

DEP SPECIFICATION

REFRACTORY LINING FOR FLUIDIZED CATALYTIC CRACKING UNIT (FCCU)

DEP 64.24.32.12-Gen.

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DESIGN AND ENGINEERING PRACTICE



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1. INTRODUCTION

1.1 SCOPE

This new DEP specifies requirements and gives recommendations for the design, supply, installation, inspection and maintenance of the refractory linings for the various components of a Fluidized Bed Catalytic Cracking Unit (FCCU).

This document is applicable for all refractory lined components of a Fluidized Catalytic Cracking Unit (FCC) or by similar names such as RFCC (Residual Fluidized Catalytic Cracking unit) or LRCCU (Long Residue Catalytic Cracking unit), e.g., the regenerator, regenerator overhead line (flue gas duct), regenerator stand pipe, regenerator cyclones, reactor, reactor riser, riser lift pot, reactor cyclones, reactor overhead line, stripper, stripper stand pipe, etc. This DEP should also be applied to other refractory lined fluidized solid handling equipment on a case by case basis.

This DEP is not applicable to the regenerator air pre-heater or the CO boiler lining or burner blocks used therein.

This DEP is applicable to both new and existing (for maintenance) equipment of FCCUs.

This DEP shall be used by the Contractor or refractory applicator to develop job specific refractory specifications and procedures.

Refractories may be installed in the field, the steel fabricator's shop or the refractory applicator's shop, as agreed between the Contractor and the Principal.

Specific operating conditions and/or refractory lining configuration are not included herein as they vary from unit to unit.

A process description and typical layout for FCCU is provided in the Informative for illustration purposes only.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them. Any authorised access to DEPs does not for that reason constitute an authorisation to any documents, data or information to which the DEPs may refer.

This DEP is intended for use in oil refining. This DEP may also be applied in other similar facilities.

When DEPs are applied, a Management of Change (MOC) process shall be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements could 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 with regard to the safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this DEP 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, the objective being to obtain agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

NOTE: The **Refractory Contractor** is the party that undertakes all, or part of, the construction design, engineering, material procurement and application of refractory products on behalf of the Manufacturer where different. The Refractory Contractor has responsibility for the quality control of supplied products along with workmanship quality control as part of the total quality system.

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

NOTE: The **Refractory Manufacturer** is the party that manufactures the refractory products and/or ancillaries for supply to the Refractory Contractor. The Refractory Manufacturer has primary responsibility for material design properties, manufacturing quality control at the manufacturing site, construction design requirements and specific procedures such as those for site product mixing, installation and curing, drying, firing and start-up. The refractory Contractor may undertake duties of the Refractory Manufacturer only if they are the actual manufacturer of the product.

The **Principal** is the party that initiates the project and ultimately pays for it. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

Term	Definition
Cold Wall Refractory System	Refractory lining systems intended for insulation and/or erosion protection of the steel shell.
DEC	Detail Engineering Contractor.
Delegated Technical Authority	A Delegated Technical Authority is a person who has received delegated authority to approve.
Erosion Resistant Refractory	Erosion resistant refractory are conventional phosphate bonded high purity alumina, refractory mixes with extreme erosion resistance (typically <5 cc erosion loss per ASTM C704) used in a hot wall configuration. Selection of product brand shall be approved by Principal, prior to use.
Hot Wall Refractory System	Erosion-resistant refractory linings placed directly on to the steel shell, in conjunction with external thermal insulation the lining; in this case both the lining and the substrate are at the process temperature. This term is also applicable for erosion resistant lining for internals.
Inspector	Authorized inspector for Contractor, Principal or Owner.
Monolithic Lining	Refers to linings formed from unshaped materials (plastic, castable) generally without joints other than for designed panels or for control of cracks and expansion.
Ramming	Use of compressive force or impact to deform a stiff refractory mix causing it to completely fill the intended volume and /or fully bond or join to previously placed refractory (API 936).

Refractory Applicator	Installer selected to supply and place the refractory linings in vessels and or pipe sections specified by the Contractor and approved by Principal.
Refractory Materials, Products and Linings	Refractory materials, products and linings dense, insulating, and/or special composite refractory materials made from non-metallic mineral components.
Reported Refractory Temperature or Maximum Service Temperature	Service temperature of a specific product reported by the refractory manufacturer under oxidising atmospheres to support refractory product selection.
Self Levelling/Self Flow Refractory Castables	Castable mixes that do not require vibration to facilitate flow characteristics. Such mixes have special additives, which aid in the self flow/self levelling characteristics, when installed.
Steel Fabricator	Company with fabrication shop capabilities completely equipped to fabricate. steel vessels and or piping equipment; also known as vessel and or pipe fabricator.
Unshaped Refractory	Refractory material supplied in unfired state ready for installation into monolithic construction. Also referred to as "monolithic refractories".
Vibration Cast	Castable installation technique whereby refractory is mixed with water and placed in a formed enclosure with the aid of external vibration, which causes the refractory to flow and consolidate to the shape of the formed enclosure.

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 (5).

Cross-references to industry standards for the testing or refractory physical properties are given in Table 1.

1.5 COMMENTS ON THIS DEP

Comments on this DEP may be sent to the Administrator at standards@shell.com, using the DEP Feedback Form. The DEP Feedback Form can be found on the main page of "DEPs on the Web", available through the Global Technical Standards web portal <http://www.shell.com/standards> and on the main page of the DEPs DVD-ROM.

1.6 DUAL UNITS

This DEP contains both the International System (SI) units, as well as the corresponding US Customary (USC) units, which are given following the SI units in brackets. When agreed by the Principal, the indicated USC values/units may be used.

2. DESIGN CONSIDERATIONS

2.1 REFRACTORY LINING DESIGN – GENERAL CONSIDERATIONS

- 2.1.1 Cold wall refractory systems could typically be with insulating refractory castable or with dense erosion resistant product depending upon the service condition or as specified in the requisition.

Hot wall refractory systems are typically with a thin wall [25 mm (1 in) or 19 mm ($\frac{3}{4}$ in)] erosion resistant product for an external or internal component, unless otherwise specified.

- 2.1.2 Cold wall to hot wall transitions shall be designed for erosion resistance, thermal protection of the low alloy steel grade, prevention of erosion/corrosion (chlorides, stress corrosion cracking, polythionic acid stress corrosion cracking). Termination of external insulation, in all such cases, shall be clearly indicated on all construction detail drawings by the Detail Engineering Contractor (DEC) for approval by Principal. Reference Figure 20a.

In such cases, it is expected that the steel shell material grades are suitable for the expected interface temperature with the given external insulation. The design and extent of external insulation shall be evaluated as part of the design and approved by the Principal prior to start of work. External insulation shall not be provided for a primary cold wall refractory system or for a section which has a cold wall refractory system due to dissimilar weld construction. For all purposes, the steel shell temperature at dissimilar weld sections shall remain no greater than 350°C (662°F).

- 2.1.3 The refractory material of any layer shall be suitable for a service temperature at least 150°C (302°F) above its highest continuous operating temperature.

- 2.1.4 Monolithic lining systems for insulating castable and vibration cast lines shall include field joint and construction joint design clearly indicated on construction design detail drawings for approval prior to construction. Flue gas ducting system, with the exception of cold wall vibration cast pipe sections and insulating refractory systems, shall be designed with proper construction joint design utilizing material permanent change specifications to control all crack sizes to be within project specification.

2.2 DESIGN - METALLIC COMPONENTS

2.2.1 Anchor types and welding

- a) Anchors for hot wall lining include all types of individual anchors (trademark, custom made), hex mesh and ancillary items such as edging bars, binding bar etc. applicable for FCCU.
- b) Anchors for cold wall lining typically include wavy-vee anchor, unless otherwise specified.
- c) Anchors for cold wall-hot wall lining transition shall be as per Figure 20, (Appendix D).
- d) All welding shall be in accordance with DEP 30.10.60.18-Gen.

2.2.2 Requirements for hex mesh

- a) Hex mesh shall be of standard type with all ribs of equal depth, joined by double clinches. Offset (unequal depth) type hex mesh and/or riveted hex mesh shall not be used. Refer Figure 1A/B, (Appendix D).
- b) Hex mesh shall be fabricated from strips, a minimum of 2.1 mm (14 ga) thick for alloy steel.
- c) Hex mesh shall be 25 mm (1 in) in depth, unless otherwise approved.
- d) Hex mesh depth shall be matched "like for like" for all maintenance applications.
- e) Individual Hex mesh cell shall be 50 mm (2 in) across the flats.
- f) Individual cells shall have a minimum of 2 lances per cell.

- g) Hex mesh and Single Hex cell shall be welded directly on the base metal. Use of spacer bars is not permitted under any circumstances.

Refer Figure 2 and Figure 3, (Appendix D) for welding pattern intended for Severe service and Standard service respectively.

Refer Figure 4 through Figure 6, (Appendix D) for Hex mesh termination and joint details.

2.2.3 Requirements for Trademark anchors

Acceptable types of anchors include (not necessarily in order of preference):

Hot wall

- Curl anchors (also called "C bars")
- Tacko® anchors
- Single Hex cells/Half Hex cells
- Flex steel/Floor steel

Cold wall

- Wavy-vee anchor

Anchor grade shall be SS 304; depth of anchors shall be 25 mm (1 in), unless otherwise specified. Vendor standard thickness of 2 mm (14 ga) is acceptable.

Refer Figure 7, (Appendix D) for Curl anchor orientation and weld pattern.

Refer Figure 8, (Appendix D) for Tacko® anchor weld pattern.

Single Hex Cell shall be 50 mm (2 in) across the flats. Refer Figure 9, (Appendix D).

2.2.4 Requirements for Custom made anchors

Custom made anchors include the below but not limited to the following types:

- a) Straight punch tab
- b) Monster tab
- c) Flexible tab (special tab/variable angle tab, straight flex tab)
- d) L tab or fixed angle tab
- e) U tab
- f) Radius ring (semi-circular/half-round) tab

Anchor grade shall be SS 304 with submerged lances; Depth of anchors shall be 25 mm (1 in), unless otherwise specified. Vendor standard thickness of 2 mm (14 ga) is acceptable, unless otherwise specified in the drawings with a higher gauge for special/niche applications.

Refer to Figure 11 through Figure 15, (Appendix D) for Custom made anchor design details.

Refer to Figure 16 through Figure 19, (Appendix D) for various anchor combination systems described above.

2.2.5 Anchor design and weld requirements – Cold wall

2.2.5.1 Refer to Figure 10, (Appendix D) for details on wavy-vee anchor.

2.2.5.2 For cold wall lining layers, Wavy Vee type anchors with equal or unequal legs are the most preferred type of anchor. The material grade shall be of SS304(H) material, "bright" solution annealed after forming. 6 mm ($\frac{1}{4}$ in) diameter rod anchor shall be used for medium weight castable and 8 mm ($\frac{5}{16}$ in) diameter rod anchor shall be used for dense vibrocast lining. The anchor density shall be 20 to 30 anchors per square metre for vertical sections and 40 to 50 anchors per square metre for overhead sections. Anchor layout can either be square or staggered.

- 2.2.5.3 Each anchor weld shall be tested by hammer blow. Anchors that do not produce a clear bell sound shall be rewelded.
- 2.2.5.4 Undercutting on the anchor exceeding $\frac{1}{8}$ th of the anchor diameter shall be repaired or replaced.

2.2.6 Metal needle (fiber) reinforcement

- 2.2.6.1 Where site specific specifications require the addition of stainless steel reinforcement hooked ended drawn, 0.4 mm (0.015 in) diameter, 19 mm ($\frac{3}{4}$ in) long, or melt-extract type, 0.5 mm (0.02 in) diameter and 19 mm ($\frac{3}{4}$ in) length in SS-304 grade shall be added to the mix, as described below:

- 2% by weight for all areas with single point anchors
- 2% by weight for critical areas such as swage, lift pots, etc. with thick cold wall lining configuration

NOTE: SS needles shall be added to the refractory mix using a 12 mm (1/2 in) aperture hardware screen to ensure even distribution and to prevent clogging during the mixing process.

3. INSTALLATION OF ANCHORS

3.1 GENERAL CONSIDERATIONS

- a) Welding of anchors in the steel fabrication shop may be manual, semi-automatic, or by semi-automatic stud gun, if pre-qualified and approved. Welding of anchors in the field shall be manual or semi-automatic only.

Stud welding in the shop is permitted on new steel. Stud welding on in service equipment requires prior approval from the Principal or location engineering department.

- b) Welding consumables used shall be in accordance with the table below. All welding procedures used for the welding of anchoring systems, including semi-automatic stud welding, shall be qualified in accordance with DEP 30.10.60.18-Gen. prior to the start of work.

Base Metal	Anchor Grade		
	SS 304 Individual Anchors and Hex	SS 321 Individual Anchors	SS 410S Hex
Carbon Steel	SS 309	N/A	SS 309
Low Alloy	SS 309	N/A	SS 309
SS 304(H)	SS 308 (H)	N/A	N/A
SS 321	SS 347	SS 347	N/A

- c) Welders and welding operators shall be specifically trained to make proper welds. Each welder or welding operator must be tested on an actual anchor in all positions to be used on the work. Any other training or qualification requirements proposed by the Contractor shall be approved by the Principal.
- d) Any anchor weld on low alloy steel (with or without PWHT) requires minimum pre-heat temperatures. DEP 30.10.60.18-Gen. shall be referred to in all such cases.
- e) Areas for anchor attachment welds shall be ground or blasted to commercial cleanliness prior to welding.
- f) All anchors supplied whether to shop or directly to customer site shall be PMI checked (typically every hex mesh sheet and 5% for bulk individual anchor items) and certified prior to use. Random PMI shall be done on "as installed" anchors.
- g) Colour coding of procured anchors should be done at shop/site at anchor fabrication source for positive identification, and shall be used when two grades of same anchor are used.
- h) Rolling direction for Hex mesh shall be shown in the purchase document or drawings.
- i) Hex mesh shall be used for pipe sections beyond 450 mm (18 in) diameter. Flex steel (Floor steel) shall only be used as an anchor choice for extreme low diameter pipe sections where installation of other anchor types is not possible.
- j) Hex mesh shall be installed circumferentially in sections as large as practical.
- k) Fabrication, where hex is fit and welded to flat plate, then the plate and hex are formed (pressbrake, or rolling) is acceptable only if the specific combination of rolling diameter, base plate thickness, and base plate material are pre-approved by the principle. Acceptance can be made based on any of (a) test sample, (b) prior work and (c) first Operation. Acceptance will include visual inspection of welds, and deformation of the hex bars (gaps between bars, opening of clinches, buckling of bars in the crotch). The acceptance includes details of bridging of anchors across

the seams between prerolled sections.

- l) Joints between adjoining hex panels shall have all end terminations welded to the plate (one side). The gap between adjoining panels shall be such that the refractory contained in the gaps shall be between $\frac{1}{2}$ and $1\frac{1}{2}$ hexagons in area and the area needs to be less than 2:1. Longitudinal joints of hex mesh panels shall be offset and reinforced with bridging strips to avoid continuous longitudinal seams.
- m) Hex mesh shall be welded on each strip to the base metal every other hex for standard service and every hex for severe service. Hex mesh, trademark and custom made anchors shall have a 5 mm ($\frac{3}{16}$ in) weld, 25 mm (1 in) long at each weld location. At hex terminations, each end bar shall be welded to the base metal with 12 mm ($\frac{1}{2}$ in) long single fillet welds.
- n) Welding details for all individual anchors shall be in accordance with drawings included in this DEP.

3.2 ANCHOR WELDING - QUALITY ASSURANCE

- a) All anchor welds shall be visually inspected 100% after slag removal. Depending on local conditions and construction practices, the Principal holds the discretion to specify bend test, dye penetrant examination of welds and/or hammer test (up to 10%) for individual anchors (wavy-vee, trademark and custom made type) in addition to the visual inspection of the welds.
- b) Anchor welding shall be by GMAW or GTAW process in shop. SMAW and FCAW welding process shall only be used with prior approval from the Principal. Approval requires consideration of surface cleaning process prior to welding.
- c) Field installation of anchors shall be by SMAW process. Any other welding process requires prior approval by the Principal.

4. INSTALLATION OF REFRACTORY

4.1 GENERAL REQUIREMENTS

- a) The standards for physical property testing to be applied for the various refractory specifications shall be as outlined in Table 1.

Table 1 Acceptable material test standards

Properties	Standard References	
Permanent Linear Change	ASTM C113, ASTM C179, API 936	EN 1402-6, ISO 2477, ISO 2478
Porosity	ASTM C20	ISO 5017
Thermal Conductivity	ASTM C201, ASTM C417, ASTM C1113	ISO-8894-1, ISO-8894-2, EN 993-15, EN 1402-5
Density (true and bulk)	ASTM C134, ASTM C830, ASTM C914, API 936	EN 1402-6, EN 993-1, EN 1094-4, ISO-5016, ISO 5017
Cold Crushing Strength	ASTM C133	EN 1402-6, EN 993-5, EN 1094-5, ISO-8895, ISO 10059-1, ISO 10059-2
Modulus of Rupture	ASTM C133	EN 1402-6, EN 993-6, EN 993-7 ISO-5014
Hot Modulus of Rupture	ASTM C583	ISO-5013, EN 993-7, EN 1402-6
Refractoriness under Load	ASTM C832, ASTM C16	ISO-1893, EN 993-8, EN 1402-6
Abrasion Resistance	ASTM C704	ISO-16282
Chemical Analysis	XRF	ISO-12677, ISO-21587-1, ISO-21587-2, ISO-21587-3
Sampling and Preparation	ASTM C862, ASTM C865, API 936	EN 1402-5

NOTE: Testing will be generally performed in accordance with primary standards. However, in case of non-availability of test facility for completion in accordance with primary standards, alternative test standards may be used with the consent of the Principal.

- b) Surface preparation prior to refractory lining shall be per Sa 2.5.
- c) Before the equipment is pressure tested, all metal anchor systems and hardware shall be installed by the vessel and/or pipe fabricator. The inspector shall approve the completed anchor installation before the pressure test is performed. If additional metal anchors are required, the Refractory Contractor must have written approval for installation. This activity shall constitute a "Hold Point" on the Inspection & Test Plan (ITP).
- d) All required stress relieving shall be performed before hydrostatic testing. Hydrostatic testing shall be completed before the refractory is installed.
- e) Unless otherwise specified in project specifications, the Refractory Contractor is responsible for all surface preparation. Prior to installing refractory anchors the steel shall be commercially blasted using dry, hard, sharp abrasive to meet the requirements of SSPC-SP-6 or equal. Blast refuse shall be removed before lining is started. For all maintenance cases irrespective of the areas, spot grinding is required at welding spots to ensure clean metal surface prior to welding. As an alternative practice for larger areas when spot grinding may not be feasible, it is an acceptable

practice to use grit blasting to obtain an equivalent surface finish.

- f) Refractory installation shall be done by casting, vibration casting, ramming or pneumatic gunning. The technique shall be indicated in bid documentation and upfront by the Refractory Contractor for approval by the Principal. Applicator qualifications, approval by Principal and additional approvals shall be required to use alternative techniques.
- g) Refractory mixing and placement shall be done in accordance with written procedures provided by the Refractory Contractor and approved by the Principal.
- h) Material intended for casting shall not be pneumatically installed. However, vice versa may be applicable with prior approval from the Principal.
- i) All materials shall be stored in a cool, dry location away from direct sunlight prior to installation. Damaged or perforated containers shall be rejected.
- j) The mixing equipment shall be clean and free of solidified hydrates, debris and in proper working order prior to mixing.
- k) All nozzle openings shall be plugged with tapered plugs than extend beyond the final thickness of refractory lining. The plugs shall be greased for easy removal after installation.
- l) Refractory lining thickness shall be in accordance with design drawings.
- m) If required, metal surfaces in contact with green refractory shall be dampened prior to refractory installation. No water shall be used on surfaces in contact with uncured phosphate bonded refractory.
- n) The temperature of the air and vessel shell at the installation site shall be in accordance with the Manufacturer's recommendation and as minimum standard maintained between 10°C (50°F) and 32°C (90°F) during refractory installation and 24 hours thereafter. For colder weather conditions, heating or external insulations (external to component) should be used to maintain temperature above the specified limit. For hotter weather conditions than specified, shading, water spraying (external to component) and/or air conditioning should be used to maintain temperatures below the maximum limit.
- o) Wet mix material temperature shall be maintained between 15°C (60°F) and 27°C (80°F). The refractory mix temperature shall be recorded during installation by inserting a thermometer into the freshly prepared mixture. Chilling both dry materials (refrigerated container) prior to use and water (ice box) should be used as an option to lower wet mixture temperature to the specified limits.
- p) Where steel protrudes through castable linings such as nozzle, sleeves and all structural members, they shall be wrapped with ceramic paper to provide room for thermal expansion of the metal and to prevent the lining from bonding to the metal part. Such nozzle protrusions beyond the lining surface may require erosion resistant lining depending on the application or component. However, for applications requiring higher grade of ceramic paper, conventional alumino-silicate based ceramic fibre or Alkaline Earth Silicate paper shall be used. The fibre shall be properly secured in place with cling film or chloride free masking tape. The thickness of paper shall be as follows:
 - pipe OD ≤ 350 mm (14 in) 3 mm ($\frac{1}{8}$ in)
 - pipe OD > 350 mm (14 in) 6 mm ($\frac{1}{4}$ in)
- q) As minimum, standard water used for mixing refractory shall be fresh, clean and suitable for drinking. However, water shall not contain more than 50 ppm of chlorides. The water shall generally be free of or within the Manufacturer's specification limits for contents of oil, acid or alkali materials.
- r) The shelf life of unshaped refractory shall be verified before any installation. Refractory materials should be no more than 4 months old from date of initial

acceptance test. After 4 months, pre-qualification testing requirements should be considered prior to use.

4.2 INSTALLATION BY PNEUMATIC GUNNING – COLD WALL

- a) Only qualified and experienced personnel shall be used for pneumatic application.
- b) Gun grade refractory castable shall be applied in accordance with the Manufacturer's recommendations with the installation Contractor procedures.
- c) Water and air pressure shall be at steady pressure as recommended by the Manufacturer and stated in the installing Contractor installation procedures to obtain desired physical properties and control rebound losses.
- d) Gunned linings shall be applied in horizontal circumferential bands, starting at the bottom and working upwards. Bands shall be 1.5 - 2 m (5 to 6.5 ft) high and the scaffold platform construction, where applicable, shall align with this requirement. Scaffold supports in front of the wall shall be arranged in such a way that at least a space of 750 mm (30 in) is maintained for gunning.
- e) Full 360° bands shall be completed in one gunning operation. Therefore a "wet-to-wet" installation procedure is advisable, i.e., 2 nozzle operators starting one after another and continuing in opposite directions.

No interruptions or cold joints (vertical joints) shall be allowed (example, 'dense bed' area and transition areas) without prior approval by the Principal

- Where interruptions occur, the lining shall be cut back to the shell leaving a straight but rough surface with an angle of 80° - 90° to the shell to form a key for subsequent refractory application.
 - All cold joints and shot boards shall be cleaned carefully of debris and rebound material. Immediately, installation is interrupted and the cleanliness must be verified before the resumption of installation.
 - In case of interruption in installation for more than 15 minutes, sections of lining which are not to full thickness shall be removed to the shell or underlying back-up layer (as applicable) and reinstalled in one continuous full thickness application.
 - Rebound shall not be reused under any circumstances.
- f) Down hand gunning beyond 15° below the horizontal line is not permitted.
 - g) In specific wear areas (example: lower swage of regenerator), minimum 150 mm (6 in) thick lining, with a smooth transition into the designed thickness of the adjoining walls, shall be applied.

Alternative-I

The 'hot face' layer could incorporate continuous hex mesh armour for 25 mm (1 in) thick erosion resistant lining. The back layer, in such a case, shall be with 125 mm (5 in) thick medium weight insulating castable. Anchors shall be suitably designed to suit the two shot lining.

The Contractor shall submit a detailed drawing of the exact configuration, taking into account the following guidelines:

- a. Studs 10 mm ($\frac{3}{8}$ in) diameter x 125 mm (5 in) long, with a pitch of approximately 250 mm (10 in) with staggered centres, are welded in the transition area.
- b. The backup layer of 125 mm (5 in) thickness shall be applied first by gunning up to the tip of the stud/washer plate assembly.
- c. After completion of the backup layer, the stud tips and washer plate shall be cleaned and tack welded.

- d. Hex mesh panels shall be welded onto the support plates and joined together with use of punch-tabs, where required at terminations;
- e. Erosion resistant refractory shall then be installed by ramming

Refer Figure 21, (Appendix D) for design guidelines.

Alternative-II

Consisting of a single layer constituting 150 mm (6 in) thick insulating castable reinforced with 2% by weight stainless steel needles.

4.3 INSTALLATION BY VIBRATION CASTING – COLD WALL

- a) Forms shall be sufficiently rigid to withstand the hydrostatic load of the refractory and dynamic vibration load. Forms shall be minimum 5 mm ($\frac{3}{16}$ in) thick carbon steel grade. Pours exceeding 1000 mm (3 ft) high and 600 mm (24 in) pipe ID shall have stiffening rings on the form. High density foam for the formwork may be used to form contours, fillets and field joints.
- b) Forms shall be substantially leak tight. Joints shall be welded or bolted and gasketed. Suspect areas may be checked by water filling prior to installation. Silicone caulking shall be used for all formwork joints. However, caulking large gaps (>5 mm/ $\frac{3}{16}$ in) are not acceptable.
- c) Forms for pipe sections shall be concentric with the pipe. End truing rings are required. Pipe lining thickness variation at the joint shall be -0, +5 mm (-0, $+\frac{3}{16}$ in) for lining thickness less than 50 mm (2 in) and -0, +5 mm (-0, $+\frac{1}{4}$ in) for thicker lining. The edge of the refractory shall form a plane perpendicular to the pipe axis. The variation from an ideal plane shall be less than 5 mm ($\frac{3}{16}$ in) for pipe diameter lesser than 600 mm (24 in) and 10 mm ($\frac{3}{8}$ in) for larger pipe.
- d) If the pipe is to be vibracast lined, the sub-assemblies shall be carefully laid out in consultation with technical authorities and be subject to approval by the Principal.
- e) Small nozzles, such as PI and TI taps, shall generally be cast solid with the opening drilled after curing.
- f) Vibrators shall be used on the shell unless specifically approved for use on formwork by the Principal. Vibrators shall have a total force equal to at-least 100% of the total weight being vibrated (form and green refractory). Each vibrator shall be independently controlled. The Refractory Contractor shall describe in written procedures the number of vibrators to be used in job specific castings including how they will be operated during lining installation. The Refractory Contractor shall insure vibrator layout has sufficient vibrators and in proper layout to eliminate “dead” zones and to provide consolidation of all refractory, without over vibration and segregation of any refractory components.
- g) The vibrators shall be attached onto steel pads which are tack welded to the steel shell. Welding the vibrator to the shell should require special and specific permission. Chain Mounting of vibrators is another preferred method.
- h) Vibrator type, size, force, frequency air delivery or energy requirements and attachment method shall be included in the installation procedure which shall be reviewed and approved by the Principal.
- i) Adequate spare vibrators, compressors, mixers, hoists, etc. are required on site or shop and shall be stated in the installation procedure.
- j) Generally, components shall be cast as a single pour. Larger sections which may require a cold joint due to free fall limits shall be reviewed by the installer and the Principal to determine the least detrimental location and design.
- k) Mixer location shall be immediately adjacent to, and preferably above the work piece, to minimize post mixing handling and installation of the wet mix within the given working time. Placement shall be completed within 10 minutes from end of