-shipment testing
 - b) Crew and Procedure Testing
 - c) Production Testing
 - 7. Crew and procedure qualification.
 - a) Mock-up for cast or cast-vibration application
 - b) Mock-up for ramming qualification
 - c) Mock-up for gunite applications
 - d) Mock-up for other placement technique approved by BP.
 - 8. Quality control program
 - a) Designated Quality Control person
 - b) Installation Records/forms.
- g. Refractory lining shall be installed only after piping and equipment to be refractory lined have been completed and pressure tested, unless otherwise approved by BP.
- h. Situations where equipment internals prevent proper installation of refractory linings shall be brought to BP's attention for resolution.
- i. Requirements for any new refractory application not covered in this standard shall be submitted to BP for approval.



- j. All substitution and/or deviations from this specification must have written approval from BP.
- k. In the event of conflict between this standard and other job drawings or data, the Refractory Installer or equipment Manufacturer affected by the conflict shall immediately notify BP and request a resolution with refractory specialist. No liberty shall be taken to assume which instruction shall govern.

7. Refractory Packaging, Shipment and Handling

- a. Packaging of refractory materials shall comply with section 9 of GIS 72-001
- b. Shipment of hydraulic setting refractories shall be scheduled to insure that age of binder is less than 3 months old at the time of shipment and less than 9 months old at time of refractory installation. Refractory manufacturer shall indicate on shipping documents the code date for cement used in products.
- c. Chemically bonded refractories and plastic refractories shall be less than one month old at time of shipment and less than 6 months old at time of installation.
- d. Marking – Each bag, box or pail shall have the specific information defined in section 9 of GIS 72-001.
- e. Chemically bonded refractories shall be shipped in vapor tight plastic or cardboard enclosures protected from mechanical damage. Each container shall be marked with a code date of manufacturing and pallet numbers.
- f. For field or shop linings, protection from moisture shall be provided during shipping, handling, and storage. Material longest in storage shall be used first.
- g. The BP contracted equipment fabricator or contractor shall be responsible for protecting, during shipment, equipment with refractory installed prior to arrival at the job site. Repair of a lining damaged during shipment is the responsibility of the equipment fabricator.
- h. For shop lined panels, panels shall be packaged to minimize abrasion to the lining surface during shipment.
- i. Any opened or damaged refractory carton/container shall be discarded. All refractory exceeding the specified shelf life shall be discarded unless qualified with additional testing and approved by BP.

8. Surface Preparation

- a. Surfaces to be refractory lined (including edging bars, anchors, hexmesh and vapor stops) shall be abrasive-blast cleaned and free of foreign material such as oil, grease, rust, rust inhibitors, loose particles, etc. unless otherwise directed by BP.
- b. Abrasive-blast cleaning shall be in accordance with SSPC SP 6 and surface appearance shall be in accordance with SSPC Vis1, except for areas identified as areas susceptible to dew point corrosion.
- c. All surfaces where shell coatings are applied for corrosion protection, shall be abrasive blasted to a near white finish (SSPC-SP 10). If the coating is not applied in a timely manner and rust forms on the shell, the surface shall be abrasive blasted to comply with surface requirements. This process shall be administered as necessary to ensure that the SSPC-SP10 finish is available for coating the shell.
- d. All coatings applied to the interior shell of a vessel or other heated equipment (furnaces, heaters, incinerators, etc.) for corrosion protection shall be approved by BP.

