

Application of Refractory Castable

Procedure

This Standard replaces and cancels its previous revision.

The CONTEC - Authoring Subcommittee provides guidance on the interpretation of this Standard when questions arise regarding its contents. The Department of PETROBRAS that uses this Standard is responsible for adopting and applying the sections, subsections and enumerates thereof.

Technical Requirement: A provision established as the most adequate and which shall be used strictly in accordance with this Standard. If a decision is taken not to follow the requirement ("non-conformity" to this Standard) it shall be based on well-founded economic and management reasons, and be approved and registered by the Department of PETROBRAS that uses this Standard. It is characterized by imperative nature.

Recommended Practice: A provision that may be adopted under the conditions of this Standard, but which admits (and draws attention to) the possibility of there being a more adequate alternative (not written in this Standard) to the particular application. The alternative adopted shall be approved and registered by the Department of PETROBRAS that uses this Standard. It is characterized by verbs of a nonmandatory nature. It is indicated by the expression: **[Recommended Practice]**.

Copies of the registered "non-conformities" to this Standard that may contribute to the improvement thereof shall be submitted to the CONTEC - Authoring Subcommittee.

Proposed revisions to this Standard shall be submitted to the CONTEC - Authoring Subcommittee, indicating the alphanumeric identification and revision of the Standard, the section, subsection and enumerate to be revised, the proposed text, and technical/economic justification for revision. The proposals are evaluated during the work for alteration of this Standard.

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CONTEC

Comissão de Normalização
Técnica

SC - 09

Thermal Insulation and
Refractories

Introduction

PETROBRAS Technical Standards are prepared by Working Groups - WG (consisting specialized of Technical Collaborators from Company and its Subsidiaries), are commented by Company Units and its Subsidiaries, are approved by the Authoring Subcommittees - SCs (consisting of technicians from the same specialty, representing the various Company Units and its Subsidiaries), and ratified by the Executive Nucleus (consisting of representatives of the Company Units and its Subsidiaries). A PETROBRAS Technical Standard is subject to revision at any time by its Authoring Subcommittee and shall be reviewed every 5 years to be revalidated, revised or cancelled. PETROBRAS Technical Standards are prepared in accordance with PETROBRAS Technical Standard N-1. For complete information about PETROBRAS Technical Standards see PETROBRAS Technical Standards Catalog.

Foreword

This Standard is the English version (issued in 02/2021) of PETROBRAS N-1617 REV.G 06/2016. In case of doubt, the Portuguese version, which is the valid document for all intents and purposes, shall be used.

1 Scope

1.1 This Standard establishes the conditions required for storage and application of refractory castable.

1.2 This Standard applies to designs initiated after its date of issuance as well as to existing equipment items when they undergo maintenance or reform.

1.3 This Standard contains Technical Requirements and Recommended Practices.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

PETROBRAS [N-9](#) - Tratamento de Superfícies de Aço com Jato Abrasivo e Hidrojateamento;

PETROBRAS [N-133](#) - Soldagem;

PETROBRAS [N-1728](#) - Concreto Refratário;

PETROBRAS [N-1910](#) - Projeto de Revestimento de Concretos Refratários;

[PG-2AT-00291](#) - Aplicação de Revestimento Refratário - Qualificação de Pessoal;

ABNT [NBR 13320](#) - Materiais Refratários - Determinação da Fluidez de Concretos Convencionais e de Fluência Livre;

ABNT [NBR 15239](#) - Tratamento de Superfícies de Aço com Ferramentas Manuais e Mecânicas;

ASME Boiler and Pressure Vessel Code - [Section IX](#) - Qualification Standard for Welding and Brazing Procedures, Welders, Brazers, and Welding and Brazing Operators.

3 Terms and Definitions

For the purposes of this document, the following terms and definitions apply.

3.1 curing

chemical reactions that occur at low temperatures after water is added to the castable. The curing time is the time period between the beginning and end of such reactions

3.2**hydraulic curing**

treatment given to the castable after its application to ensure water retention in order to allow for the continuity of the reactions observed during the curing process

3.3**course**

an area in which refractory castable can be applied before the material placed at the beginning of the refractory application begins to set

NOTE In cylindrical vessel applications, a course represents the concrete ring applied horizontally to the shell, with the height being sized in such a manner as to allow it to be closed before the concrete begins to set.

3.4**initial setting**

it is characterized by loss of the consistency needed for application of the material after water is added to the mix

3.5**rebound material**

gunning castable which bounces away from the wall due to factors, such as: excess pressure, lack of pre-wetting, angle of inclination of gun nozzle, insufficient bonding material or inadequate grain size

3.6**workability**

property that allows refractory materials, when wetted, to be molded and worked with greater ease, depending on their consistency and plasticity

4 General Conditions**4.1 Storage**

4.1.1 Concrete shall be stored in a dry, well-ventilated location, not subject to excessive heat and protected from direct sunlight.

4.1.2 The maximum piling of packages per pallet shall be in accordance with the manufacturer's criteria. In the absence thereof, the following criteria shall be followed:

- a) five metallic packages;
- b) ten multi-sheet paper or plastic bags.

4.1.3 Concrete shall be stored in such a manner as to allow for the control of validity periods and consumption on a first-in first-out (FIFO) basis of warehouse material, which shall be properly handled so as to prevent damages.

4.1.4 There shall be no direct contact with the floor, and the material shall be laid on pallets.

4.1.5 In those cases in which the castable is stored for a period of time greater than the validity period for use or whenever it is necessary to prove the quality of the material, the inspection provided for in PETROBRAS N-1728 shall be repeated for revalidation of the material, with a validity of 3 months.

4.2 Homogenization and Mixing

4.2.1 Castable shall be perfectly homogenized in the dry condition before water is added according to the instructions provided by the castable manufacturer. The percentage of added water shall be the same as that used in the test for qualification of the application procedure (see 4.3).

4.2.1.1 Metallic fibers shall be added during the homogenization process by passing them through a 6 mm to 8 mm mesh sieve so that they can be uniformly distributed throughout the entire volume of the castable.

4.2.1.2 The total contents of each castable package shall be homogenized, even when the quantity used is smaller than that of the packaged unit.

4.2.2 No material shall be added to the castable received from the manufacturer, except metallic fibers, where applicable.

4.2.3 Castable from a particular manufacturer shall not be mixed with castable from other manufacturers.

4.2.4 Mix only the sufficient quantity of castable to be applied before the initial setting.

4.2.5 Mixers shall be of sufficient capacity to ensure a continuous supply of castable during application.

4.2.6 Water used for the mixing and wetting process shall be potable or industrial, with chloride content less than 200 ppm for surfaces in carbon steel and alloy steel, and 50 ppm for stainless steel.

NOTE The maximum temperature of water shall be 24 °C.

4.2.7 The temperature of the mixture shall be kept between 19 °C and 24 °C during the application, and the temperature of water or concrete may be changed for that range to be reached.

4.2.8 The mixing recipients shall be metallic and watertight as well as cleaned (at each mixture) and dried.

4.2.9 The castable has well mixed when:

- a) no segregation is observed between grains;
- b) no regions wetted differently are observed;
- c) proper consistency is achieved.

4.3 Application Procedure

The following information set out in the qualification shall be included in the application procedure in the indicated sequence:

- a) application method;

- b) application position (vertical or overhead);
- c) method and degree of surface preparation;
- d) lining thickness and type of anchorage;
- e) material, manufacturer and commercial reference;
- f) percentage and type of metallic fiber to be added (when applicable);
- g) water proportioning range;
- h) mixing method, type of mixer and capacity;
- i) workability (when applicable);
- j) safety requirements for handling refractory material;
- k) requirements for handling and disposal of wastes (packaging and leftover materials);
- l) if the castable is applied through the spraying method, the following shall be defined:
 - distance between gun nozzle and plate;
 - operating air pressure of gunning machine;
 - type, model and manufacturer of gunning machine;
 - height of each course;
- m) if the castable is applied through the pouring method, the following shall be defined:
 - type of formwork to be used;
 - height of each course;
 - period of time to complete the course;
 - compaction technique;
 - stripping time;
- n) if the castable is applied through the pouring method with external vibration, in addition to the provisions in m), the following shall be defined:
 - vibrator (manufacturer, type, model, characteristics);
 - quantity, location and sequence of operation of vibrators;
 - maximum/minimum vibration time;
 - vibration variables (frequency and acceleration);
- o) if the castable is applied through the pouring method by pumping, in addition to the provisions in m), the following shall be defined:
 - pumping equipment (manufacturer, type, model, characteristics);
 - layout for installation, piping, and accessories;
 - pumping points, application sequence;
 - pipe cleaning and lubrication method;
 - define the fluidity (ABNT [NBR 13320](#)) required for application (parameters and frequency of verification test);
- p) wetting and curing technique.

NOTE Whenever any of the variables mentioned in a), b), e) and g) is modified, the procedure shall be requalified.

4.4 Refractory Application

4.4.1 For regions to be welded in the assembly phase the lining application shall be interrupted according to the orientations contained in the design.

4.4.2 In the absence of the orientation mentioned in 4.4.1, use the recommendations of Table 1. **[Recommended Practice]**

Table 1 - Minimum Distance From Lining to Weld Bead

Types of lining		Minimum distance (mm)	
		Welding on lining side	Welding on opposite side
Anchored to hexagonal wire mesh or "S" anchor fitting		100	100
Monolithic		100	35
Dual layer	1 st layer	100	50
	2 nd layer	200	100

4.4.3 For dual layer, the weld joining hexagonal wire mesh panels shall be located on a row of threaded or welded anchors.

4.4.4 The castable shall only be applied up to two hexagons before the region of the weld joining hexagonal mesh panels.

4.4.5 Whenever possible, equipment parts shall be previously adjusted before the castable is applied so as to avoid the need for adjustments among parts of the equipment in the assembly phase as this could cause damages to the lining. **[Recommended Practice]**

4.4.6 When the castable is applied before assembly on long parts, care shall be taken in the assembly phase so as to avoid bending of the part.

4.4.7 During the refractory application phase, observe the minimum time periods for moving parts, in accordance with Table 2.

Table 2 - Minimum Time Periods for Moving Parts

Types of castable	Change of position and/or small displacements	Field transportation and assembly
Chemical setting castable up to 1" thick	12 hours	24 hours
Hydraulic setting castable of any thickness or chemical setting castable over 1"	24 hours	48 hours
NOTE 1 The above time periods may be modified according to the manufacturers recommendations, provided due care is taken to prevent structural damages to the castable. [Recommended Practice]		
NOTE 2 Parts on which refractory plastic was applied shall be dried with localized heating before assembly.		

4.4.8 On hot days (ambient temperature above 30 °C), during the hydraulic curing and application phases, care shall be taken to keep the plating temperature below 30 °C (e.g.: water spraying, nighttime application, etc.).

4.4.9 On cold days (ambient temperature below 10 °C), during the application and hydraulic curing phases, care shall be taken to keep the temperature of the plate at a temperature above 10 °C (e.g.: water spraying).

4.4.10 All heat treatments, pressure tests and plate inspections shall be completed before the castable is applied. Pneumatic tests may be done after refractory application, leaving the joints being tested without lining.

NOTE For equipment on which refractory has been applied during the manufacturing and/or assembly phase the pressure test may be performed after refractory application, in specific situations, provided all technical requirements are verified and the recommendations of the manufacturers of refractory material and of the designer are followed. The procedure for application, drying, pressure testing and inspection of the dry refractory material after the pressure test shall be previously approved by PETROBRAS.

4.4.11 Expansion joints in castables applied between two metallic walls and on piping or metallic structures crossing refractory walls shall be in compliance with PETROBRAS [N-1910](#).

4.5 Air Drying

After curing, the lining shall be air dried at ambient temperature for, at least, 24 hours by natural or forced ventilation.

4.6 Drying by Heating

4.6.1 Drying by heating shall be carried out considering the type, class, thickness, volume and application method of the castable, as well as the geometric shape of the equipment, in accordance with the recommendations of the castable manufacturer and equipment designer.

4.6.2 In the absence of recommendations from the concrete manufacturer and equipment designer, drying by heating shall comply with the requirements of Table 3.

Table 3 - Heating Dryout Schedule

Ramp and Heating Stages	Concrete Type	
	Insulating or semi-insulating	Dense
Initial Heating Rate	50 °C/h	30 °C/h
1st stage 120 °C to 150 °C	8 h for 50 mm thick and 2 h for each 25 mm added 6 h for thickness less than 50 mm	
Heating Rate	50 °C/h	30 °C/h
2nd stage 320 °C to 380 °C	1 h for each 25 mm, being at least 5 h	
Heating Rate	50 °C/h	30 °C/h
3rd stage 540 °C a 600 °C	1 h for each 25 mm, being at least 5 h	
Heating rate up to operation temperature	50 °C/h	50 °C/h

4.6.2.1 If the thermal cycle is interrupted, it will be possible to return to the interruption temperature at a maximum heating rate of 50 °C per hour.

4.6.2.2 In case the equipment is expected to go into operation immediately after it is dried out, the temperature shall be raised at a heating rate of 50 °C per hour up to the operating temperature. If that is not the case, it shall be cooled at a rate of 50 °C per hour.

4.6.2.3 For equipment in which the operating temperature is below 600 °C, the second or third stage shall be at the operating temperature, with duration as per Table 3

4.6.2.4 Before drying with heating, shall be checked if the parts subject to displacement at high temperature are free to absorb the thermal expansion of the equipment (eg: supports, guides, expansion joints and expansion points).

4.6.3 For drying by heating, the use of hot air circulation equipment or burners operating with the maximum possible excess air is recommended. **[Recommended Practice]**

4.6.4 For drying by heating with hot air circulation (convective drying), shall be established a procedure that contains at least the following information:

- a) drying curve;
- b) air flow from the fans;
- c) identification of the points for monitoring the temperature inside the equipment;

NOTE It is recommended to monitor the temperature in a region close to the burner, in the middle section of the equipment and at the gas outlet. Additionally, it shall be predicted point (s) for monitoring the side temperature. **[Recommended Practice]**

- d) details of the start operations of the burners and action in case of interruption of flame or energy.

4.6.5 For convective drying, the following guidelines and requirements shall be met:

- a) there should be no direct flame incidence in the refractory;
- b) the burners shall have sensors for flame monitoring;
- c) permanent technical supervision (24 hours);
- d) audible alarm and safety devices (solenoid valves) that act in the fuel cut in case of absence of flame or energy;
- e) there shall be no exposure of metal parts of the side, such as field joints;
- f) provide registration of the drying curve signed by the technician responsible;
- g) the continuity of the drying curve monitoring record shall be guaranteed, even in the event of a power failure (use of a generator or no-break);
- h) the execution and monitoring team shall be trained according to the system's drying and operation procedure;
- i) the temperature control during the drying curve shall be automatic.

4.6.6 Coatings that have already dried shall not be placed in service at a heating rate exceeding 50 °C per hour in the first two hours and subsequently follow the normal heating curve of the equipment

4.6.7 Coatings that have already dried, but that have been soaked during equipment shutdown, shall be put into service according to Table 3, limited to the 1st stage. After the 1st stage, follow the normal heating curve of the equipment.

4.6.8 Drying by heating on repaired areas shall be carried out as follows:

- a) total repaired areas less than 0,5 m² may be placed in service after initial curing without drying; **[Recommended Practice]**
- b) total repaired areas between 0,5 m² and 3,0 m² shall be dried out after initial curing, with the heating rate being limited to 50 °C per hour up to 200 °C, remaining for 1,5 hours for every 25 mm of lining thickness; afterwards, drying may continue;
- c) total repaired areas greater than 3,0 m² or exceeding 20 % of the total of the installation shall be cured and dried as if they were a completely new lining.

4.7 Surface Preparation

4.7.1 The surface shall be prepared by commercial abrasive blasting in accordance with PETROBRAS [N-9](#), Sa 2 grade, or with mechanical tools, in accordance with ABNT [NBR 15239](#), grade St 2.

4.7.2 After the surface has been prepared, it shall be cleaned to be free from sand, dust and oil residues.

4.8 Anchoring Devices

4.8.1 The type of anchoring, the material and its welding, including the stud welding method, shall be in accordance with PETROBRAS [N-133](#), [N-1728](#) and [N-1910](#), and welders shall be qualified in accordance with ASME [Section IX](#).

4.8.2 Calendering of the hexagonal mesh shall be carried out in the horizontal direction of strips.

4.8.3 The welds joining mesh panels shall be performed in accordance with PETROBRAS [N-1910](#).
[Recommended Practice]

4.8.4 The ends of “V” and “Y” anchors shall be protected in accordance with PETROBRAS [N-1910](#).

4.8.5 For application of threaded studs or “Y” anchor fittings, these shall have the threaded part protected during application of the first layer of castable.

4.8.6 For application of anticorrosive protection on plating provision shall be made for the product not to adhere to the surface of the anchoring devices, except for the weld region.

5 Specific Conditions

5.1 Hydraulic Setting Castables

5.1.1 Homogenization and Mixing

Homogenization and mixing of hydraulic setting castables shall be carried out in a mixer of relative movement between the blades and the bucket.

5.1.2 Hydraulic Curing

5.1.2.1 After the castable has been applied, wetting shall be ensured from the beginning of the setting process for at least 24 hours after the last lining section has been applied.

5.1.2.2 The beginning of the setting process may be characterized when cement is dry to the touch.
[Recommended Practice]

5.1.2.3 During the entire curing period, one of the requirements below shall be followed:

- a) alternative 1: apply a thin layer of water spray over the entire surface of the coating, taking care not to wash away the surface. Water shall be sprayed until the curing process has been completed. The quality of the water used in spraying shall be similar to that used in the mixture (see 4.2.6);
- b) alternative 2: apply a paraffin-based waterproofing film to ensure the moisture required for curing.

5.2 Chemical Setting Castables

5.2.1 Homogenization and Mixing

5.2.1.1 Only the quantities of castable that may be applied at the maximum time interval determined by the beginning of the setting process of the material shall be mixed, according to the manufacturer's instructions.

5.2.1.2 In the case of castables supplied with two components, when using planetary mechanical mixer, the liquid shall be added first and, after that, add the castable. For other types of mixers, reverse the mixing order, considering the castable first and then the liquid component.

5.2.1.3 Whenever the application is made at an ambient temperature exceeding 30 °C, the following procedure is recommended to delay the initial setting: **[Recommended Practice]**

- a) use cold mixing water (2 °C to 5 °C);
- b) try working at night (during hours of less heat);
- c) keep the mix cooled, if possible.

5.2.2 Thickness Recomposition Application

5.2.2.1 The recomposition of the coating thickness is a practice restricted to the services of equipment maintenance after operation.

5.2.2.2 In the absence of apparent anchoring, the restoration of the coating can only be carried out if the eventual detachment does not cause a risk of obstruction, damage or operational disturbance, and shall be previously evaluated.

5.2.2.3 For thin coatings, up to 25 mm, in the presence of apparent anchoring, the coating can be recomposed by filling the empty volume in the anchoring. The final thickness after recomposition shall not be greater than the original thickness of the coating.

5.2.2.4 For coatings with thicknesses greater than 25 mm, in the presence of apparent anchoring, the coating can be recomposed, provided that the anchoring remainder is sufficient to sustain the restoration.

NOTE 1 It is recommended that the total thickness of recomposition does not exceed twice the height exposed of the anchor clamp. **[Recommended Practice]**

NOTE 2 For the recomposition of thicknesses greater than that established above, the use of auxiliary devices for anchoring is allowed, since previously assessed for risk detachment as described in 5.2.2.2.



6 Refractory Application Methods

6.1 Pouring

6.1.1 Application

Applicable only to hydraulic setting castable and shall be carried out by manual compaction, internal vibration, external vibration or free flow.

6.1.2 Qualification

6.1.2.1 The procedure qualification shall establish the information contained in 4.3. Excepted the application by external vibration, the qualification shall be carried out on a panel placed in the horizontal position on a carbon steel plate, with minimum dimensions of 600 mm x 600 mm and a thickness for refractory application of 100 mm.

NOTE The panels must be constructed in such a way that the bottom plate is removable, with the anchoring clamps screwed

6.1.2.2 The qualification of the application procedure by external vibration must be carried out in a specifically prepared prototype, with the basic dimensions (except height) of the parts to be coated.

NOTE 1 The prototype must receive anchoring clamps on 50% of the surface to be coated.

NOTE 2 During the application of concrete by external vibration to qualify the procedure the vibration parameters (frequency and acceleration) must be measured and monitored.

6.1.2.3 The procedure for external vibration shall be qualified on a prototype specifically prepared with the basic dimensions (except height) of the parts to be lined.

6.1.2.4 After hydraulic curing, the bottom plate of the panel shall be removed and the material cut in two orthogonal directions and in the case of the prototype (external vibration), its formwork shall be removed and there shall be no indication of:

- a) voids;
- b) excessive porosity;
- c) segregation;
- d) agglomeration of metallic fibers.

6.1.2.5 Test specimens shall be cut out from the panel or prototype (external vibration), and the tests indicated in 7.5.6 shall be performed.

6.1.3 Forming and Stripping

6.1.3.1 Formwork shall be made of steel or waterproof wood with sealing on joined parts so as to retain the water needed for cement hydration reactions. Provision shall be made for internal and external stiffening rings and ribs in the application by external vibration.

6.1.3.2 For waterproofing of the formwork and in order to facilitate stripping, a stripping agent compatible with the castable may be used on the surface in contact with the castable. **[Recommended Practice]**

6.1.3.3 If the surface of the castable after stripping is too smooth due to laitance formed near the walls of the formwork, it should be roughened by brushing or blasting before the drying process in order to facilitate water release. **[Recommended Practice]**

6.1.3.4 The maximum free fall for pouring shall be 2,5 m. For heights above 2,5 m a specific application test shall be performed, ensuring there is no material segregation.

6.1.3.5 Formwork shall be installed in such a manner as to ensure the thickness of the lining within the tolerances indicated in 7.5.3.

6.1.3.6 The difference in level in the joint regions of the formwork shall not exceed 5 mm.

6.1.3.7 Stripping shall be performed after the hydraulic curing period (24 hours), and such stripping may be anticipated, provided the necessary precautions are taken to prevent structural damages to the material. **[Recommended Practice]**

6.1.4 Thickening

6.1.4.1 Thickening shall be carried out in successive layers for the castable to be fully accommodated without leaving voids, particularly in areas with sharp corners and irregular geometry.

6.1.4.2 In case of pouring with internal vibration, thickening shall be performed with immersion bar type vibrators (at least 12 000 vibrations per minute) with a maximum duration of 1 minute.

6.1.4.3 For pouring with external vibration, the number of high frequency pneumatic vibrators (17 000 vibrations per minute) shall be calculated according to the total weight of the part and the acceleration needed for the type of castable used, with such machines being placed at levels.

6.1.4.4 Thickening for external vibration shall be performed through the progressive operation of the levels of vibrators, with the acceleration imposed on the part being controlled. The vibration parameters shall be similar to the values practiced in the qualification of the procedure, and must be measured and monitored during application. The application service shall not be performed after the start of catch.

NOTE The bid for concretes applied by external vibration must coincide with the stretch to be refracted.

6.1.4.5 Castable shall be continuously poured and compacted without any interruptions in the application.

6.1.4.6 Facilities shall be provided for internal cleaning of the formwork before application.

6.1.4.7 For application of castable by free flow, care shall be taken to prevent air pockets within the lining on parts with a geometry unfavorable to the pouring process.

6.1.4.8 For application of castable by pumping the following precautions shall be taken:

Install the piping of the pump (preferably rigid), in such a manner as to prioritize the shortest distance between the pump and the application area, preferably using long-radius bends and quick couplings for connections, as well as a flexible hose only at the end, to allow adjustments and movements during the pumping operation. **[Recommended Practice]**

6.1.5 Interruption in Application

When the application needs to be interrupted for a period of time longer than that required for the initial setting of castable, the following requirements shall be met:

- a) the surface of the cut shall be roughened;
- b) the cut surface shall be dampened with water when the application is resumed;
- c) all leftover concrete shall be completely removed from anchoring fittings and exposed surfaces of the plate.

6.2 Gunning Method

6.2.1 Application

6.2.1.1 Applicable preferably on equipment over 2 m in diameter. **[Recommended Practice]**

6.2.1.2 It shall not be applied in the same direction as gravity.

6.2.2 Qualification

6.2.2.1 Qualification of the procedures shall establish the information contained in 4.3. It shall be performed on an especially prepared carbon steel plate with minimum dimensions of 600 mm x 1 200 mm and with a thickness for refractory application of 100 mm.

NOTE All individuals responsible for application shall be qualified according to PETROBRAS [PG-2AT-00291](#), adopting the variables obtained in the qualified procedure.

6.2.2.2 Panels shall be built in such a manner as to ensure that the bottom plate is removable, with bolted anchor fittings.

6.2.2.3 The panel shall be placed at the same position as that indicated for application on the equipment (vertical or overhead).

NOTE For application in the vertical position, a standard panel without anchor fittings may be adopted. **[Recommended Practice]**

6.2.2.4 Upon completion of the application, hydraulic curing shall be started in accordance with 5.1.2.

6.2.2.5 After hydraulic curing, the bottom plate of the panel shall be removed and the material shall be cut in two orthogonal directions and there shall be no indication of:

- a) voids;
- b) excessive porosity;

- c) double layer (rolling);
- d) segregation;
- e) inclusion of rebound;
- f) agglomeration of metallic fibers.

6.2.2.6 Test specimens shall be cut from the panel and the tests indicated in 7.5.6 shall be performed.

6.2.3 Homogenization and Mixing

Before loading the castable into the gunning machine, it shall be homogenized in the dry state and then undergo a pre-wetting process. The water dosage shall be that needed to obtain application conditions (reduction of powder and constant flow in hoses) and shall be the one determined in the qualification of the procedure and/or instructions of the manufacturer.

6.2.4 Application Technique

6.2.4.1 The jet may be preferably projected perpendicularly to the surface with small circular and horizontal movements until the design thickness is reached. In those cases in which it is not possible for the jet to be applied perpendicularly to the surface, a maximum inclination of 30° is accepted.

6.2.4.2 The final thickness may not be reached by applying more than 1 layer. When necessary, apply excess castable by removing it immediately after application.

6.2.4.3 Courses shall be applied at all times in a continuous and ascending manner, with each of them being closed before the castable begins to set.

6.2.4.4 Rebound shall not be reused.

6.2.4.5 The rebound shall be prevented from reaching areas on which refractory castable has already been applied.

6.2.4.6 Machined surfaces, nozzles and instruments shall be protected with wood or canvas so as to avoid damages when the castable is applied.

6.2.5 Interruption in Application

When the application needs to be interrupted for a period of time longer than that required for the castable to begin to set, the following requirements shall be met:

- a) a cut shall be made perpendicularly to the plate;
- b) the cut surface shall be roughened;
- c) the cut surface shall be dampened with water when the application is resumed;
- d) thoroughly clean the anchor clamps and exposed sheet surfaces of all remaining castable.

6.3 Hand Tamping Method

6.3.1 Application

Applicable only to dense castables, except those of the low cement type.

6.3.2 Qualification

6.3.2.1 Qualification of the procedure shall establish the information contained in 4.3. It shall be carried out on a panel, 300 mm x 300 mm in size.

NOTE All individuals responsible for application shall be qualified in accordance with PETROBRAS [PG-2AT-00291](#), adopting the variables obtained in the qualified procedure.

6.3.2.2 Panels shall be built in such a manner as to ensure that the bottom plate is removable. In the case of “S” anchor fittings, these shall be bolted.

6.3.2.3 The panel shall be placed at the position indicated for application on the equipment (vertical or overhead).

6.3.2.4 After curing the front part shall be visually examined to make sure that the castable is flush with the extremity of the mesh or “S” anchor fitting. In addition, the bottom plate of the panel shall be removed and the material shall be examined, without indications of:

- a) voids;
- b) segregation;
- c) agglomeration of metallic fibers.

6.3.2.5 For qualification of the procedure, besides the panel, test specimens shall be cast by tamping and the tests indicated in 7.5.6 shall be performed. Test specimens shall be prepared with the same material mix used on the panel and air-dried during 24 hours.

6.3.3 Application Technique

6.3.3.1 The application on mesh shall be performed by manually filling the hexagons and diamonds, tamping the castable of each hexagon/diamond by means of a rubber or plastic hammer, so as to ensure the highest possible level of compaction. The latter may be observed by laterally spreading the castable through the openings between adjacent hexagons/diamonds and beneath the strips comprising the mesh.

6.3.3.2 Application on an “S” anchor fitting shall be made by manually pressing the castable between adjacent anchor fittings and then tamping it with a rubber or plastic hammer, so as to achieve the highest possible level of compaction. The level of compaction may be observed by laterally spreading the castable through the openings of the anchor fittings and beneath them.

6.3.3.3 After compaction, the surface of the castable shall be flush with the upper extremity of the mesh or “S” anchor fitting, that is, after the application, the contour of each hexagon/diamond or “S” anchor fitting shall be perfectly defined and visualized.

6.3.3.4 For cyclones of the FCC unit regenerator, it is recommended that the surface finish of the castable be smooth and of low roughness. **[Recommended Practice]**

6.3.3.5 Refractory plastic shall be accommodated by tamping with a small pneumatic hammer or, manually, with a rubber or plastic hammer.

6.3.4 Interruption in Application

6.3.4.1 If the application on a hexagonal mesh needs to be interrupted, such interruption shall be made on hexagons/diamonds completely filled, with the castable from the partially filled ones being removed. When the application is resumed, the hexagons/diamonds to be covered with refractory, mixers and trays shall be completely cleaned.

6.3.4.2 When the application on an “S” anchor fitting needs to be interrupted, the following requirements shall be met:

- a) the cut shall be made perpendicularly to the plating;
- b) the cut surface shall be roughened;
- c) the cut surface shall be dampened with water when the application for hydraulic castable is resumed;
- d) all leftover refractory material shall be completely removed from anchor fittings and exposed surfaces of the plate.

7 Quality Control

7.1 Material Receiving

Receiving inspections for castables and complementary materials shall be performed in accordance with PETROBRAS [N-1728](#).

7.2 Storage

Storage conditions of the castable shall be inspected in accordance with 4.1.

7.3 Surface Preparation

Surface preparation shall be visually inspected in the entire area to be covered with refractory material and shall be in accordance with 4.7.

7.4 Attachment of Anchoring Device

7.4.1 Anchoring devices shall be inspected preferably during welding as follows:

- a) 100 % of anchoring devices shall be visually inspected, checking the spacing and distribution of anchor fittings, which shall be in accordance with PETROBRAS [N-1910](#) or with the equipment design;

NOTE 1 In the case of meshes, check the welds joining panels and the perpendicularity of the strips in relation to the flow.

NOTE 2 It is recommended, when possible, to avoid the welding of anchor clamps on weld strands on the equipment side. **[Recommended Practice]**

- b) check the dimensions and visual conditions of the weld of anchor fittings in accordance with PETROBRAS [N-1910](#) on 100 % of anchoring devices, with acceptance as per e);
- c) perform the hammering test on 20 % of anchoring devices chosen at random, in order to check different sound effects characterizing the existence or otherwise of metallic discontinuities, which shall not be accepted;
- d) bend 2 % of anchoring devices selected at random 15° and return to the original position, there shall not be weld rupture;

- e) acceptance criteria for dimensions and visual inspection of welds, according to the technical design specification, plus the following items:
- lack of fusion is not accepted;
 - spatters are acceptable;
 - dents are acceptable only on the shell side.

NOTE 1 In case a flaw is detected, eliminate it and proceed with the inspection on anchor fittings adjacent to the defective one.

NOTE 2 Slag shall be removed on 100 % of anchor fittings.

7.4.2 Anchoring devices welded by the stud welding process shall be inspected as follow:

- a) 100 % of anchoring devices shall be visually inspected;
- b) welds shall be free from cracks and/or lack of fusion;
- c) spacing and distribution shall be in accordance with PETROBRAS N-1910 or with the equipment design;

NOTE It is recommended, when possible, to avoid the welding of anchor clamps on weld strands on the equipment side. **[Recommended Practice]**

- d) 20 % of anchoring devices selected at random shall be bent 15° and returned to the original position and there shall not be weld rupture;
- e) welding parameters and equipment, supports of anchor fittings and cables shall be reevaluated at the beginning of each work shift as well as at every 300 welded anchor fittings and the necessary adjustments shall be made;
- f) the hammering test shall be performed by breaking the ceramic ferrule on 100 % of welded anchor fittings.

NOTE In case a flaw is found, eliminate it and proceed with the inspection on anchoring devices adjacent to the defective one.

7.5 During Application

7.5.1 Upon opening packages, the castable shall be checked for the presence of lumps. Lumps are only accepted when they can be manually dissolved.

7.5.2 A check shall be performed to determine if the water dosage, the mixing time, the workability, the percentage of metallic fibers (when applicable) and other variables defined in the application procedure are being followed.

7.5.3 Check the thickness of the coating and its tolerances as specified in the design.

NOTE In the absence of these specifications, a measurement may be made for every 10 m² of area covered with refractory material, allowing the following tolerances: **[Recommended Practice]**

- a) from 0 to + 5 mm for a design thickness up to 75 mm;
- b) from -5 mm to +10 mm for a design thickness up to 200 mm;
- c) from -10 mm to + 20 mm for a design thickness over 200 mm.

7.5.4 The difference in level in the refractory castable in the joint regions shall be reduced in case it is greater than 15 mm.

7.5.5 Check if the castable is flush with the mesh or “S” anchor fitting in the entire area covered by the refractory lining. A tolerance of -1 mm, +2 mm is allowed. **[Recommended Practice]**

7.5.6 During application tests shall be performed on specimens.

7.5.6.1 One sample should be removed per workday, per work front and per source of material supply in accordance with the Table 3. **[Recommended Practice]**

7.5.6.2 Upon completion of application on test panels or on formwork, hydraulic curing shall be started in accordance with 5.1.2 until the curing process has been completed (except for chemical setting castable).

7.5.6.3 Specimens shall be obtained (cutting or stripping) from each sample for the tests described in Table 3.

Table 3 - Test on Test Specimens

Tests	No. of Specimens	Material	Dimensions (mm)
Cold crush strength: - heated at 815 °C	3	Insulating	114 x 114 x 63 or 229 x 114 x 63
		Semi-Insulating/Dense	50 x 50 x 50
Erosion resistance: - heated at 815 °C	3	Antierosive	115 x 115 x 25
Permanent linear change: - heated at 815 °C	2	All	50 x 50 x 100
Bulk density: - dried at 110 °C	2	All	Use any of the above specimens

7.5.6.4 Test specimens shall be dried out and burned as follows:

- air drying during 24 hours;
- maximum heating rate of 150 °C per hour up to 110 °C;
- residence at a temperature of 110 °C until a constant mass is obtained;
- heating rate of 150 °C per hour up to 815 °C;
- residence time of 5 hours at a temperature of 815 °C;
- cooling at a maximum rate of 150 °C per hour.

7.5.6.5 Test results shall be in accordance with Annex A of PETROBRAS [N-1728](#).

7.6 After Curing and Air Drying

7.6.1 The entire surface covered with refractory castable shall be checked for the existence of:

- cracks: a maximum width of 1 mm or a maximum depth of 1/3 of the thickness of the castable layer is admitted, with a spacing between cracks less than 300 mm being unacceptable; **[Recommended Practice]**
- deficient curing or brittle region: a 3 mm diameter metallic knife shall be inserted every 10 m² of area covered by the refractory castable, to a maximum depth equal to 1/10 of the thickness of the castable. **[Recommended Practice]**

7.6.2 For castable applied by manual tamping, the entire surface shall be visually inspected for the presence of clearances between the refractory castable and the sides of the hexagon/diamond or "S" anchor fitting. A maximum width of 1 mm, a maximum depth of 1 mm or a maximum length of 10 mm is allowed. More than one clearance per hexagon/diamond or "S" anchor fitting is not admitted. **[Recommended Practice]**

7.6.3 The hammering test shall be performed by means of a 250 g steel ball hammer at least 24 hours after the application, with a distance of 1 000 mm between impact centers, on 100 % of the area covered by the refractory lining. Different sound effects representing failures such as voids or deficient compaction in areas larger than 300 mm x 300 mm shall not be allowed.

7.6.4 Defective areas shall be repaired.

7.7 After Drying by Heating

7.7.1 The entire surface covered by the refractory lining shall be checked for the existence of:

- a) cracks: a maximum width of 2 mm or a maximum depth of 1/3 of the thickness of the layer of castable is accepted, with a spacing between cracks less than 300 mm being unacceptable; **[Recommended Practice]**
- b) fall of material: will only be accepted if no more than 1/5 of the thickness of the layer of castable is affected, provided it does not exceed 10 % of the area covered with refractory lining. **[Recommended Practice]**

7.7.2 The hammering test on concrete shall be performed by means of a 250 g steel ball hammer, with a distance of 1 000 mm between impact centers, on 100 % of the area covered by the refractory lining. Different sound effects representing failures such as voids or deficient compaction shall not be detected.

7.7.3 Defective areas shall be repaired.

8 Repair

8.1 Repair work shall be done after removal of the damaged lining on the total thickness of the respective layer.

8.2 The area to be repaired shall cover at least three anchoring devices.

8.3 The groove made on the periphery of the area under repair shall be directed toward the inside of the castable originally applied so that the surface of the groove has a slight inclination.

NOTE In the case of field repairs or splices made with free flowing concrete the bevel inclination may be made in such a manner as to follow the observations in 6.1.4.7.

8.4 The roughness of the grooved region shall be obtained by punching.

8.5 Before the new castable is applied, the grooved region shall be dampened with water similar to that used in the mixture (see 4.2.6).

8.6 The repaired area shall be dried out according to 4.6.

8.7 The technical feasibility of any other alternative repair procedure shall be analyzed and previously approved by PETROBRAS.

INDEX OF REVISIONS

REV. A, B, C e D

There is not index of revisions.

REV. E

Affected Parts	Description of Alteration
All	Revised

REV. F

Affected Parts	Description of Alteration
All	Revised

REV. G

[illegible]