Product Application Instructions:
Castables for Gunning

In cases where individual installation instructions have been issued for a specific product, those instructions shall take precedence over the present document.

1. Scope of Application

This instruction applies to the installation of dense and lightweight (insulating) refractory castables designed for gunning applications, belonging to the PCOGun, PCOGun Nx, and PCOGun ISO (formerly ISOGun) product lines. These products are based on hydraulic or hybrid bonding systems.

This document provides recommendations regarding storage, preparation, and installation of refractory castables applied by the gunning method. It serves as a guide to good installation practices, which should be followed to ensure proper performance, durability, and safe operation of the refractory lining.
If any questions or problems arise during application, please contact the PCO Technical Department by e-mail at: konsultacja@pco.pl

2. Glossary of Terms

PCOGun refractory castables – Dry gunning refractory castables composed of refractory raw materials, intended primarily for working linings. A high-alumina cement bonding system is used.
PCOGun Nx refractory castables – Dry gunning refractory castables composed of refractory raw materials, intended mainly for working linings, characterized by enhanced mechanical strength and corrosion resistance. A hybrid bonding system is used, allowing for a reduced heat-up and dry-out time of the refractory lining.
PCOGun ISO lightweight (insulating) gunning castables – Dry gunning castables based on lightweight refractory aggregates, typically with a bulk density below 1.5 g/cm³. They are used primarily for their thermal insulation properties, usually installed behind dense refractory layers or, under specific conditions, as a working lining.
Gunning / Spraying - A method of installing refractory castables by pneumatic conveying and spraying of the refractory mix onto the substrate using a special spray nozzle. In this process, the dry mix is transported by compressed air to the nozzle, where it is mixed with water and then dynamically projected onto the lining surface.
Shutter - A temporary structure (typically made of plywood or metal) used to support freshly applied refractory material until it sets and achieves the required mechanical strength.

3. Storage

3.1. Storage Location and Conditions

The materials may be supplied in 25 kg paper bags or in big bags placed on pallets. They shall be stored in a dry and well-ventilated area. If the packaging is additionally protected with plastic foil, free air circulation beneath the pallet must be ensured in order to prevent moisture condensation inside the packaging. Storage in areas with elevated humidity is not recommended.

In the case of short-term outdoor storage in areas exposed to precipitation, the material must be protected against moisture ingress, for example by using a waterproof tarpaulin or other suitable covering.

The recommended storage temperature is between 10°C and 25°C. Storage at other temperatures is permissible; however, prior to installation the material must be conditioned to the recommended temperature range in order to ensure optimal application conditions.

Improper storage conditions may negatively affect the material properties during application or in service.

3.2. Pallet Stacking

Pallet stacking is permitted provided that the ground surface and pallet surfaces are level and stable. It is not recommended to stack more than two (2) pallet layers on top of each other. Situations where pallets containing dense castables are stacked on pallets with lightweight castables should be avoided.

As a matter of good practice, materials of the same grade should be used in the order of delivery, in accordance with the FIFO principle (First In – First Out).

3.3. Shelf Life

The shelf life of refractory castables is specified in the Product Technical Data Sheet and typically ranges from 6 to 24 months from the date of manufacture. The production date is indicated on the side of the bag or on the pallet label. Symptoms of material ageing may include extended setting time and reduced mechanical strength. Materials should be used starting from the oldest batches. If the shelf life has been exceeded, the material shall be tested prior to approval for use. It is recommended to use the material immediately after opening the package.

4. Shutter, Joints and Anchoring Systems

4.1. Shutter

Shutter shall be made of non-absorbent materials with high mechanical strength. Most commonly, coated (lacquered) plywood shutter with a thickness of 18 mm is used, ensuring durability and protection against moisture absorption from the refractory material.

4.2. Steel Anchoring

Most refractory linings gunned with PCOGun, PCOGun Nx and PCOGun ISO castables require the use of steel anchoring systems. Steel anchors are manufactured from appropriately selected steel grades and are fixed to the load-bearing structural elements supporting the refractory lining.

The anchoring system, including anchor shape, length, steel grade and anchor spacing, shall always be designed based on the lining design documentation.
An incorrect anchoring system selected for a given application and operating conditions may result in serious damage to the refractory lining.

Prior to application of the castable, it is recommended to inspect the quality of anchor welds, for example by performing a bending test in accordance with ISO 14555 standard. A properly executed weld should allow the anchor to be bent to an angle of 60° and return to its original position without any damage to the weld joint.

When using steel anchors, it is recommended to apply plastic expansion caps on the anchors top.

4.3. Ceramic anchors

Ceramic anchors, in comparison to steel anchors, can operate at significantly higher temperatures, making them particularly suitable for the most thermally loaded areas of the refractory lining.

When using ceramic anchors, it is recommended to provide expansion allowance by applying either: a bituminous coating with a thickness of approximately 1-2 mm or wrapping the anchor with ceramic fiber paper of equivalent thickness. Care must be taken to preserve the original serrated (ribbed) external geometry of the anchor.

5. Preparation for Installation

5.1. Personal Protective Equipment (PPE)

During installation, personal protective equipment (PPE) appropriate to the nature of the work and environmental conditions shall be used. In particular, the use of protective goggles, protective gloves, dust masks, and protective clothing is required.

Prior to installation, the operator shall familiarize himself with the operating instructions of the equipment, especially the gunning machine manual.

5.2. Material Consumption

The quantity of dry refractory castable required to produce 1 m³ of lining is specified in the Product Technical Data Sheet. When planning material consumption, it is recommended to allow for an additional: 5–10% for dense gunning castables, and 10–15% for insulating gunning castables, to compensate for losses caused by, among others, damaged bags, spillage during handling, and rebound generated during application.

5.3. Application Temperature

The temperature of the material in the bags, the mixing water, and the ambient environment has a significant influence on the gunning process and the quality of the installed lining.

During winter conditions, when the material may be stored at low temperatures, the bags shall be placed in a heated room at a minimum temperature of 15°C for at least 48 hours prior to installation.

During summer, when storage temperatures are high, the material should be stored in a cool area for 48 hours before use. Shutter surfaces should be cooled by spraying with water, ensuring that no free water remains inside the shutter. If water accumulates inside the **shutter**, it must be removed and the surface dried prior to application.

Gunning shall be carried out at an ambient temperature between 10°C and 25°C.

If the gunned material freezes before completion of setting, the final mechanical strength may be reduced. Therefore, until the lining has been fully heat-treated, conditions promoting freezing must be avoided.

5.4. Preparation of the Gunning Machine

Prior to commencing the gunning process, careful preparation of the gunning machine and all associated systems — pneumatic, material conveying and water supply systems — is required. Proper preparation ensures stable operation, minimizes the risk of equipment failure, and allows the required spraying parameters to be achieved.

Before inspecting the technical condition of the gunning machine, the operator shall refer to the equipment operating manual. The machine manufacturer's instructions take precedence over them recommendations provided in this document.

5.4.1. Inspection of the Gunning Machine Technical Condition

Before start-up, the overall technical condition of the gunning machine shall be inspected, with particular attention paid to the following:

- Tightness of the pneumatic and water systems,
- Wear of working components, such as front plates, rotors, seals and wear plates (depending on the type of gunning machine),
- Proper fastening of all couplings, fittings and connections,
- Absence of mechanical damage that could affect operational safety or application quality,

Any detected defects or irregularities must be eliminated prior to commencing work.

5.4.2. Preparation of the Water Supply System

The water supply system is responsible for the proper wetting of the refractory mix and therefore shall be prepared with particular care. The following steps shall be performed:

- Ensure that the supply water pressure complies with the requirements of the gunning machine (typically minimum 4–5 bar at the inlet),
- Check the water ring and the water inlet orifices in the nozzle for unobstructed flow,
- Flush the system to remove any contaminants or residues,
- Verify that the control valves operate smoothly and allow precise adjustment of the water flow,

The water used for gunning shall be clean and meet the requirements of potable water quality. Its pH value shall be in the range of 6–8, and the recommended water temperature is 10–25°C.

The use of seawater and contaminated water is not permitted. This includes water containing, among others, sulphur, chlorine, magnesium, ammonia or carbonates in concentrations exceeding 1000 ppm, as well as water containing sugars or suspended solids.

5.4.3. Preparation of the Material Conveying System

In order to ensure a stable and continuous flow of the refractory castable, the following actions shall be taken:

- Check the clearance and unobstructed condition of the material conveying hoses,
- Ensure that the hoses are straight, without loops, kinks or twists,
- Verify the condition of the internal hose surfaces, ensuring the absence of hardened residues, moisture or foreign bodies,
- Clean the loading hopper and all surfaces in contact with the material,

The feeder/rotor shall also be inspected to ensure smooth and continuous operation.

5.4.4. Inspection of the Pneumatic System

Compressed air shall be supplied in a quantity sufficient to ensure stable material conveying and the required spraying performance. Before start-up, the following checks shall be carried out:

- Verify that the operating air pressure complies with the requirements specified by the gunning machine manufacturer,
- Clean air filters and moisture separators, if installed.
- Ensure that air hoses and pipelines are free from obstructions and leak-tight,
- Check the proper operation of pressure control and regulating valves,

5.4.5. Preparation of the Spray Nozzle

The spray nozzle is a critical component directly influencing the quality and consistency of the gunning process. Prior to application, the following steps shall be performed:

- Inspect the technical condition of the nozzle and the water ring,
- Remove any contaminants, deposits or residues from previous operations,
- Ensure that all water and air supply channels are fully unobstructed,
- Verify the correct assembly of the nozzle and the tightness of hose connections,

5.4.6. Functional Test Prior to Application

After all components have been properly prepared, a short functional test run shall be performed, either without material or using a small quantity of material, in order to:

- Verify the stability of air and water flow,
- Ensure that parameter adjustment is smooth and responsive,
- Confirm the proper operation of the spray nozzle and mixing system,

Only a properly prepared gunning machine ensures: Homogeneous wetting of the refractory mix, minimal rebound, stable and controlled application process.

6. Application by the Gunning Method

6.1. Introduction

The dry gunning method is a refractory installation technique in which the dry refractory mix is pneumatically conveyed from the rotary gunning machine through hoses to the spray nozzle. Wetting of the dry refractory mix takes

place inside the spray nozzle water ring, where water is injected under pressure. At the final stage, the moistened material is projected under pressure onto the lining surface.

The gunning process is defined by four main parameters that shall be taken into account during application:

1. Type of applied material – PCOGun, PCOGun Nx, PCOGun ISO,
2. Machine output, including rotor speed, rotor size and outlet hose diameter,
3. Compressed air pressure for dry material conveying,
4. Water supply pressure,

Prior to commencing gunning, the operator shall familiarize himself with the operating instructions of the gunning machine. The machine manufacturer's instructions take precedence over the recommendations provided in this document.

Due to differences in gunning machine design and the properties of refractory castables, it is not possible to define a single, universal set of standard installation parameters. In practice, during gunning the operator shall:

1. Continuously adjust one or more parameters (e.g. water flow, air pressure, nozzle distance and angle),
2. Observe the behaviour of the sprayed material,
3. Aim to achieve optimum compaction and a uniform lining structure,

Proper parameter adjustment and operator experience are critical to achieving a correct installation result and a durable refractory lining.

6.2. Air Pressure

The air flow at the nozzle shall be stable and maintained within a pressure range of 1.8 to 2.5 bar. Materials with a higher bulk density require operation within the upper range of air pressure. The operator shall adjust the air pressure in such a way that the material is applied with minimal rebound. For insulating gunning castables, it is necessary to maintain not only minimal rebound but also limited compaction of the applied material; therefore, smooth and precise pressure regulation is essential. Excessively high air pressure results in increased material density and rebound (re-bond), whereas excessively low pressure leads to insufficient compaction and reduced lining strength.

6.3. Water Pressure

The water pressure at the nozzle shall be maintained within a range of 4 to 5 bars in order to ensure complete wetting of the material passing through the water ring. In most cases, the use of a booster pump is required to increase the water pressure within the system. Typical water consumption ranges from 250 to 1200 litres per hour, depending on: the type and quality of the refractory material, the output of the gunning machine, the type of applied castable.

6.4. Application

The appearance of the freshly applied refractory material is the best indicator of the correct water-to-mix ratio.

Properly gunned material should exhibit a wet, slightly glossy appearance, which disappears shortly after the spray stream is moved away from the application area. The coarser aggregate fractions should clearly penetrate into the sprayed material, creating small impact craters at the point of contact. This indicates proper compaction and optimal material consistency.

Symptoms of incorrect water dosing:

- Insufficient water content: The surface becomes sandy and rough, and the material does not compact properly,
- Excessive water content: Material slumping, surface folding, or structural collapse may occur,

Ensuring homogeneity of the sprayed mix

Lack of homogeneity in the gunned mix is most commonly caused by improper water mixing inside the nozzle. Typical causes include:

- Insufficient supply water pressure,
- Clogged or partially blocked orifices in the nozzle water ring,

To prevent such issues, the water ring shall be regularly inspected and cleaned during operation, ensuring stable wetting and uniform lining structure formation. Both the water ring and the spray nozzle must be kept in good technical condition. Systematic cleaning is essential to maintaining consistent spray quality. Before starting the gunning operation, the operator shall also ensure that the supply hoses are laid out without kinks, twists or loops, as these may restrict the flow of air, material or water and result in intermittent blockages within the system.

Parameter Adjustment and Nozzle Handling

The air pressure, water pressure and material feed rate shall be continuously monitored and adjusted to ensure: Stable material flow, full homogeneity of the sprayed mix, correct consistency of the material exiting the nozzle. All parameter adjustments shall be carried out outside the application area in order to avoid surface defects. Once the correct flow parameters have been established, the operator shall direct the spray stream toward the lower part of the application area and then continue upwards. The application shall be performed using circular movements, allowing the material to be evenly compacted and uniformly distributed over the substrate.

Nozzle Distance and Angle

- The nozzle shall be maintained at a distance of 500–1200 mm from the surface.
- For lining thicknesses below 100 mm, the nozzle angle should be close to 90°, ensuring proper compaction and minimizing rebound.
- For thicker linings, i.e. above 100 mm, the nozzle shall be positioned at an angle of approximately 45°, which facilitates better control of the layer build-up and improves lining stability.

6.5. Rebound Control and Proper Lining Panel Build-Up

Rebounded material shall fall or bounce away from the application area. It must not become trapped beneath freshly applied layers, as this leads to lamination, local density reduction, and weak zones within the lining structure. To avoid honeycomb structures and variations in compaction, each lining panel shall be systematically built from bottom to top until the required thickness is achieved. Gradual and uniform layer build-up minimizes the risk of void formation and ensures proper compaction across the entire lining surface.

6.5.1. Application Around Anchors

Special attention shall be paid to the areas around anchors, as their complete embedment is critical for lining durability. Ensure that the material fully fills all anchoring grooves and that no voids remain on the spiral or serrated section of the anchor. Insufficient filling leads to local loss of support and an increased risk of cracking. A properly installed lining shall be flush with the end of the anchor, without excessive material covering it.

Steel anchors: Steel anchors are typically positioned approximately 25 mm from the hot face; therefore, the **shutter** height may serve as a reference for controlling the required lining thickness.

6.5.2. Avoidance of Over-Spraying

Each panel shall be filled exactly to the required thickness, without unnecessary overbuild, excessive material application results in:

- Extended application time,
- Material losses due to subsequent trimming,
- Increased risk of surface defects,

Each panel shall be applied continuously, without interruptions, to avoid the formation of planes of weakness between successive layers.

6.5.3. Overhead (Ceiling) Gunning

When applying material on overhead surfaces, the amount of added water shall be slightly reduced to prevent the material from slumping before initial setting. A higher rebound rate should be expected, which is a natural effect of overhead application.

6.5.4. Lining Thickness Control

After completion of application, the lining thickness can be easily checked using a 2 mm diameter steel wire, bent to a length corresponding to the required panel thickness. The wire shall be inserted into the lining until the bent section is reached and then slightly rotated. Correct thickness is confirmed when:

- The wire tip rests against the furnace wall or backing layer,

- Distinct resistance is felt during rotation, indicating proper material density,

6.6. Surface Finishing

The surface obtained after gunning is generally sufficient and acceptable in its as-applied condition. If a smoother surface is required, it may be lightly scraped using the edge of a trowel or a wooden board within 15 minutes after completion of gunning. In most cases, a rough, open surface structure is preferred and shall be left without further treatment. Smoothing is not recommended, as it may seal the surface, potentially leading to cracking, delamination, or even explosive spalling during operation.

7. Curing of the Castable

After completion of the gunning process, the refractory castable shall be cured for a minimum period of 24 hours. In the case of enclosed installations (such as ducts or small vessels), the space may be tightly closed in order to retain moisture inside the lining.

For outdoor installations, the castable surface shall be protected against direct sunlight until the curing process has been completed.

8. Drying and Heat-Up

8.1 Free Drying

After completion of the curing process, the refractory lining shall be subjected to free drying at an ambient temperature of not less than 10°C for as long as possible, but not less than 24 hours. The purpose of free drying is to stabilize the lining conditions prior to controlled heat-up and to reduce the amount of free water within the castable, the presence of which could otherwise lead to undesirable chemical reactions between the lining surface and the atmosphere. The optimal solution is to carry out full drying immediately after completion of curing. If this is not possible, the lining shall not be left in a closed, humid environment. Instead, adequate ventilation shall be ensured, for example by using forced air circulation with a fan, and preferably a hot air blower. After completion of free drying, the lining must be protected from rain or water ingress, as this could negatively affect its properties.

8.2 Initial Heat-Up

Prior to commissioning, all refractory linings made of refractory castables shall undergo controlled heat-up.

General heat-up principles for PCOGun and PCOGun ISO castables:

1. Ensure continuous air flow through the furnace to remove released moisture,
2. Avoid direct flame impingement on the lining surface until the temperature exceeds 650°C,
3. Minimize temperature fluctuations to an absolute minimum,

The heat-up process shall be carried out in accordance with strictly defined heating rates and holding temperatures. These parameters depend on the type and quantity of refractory castable used as well as the total lining thickness — in general, the thicker the lining, the longer the time required for drying and firing.

Detailed heat-up guidelines are provided in Table 1.

Table 1. Recommended drying schedule for PCOGun and PCOLiteGun linings

Lining thickness	Stage	Heating rate	Target temperature	Holding time at target temperature
to 200 mm	I	10°C/h	150°C	20h
	II	15°C/h	650°C	15h
	III	50°C/h	Above 650°C	–
Above 200 mm	I	10°C/h	150°C	24h
	II	10°C/h	650°C	24h
	III	30°C/h	Above 650°C	–

Once the planned heat-up process has started, it shall not be stopped or interrupted. In the event of an unavoidable interruption, the lining shall be kept warm. If cooling is unavoidable, it shall be carried out slowly, and reheating shall follow the original heating schedule.

Improper execution of the drying and heat-up process may lead to explosive lining failure, posing a serious risk to personnel health and safety as well as to equipment and property. Therefore, it is strongly recommended that this process be conducted under the strict supervision of qualified personnel.

General principles for the initial heat-up of PCOGun Nx castables are presented in Table 2.

Table 2. Recommended heat-up schedule for PCOGun Nx linings

Lining thickness	Stage	Heating rate	Target temperature	Holding time at target temperature
to 200 mm	I	15°C/h	180°C	20h
	II	30°C/h	1200°C	–
Above 200 mm	I	10°C/h	180°C	25h
	II	30°C/h	1200°C	–