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Refractory & Insulating Materials since 1949

SITE HANDBOOK

Fundamentals · Storage · Handling · Installation · Curing · Drying · Inspection

Issue 6 – Rev. July 2026

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Customer-facing handbook – to be read together with the relevant product Technical Data Sheets and Safety Data Sheets.

Document Control

This handbook is issued and maintained by the **Linco Baxo Technical Department**. It is a controlled document. The electronic version held by Linco Baxo is the master copy; printed or forwarded copies are uncontrolled and should be checked against the current issue before use.

Revision history

Issue	Date	Summary of change	Prepared / approved
6	July 2026	Comprehensive consolidated site handbook: restructured sections, harmonised terminology and tables, English (UK) throughout, added safety guidance, drying/heat-up and inspection content, standardised notes and cross-references.	Linco Baxo Technical Dept.

Important Notice & Disclaimer

This handbook provides general guidance for the storage, handling, installation, curing, drying and inspection of Linco Baxo refractory materials. It does **not** replace the relevant product Technical Data Sheet (TDS), Safety Data Sheet (SDS), project specification, approved drawings, site procedures or local regulations. For critical applications, unusual service conditions or any deviation from the procedures described herein, the Linco Baxo Technical Department should be consulted in advance and written approval should be obtained where required.

Product performance depends on correct storage, installation, curing, drying, heat-up, operating conditions and maintenance. Linco Baxo recommendations are based on the information available at the time of issue and on standard refractory practice. Where installation, curing, drying or operation falls outside Linco Baxo control, Linco Baxo cannot warrant the in-service performance of the lining.

HOW TO READ THIS HANDBOOK

All site work shall comply with local laws, the project specification and the site safety procedures.

Where a value, temperature limit, water addition or heating curve is product-specific, always refer to the relevant Linco Baxo Technical Data Sheet.

Conventions used in this handbook

- **“shall”** – a strict safety, contractual or technical requirement.
- **“should”** – recommended best practice.
- **“may”** – optional or conditional guidance.
- **“must not”** – a prohibited practice.
- **Note / Important / Safety boxes** – highlight information, key controls and health-and-safety points respectively.

Throughout this handbook, products are referred to by **type** rather than by individual brand name, unless guidance is specific to a particular Linco Baxo formulation. Brand names are listed in Section 0.0.

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0.0 – Brand Names & Product Groups

Purpose

This section lists the Linco Baxo brand names and the product group each belongs to. Brand names are used consistently throughout the handbook and must not be renamed. Where guidance is generic, products are referred to by monolithic type rather than by brand.

Linco – unshaped alumina products

Brand	Product group
LICOFEST	Refractory / insulating castables
LINAX	Service castables
LICO-CLAY	Plastic mouldables
LICOTON	Ramming mixes & mortars
LICODRY	Free-cement castables
LICOBLOCK	Special shapes and blocks
MILBLOCK	Precast shapes
LB-FILL / LB-STICK	Mastics / adhesives
LICOGLUE	Mastics / adhesives
BLAKPOL	Dry & wet mortars
KWG 311	Coatings, glues, mastics, fillers & patches
LB MUL COAT	Refractory coatings
LB DUR COATING	Refractory coatings

Baxo – unshaped alumina products

Brand	Product group
BAXOCAST	Refractory / insulating castables
BAXOLINE	Refractory / insulating castables
BAXOPLAST	Plastic casting mix
BAXOVIBRO	Thixotropic castables (LCC – ULCC – FCC)
BAXOGUN	Castables for gunning applications
BAXOFIX / BAXOMIX	Service castables
BAXOPOL	Ready mortars
BAXOCOAT	Refractory coatings

Sirma – unshaped alumina products

Brand	Product group
SIRCAST	Regular dense castables
SIRBRATE	Low-cement castables
SIRCHEM	Free-cement castables
SIRFLOW	Self-flowing castables
PROMOCAST / SIRGUN	Medium-cement castables

Brand	Product group
PROMOGUN	Gunning castables
PROGUN	Low-cement gunning mixes
SIRPLAST	Plastic mouldables
SIRCOL	Wet mortars
SIRQUICK	Fast-service castables

Kero – unshaped aluminous and basic products

Brand	Product group
COLLIGAN	Ready mortars
KEROBOND	Ready mortars
KEROCAST	Refractory castables
KEROVIB	Thixotropic castables (LCC – ULCC – FCC)
KEROMIX	Service castables
KEROFIX	Service castables
KEROGUN	Gunning mixes
KEROPATCH	Patching mixes
KERORAM	Ramming mixes
KEROFLOW	Self-flowing mixes
KEROLAN	Refractory dry mixes
KEROCRETE	Shotcrete mixes

Maref & Sirma – shaped refractories

Brand	Product group
MAREF + production code	Fireclay and high-alumina bricks and shapes
ISOM / ALPOR + production code	Lightweight insulating bricks and shapes
KERA + production code	Specialties for the ceramic and brick industries
MAREF + production code	Specialties for the glass industry
SIRMA 95AT / 99AT	High-alumina bricks for severe service
CARBO + production code	Silicon carbide bricks and shapes

Tecref – precast refractories

Brand	Product group
REF-AL	Precast refractories based on alumina
REF-MUL	Precast refractories based on mullite
REF-COR	Precast refractories based on corundum
REF-ZIRCON	Precast refractories based on zircon

> **NOTE**
> Brand names appear here for reference only. The applicable grade, properties and limits for any given product are defined in its **Technical Data Sheet**. The full, current brand list should be confirmed with the Linco Baxo Technical Department before publication.

1.0 – Introduction to Linco Baxo Monolithics

Purpose & scope

This section introduces Linco Baxo monolithic materials, the way they are classified and the conventions used in this handbook. It applies to the full range of unshaped (monolithic) refractory and insulating products.

About Linco Baxo

Linco Baxo Industrie Refrattari S.p.A. is an Italian refractory manufacturer and supplier, part of the Linco Baxo Group of Companies and operating **since 1949**. The Group has integrated production capability in Italy, historically including castables, mouldables, ramming mixes and other monolithics (Levate plant), refractory bricks and shapes (Bondeno / Borgatti plant) and customised refractory shapes and special products (Bondeno / Zerbinate plant).

Linco Baxo supplies refractory and insulating materials for high-temperature industrial applications, including the steel, glass, petrochemical, foundry, biomass, incineration, cement, ceramic and general thermal-process industries, together with reheating furnaces.

- Italian refractory know-how and manufacturing tradition.
- Integrated refractory production capability.
- Technical support from material selection through installation and heating-up.
- Customer-specific refractory solutions and reliable quality control.
- Practical site assistance and application guidance.

Linco Baxo monolithics are produced from carefully selected, homogeneously blended raw materials. A core principle of the manufacturing policy is the **exclusion of exhausted or contaminated aggregates** from any formulation, unless otherwise formally specified and approved, so that the products are free from pollutants. Continuous monitoring and quality control are applied from raw-material selection to final testing, and an ongoing R&D programme supports both existing formulations and custom solutions.

Materials & installation methods

Linco Baxo produces refractory and insulating monolithics containing alumina, aluminosilicates, silicon carbide, zircon, magnesite, chromite and graphitic materials, together with other refractory aggregates and binders. Depending on the product type, they may be installed by casting, pouring, rodding, vibrating, slap trowelling, gunning, veneering, ramming, shotcreting, patching and other application techniques.

Classification of monolithics

Monolithic refractories are composed of aggregates and binders, with additives where applicable. They are generally classified by:

- **Type of binder** – hydraulic, chemical, ceramic or sol-bonded.
- **Condition at delivery** – dry, pre-mixed, pre-wetted, two-component or ready-to-use.
- **Installation method** – castable, gunning mix, shotcrete, mouldable, ramming mix, mortar, patching mix or coating.

This structured classification allows precise product selection tailored to operating conditions and installation requirements. The main monolithic types and the corresponding Linco Baxo brands are summarised below.

By installation method and bonding system, the main monolithic families can also be summarised as follows:

Type	Typical installation	Typical bond
Castables	Casting / vibration / rodding	Hydraulic, colloidal or chemical
Self-flowing castables	Self-flowing	Chemical or hydraulic
Gunning materials	Pneumatic spraying	Hydraulic or chemical
Pumped materials	Pumping	Hydraulic or chemical (as for castables)
Shotcreting materials	Shotcreting	Hydraulic or chemical
Ramming materials	Manual or pneumatic ramming	Hydraulic, chemical or ceramic
Plastic refractories (mouldables)	Hand or pneumatic ramming	Plastic clay bond
Dry vibrating materials	Dry vibration	Ceramic bond during heating
Mortars	Brick laying	Hydraulic or air-setting
Coatings	Brush, trowel or spray	Hydraulic or chemical

Monolithic type	Linco Baxo brand names
Regular dense & insulating castables	LICOFEST, BAXOCAST, SIRCAST, KEROCAST, BAXOLINE, SIRLITE
Plastic casting mixes	BAXOPLAST
Low-cement (LCC) & ultra-low-cement (ULCC) castables	LICOFEST PL, BAXOVIBRO, SIRBRATE, PROMOCAST, KEROVIB, SIRQUICK
Free-cement (FCC) castables	LICODRY, KEROCRETE, KEROSEAL
Gunning castables	LICOFEST TR & G, BAXOGUN, SIRGUN, PROMOGUN, PROGUN, KEROGUN
Service & repair castables	LINAX, BAXOFIX, BAXOMIX, KEROMIX, KEROFIX
Mouldables	LICO-CLAY, SIRPLAST
Ramming mixes	LICOTON, KERORAM
Dry mixes	KEROLAN
Dry & wet mortars	LICOTON MORTARS, BAXOPOL, SIRCOL, COLLIGAN, BLAKPOL, KEROBOND
Coatings, glues, mastics, fillers & patches	BAXOCOAT, LB MUL COAT, LB-FILL, LB DUR COATING, LICOGLUE, KWG 311, KEROPATCH

Classification of castables by density

In addition to binder type and installation method, Linco Baxo classifies castables by **bulk density after oven drying at 105 °C**, measured on standard cast specimens.

Castable type	Density after oven drying at 105 °C
Very lightweight	Less than 720 kg/m³
Lightweight	720–1200 kg/m³
Medium weight	1200–1840 kg/m³
Dense	More than 1840 kg/m³

> **NOTE**
> To keep the guidance clear and consistent, the following sections refer to products by monolithic type rather than by brand name, unless tailored instructions apply to a particular Linco Baxo formulation.

When to contact Linco Baxo

Consult the Linco Baxo Technical Department for material selection, for any application not fully covered by this handbook, and before deviating from the recommended procedures. See also **Section 2.3** (Planning & Precautions).

1.1 – Fundamentals of Castables

Purpose

This section gives the fundamentals of Linco Baxo castables: what they are, the main types, and the golden rules that govern their performance. Detailed step-by-step guidance is given in Section 3 (mixing, casting, gunning, trowelling) and Section 4 (curing, air drying). Brands of castables are listed in Section 0.0.

Scope

Applies to all Linco Baxo dense and insulating castables supplied as dry powders for installation by casting, pouring, vibrating, rodding or gunning.

Types of castable

Castables are refractory or insulating mixes of aggregates and a binder that are mixed with water on site and develop strength by hydraulic (or, for some grades, chemical / colloidal) bonding. The main families differ mainly by cement (binder) content:

Class (by cement content)	CaO, calcined basis[1]	Typical character
Conventional / regular cement (CC)	> 2.5 %	Higher hydraulic cement content; mixed with more water. Robust and tolerant to install; higher porosity after dry-out.
Low-cement (LCC)	1.0 – 2.5 %	Reduced cement and water; matrix optimised with fine fillers. Higher density and strength; tighter water window.
Ultra-low-cement (ULCC)	0.2 – 1.0 %	As LCC, further reduced. Highest density and strength; very sensitive to water addition and dry-out.
Cement-free / no-cement (NCC)	≤ 0.2 %	No calcium aluminate cement; alternative bond (e.g. colloidal silica / sol or hydratable alumina). Specialised grades – follow the TDS closely. (see Section 1.8 for the LICODRY range)

[1] Bands per ASTM C401. ISO 1927-1 additionally recognises a medium-cement (MCC) grade (> 2.5 % CaO, deflocculated).

Castables are further described by **placement behaviour** (self-flowing, vibratable, pumpable / gunning) and by **density** (dense vs. insulating / lightweight). These properties are independent of cement content – for example, a product may be an ultra-low-cement, self-flowing castable. The two extremes of placement and density are:

- **Self-flowing** – flows and de-airs with little or no vibration. The consistency window is narrow – control water carefully.
- **Insulating / lightweight** – porous or lightweight aggregates for low conductivity. Lower strength; install gently to protect the grains.

Key requirements (golden rules)

- **Use whole bags.** Pour the entire contents of the bag into the mixer to avoid segregation in transit. If only part of a bag is needed, dry-mix the whole bag thoroughly first, then take the required amount.
- **Store correctly.** Castables are hydraulic-setting and pick up atmospheric moisture, which shortens setting time and reduces strength. Keep bags sealed, dry and off the ground, and use within the shelf life on a first-in / first-out basis.
- **Keep everything clean.** Mixers, tools and water must be free of set material and especially of Portland cement, which shortens setting time and reduces strength.
- **Prepare the surface.** Existing brickwork should be free of loose particles and thoroughly moistened. Shuttering must be impervious to moisture and treated with a release agent.
- **Use the right mixer.** Dense castables – a paddle mixer; lightweight / insulating castables – a drum / barrel mixer. Manual mixing does not give a consistent mix and is not recommended.
- **Use clean water.** Only clean, potable water of low acidity should be used. Avoid water containing sulphates, which impairs strength and structure. See Section 3.1 for the recommended water quality.
- **Control the water.** Add water within the range given on the Technical Data Sheet. Excess water is the single most common cause of poor performance.
- **Control the temperature.** Both ambient and material temperature govern setting. Aim to place within approximately 5 – 30 °C, with material and water conditioned to suit. In cold conditions use warm (not hot) water to reach the target mix temperature, and never cast onto a frozen substrate; in hot conditions use chilled water to extend working time.
- **Mind the working time.** There is a finite window between adding water and initial set during which placing and compaction must be completed. Working time shortens in warm conditions and with lower-cement grades – plan batch sizes accordingly.

WHY WATER CONTROL MATTERS

Excess mixing water lowers density and strength, increases porosity and raises the risk of explosive spalling during dry-out.

Water addition on the TDS is a starting point obtained under laboratory conditions; it may be fine-tuned on site, but should not be exceeded for dense castables.

Workability check – “ball-in-hand” test

For dense castables, add enough water for the mix to hold together as a ball when bounced gently in the palm:

- If the ball holds its shape, the consistency is correct.
- If it crumbles apart, the mix is too dry.
- If it slumps through the fingers, the mix is too wet.

A correctly gauged ball glistens slightly, with no appreciable transfer of water and cement to the palm. The test is described in more detail in Section 3.1.

For low-cement, ultra-low-cement and self-flowing grades the ball-in-hand test does not apply: these are gauged to a target flow or vibration-flow value within a very narrow water window. Follow the TDS and Section 3.1.

Compaction, in brief

- **Dense castables** are compacted immediately with a vibrating poker (up to about Ø 50 mm, depending on wall thickness). Insert quickly and withdraw slowly to avoid segregation; keep clear of anchors and shuttering. Once setting begins, re-compaction is not possible.
- **Lightweight and medium-weight castables** are poured to a plastic consistency; medium-weight grades may be lightly rodded if necessary. Avoid heavy vibration, which compacts soft aggregates and increases density.

Protect the fresh lining

During setting, some mixing water is consumed chemically; prevent early moisture loss by covering exposed surfaces with plastic sheets, wet sacks or curing blankets and maintaining the cover for at least 24 hours, including after shuttering removal. Protect the fresh casting from direct sun exposure, strong wind and frost. Full curing and air drying are covered in Sections 4.1 and 4.2.

IMPORTANT

Setting time should only be adjusted with approved setting or retarding agents supplied by Linco Baxo. **Unauthorised additives may compromise performance.**

Common errors to avoid

- Adding extra water to improve flow – it permanently reduces strength.
- Using a paddle mixer for insulating castables (it breaks the soft grains and raises density).
- Mixing partial bags without dry-mixing the whole bag first.
- Re-mixing or re-tempering material that has started to set.
- Casting in unsuitable temperatures or onto a frozen or unprepared surface.

When to contact Linco Baxo

For grade selection, on-site water adjustment, setting-time control or any new / critical installation, and for customised heating-up schedules (see Section 7.1).

Cross-references

Section 3.1 Mixing · Section 3.2 Casting · Section 3.3 Gunning · Section 3.5 Pumping · Section 3.6 Shotcreting · Section 3.7 Self-Flowing Castables · Section 4.1 Curing · Section 4.2 Air Drying · Section 7.1 Drying & Heating Up.

1.2 – Fundamentals of Mouldables

Purpose & scope

This section covers the preparation, installation and finishing of Linco Baxo mouldables (plastic refractories), with or without shuttering, and the correct use of the pneumatic rammer. Brands of mouldables are listed in Section 0.0.

What mouldables are

Mouldables are pre-mixed plastic refractory materials made of refractory aggregates, special clays and binders, supplied at a plastic consistency ready for ramming installation. Unlike castables, the main compaction takes place during manufacture; on site, ramming mainly shapes and consolidates the material rather than compacting it from scratch. They are supplied in cartons, wrapped in plastic sheet, and can be installed with or without shuttering depending on the lining geometry.

Mouldables are distinguished mainly by bond type, which governs how they develop strength and how they must be handled:

Bond type	Develops strength by	Handling note
Heat-setting (clay-bonded)	Ceramic bond on first firing	Long working time; plasticity can be restored if stiffened (see below).
Air-setting / chemically bonded (e.g. phosphate)	Setting on exposure to air or at low temperature	Begins to stiffen once unwrapped – install promptly and keep unused material wrapped. Follow the TDS.

Storage and shelf life

Mouldables are supplied wet and will stiffen and lose plasticity over time. Store sealed and flat in a cool, dry place, protected from frost and direct heat, and use within the shelf life on a first-in / first-out basis. Keep material wrapped until immediately before use.

Preparation

Substrate

- Remove all dust, slag, scale and loose debris, and clean the working surface thoroughly.
- Check that anchors are of the correct type, correctly positioned and sound before installation begins (see Section 2.1).
- Where specified on the TDS, lightly moisten the substrate.

Material

- Unpack the mouldables. Whole pieces, broken or cut to size, can be installed to build up the required wall thickness.
- If the material has dried before use, restore its plasticity as follows: unpack the carton; place the material on plastic sheets; cover it with wet bags or damp cloths; allow the material to recover moisture gradually.

> **IMPORTANT**
> Do not immerse the material in water or add water directly, unless specifically stated otherwise in the Technical Data Sheet. Adding water or other unauthorised materials may compromise plasticity, bonding, mechanical strength and service life.

Reconditioning frozen material

If the material has frozen in its cartons, move it to an area at a temperature of not less than 15.5 °C (60 °F) and allow it to thaw slowly over 2–3 days; rapid thawing produces a soft, non-uniform consistency. Keep the protective wrapping intact during thawing and arrange the blocks so that warm air can circulate around them. The material is usable once fully thawed and it has recovered its original workability.

> **IMPORTANT**
> Chemically-bonded mouldables cannot be reconditioned once frozen and must be discarded.

Installation

- Place the first slices against the prepared surface and press them home by hand to achieve initial adhesion, then build up the thickness with successive pieces, maintaining good continuity between them.
- Where possible, install perpendicular to the stress area. The thickness of each rammed layer is set by the thickness of the slices being installed.
- Roughen each compacted layer before applying the next, to improve bonding and avoid lamination between layers.
- Install using a hand hammer of about 1–1.5 kg, or a pneumatic hammer. A pneumatic hammer should be fitted with a large, flat ramming head, about 20–50 mm in diameter.
- The ramming head may be steel or hard rubber; its shape and diameter depend on the material applied, the geometry of the lining and the operator's experience. A bench rammer is recommended for most applications; a floor rammer may be used where space allows.
- Mind the working time: air-setting grades begin to set once exposed to air – ram and finish each area before it stiffens.

Anchorage

Areas larger than 1 m² should be retained by suitable anchors; overhead and roof work requires closer anchor spacing (see Section 2.1).

Subsequent treatment & finishing

- Shape the mouldables by cutting or trimming to the required dimensions, then roughen the surface with a nailed board or similar tool.
- **Vent holes:** make holes with a steel pin (about 3 mm diameter) at staggered intervals of approximately 150–200 mm, preferably through the full wall thickness, angled upward at about 30–45°, to improve drying.
- **Shrinkage control:** notch the surface with a board about 1 mm thick to about one quarter of the wall thickness. The resulting sections should not exceed roughly 800–900 mm. In burner areas, position the notches across the thinnest section.
- Check the finished surface for cracks, cavities or poorly compacted areas.

Pneumatic rammer for plastic materials

A pneumatic rammer is a compressed-air tool used to install and consolidate plastic refractory materials inside furnaces, boilers, incinerators, heat-treatment furnaces and similar equipment. It generates rapid, repeated blows that reduce voids and air pockets and improve the final density and strength of the lining.

Before use

1. Verify that the air pressure complies with the equipment specification, **normally between 5 and 7 bar** unless otherwise indicated.
2. Check the condition of the pneumatic hoses and fittings.
3. Put on personal protective equipment (helmet, safety glasses, gloves, hearing protection, safety shoes).
4. Connect the rammer to the compressed-air supply.
5. Perform a no-load test before starting installation.

Ramming & compaction

- Start from the deepest areas and proceed in layers, generally 50–100 mm thick.
- Compact each layer until a homogeneous, compact mass is obtained.
- Angle the rammer head slightly (about 45° where practical) to avoid lamination between layers.
- Overlap the rammed areas slightly to avoid weak joints, and completely fill the spaces around anchors and corners.
- Do not hold the rammer in one position too long, as this causes excessive local densification and uneven compaction.

> **NOTE**
> Correct ramming increases density and mechanical strength, reduces porosity, improves adhesion to anchors and the substrate and lengthens lining life. Pneumatic rammers and accessories can be supplied by Linco Baxo on request.

Drying & initial heating

After installation, follow a controlled drying and heating schedule in accordance with the relevant Technical Data Sheet or project specification. Controlled heating removes residual moisture gradually and develops the lining properties safely up to operating temperature. Unlike hydraulic-bonded castables, mouldables do not require a wet-cure hold before heat-up. See Section 7.1.

> **SAFETY**
> Heating too quickly can cause internal steam formation, cracking, spalling or detachment of the lining. Pneumatic tools are a noise hazard – hearing protection is mandatory.

When to contact Linco Baxo

For heating-up curves for specific or new installations, anchor design for large areas, and supply of installation equipment.

Cross-references

Section 1.3 Ramming Mixes · Section 2.1 Anchors · Section 7.1 Drying & Heating Up.

1.3 – Fundamentals of Ramming Mixes & Patches

Purpose & scope

This section covers the preparation and installation of Linco Baxo ramming mixes and patching materials, both one-component and two-component systems. Brands are listed in Section 0.0.

Bond types & supply

- **Ceramic-bonded ramming mixes (code "K")** are supplied ready for use, at the correct consistency, in multi-ply hermetic bags that keep the bond effective.
- **Chemically-bonded ramming mixes (code "CH")** are supplied as a two-component system: the dry / semi-wet aggregate in bags or buckets and the liquid binder in drums or tanks.
- **Patches** may be one- or two-component and can be installed by ramming or by trowelling, whereas ramming mixes are installed only by ramming.

Surface preparation

Existing brickwork must be free of all loose particles. In some cases the surface is painted with a liquid primer / binder before installation – follow the relevant product instructions.

Mixing & recomposition

Ready-to-use "K" mixes normally need no preparation. If the mix has become too dry through long storage, or where a two-component system is used, prepare it in a paddle mixer:

1. Mix the aggregate component on its own for about 1–2 minutes.
2. Add about two-thirds of the specified liquid binder, then add the balance gradually while mixing until the required consistency is reached – normally within 3–4 minutes.
3. For a partly dry "K" mix, restore consistency by adding water through a sprinkler nozzle, following the Linco Baxo quantities and procedure.

IMPORTANT

Water must not be added to ramming mixes. A limited amount of water (about 3–5%) may be added to patches only. Always confirm the recomposition method and target consistency for patches with the Linco Baxo Technical Department.

Shuttering

Position the shuttering so that the direction of ramming is vertical to the stress area. Because of the high forces during installation, the shuttering must be firm and abrasion-resistant on the inside, and treated with a release agent (e.g. crude oil or wax) to ease removal and prevent adhesion. See Section 2.2.

Ramming

Compaction is carried out with pneumatic rammers. The ramming head may be steel or hard rubber; its shape and diameter depend on the material applied, the geometry of the lining and the operator's experience. A bench rammer is recommended for most applications; a floor rammer may be used where space allows. Typical operating data are:

Parameter	Typical value
Frequency	about 15 Hz at 6 bar
Piston stroke	150–180 mm
Force of impact	2.5–4.5 m·kp (≈ 25–45 J)
Rammer head	rectangular base about 70 × 20 mm, ground to a wedge shape

- Use an angular (triangular or square) piston rod to keep the rammer head in a steady direction; the wedge head gives better layer compaction.
- Place the mix behind the shuttering in layers not exceeding 50 mm in height and compact each layer thoroughly.
- Roughen each compacted layer before applying the next, especially on flat surfaces such as hearths.
- Where anchors are installed, pay particular attention to the bond between anchor and material.

> **NOTE**
> **Do not keep adding material continuously while ramming.** Fill and fully compact one layer at a time; continual filling during ramming prevents a proper monolithic mass from forming.

Removal of shuttering & subsequent treatment

Shuttering may be removed immediately after ramming, provided the rammed unit is not disturbed before heating up.

Reconditioning frozen material

If the material has frozen in its packaging, move it to an area at a temperature of not less than 15.5 °C (60 °F) and allow it to thaw slowly over 2–3 days; rapid thawing produces a soft, non-uniform consistency. Keep the protective wrapping intact during thawing and arrange the blocks so that warm air can circulate around them. The material is usable once fully thawed and has recovered its original workability.

> **IMPORTANT**
> Chemically-bonded ramming mixes and patches cannot be reconditioned once frozen and must be discarded.

Drying & heating up

Unless the relevant Technical Data Sheet or project specification states otherwise, the following indicative schedule applies to ramming mixes:

Stage	Schedule
Hold at 100 °C	24 h
Hold at 200 °C	48 h
200 → 600 °C	20 °C/h
600 °C → operating temperature	30 °C/h

> **NOTE**
> Heating-up curves for specific or new installations can be supplied by Linco Baxo. See Section 7.1 for the general principles of drying and heating up.

Safety notes

> **SAFETY**
> Pneumatic rammers are a significant noise and vibration hazard; use hearing protection and manage hand-arm vibration exposure. Two-component chemical binders may be irritant or corrosive – follow the Safety Data Sheet and wear appropriate PPE.

Cross-references

Section 1.2 Mouldables · Section 2.1 Anchors · Section 2.2 Shuttering · Section 7.1 Drying & Heating Up.

1.4 – Fundamentals of Mortars

Purpose & scope

This section covers the preparation and use of Linco Baxo dry and wet mortars for laying brickwork and shapes. Brands are listed in Section 0.0; brickwork jointing is covered in Section 9.2.

Bond types

Mortars are classified by their bond – hydraulic, ceramic or chemical – which determines how they are mixed, whether the surface is pre-wetted, and the working time available.

Mixing – dry mortars

- Use drinking (potable) water unless another bonding liquid is specified and use clean tools.
- Use the whole content of a bag; if using part of a bag, thoroughly mix the whole bag first.
- Adjust the working consistency by adding water within **± 10%** of the indicated amount.
- A paddle mixer is recommended; small amounts may be mixed with a putty knife or trowel.
- Mix hydraulically and highly reactive bonding mortars with water in small portions (up to about 20 kg) and use them within their working life of about **30 minutes**.
- Let ceramic-bonding mortars stand for about 1 hour after water mixing before use.

Wet mortars

Wet mortars are supplied ready-mixed in buckets. If a wet mortar has segregated through ageing, it can usually be restored by remixing with a drill-mounted paddle.

Preparation of the surface (underlayer)

The surfaces to be jointed must be clean and free of dust. Pre-wetting depends on the bond type:

Bond type	Pre-wetting
Hydraulic bond	Required
Ceramic bond	Permitted
Chemical bond	Prohibited

Processing

- **Minimum processing temperature 5 °C.**
- **Joint width should not exceed 2 mm.**
- Spread the mortar evenly onto the surfaces to be joined, then insert the brick.
- Throw away set mortar residues and keep working devices clean.

First heat-up

- For hydraulically-bonding mortar, wait about 24 h before first heat-up.
- The heating-up curve does not depend on the mortar type but on the nature of the whole lining.

> **NOTE**
> Because the first heat-up is governed by the complete lining, follow the heating schedule for the lining as a whole (Section 7.1), not a schedule for the mortar alone.

Common errors to avoid

- Pre-wetting a surface before a chemically-bonded mortar (prohibited).
- Re-tempering mortar that has passed its working life.
- Joints wider than 2 mm, which weaken the brickwork and increase shrinkage effects.
- Adding excess water.
- Using dirty tools or contaminated mixing water.
- Applying mortar to dusty or contaminated surfaces.

Cross-references

Section 1.6 Storage · Section 9.2 Brickwork Installation · Section 9.3 Mortars & Coating Installation · Section 7.1 Drying & Heating Up.

1.5 – Storage – Castables & Dry Mortars

Purpose & scope

This section gives storage instructions for Linco Baxo castables and dry mortars, which are perishable materials packed in multi-ply paper bags on shrink-wrapped pallets. Correct storage protects the binder and preserves shelf life.

Key requirements

- Store in a cool, dry, ventilated warehouse, kept off the floor and away from the walls.
- Protect from moisture, rain, frost, direct sunlight and excessive heat.
- Retain the original shrink-film around the pallet for as long as possible as extra protection.
- Store pallets separated by material type, commercial name, manufacturing date and production batch.
- Do not stack pallets of insulating castables, to avoid compressing the soft lightweight aggregate grains.

IMPORTANT

Moisture can start the binder setting inside the bag and reduce the strength of the castable. Material affected by moisture must be discarded.

Outdoor storage (when unavoidable)

If castables and dry mortars must be stored in the open air, place them on a ventilated platform off the ground and cover them with strong tarpaulins so that neither rain nor ground moisture reaches the bags. Ensure adequate ventilation under the cover to prevent condensation build-up, and carry out a periodic visual inspection (at least monthly) of bags stored outdoors, checking the integrity of the tarpaulins and the absence of water ingress or condensation underneath. Cover the storage-area floor with a plastic sheet to stop moisture migrating up from the ground.

Cold and hot conditions

Condition	Action
Cold	Store frost-free so the mixing water will not freeze when added. If frost-free storage is not possible, move the bags to a warmer area at not less than 15 °C for at least 48 h before adding water.
Hot	Keep pallets dry and as cool as possible, never in direct sunlight. Before mixing, move pallets to a cooler area at about 18–20 °C for at least 48 h.

Typical storage conditions & shelf life

As a general rule, when stored cool, dry and ventilated at a temperature not exceeding +35 °C and not below +1 °C, with relative humidity of 60 ± 10%, the following shelf life is expected:

Product type	Indicative shelf life
Regular dense & insulating castables	12 months
Dry mortars, chemical bond	12 months
LCC, ULCC, FCC castables	9 months
Two-component mix – dry aggregate	12–18 months
Two-component mix – hydraulic binder	12 months
Two-component mix – chemical binder	6–9 months

NOTE

Castables may be supplied, upon customer request, as a two-component mix. This option may be considered for remote sites or overseas projects where the installation is expected to take place significantly later than the delivery date, and where long transit or storage times are anticipated.

However, this supply method requires correct dosing and mixing of the components on site. Any deviation from the prescribed proportions may affect the final properties of the material. For this reason, the two-component supply option should be evaluated case by case with Linco Baxo technical support.

Before use

- Verify that the product is within its shelf life.
- Inspect bags for damage or moisture ingress.
- Do not use material showing signs of hardening or lump formation.
- Always use the oldest production batches first (first-in / first-out).

Material at or beyond shelf life

Castables and dry mortars that have been stored beyond their shelf life are not recommended for installation, even if they appear to be in good condition. Their properties may be impaired and the performance of the lining may be affected.

Expired material must not be used without prior assessment and written confirmation from Linco Baxo. Where the material is no longer considered suitable for use, replacement material should be arranged before installation. See Section 1.7 for the full assessment of expired material. If in any doubt, seek the advice of a Linco Baxo refractory expert.

Cross-references

Section 1.6 Storage of Ramming Mixes, Mouldables, Wet Mortars, Patches & Coatings · Section 1.7 Shelf Life & Expired Material · Section 9.1 Storage of Non-Perishable Refractories.

1.6 – Storage – Ramming Mixes, Mouldables, Wet Mortars, Patches & Coatings

Purpose & scope

This section gives storage instructions for the moisture-containing product families, where the priority is to prevent loss of moisture (and, for chemical binders, to keep the bond effective).

Packaging by product family

Product	Packaging
Mouldables	Pre-compacted cartons; one-component mouldables already contain the moisture required for installation.
Ramming mixes – K (ceramic) range	Multi-ply hermetic bags, to prevent the chemical binder becoming ineffective; one-component mixes already contain the required moisture.
Ramming mixes – CH (chemical) range	Two-component: dry aggregate in multi-ply bags, binder in buckets.
Mortars & patches	Buckets; patches may be two-component, usually in buckets.
Coatings, glues & finishing products	One- or two-component, in multi-ply bags or buckets.

Key requirements

- **Avoid loss of moisture,** especially when products are delivered to hot countries with low atmospheric humidity.
- Cover the storage-area floor with a plastic sheet before storing the products, to stop moisture migrating toward the ground.
- Keep products sealed in their original packaging until use.

Transportation

Protect packaging from mechanical damage and moisture ingress during transport. Keep products in their original packaging and, where two-component systems are used for long-distance shipment, verify that both components remain correctly sealed on arrival.

Typical storage conditions & shelf life

Parameter	Value
Ambient temperature	25 °C ± 5 °C
Relative atmospheric humidity	60% ± 10%
Shelf life (most products, stored correctly)	about 9 months
Shelf life – wet mortars	about 6 months

> **NOTE**
> Indicative shelf-life values assume correct storage. Where the Technical Data Sheet states a different value, the TDS takes precedence. See Section 1.7 before using any material at or beyond its shelf life.

Cross-references

Section 1.5 Storage of Castables & Dry Mortars · Section 1.7 Shelf Life & Expired Material.

1.7 – Monolithic Shelf Life & Expired Material

Purpose & scope

This section explains why monolithic refractories have a limited shelf life, the risks of using expired material, and the best practice for verification, storage and disposal. It applies to all monolithic products (castables, mortars, gunning mixes, ramming mixes, plastics, patches and coatings) and to their liquid binders supplied separately.

Why shelf life matters

Using expired monolithic materials can pose serious operational, technical and safety risks. These arise mainly from deterioration or premature reaction of the bonding systems – calcium aluminate cement, chemical binders and silica sol – and from moisture absorbed during storage. These factors can compromise performance and, in severe cases, lead to structural failure, explosive spalling or steam explosions during heating.

Pre-fired refractory bricks can generally be stored for several years under suitable conditions. Monolithic refractories, however, normally have a strict shelf life – **typically up to a maximum of 12 months from the date of manufacture** – unless otherwise specified in the relevant technical documentation. Shelf life depends on the bond system: liquid and colloidal-silica (sol) binders are often shorter-lived and must never be allowed to freeze, as freezing gels the sol and ruins it irreversibly. Always follow the shelf life stated on the TDS for the specific product.

Structural & operational risks

Risk	What happens
Carbonation	A higher tendency to carbonate, forming soluble salt deposits that affect the bonding structure and may degrade the lining prematurely.
Steam explosions & explosive spalling	Absorbed moisture can flash to steam if heated too rapidly, generating high internal pressure.
Premature lining failure	Calcium aluminate cement, chemical binders and silica sol may react prematurely or degrade, reducing bonding and mechanical strength.
Equipment damage	If the lining fails, the shell may be exposed to extreme temperatures, causing deformation, overheating or melting of the steel.
Reduced thermal-shock resistance	Poor density, bonding and microstructure make the lining more prone to cracking, crumbling or detachment under thermal cycling.
Process contamination	Flaking, dusting or shedding can contaminate the product in glass, steel and similar processes.
Increased energy loss	Compromised or thinned layers lose insulating function, raising heat loss and fuel consumption and creating unsafe hot spots.

Health & environmental hazards

- **Respirable crystalline silica dust.** Handling, breaking out or removing degraded refractory can generate airborne respirable crystalline silica, which can cause serious occupational disease, including silicosis and lung cancer. Use appropriate PPE and dust controls.
- **Dust & chemical irritation.** Airborne dust from deteriorated refractory and cementitious binders can irritate or injure the skin, eyes and upper respiratory tract; alkaline cement dust may also cause chemical irritation or burns.

SAFETY

Respirable crystalline silica – indicative occupational exposure limits (8-h TWA): EU binding limit 0.1 mg/m³; several countries set stricter limits (e.g. Italy 0.05 mg/m³). Always apply the limit in force at the site.

Confirm the applicable national exposure limits and dust-control measures with the site safety function before breaking out refractory.

Recognising suspect material

Set aside and report, rather than install, any material showing:

- Hardened lumps, "balls" or a partially set mass in a castable or powder mix.
- Caked, damp or hardened powder, or packaging that is torn, wet or damaged.
- Liquid or sol binders that are gelled, separated, frozen or discoloured.
- Plastics or ramming mixes that have stiffened, dried out or show signs of mould.
- A missing, illegible or expired batch label.

Handling & best practice

- **Verify packaging & batch certificates.** Check the manufacturing date, expiry date, packaging condition and batch documentation before applying any monolithic material.
- **Respect storage requirements.** Store in a dry, covered, well-ventilated environment protected from moisture, rain, frost, excessive heat and weather. Poor storage reduces effective shelf life.
- **Do not use expired material.** Expired monolithic materials must not be installed unless formally assessed and approved in writing by the Linco Baxo Technical Department.
- **Dispose of expired material correctly.** Handle as waste and dispose of in accordance with applicable local laws, environmental regulations and site procedures.

IMPORTANT

When in doubt about the condition or age of any material, stop and consult the Linco Baxo Technical Department before installation.

Cross-references

Section 1.5 & 1.6 Storage · Section 7.1 Drying & Heating Up · Section 4.2 Air Drying & Ventilation.

1.8 – Cement-Free Fast-Firing Castables

Purpose & scope

LICODRY is Linco Baxo's range of cement-free castables (FCC) bonded with the inorganic colloidal-silica binder SILCO GEL instead of calcium aluminate cement. This section covers what the range is, how it is bonded, and the handling points specific to it. For the shared mechanics, follow the standard sections (mixing 3.1, casting 3.2, heat-up 7.1); this section gives only where LICODRY differs.

What LICODRY is

- A cement-free, lime-free (no CaO) castable in which the bond is provided by SILCO GEL, an inorganic colloidal (nano-)silica chemical binder.
- Supplied as a **two-component** system: a dry aggregate/matrix component in bags, and the SILCO GEL liquid binder supplied separately.
- **No mixing water is added** – the SILCO GEL replaces the mixing water. On setting, the colloidal silica gels to a continuous SiO_2 network that develops mechanical strength at room temperature and provides a direct path to a ceramic (sintered) bond on first firing.
- The range spans alumina-based, silicon-carbide-based, SiC–zirconia and zirconia-based grades, with classification temperatures from about 1450 to 1880 °C (in a neutral, non-corrosive atmosphere).

The SILCO GEL binder

Property	Value
Type	Inorganic colloidal-silica chemical binder, low in alkali
Appearance	Opaque liquid
Particle Size	15–20 nm
SiO_2 content (at 1025 °C)	99.8 %
Bulk Density	≈ 1290 kg/m³

The low alkali content and nano-scale particle size give good flow and workability at low liquid addition. Dose the SILCO GEL strictly per the grade's Technical Data Sheet.

Why cement-free

- **Faster, safer heat-up.** With no cement hydrates and essentially no free water, there is no hydrate-decomposition water and little steam to release, so the steam-spalling risk is greatly reduced and the dry-out/heat-up schedule is far shorter – of the order of half that of conventional and LC/ULC castables. See Curve D in Section 7.1.
- **Higher refractoriness and chemical resistance.** The absence of CaO removes the low-melting lime-bearing phases that limit hot strength in cement-bonded systems, improving refractoriness and resistance to slag, alkali and chemical attack.
- **Lower installed cost and energy.** The much shorter pre-heat reduces downtime and fuel; no special placement equipment is required.
- **Microstructural stability** under thermal cycling, suiting severe-duty positions such as molten-metal and slag-contact areas (for example, steel-ladle safety linings).

Mixing

- Use whole bags of the dry component; if part of a bag is used, dry-mix the whole bag first (see Section 3.1).
- Add SILCO GEL, not water. Add the binder to the dry component per the TDS dosage and mix to the required consistency. Do not add water – water addition defeats the cement-free chemistry and impairs the bond.
- A paddle mixer is suitable; keep all tools and containers clean. Observe the working time (pot life) on the TDS, and do not re-temper material that has begun to gel.

Placement

- LICODRY grades are installed by casting or vibration, as stated on the TDS; vibrating grades are consolidated on a vibrating table (shapes) or by poker/vibration (linings), in the same manner as dense vibrated castables (see Section 3.2).
- Gunning versions, where offered, are prepared by ramming and/or casting per the binder TDS.

Setting, curing & heat-up

- LICODRY sets **chemically** (colloidal-silica gelation), not hydraulically. It therefore does **not** require the 24-hour wet-cure used for cement-bonded castables, and must not be kept wet (see the note in Section 4.1).
- After setting, follow the fast dry-out/heat-up schedule on the TDS – Curve D in Section 7.1 (first heat-up of the order of 69 h, against ~176 h for LC/ULC on Curve C). Temperatures refer to the hot gas, not the lining surface.

Storage & shelf life

- Store the dry component and the SILCO GEL binder per Section 1.7. As a colloidal-silica (sol) binder, **SILCO GEL must never be allowed to freeze** – freezing gels the sol and ruins it irreversibly – and it must be kept sealed and used within its shelf life.
- Keep the two components matched and traceable to the same supply, and confirm the binder is within date before use.

SAFETY

LICODRY generates far less steam on heat-up than cement-bonded castables, lowering the spalling/steam-explosion risk, but a controlled TDS schedule is still required. SILCO GEL is a low-alkali inorganic binder; handle per its Safety Data Sheet. Observe dust precautions when handling the dry component (respirable silica) and skin/eye protection when handling the binder.

When to contact Linco Baxo

For grade selection, binder dosage, fast heat-up schedules for a specific lining, and any severe-duty or new application.

Cross-references

Section 1.1 Fundamentals of Castables · Section 1.7 Monolithic Shelf Life & Expired Material · Section 3.1 Mixing · Section 3.2 Casting · Section 4.1 Curing · Section 7.1 Principles of Drying & Heating Up.

2.1 – Anchor Systems (Metallic & Ceramic)

Purpose & scope

This section gives general guidance on metallic and ceramic anchors used to support refractory and insulating linings. Anchor type, quality, pitch and pattern are defined at the design stage and on the project drawings; this guidance does not replace them.

Function & selection

Furnace linings are supported by anchorage welded or bolted to the shell, used singly or in combination. A wide range of flexible and fixed anchors and supports is available for different positions, temperatures and process conditions. The choice of type, quality, pitch and pattern is determined during design, taking into account lining thickness, position, service conditions and the method of installation.

IMPORTANT

Anchor type, material, spacing and pattern shall follow the approved project drawings and the client specification. Where these differ from this handbook, the project documents take precedence.

Metallic anchors – maximum temperatures

The maximum allowable temperature of a metallic anchor depends on the furnace atmosphere and the anchor section. In normal oxidising atmospheres without sulphur, the following temperatures should be regarded as the maximum at the hot tip of the anchor:

Steel or alloy	Max. hot-tip temperature
Carbon steel	590 °C
18% Cr – 8% Ni (Type 304)	870 °C
25% Cr – 20% Ni (Type 310)	1100 °C
20% Cr – 32% Ni (e.g. Alloy 800)	1100 °C
23% Cr – 60% Ni (e.g. Inconel 601)	1200 °C

SAFETY

When the fuel contains more than 0.5% sulphur by weight, carbon-steel anchors must be avoided.

Installation requirements

- The anchor length should place the tip about 12.5–25 mm from the hot face, and the anchor thickness should suit the application. In all cases, follow the client specification.
- Anchors welded to the casing must be securely attached without weld undercut. It is recommended that the strength of some welds be tested before the castable is installed.
- **Bend test:** any properly welded anchor should withstand being bent 15° from the as-welded position in the direction of greatest resistance, and back, without evidence of weld failure.
- Wrap the anchors with tape or coat them with bituminous paint to allow the metal to expand when the lining is heated. This reduces the risk of cracks near the anchors and lowers the heat load on them. Manufacturer-applied soft plastic coatings are also available.

Ceramic anchors

- Use ceramic anchors where the construction must be more robust through the whole lining thickness, or where the temperature exceeds the working range of metallic anchors.
- Ceramic anchors should be at least as heat-resistant as the lining they support.
- Although their tips are designed to face the furnace interior, place them about 2 mm back from the hot face of the lining.
- Secure ceramic anchors firmly in a metal anchor fixed to the casing before the refractory is placed.

Metallic anchors welded on a convection wall

Metallic anchors welded on a convection wall

Ceramic anchors on a side wall of a reheating furnace

Common errors to avoid

- Carbon-steel anchors in sulphur-bearing atmospheres.
- Anchor tips set flush with, or proud of, the hot face.
- Omitting the expansion-allowance coating on metallic anchors.

Cross-references

Section 2.2 Shuttering · Section 2.3 Planning & Precautions · Section 3.2 Casting · Section 6.1 Joints.

2.2 – Shuttering

Purpose & scope

This section covers the design and treatment of shuttering (formwork) for castable linings.

Key requirements

- Construct shuttering from non-absorbent, strong, waterproof material – most usually metal plate or wood.
- The structure must be strong enough not to flex under the load of the castable.
- All joints in the shuttering shall be watertight, to avoid the escape of water carrying fine cement-rich material.
- Oil or otherwise treat the shuttering so it strips easily; choose a release agent that does not react with the castable surface.
- Install each metallic support at a pitch of about 400–500 mm to prevent the shuttering bending.

Leakage and very-light-weight castables

Leakage is most noticeable when casting very-light-weight castables, which need a relatively large quantity of water.

> **IMPORTANT**
> **If leakage occurs, do not reduce the water content to thicken the castable.** This changes the physical properties of the material and increases density, causing a shortage of material. Solve the problem by modifying the shuttering instead.

Common errors to avoid

- Absorbent or leaking shuttering that draws water and fines out of the mix.
- Insufficient support spacing, allowing the form to bow under load.
- Release agents that stain or react with the cast surface.

Cross-references

Section 2.1 Anchors · Section 3.1 Mixing · Section 3.2 Casting.

Convection corbels shuttering of a petrochemical heater

2.3 – Planning & Precautions

Purpose & scope

This section covers the planning, environmental control and site preparation needed before installing monolithic refractories, so that the work proceeds without interruption and the lining develops its intended properties.

Plan the operation

Before installation begins, confirm that all materials and the necessary equipment are available, or will be available when required, and that they comply with the Linco Baxo guidance in this handbook. Plan the work so each section can be completed without interruption, including the time required for curing and drying, and ensure enough shuttering is available for the planned rate of installation.

Ambient temperature

- During placement and curing, the surrounding environment shall be between **10 °C and 32 °C**. This also applies to any surface the castable contacts, such as the furnace shell or an existing lining. Take suitable action to maintain this range if necessary.

For work below 10 °C see Section 5.1; for work above 32 °C see Section 5.2.

Water

The water added to the dry castable shall be between **10 °C and 25 °C**. Use only clean, potable water of low acidity, free of salt, sugar and other foreign matter. If the quality is uncertain, have it analysed against the following guideline limits:

Parameter	Recommended limit
pH	6.5 – 8.35
Calcium (Ca^{2+})	less than 300 ppm
Magnesium (Mg^{2+})	less than 300 ppm
Sodium + potassium (Na^{+} + K^{+})	less than 150 ppm
Chloride (Cl^{-})	less than 200 ppm
Iron (Fe^{3+})	less than 300 ppm
Sulphate (SO_4^{2-})	less than 200 ppm
Residue after evaporation at 180 °C	less than 1500 ppm

> **NOTE**
> If the water does not meet these limits, use demineralised water. Keep water storage and handling equipment clean to avoid contamination. For further advice, consult Linco Baxo.

Personnel, tools & equipment

- Ensure enough labour and equipment are on site to complete the job in the allowed time, including curing and drying.
- Mixers must be clean and free of Portland cement, which causes quicker setting and reduced strength.
- Keep all tools – mixers, buckets, wheelbarrows, trowels and vibrators – in clean condition.
- Keep the mixer and surrounding area clean and sheltered from the weather.
- The steel surfaces to be lined shall be dry and clean, free of loose mill scale, rust, grease, oil, dirt and similar foreign matter.

Site-readiness checklist

- Materials verified – type, brand, manufacturing date, batch and shelf life checked (Sections 1.5–1.7).
- Anchors installed, welds checked and bend-tested where required (Section 2.1).
- Shuttering built, watertight, supported and treated with release agent (Section 2.2).
- Mixers, vibrators and tools clean and functional; correct mixer type available (Section 2.4).
- Clean potable water available, within temperature and quality limits.
- Ambient and surface temperatures within 10–32 °C.
- Curing materials (sheets, wet sacks, blankets) and dry-out plan ready (Sections 4.1, 7.1).

> **NOTE**
> For owner-specified work, installation quality control may follow a recognised standard such as API 936, with defined inspection hold points for materials, equipment, personnel qualification and as-installed testing (see Section 8).

Cross-references

Section 2.4 Equipment & Workforce · Section 3.1 Mixing · Section 5.1/5.2 Temperature Conditions · Section 8 Sampling & Testing.

2.4 – Equipment & Workforce

Purpose & scope

This section gives an indicative guide to the workforce, tools and equipment typically required to install about 300–400 m³ of insulating and refractory monolithics in a medium-sized reheat furnace. It is for reference only and is not comprehensive: installation companies apply their own standards and difficulty factors, which vary from site to site.

Workforce & personnel (minimum per shift)

Role	Number
Linco Baxo field supervisor	1
Foreman	1
Bricklayers	4
Hodmen	6
Welders / carpenters	2

Equipment & tools (minimum per team per shift)

- 1–2 paddle mixers for dense castables and/or barrel mixers for insulating castables.
- 1–2 gunning machines (if gunning is required), with air-pressure regulation – essential for insulating castables to avoid loss of yield.
- 1 wire cutter for bricks and 1 disk cutter, each with 5 spare disks.
- 4 wheelbarrows, 10 plastic buckets, 2 water drums, 1 water measure, 1 drill, 1 mortar mixer.
- Toolkit with 2 grinding machines and 5 diamond spare disks Ø 150 mm; 1 stapling machine; 1 iron saw.
- Timber and formwork: pack-props, small wooden beams, fillets, panels, multilayer panels for nose shutters, scaffolding horses.
- Consumables: tar paper for construction joints, tar to coat metallic anchors, nails, monkey wrenches, angles, polythene rolls, polystyrene and dismantling paint.

Mixer selection

A paddle mixer is strongly recommended for dense castables and a barrel (drum) mixer for insulating castables.

Mixer	Use	Reason
Paddle mixer	Dense castables	Mixes evenly at a much lower water content, giving maximum strength at optimum density.
Barrel / drum mixer	Insulating castables	Gentle action protects soft, compressible aggregates; a paddle mixer would grind the grains, raising density and lowering yield.

IMPORTANT

Too much water reduces density and strength; too little reduces yield and may leave a shortage of material on site. Keep mixers free of Portland cement to avoid quick setting and reduced strength.

Cross-references

Section 2.3 Planning & Precautions · Section 3.1 Mixing · Section 3.3 Gunning.

Gunning Machine


Paddle Mixer


Disk Cutter

3.1 – Mixing of Castables

Purpose & scope

Correct mixing is the single most influential site operation affecting the final strength, density and durability of a castable lining. This section sets out the preparation, water control and mixing discipline required for dense and insulating castables.

Preparation before mixing

- All equipment and tools that come into contact with the castable shall be clean and free of set material, Portland cement and other contaminants. Clean the mixer out between batches and at every break.
- Existing brickwork shall be free of loose particles and thoroughly moistened (but not saturated) so that it does not draw water from the fresh castable.
- Shuttering shall be impervious to moisture and should be coated with an approved release agent (for example crude oil or wax) before installation.
- Use whole bags. Pour the entire contents of each bag into the mixer to avoid segregation in transit. If part of a bag must be used, dry-mix the whole bag first, then take the required quantity.
- Have the correct quantity of water measured out in advance (by weight or calibrated volume) – never estimate it by eye.

Mixer & mixing water

Manual mixing does not produce a consistent mix and is not recommended. Mechanical mixing is essential – a paddle mixer for dense castables and a barrel (drum) mixer for insulating castables (see Section 2.4). The paddle mixer matters for dense grades because it blends the mix evenly at a much lower water content, which is what delivers full density and strength; it must not be used for insulating grades, as it grinds the soft aggregate and raises density.

Only clean tap water shall be used. Water containing sulphates, and excessively hard or soft water, shall be avoided as it impairs strength and structure (see the water-quality specification in Section 2.3). Mixing water shall be at a controlled temperature – above 10 °C, best around 20 °C, and never above 30 °C; in hot conditions use chilled or iced water (see Sections 5.1 / 5.2).

Mixing procedure

- Dry-blend the material briefly to homogenise it before adding water.
- Add 80–90 % of the water specified by Linco Baxo, then add the remainder gradually while mixing until the correct consistency is reached.
- Continue mixing to a uniform, lump-free consistency – insufficient mixing leaves dry pockets; over-mixing damages lightweight aggregate (see below).

Recomposition of two-component castables

Several castables are supplied for large or distant projects as two separate components – inert aggregate in one group of bags and binder in another – batched so that complete bags are combined without weighing on site. Recomposition shall follow Linco Baxo instructions exactly, under close supervision:

1. Dry-mix the components by paddle mixer for at least two minutes; if mixing by hand, turn the whole batch over at least six times in a clean container or on a clean surface.
2. Add 80–90 % of the water specified by Linco Baxo, then add the remainder gradually while mixing until the correct consistency is reached.

Water addition

The water quantity given on the Linco Baxo data sheet is theoretical – derived from laboratory tests at 20–24 °C and 45–50 % relative humidity – and may be fine-tuned on site under the close control of the supervisor.

Castable type	Water guidance
Insulating castables	Use the data-sheet addition, adjusted to site conditions; minor discrepancies between data sheet and site are expected.
Conventional dense castables	Use the minimum water needed to install the material, never exceeding the data-sheet figure. Gauge by the “ball-in-hand” test.
Low-cement, ultra-low-cement & self-flowing	Gauge to the flow / vibration-flow value on the TDS, not by the ball-in-hand test. The water window is very narrow – do not exceed the figure given.

“Ball-in-hand” test (dense castables)

Add enough water for the castable to hold together as a ball when bounced gently in the palm. Too dry, the ball crumbles; too wet, it slumps through the fingers. Correct consistency gives a slight glisten to the surface with no appreciable transfer of water and cement to the palm. (See sketches: Dry / Correct / Wet.)

Mixing time & batch size

- Mixing time is normally about 3 minutes and shall be controlled. Over-mixing of lightweight insulating castables breaks down the soft, compressible aggregate and changes the material properties.
- Mix only batches that can be installed within 20 minutes of adding water – reduce to 10 minutes in hot conditions.
- Castables must not be re-mixed or re-tempered with extra water once they have stiffened or started to set; such material shall be discarded.

IMPORTANT

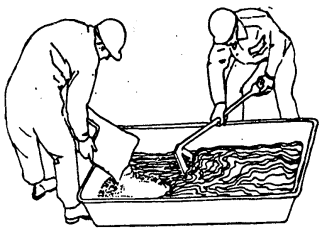
Too much water lowers density and strength; too little reduces yield and may leave a shortage of material on site. Water control is the supervisor’s primary responsibility during mixing.

When to contact Linco Baxo

Where site conditions force a water addition materially different from the data sheet, or where setting behaviour is abnormal, consult the Linco Baxo Technical Department before proceeding.

Cross-references

Section 1.1 Fundamentals of Castables · Section 2.3 Planning & Precautions · Section 2.4 Equipment & Workforce · Section 3.2 Casting · Section 5.1 / 5.2 Temperature Conditions.



3.2 – Casting

Purpose & scope

This section covers the placing, consolidation and finishing of castables installed by pouring into shuttering, for both dense and insulating grades

Before Casting

- Confirm the shuttering is secure, watertight and coated with release agent, and that anchors are correctly positioned and sound (see Sections 2.1 and 2.2).
- Confirm the mixed batch is within its working time and check the intended lining thickness against depth references.

Key requirements

- The castable shall be installed immediately after mixing and poured so as to minimise segregation. Place the material close to the surface – do not drop it from height.
- Pour slowly into position so that every undercut and profile is completely filled and no air pockets form.
- Maintain the furnace casing and lining temperature between 10 and 32 °C throughout placing and curing. Above 32 °C, iced water is recommended for mixing; below 10 °C, condition the materials and mixing water (see Sections 5.1 / 5.2).

Consolidation

Castable type	Consolidation method
Insulating	Rodding or tamping is usually sufficient. If a vibrator is used, a light poker should move the castable rather than compact it – over-compaction breaks soft/exfoliated aggregate, raising density and reducing yield.
Dense	Vibration is beneficial and reduces entrapped air to achieve optimum density. Stop when no air rises from the mix – generally within 2–3 minutes.
Self-flowing	De-airs and levels with little or no vibration; follow the TDS. Do not over-vibrate, as this causes segregation.

> **NOTE**
> Water accumulating on the surface during vibration indicates the mix is too wet – reduce water in the next batch. Move the vibrator slowly and deliberately, letting the castable flow in behind it, and pay special attention to corners and anchors while keeping the poker clear of the anchors and shuttering. Do not vibrate once the castable has begun to stiffen. Consolidation shall be carried out with a separate, hand-held immersion (poker) vibrator; vibrating equipment mounted on a gunning, pumping or shotcreting nozzle must not be used to compact cast material (see Appendix A).

Continuity & construction joints

- Once started, placing shall continue without interruption until the section is complete.
- If an interruption is unavoidable, cut the wet edge back at right angles for the full thickness of the lining (or layer); remove and discard all material ahead of the cut.
- As a practical guide, treat any interruption of more than about 20 minutes as a construction (cold) joint and apply the cut-back procedure above, rather than placing fresh material against a partially stiffened edge (see Appendix A).
- Time consecutive batches so that the previous batch has not begun to set. Each batch shall be placed to the full lining thickness rather than built up in layers.

- For multi-layer linings, treat the surface of the first layer to prevent it absorbing water from the next, and never add a layer before the previous one is complete.

Section sizes

Casting position	Recommended section
Horizontal	About 1 m × 1 m; not larger than 1.5 m × 1.5 m. Divide large surfaces into smaller, manageable sections.
Vertical	Shuttering at least 0.5 m high × 1.5 m long; cast evenly along the length and consolidate to a homogeneous lining.
Circular stacks / ducts	Often cast horizontally and rotated in stages – 4 steps (90°) for diameters below 1.5 m (3 minimum); more steps for larger diameters.

> **NOTE**
> For circular stacks and ducts cast by rotation, insulating grades may be installed with slightly reduced mixing water to stiffen the mix so it does not slump from the rotated section. This raises density somewhat but greatly eases installation; it is a sanctioned exception to the standard water rule and shall be agreed with the Linco Baxo Technical Department. It does not apply to dense castables.

Finishing & allowances

- Level the surface with a screed or wood float; do not trowel to a smooth finish (a troweled skin traps steam and can spall on dry-out).
- Cover the finished surface and begin curing immediately (see Section 4.1).
- Allow about 5–10 % extra material for damaged bags, spillage and residue; increase to 10–20 % or more in difficult or remote locations.

Common errors

- Over-vibration causing segregation; insufficient consolidation leaving voids at corners and anchors.
- Building up thickness in thin layers instead of placing the full thickness in one operation.
- Reducing water to overcome shuttering leakage – this changes the castable properties and must not be done (see Section 2.2).

Cross-references

Section 3.1 Mixing · Section 2.1 Anchor Systems · Section 2.2 Shuttering · Section 3.7 Self-Flowing Castables · Section 4.1 Curing · Section 5.1 / 5.2 Temperature Conditions · Section 6.1 Joints.

3.3 – Gunning

Purpose & scope

Gunning is a faster installation method in which pre-damped castable is pneumatically conveyed and projected onto the lining surface through a nozzle fitted with water injection. Linco Baxo formulates a range of materials specifically for gunning, installed on the dry-gunning (pre-damped) principle.

Before Gunning

- The receiving surface shall be clean and sound, with anchors correctly positioned (see Section 2.1). Do not gun onto frozen surfaces or below 10 °C (see Sections 5.1 / 5.2).
- Expect higher rebound during the initial pass against bare steel.

Equipment & pressures

The gunning machine shall allow full regulation of both air and water pressure. Indicative settings are:

Castable type	Air pressure	Water pressure
Dense	1–10 bar	0–5 bar
Insulating	5 bar (≈ 8000 l/min)	7 bar

> **NOTE**
> Correct air-pressure regulation is essential for insulating castables to avoid compaction of the soft exfoliated grains, which would increase density and reduce yield. Air and water pressures actually required depend on hose length, nozzle size and hose diameter, working height and material type; the indicative flow rate is not a fixed equivalent of the stated pressure and should be confirmed for the specific nozzle and hose configuration in use.

Pre-damping

- Pre-damp in a dedicated pre-dampener where possible; otherwise use a paddle mixer placed immediately next to the gunning machine.
- Pre-damping water is approximately one fifth of the total water added at the nozzle; the remainder is added as a fine spray at the nozzle, up to the maximum the material accepts without slumping.
- Mix the pre-damped material until homogeneous and free of lumps, and use it within 20 minutes.

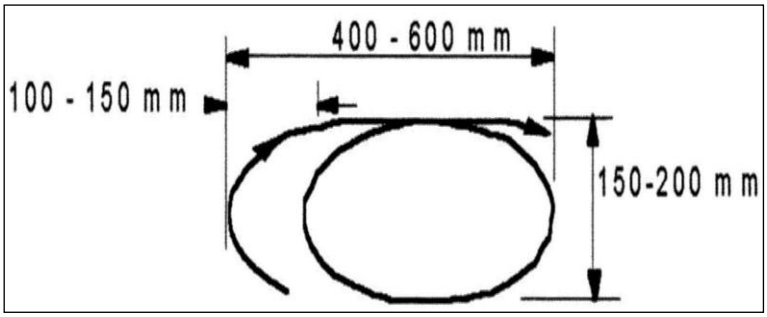
The water figure on the data sheet is not used directly for gunning, as the nozzle water addition must be matched to the machine. Pre-damping reduces nozzle dust, improves operator visibility and gunnability, and minimises segregation and rebound.

Application technique

- Hold the nozzle at about 90° to the surface, roughly 1 m away (depending on density), moving it in a small circular motion to reduce rebound and lamination risk.
- Build the material gradually to full thickness over a small area at a time; on vertical walls work from bottom to top so rebound does not stick to the shell or anchors below.
- Always work along the wet edge of the band just finished, reaching full thickness quickly before moving to the next area.
- Ensure no rebound material is trapped in the stream of fresh material – entrapped rebound leaves voids and weak areas.
- Maintain direct communication between nozzle and machine operators – a two-way system is recommended where they cannot see each other.
- Keep gunning continuous until the section is complete. If an interruption exceeds 10–15 minutes, cut out and remove any area not gunned to full thickness; never build over previously applied

material to make up thickness. Cut unfinished edges back at right angles to the backing surface, and discard all material ahead of the cut; never build over previously applied material to make up thickness.

- For multi-layer linings, treat the surface of the first layer to prevent it absorbing water from the next.



Thickness control & finishing

- Work in sections of roughly 2 m × 2 m. Control thickness with profile boards equal to the lining thickness: gun alternate sections, let them set, strike the boards, then gun the intervening sections. For spherical surfaces, use Ø 2 mm guide pins welded at 600 mm spacing, cut to lining thickness.
- A normal gunned finish is pitted by 3–10 mm (depending on maximum aggregate size); where precise thickness is required, gun slightly over-thickness and trim back with a trowel, steel float or – better – a nailed brush as soon as possible after gunning.
- A smooth trowelled finish must be avoided.
- Rebound material must be removed and discarded – never re-used.

Rebound & allowances

Rebound loss rises for thin linings versus thick ones, and for overhead work versus vertical walls – which is why the difficulty factors below are highest for roofs. The total gunning allowance is the sum of material, site and job-difficulty allowances:

Case	Material	Site	Difficulty	Total
Domestic – vertical walls	10 %	5 %	10–15 %	25–30 %
Domestic – roofs	10 %	5 %	30–40 %	45–55 %
Difficult/remote – vertical walls	10 %	10–15 %	10–15 %	30–40 %
Difficult/remote – roofs	10 %	10–15 %	30–40 %	50–65 %

Engineering companies apply their own standards within these ranges; the best installation teams stay near the lower limits. Consult a Linco Baxo specialist for material selection and allowance estimates.

SAFETY

Gunning is a high-pressure, high-dust operation. Wear eye protection, a dust mask (respirable crystalline silica), hearing protection, gloves and a hard hat; keep clear of high-velocity rebound. Fit hose whip-checks and depressurise before clearing blockages.

Cross-references

Section 2.4 Equipment & Workforce · Section 3.1 Mixing · Section 3.4 Slap Trowelling · Section 3.5 Pumping · Section 3.6 Shotcreting · Section 5.1/5.2 Temperature Conditions.

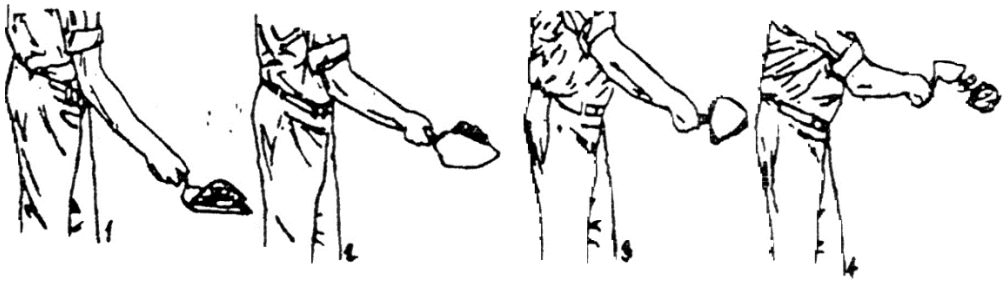
3.4 – Slap Trowelling

Purpose & scope

Trowelled linings are not generally permitted, and some engineering companies accept trowelling for contouring only. However, castables may sometimes only be installed by trowelling – for very thin linings or difficult positions where casting or gunning is impractical. This section describes the correct technique.

Before Trowelling

- The surface shall be clean and thoroughly moistened (not saturated), and the wire mesh, lath or anchoring shall be correctly fixed before work begins (see Section 2.1).
- Observe the same temperature discipline as for casting (see Sections 5.1 / 5.2).



Technique

Slap trowelling places small quantities of stiff-consistency castable, picked up on a trowel and "thrown" against the surface with an upward sweep of the arm and a flick of the wrist, so that it sticks, penetrates wire mesh or lath, and consolidates with material placed before and after.

- Use the minimum water needed for a stiff consistency. Water content may be varied to suit the craftsman, but extra water must not be added to a stiffening mix – re-tempering reduces strength, so discard any mix that becomes too stiff.
- Mix smaller batches if material is stiffening before use, and place manageable amounts near the work point.
- Work from bottom to top, left to right, or bottom-left to top-right.
- Where the anchoring has small openings, a less desirable "pushing" approach may be necessary – the castable is picked up on the underside of the trowel and pushed through the anchoring so that it sticks and consolidates with the material already placed.

Finishing

- Apply in a single full-thickness layer. Castable must not be applied in thin multiple layers, which peel and spall during curing and on heating.
- Trim with the trowel edge or screen with a board to the correct thickness, using the minimum trowel action. Do not add water to the surface; a damp cloth may be used to give a textured finish.
- Cover the finished lining and begin curing promptly – thin trowelled sections dry out quickly (see Section 4.1).

IMPORTANT

Excessive working of the surface draws water, fines and cement binder to the surface, causing cracking and spalling during curing and almost certainly on exposure to high temperature.

Cross-references

Section 2.1 Anchor Systems · Section 3.2 Casting · Section 3.3 Gunning · Section 4.1 Curing · Section 5.1 / 5.2 Temperature Conditions.

3.5 – Pumping

Purpose & scope

Pumping is a method used to transport castable from the mixer to the point of placement, particularly useful for large volumes or areas of difficult access where wheelbarrow or bucket transport is not practical. During pumping, the castable is mixed and transported simultaneously.

Pump types

- Screw pump and twin-piston pump: the castable must be prepared in a separate paddle mixer before being fed into the pump.
- Auto-mixing (autoclave) pump: the castable is prepared directly in the vertical paddle mixer integrated into the pump.

Dry process vs. wet process

- The dry process is not recommended: without forced mixing, the castable does not leave the discharge head in a homogeneous state, but segregated.
- The wet process is the recommended method: the castable is prepared and mixed before transport, ensuring a homogeneous material at the point of placement.

IMPORTANT

The pumping method and equipment shall be confirmed with the Linco Baxo Technical Department for each application; not all products are suitable for pumping.

Cross-references

Section 3.1 Mixing · Section 3.2 Casting · Section 3.6 Shotcreting · Section 3.7 Self-Flowing Castables.

3.6 – Shotcreting

Purpose & scope

Shotcreting is an installation method derived from the underground construction and tunnelling industry. It uses pumpable low-cement (LCC) and ultra-low-cement (ULCC) castables, installed without shuttering but with divider strips between sections.

Operating principle

The castable is mixed in a paddle mixer with the required quantity of water, then pumped at high pressure to the shotcreting nozzle by a twin-piston pump. At the nozzle, the material is projected by compressed air while a setting accelerator is injected simultaneously, giving immediate gelling and stiffening. This provides sufficient stability and adhesion for application to vertical surfaces and overhead (soffit) areas, with virtually no rebound.

Required equipment

- Paddle mixer.
- Twin-piston pump.
- Accelerator dosing pump.
- Compressed-air supply with delivery line.
- Shotcreting nozzle.

Technical requirements

- Minimum placement thickness: 80 mm, for technical reasons related to the process principle.
- Shotcreting equipment requires long set-up times and intensive maintenance: the theoretical output of the equipment should not be confused with the actual productive output during a working shift.
- Surface finishing must be carried out immediately after spraying, before setting begins.

Cross-references

Section 3.3 Gunning · Section 3.5 Pumping · Section 3.7 Self-Flowing Castables · Section 4.1 Curing.

3.7 – Self-Flowing Castables

Purpose & scope

Self-flowing (self-levelling) castables are LCC, ULCC and FCC products formulated to flow and de-air under their own weight, with little or no mechanical consolidation. This section complements the general placing guidance in Section 3.2.

Key characteristics

- Narrow consistency window: water addition must be tightly controlled within the range given on the Technical Data Sheet. Even small deviations affect flow and de-airing behaviour (see Section 1.1).
- Workability check: use the flow-table test specified in the Technical Data Sheet or project specification, rather than the ball-in-hand test used for dense castables (see Section 3.1).

Placement

- Pour continuously from a single point, or a limited number of points, allowing the material to flow and level itself; avoid unnecessary manipulation.
- Once poured, do not disturb the surface: self-flowing castables achieve their finish through self-levelling rather than trowelling or screeding.

Consolidation

IMPORTANT

Self-flowing (self-levelling) castables must never be vibrated. They de-air through their own flow behaviour; vibration alters their rheological characteristics and can cause segregation or loss of flow.

Cross-references

Section 1.1 Fundamentals of Castables · Section 3.1 Mixing · Section 3.2 Casting · Section 6.1 Joints.

4.1 – Curing

Purpose & scope

When water is added to castables containing calcium aluminate cement, hydration occurs and generates heat. Enough heat is released to drive off some moisture as steam, which can prevent full hydration. Curing keeps the lining damp and cool so that water remains available for the cement to develop its optimum strength.

Curing method

- Keep the lining surface damp and cool: spray with clean fresh water at frequent intervals, or cover with wet sacks kept continuously wet. For ducts and small vessels, air-tight closing to retain internal moisture is an alternative.
- Start curing immediately after initial set – once the lining is hard enough that spray water will not wash out surface cement – and continue for at least 24 hours. Forms and shuttering may remain in place.
- Maintain the lining temperature between 10 and 32 °C throughout curing.

> **NOTE**
> This wet-curing regime applies to calcium-aluminate-cement (hydraulically bonded) castables. Sol-gel, phosphate-bonded and no-cement grades cure differently and some must not be kept wet – follow the relevant TDS.

Temperature conditions

Condition	Curing guidance
Cold (low evaporation)	Wet curing may be unnecessary, but the lining must be kept above 10 °C and must never freeze during setting and curing (see Section 5.1).
Hot (high evaporation)	evaporation)Wet curing is critical – keep the lining damp and cool for the first 24 hours and shade from direct sunlight in the open air (see Section 5.2).

Curing compound option

CURING MIX 106 is a spray-applied liquid that forms a protective film/membrane, isolating the castable from the atmosphere, supporting safe hardening and helping to prevent surface dust, mould and alkali hydrolysis. Used as an alternative to continuous wet curing, it removes the need for repeated re-wetting and its film normally lasts long enough to cover transport and intermediate operations before drying out. Apply to the wet castable and repeat after setting; refer to the relevant data sheet.

Critical controls

- Refractory-lined equipment shall not be moved on site until curing is complete, and shall not be packed or transported until air drying has been carried out (see Section 4.2).
- Steel-casing stiffening shall prevent flexure and distortion that could damage the lining.

Cross-references

Section 3.2 Casting · Section 4.2 Air Drying & Ventilation · Section 5.1 / 5.2 Temperature Conditions · Section 7.1 Principles of Drying & Heating Up.

4.2 – Air Drying & Ventilation

Purpose & scope

After curing, and before any initial heating, the castable lining shall be air dried at an ambient temperature above 10 °C for as long as possible – not less than 72 hours – to reach stable conditions. Air drying removes free water that would otherwise drive undesirable reactions between the lining surface and the atmosphere.

Alkali hydrolysis & carbonation

Freshly placed lightweight castables left undried in a damp, humid environment for a sustained period are prone to alkali hydrolysis (AH), also called carbonation. It occurs more readily with insulating castables based on porous aggregates that absorb high percentages of mixing water, and is aggravated by high-humidity sites and closed, unventilated spaces such as box-type furnaces. AH and carbonation are accelerated by the movement of water through the lining, so stopping water penetration is key to suppressing them.

Recommended practice

- Ideally, fully dry the lining immediately after curing.
- Where immediate drying is not possible, do not leave the lining in a closed, humid environment. Provide good natural ventilation or, preferably, forced ventilation over the whole surface with an adequate fan or hot-air blower.
- A pre-dry-out at about 260 °C for roughly 45 hours partially removes water and usually reduces AH risk.
- CURING MIX 106 forms a membrane that delays carbonation mainly by stopping water penetration (see Section 4.1).

Shop-lined modules

Where steel-casing modules are lined in the shop to reduce site time, air dry and ventilate the lining before packing for transport, and ensure the packaging protects it from water ingress. Fully cured and dried linings must not be left exposed to rain, which damages their properties.

> **NOTE**
> The air-drying operation is of greatest importance for lightweight insulating castables, owing to the high percentage of mixing water they require.

Cross-references

Section 1.7 Monolithic Shelf Life & Expired Material · Section 4.1 Curing · Section 7.1 Principles of Drying & Heating Up · Section 9.4 Ceramic Fibres.

5.1 – Low Temperature Conditions (below 10 °C)

Purpose & scope

Neither dense nor insulating castables shall be installed when the ambient temperature is below 10 °C. This section sets out the measures needed to maintain a safe temperature where cold-weather working cannot be avoided.

Maintaining temperature

- Maintain a minimum of 10 °C by artificially heating the water, the castable and the surrounding area – including the furnace shell – until the material has been cured and dried.
- In an open shop it may be necessary to lag the unit being lined and to provide adequate heaters to hold satisfactory temperatures.
- Store castables frost-free and move them to an area of at least 15 °C for at least 48 hours before installation.
- Maintain the minimum temperature for at least 24 hours after casting; some products – particularly slower-curing CAC-based formulations – may require up to 48 hours. Always confirm the specific value in the relevant Linco Baxo Technical Data Sheet before removing shuttering or protective covers.

Electrical heaters

Mixing water & mix temperature

- Mixing water shall be above 10 °C and is best heated to about 20 °C, never exceeding 30 °C.
- Control the dry-mix and water temperatures so the wet mix is always above 10 °C.
- For gunning, warmer material improves gunnability and reduces rebound; the recommended water temperature is 20–25 °C.
- Setting time may be adjusted with an accelerating agent supplied by Linco Baxo on request.

Temperature logging

Record ambient, mix and substrate temperatures at regular intervals (e.g. hourly) using min/max thermometers or thermocouples, keeping a site log as quality documentation – consistent with the monitoring approach used during dry-out (Section 7.1).

Curing, drying & frost

During application and curing the lining must stay above 10 °C and must never be allowed to freeze. After curing, air dry above 10 °C for as long as possible to reach stable conditions – especially important for lightweight insulating castables with their high mixing-water content.

IMPORTANT

The damaging effect of freezing depends on the free-water content. A fully dried castable is only marginally affected by frost, whereas a wet or partially cured lining can be seriously damaged.

Cross-references

Section 1.5 Storage · Section 3.1 Mixing · Section 4.1 Curing · Section 4.2 Air Drying · Section 5.2 High Temperature Conditions.

5.2 – High Temperature Conditions (above 32 °C)

Purpose & scope

High ambient temperatures accelerate setting and evaporation and raise the risk of cracking and explosive spalling. This section sets out the precautions for hot-weather working.

Storage, water & mix temperature

- Store castables in a cool, dry, ventilated warehouse out of direct sun; keep the dry-mix temperature below 32 °C, cooling it before use if necessary.
- Use cool fresh water, or chilled water if required – but never below 5 °C. Control water and dry-mix temperatures so the wet mix is always below 25 °C.
- If the steel casing is exposed to sunlight, cool it during installation, setting and curing to below 32 °C by shading and/or spraying its outside with water.

Placing & consolidation

- High-temperature castables stiffen quickly; restore consistency by rodding or tamping rather than by adding water. Avoid excess water and, if necessary, mix and install smaller batches.
- A retarding agent is available from Linco Baxo on request to extend working time.
- For gunning, take the same precautions as for casting and keep the mixer, dry mix and water out of sunlight.

Curing

Maintain the lining below 32 °C and keep it damp and cool for the first 24 hours. This is especially important for castables with a high heat of hydration, which are particularly vulnerable to cracking and explosive spalling if not correctly cured (see Section 4.1). Where none of these measures is sufficient, carry out the installation at night.

Cross-references

Section 3.1 Mixing · Section 3.2 Casting · Section 4.1 Curing · Section 5.1 Low Temperature Conditions.

6.1 – Joints of Castable Linings

Purpose & scope

Refractories expand when heated. Joints are provided to accommodate thermal expansion and to control shrinkage so that the lining and shell are protected from unrelieved stresses. The type, position and spacing of joints are determined by the engineer responsible for the design of the unit.

Expansion joints

- Expansion joints permit thermal expansion where the designer considers them necessary, protecting both lining and shell.
- They are generally placed at regular spacing not greater than 1.5 m in both horizontal and vertical directions.
- Where panel construction is used, joints between adjacent panels should be packed with ceramic fibre of an adequate service-temperature limit, such as blanket or felt.

Separation joints & score cuts

- Separation joints and score cuts distribute the lining shrinkage uniformly and prevent random cracking, at a regular spacing of no more than 1.5 m horizontally and vertically.
- Score cuts are made manually before the castable sets, approximately 1.5 mm wide and 25 mm deep.
- Cuts are always required with dense-type castable facings, and are recommended (though not strictly required) with medium-weight and lighter facings.

IMPORTANT

Score cuts shall be made before the castable hardens. They must not be cut by grinding after installation once the castable has set.

Cross-references

Section 1.1 Fundamentals of Castables · Section 3.2 Casting · Section 7.1 Principles of Drying & Heating Up · Section 9.4 Ceramic Fibres.

7.1 – Principles of Drying & Heating Up

Purpose & scope

Before a furnace or plant is operated, the refractory lining must be fully dried. Efficient, professional drying and safe heat-up discharge the free and chemically bonded water, minimise the risk of steam explosion and thermal shock, and bring the lining to optimum condition before start-up. This section explains the principles and the general procedure; it does not give a universal heating curve, because the correct schedule depends on the specific material, lining thickness, geometry and equipment. Always follow the relevant Linco Baxo Technical Data Sheet, the project specification, or a schedule issued by Linco Baxo. Indicative curves for the main material groups are given at the end of this section.

Water in the lining

Only about one quarter of the mixing water is consumed by the hydraulic bond; the remainder stays in the lining and must be removed by heat. Dense castables have low porosity and permeability, which means few escape routes for water and steam, so water must be released slowly to avoid the internal pressure that causes cracking or explosive spalling. The residual water is held in three forms, each released over a distinct temperature range:

Water form	Released at	Notes
Free (physical) water	≈ 100–110 °C	The boiling/ebullition stage near 100 °C is the most critical; hold to release water gradually.
Physically/chemically bonded water (hydrate shell)	≈ 250–350 °C	Released as the calcium aluminate cement hydrates decompose.
Crystalline-bonded water	≈ 600–650 °C	The last water to leave the structure.

Stages of water removal

Stage	What happens
Curing	Cement hydration; lost moisture is replaced to develop strength (Section 4.1).
Air drying	Free water is removed at ambient temperature above 10 °C to reach stable conditions (Section 4.2).
Dry-out / first heat-up	Controlled heating removes the remaining free water and, at higher temperatures, the chemically combined water held in the cement hydrates.

General rules for dry-out

- Dry-out must follow a defined curve based on the type/quality of castable and the lining thickness. The greater the thickness and the higher the density, the longer the process.
- Dry-out must **never** be stopped or interrupted. If an interruption is unavoidable, keep the lining warm, or cool it down following the original curve.
- Maintain a continuous hot-air flow through the whole furnace to carry moisture away.
- Mobile burner equipment is generally used, because the plant's own burners usually cannot regulate the low-temperature range accurately enough for a successful temperature progression.
- Do not direct free flames onto the refractory lining below 650 °C.
- Avoid rapid temperature changes.
- Indicated temperatures always refer to the hot gas / hot air, never to the lining surface — the temperature inside the material always lags behind, which provides a margin of safety.

- For a lining made of several refractories, select the temperature curve of the material with the lowest permissible heating rate.
- Do not start drying & heating up until 24 hours after installing castables or mortars (plastic and ramming mixes excepted), so that setting is not prematurely interrupted.

IMPORTANT

Dry-out success depends on more than the heating curve. Burner size and placement, exhaust location, air volume and velocity, thermocouple placement and the drying equipment must all be addressed. This work is not always part of the services provided by the refractory installer.
Linco Baxo recommends engaging an experienced dry-out contractor with professional burner equipment. Linco Baxo can provide heating-up curves for specific applications, particularly for new installations and critical service; the curve depends on the nature of the whole lining rather than on a single component.

Site requirements

These requirements are independent of the heating medium used:

- After installation, no additional water (rain, tap water or similar) shall enter the furnace/plant, to prevent condensed water. Protect the plant against frost.
- The furnace/plant must be tight. Close all openings not needed for hot-gas discharge so that a slight excess pressure is maintained; this stops the incoming hot air from streaming through without effect.
- Fit a control valve at the hot-gas discharge to regulate the excess pressure. At the same cold-air rate, the air volume at least doubles by the time drying temperatures reach 500 °C — which is why the control valve is so useful.

Preparation

Drying & heating up is prepared as follows: set up the supply lines; set up the fans; set up or install the burners in front of the defined openings; and install the thermocouples at the specified locations. Then run a cold-operation test of the fans and thermocouples, test the tightness of the gas, oil and compressed-air lines, and visually inspect the vessel seals.

The following must also be checked in advance:

- How the moist flue gas (exhaust vapour) will be discharged.
- Whether condensate can be discharged and its build-up prevented.
- Whether there is a sealing-off on the flue-gas side to other parts of the furnace/plant.
- Whether pressure parts or boiler pipes are — or must still be — filled with water; if so, a new thermal (heat) balance must be prepared.

With complicated furnaces/plants it may be necessary to carry out a risk (danger) analysis and prepare a checklist of the required testing steps (see Table A). A sufficient number of fire extinguishers must be located in the vicinity of the burners.

Table A — Example checklist / testing list for dry heating

No.	Description of check / test	Responsibility (Customer / Contractor)	Checked by	Result
1 General				
1.1	Drying & heating-up regulation (procedure exists / approved)			
1.2	Acceptance of the refractory lining			
1.3	Flue-gas discharge on site (in position)			
2 Heating equipment to perform drying & heating-up work				
2.1	Conformity declaration / CE mark / permits			
2.2	Cordoning off of burner areas			
2.3	Number and type of burners according to procedure			
2.4	Positioning (arrangement) of burners according to procedure			
2.5	Positioning (arrangement) of thermocouples according to procedure			
2.6	Temperature-recording equipment checked			
3 Gas				
3.1	Gas pipelines / gas control routes checked for tightness (leaks)			
3.2	Permits for gas hoses on site			
3.3	Gas pressure controller installed (if required)			
3.4	Safety shut-off device installed for specific purpose			
3.5	Function test of gas control routes and burners successful			
3.6	Function test of safety features on burner equipment successful			
4 Safety measures				
4.1	Cordoning off of safety-relevant areas			
4.2	Extinguishers in position with valid inspection sticker			

Execution

- Position the burners so that the heating energy is guided through door openings or manholes into the inside of the furnace/plant, reaches all areas to be dried, and then flows out through the chimney (or emergency chimney).
- Inject air via the fan to mix with the burner flame. Any flame forming directly at the burner outlet nozzle must not impinge on the refractory lining.
- Keep the temperature in the immediate burner area within a limit, checked by a thermocouple placed directly in the burner area.
- Protect endangered areas with ceramic / soluble-wool blankets or other heat-insulation materials.

- Start only once preparation is complete and the customer has given the go-ahead, following the drying & heating-up curves provided by Linco Baxo or the refractory engineering company.

Estimating the schedule

There can be major differences in the permissible temperature gradient between materials, so only recommendations and minimum requirements are given here. Up to 100 °C it is generally not necessary to adhere to a specific temperature progression: heat transmission is relatively low and the steam pressure cannot exceed 1 bar. Drying is fastest in the low-temperature range, so — especially with plastic mixes — it makes sense to include holding periods at about 120–150 °C. Table B gives standard durations and the applicable curve for each material type.

> **NOTE**
> For general orientation only, API Standard 936 (Refractory Installation Quality Control) publishes indicative dry-out schedules for conventional castables by density class (below 1200 kg/m³, 1200–1600 kg/m³ and 1601–2240 kg/m³), with heating rates of 28 to 56 °C/h and a comparative "Dryout Index" of 23 to 40 hours for a 127 mm single-layer lining heated from 10 °C to 705 °C. These figures remain subordinate to the specific Linco Baxo TDS or dedicated dry-out schedule for the product installed. For complex units – more than one burner, more than two flue-gas exit points, or eight or more thermocouples – API 936 recommends that the dry-out plan be reviewed by an engineer experienced in the dry-out of complex systems (see Appendix A).

Table B — Standard drying & heating-up durations and applicable curve

Type of material	Duration (h)	Curve	Setting & air-drying (h)
Plastic mixes, mouldables and ramming mixes	113	A	24
Dense, standard refractory castables	112	B	24
Insulating refractory castables	112	B	24
Dense refractory castables, medium and low cement content	176	C	48
Self-flowing (self-levelling) dense refractory castables	176	C	48
FC castables (Licodry)	69	D	12
Brickwork of alumina bricks / blocks / shapes	30	E	12
Fired mullite and sillimanite shapes	95	F	24
Fired high-alumina shapes	95	F	24
Fired zircon and zircon-mullite shapes	96	G	24
Unfired itemized shapes	—	See underlying castables	—

Disturbances, cooling & instrumentation

- If heating is disturbed, continue increasing the temperature from the level reached at the end of the disturbance. A holding period already completed need not be repeated; but if the disturbance occurs during a holding period, the entire heating period must be repeated.
- Cool down with extreme care, as dangerous tensile stresses can occur. Water or ducted (forced) air must not be used for cooling.
- Measure temperatures preferably with NiCr-Ni thermocouples; higher ranges with Pt-RhPt thermocouples with a sheath. They are easy to operate, record temperature precisely and, being small, barely influence the lining.

- Position thermocouples projecting 80–100 mm into the furnace chamber, not touching the lining, and clear of direct flame radiation or shadow so the readings are not falsified. The specified reference measuring locations are decisive for temperature control.
- A thermocouple recording the waste-gas temperature near the burner controls the rate of temperature rise. Where steam build-up is excessive, hold the temperature until the build-up subsides.
- Keep the hot-gas volume high enough to prevent condensation, and operate the burner with at least 50 % excess air.

SAFETY

Personnel shall be kept clear of openings and burner exhausts during dry-out. Steam release and the risk of spalling make the first heat-up a controlled operation under competent supervision.
Cordon off burner and safety-relevant areas, and keep a sufficient number of inspected fire extinguishers near the burners.

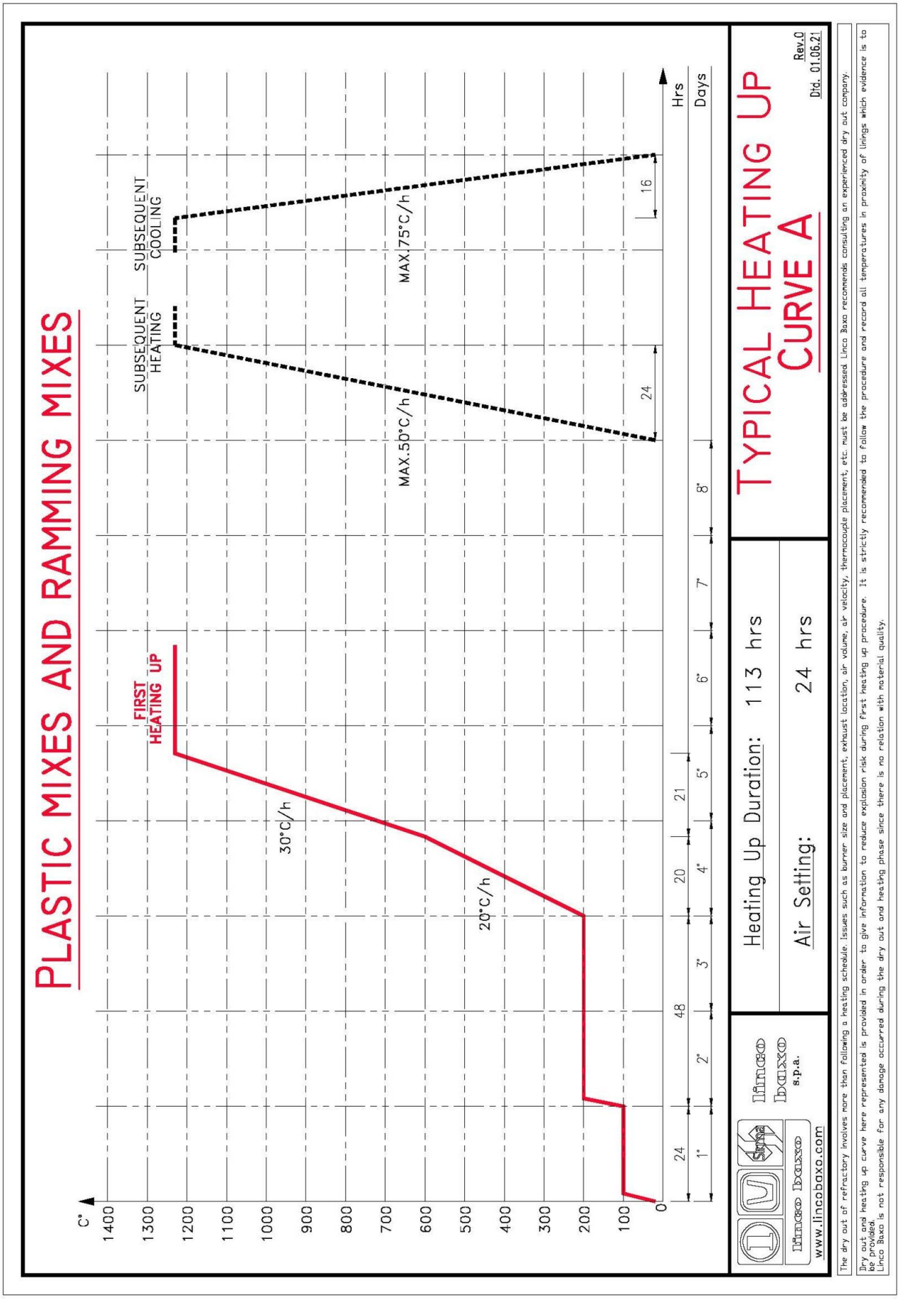
Typical heating-up curves

NOTE

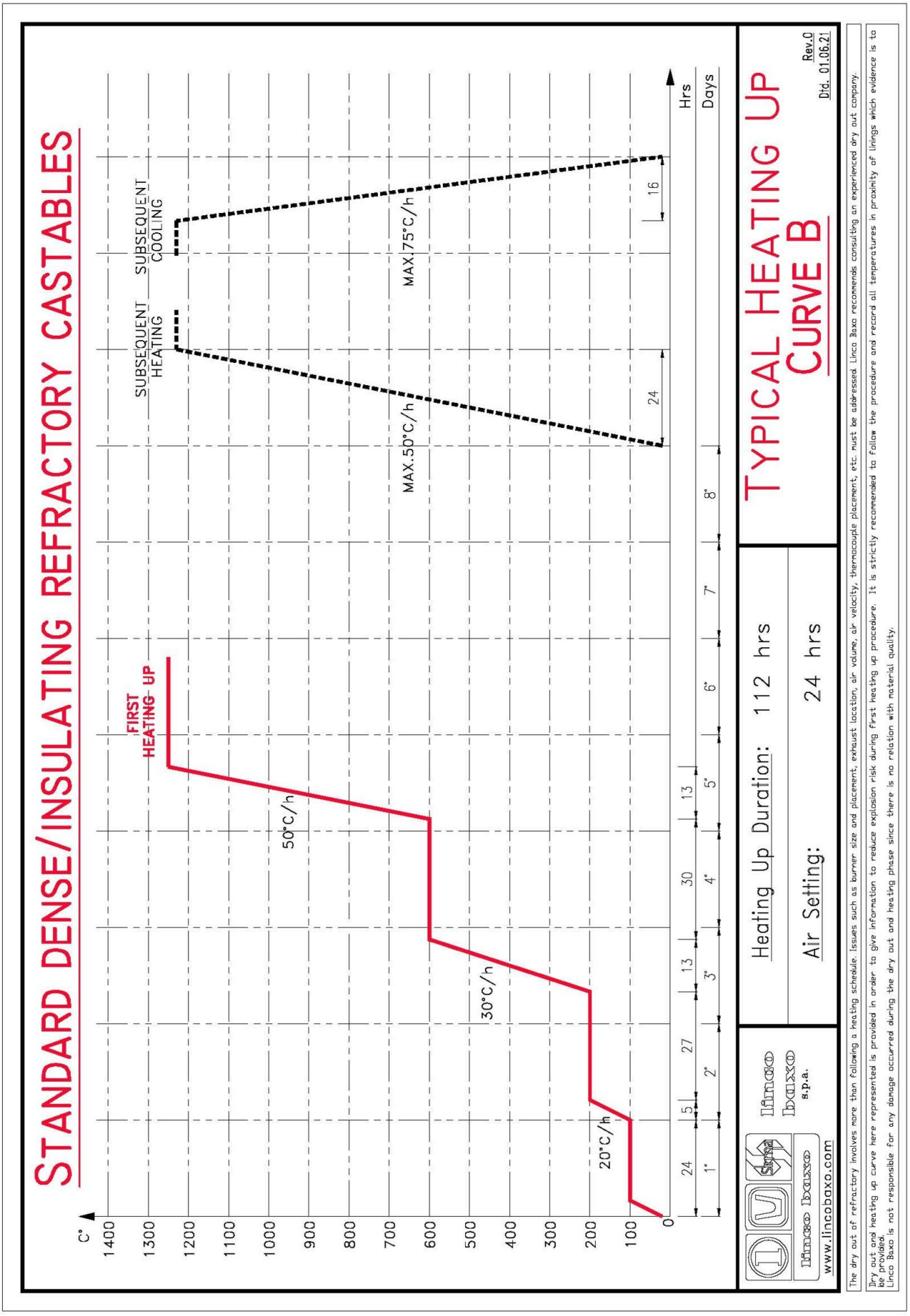
The curves below are indicative and are provided to reduce explosion risk during the first heat-up. They give the first heat-up schedule together with the maximum rates for subsequent heating (≤ 50 °C/h) and cooling (≤ 75 °C/h). For a specific lining, follow the schedule issued by Linco Baxo or the project specification. Temperatures refer to the hot gas / hot air, not the lining surface.

Cross-references

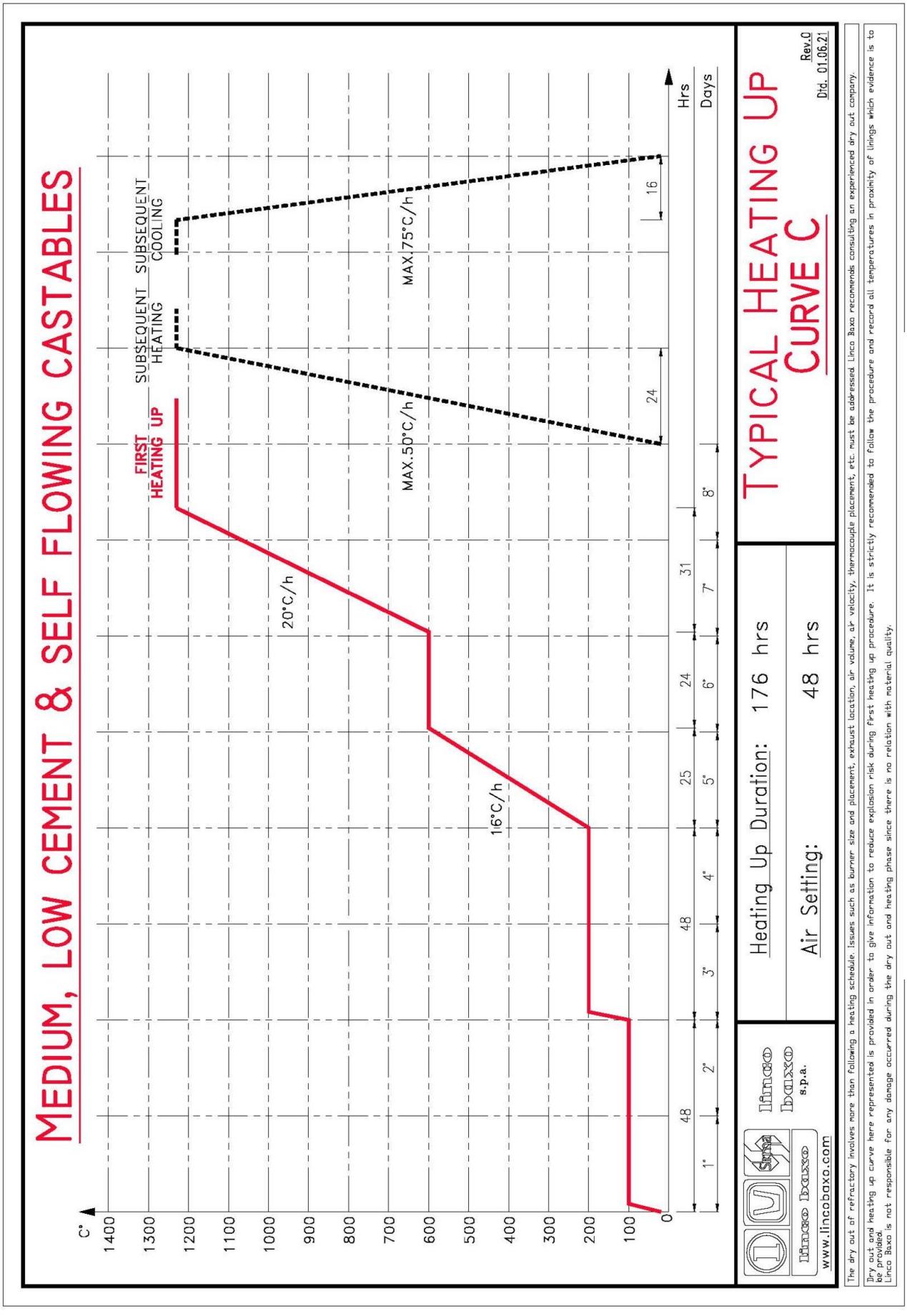
Section 4.1 Curing · Section 4.2 Air Drying & Ventilation · Section 6.1 Joints · Section 7.2 Lining Inspection · Section 8.3 As-Installed Tests.



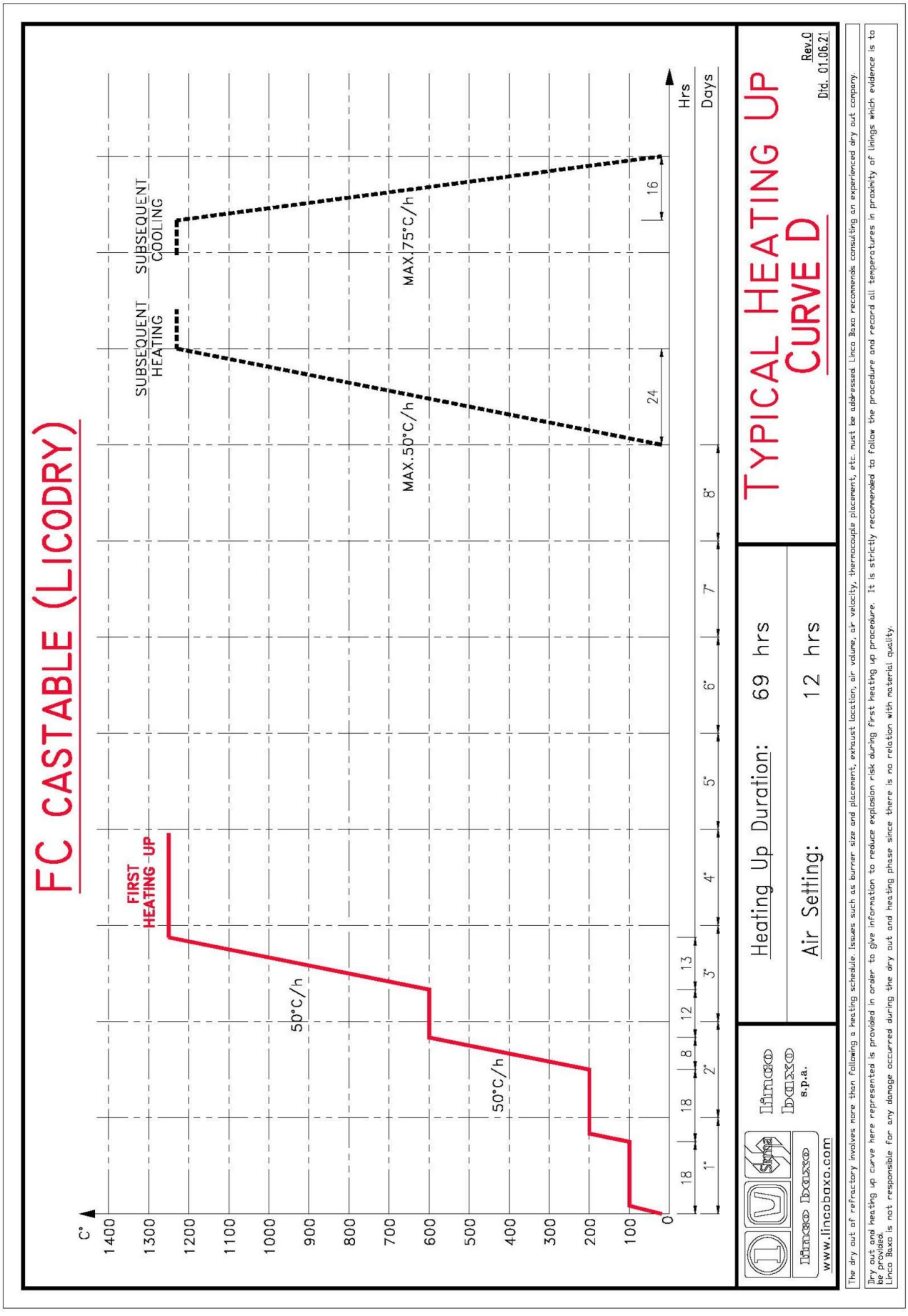
Curve A — Plastic mixes, mouldables and ramming mixes. First heat-up 113 h;



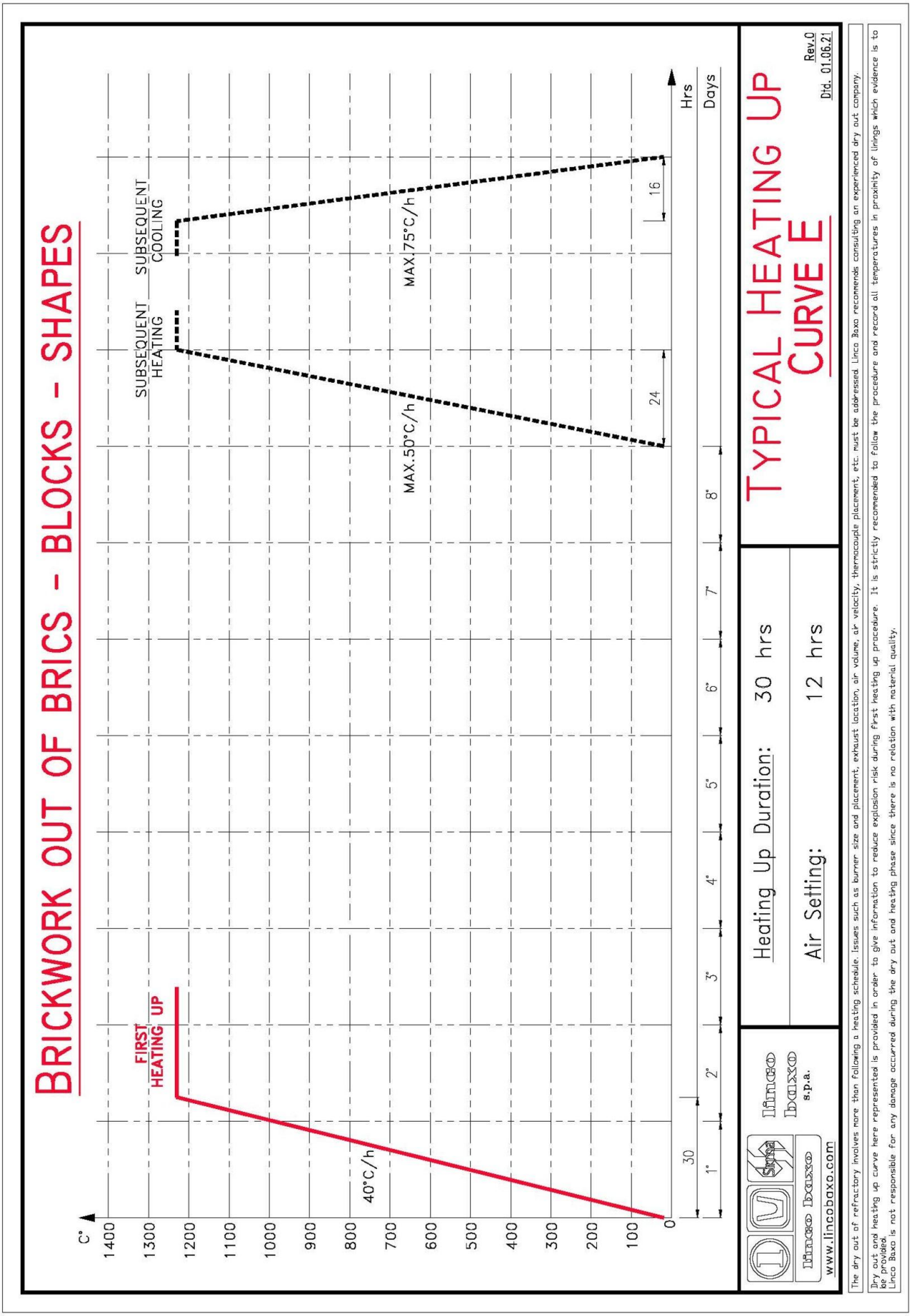
Curve B — Dense standard and insulating refractory castables. First heat-up 112 h;



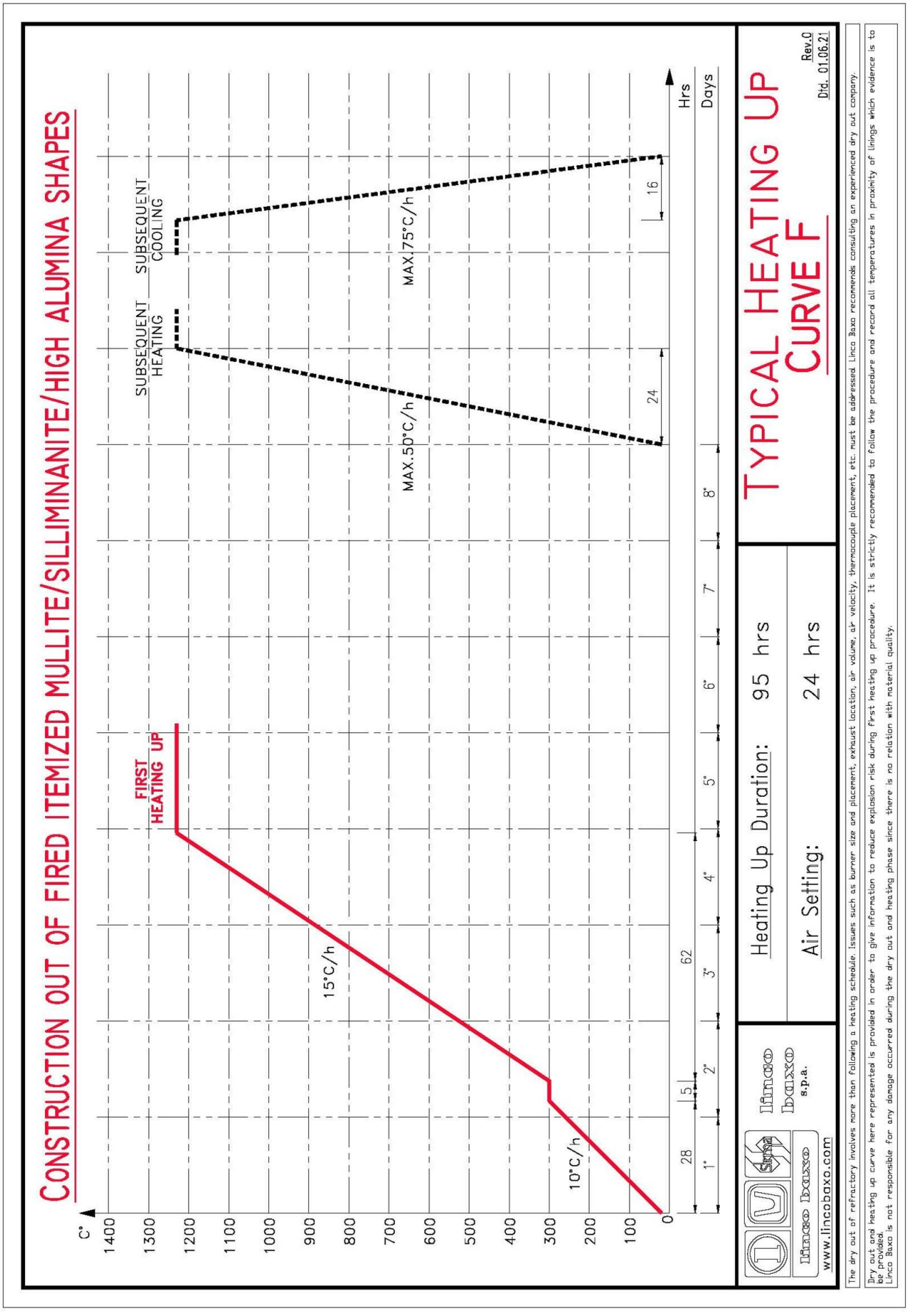
Curve C — Medium- and low-cement, and self-flowing dense castables. First heat-up 176



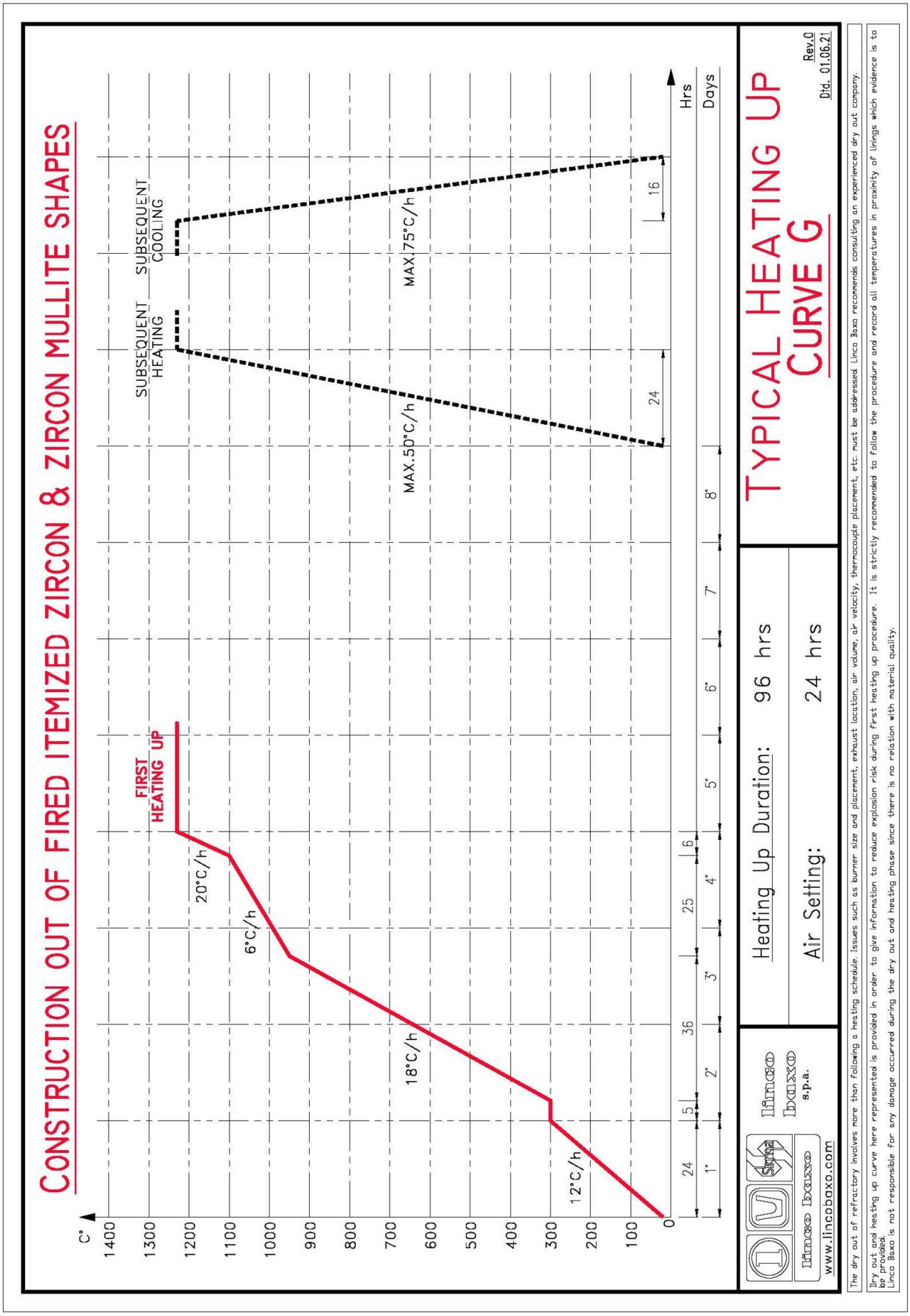
Curve D — FC castables (Licodry). First heat-up 69 h; setting/air-drying 12 h.



Curve E — Brickwork of alumina bricks / blocks / shapes. First heat-up 30 h; setting/air-



Curve F — Fired mullite, sillimanite and high-alumina shapes. First heat-up 95 h;



Curve G — Fired zircon and zircon-mullite shapes. First heat-up 96 h; setting/air-drying

7.2 – Lining Inspection

Purpose & scope

Inspection confirms that the installed lining meets the project requirements and will withstand service conditions. The lining shall be inspected only by experienced engineers. Acceptance criteria, hold points and documentation should follow the project specification; where a recognised framework is required, the principles of API 936 for monolithic refractory installation provide a suitable basis. The criteria below are typical defaults and apply where the project specification does not state otherwise.

When to inspect

- Inspect both after air drying and after firing (dry-out). Faults sound more clearly in fired linings than in air-dried ones, so post-dry-out sounding locates them more reliably.
- For multi-layer linings, carry out the hammer test on each layer, after the back-up layer(s) have cured.
- Linings tend to move on heat-up and develop further cracks on cooling, so the post-firing inspection is decisive.

Visual Inspection

- Check overall condition: cracks or local concentrations of cracks, spalling, voids, cold joints and surface laminations.
- Confirm the surface finish is satisfactory and the dimensions (including lining thickness at profiles and around penetrations) match the approved drawings.
- Check anchors: correct type, spacing and coverage, with anchor tips not exposed at the hot face.
- Inspect expansion and construction joints for correct size and position, and for foreign matter that could resist lining movement. Clean out and repack any affected joint with the correct material.

> **NOTE**
> Fine drying cracks are common in monolithic linings and are not necessarily a defect. Distinguish acceptable shrinkage cracking from structural cracking against the criteria below and the project specification; refer doubtful cases to the Linco Baxo Technical Department.

Crack acceptance criteria (typical):

- Repair individual cracks wider than 3 mm.
- Repair complete areas of random cracks up to about 3 mm wide where the cracks are within 300 mm of each other.
- Repair criss-cross cracking that forms "blocks", regardless of crack width, as these blocks tend to fall out with time and temperature.

Audio inspection (hammer test)

- Strike the lining over its entire area with a ball-pein machinist's hammer of about 450 g, following the specified grid – for example roofs at ~600 mm intervals, side walls and floors at ~900 mm intervals.
- A clear, homogeneous ring indicates sound material; a dull or drummy response indicates voids, delamination or poor bond. Interpretation requires an experienced ear.

Sounding acceptance criteria (typical):

- Repair any drummy or abnormal area larger than 150 mm × 150 mm.
- Repair soft or "dry fill" areas that reduce the effective lining thickness by more than one quarter, or that are more than 13 mm deep.

Extent of defects & replacement

Where the total defect area – voids, dry fill, cracks wider than 3 mm, or any defect in designated critical surfaces – exceeds about 35 % of the total lining surface, the lining is normally replaced in full. The decision on repair versus replacement rests with the inspector or the Owner's Engineer.

Records & timing

- Record observations, locations and defects with photographs, and reconcile them against the agreed acceptance criteria and hold points.
- Assess drying shrinkage cracking against the criteria rather than rejecting it automatically.

Cross-references

Section 6.1 Joints · Section 7.1 Principles of Drying & Heating Up · Section 7.3 Repairs · Section 8.3 As-Installed Tests.

7.3 – Repairs

Purpose & scope

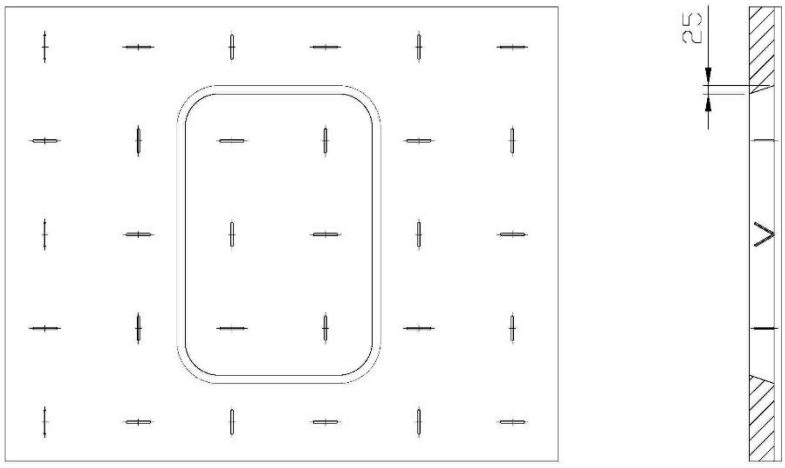
This section gives the principles and typical dimensions for repairing localised damage to monolithic linings. Repair with the same material originally installed and, wherever possible – particularly over large areas – the same installation method. Material selection and repair limits are application-specific; confirm them with the Linco Baxo Technical Department. The dimensions below are typical defaults and apply where the project specification does not state otherwise.

Assess first

Identify the extent of the damage and its cause – mechanical, thermal, chemical or installation-related – so the repair addresses the cause and not only the symptom.

Area repairs (defect larger than 150 × 150 mm)

- Remove the full thickness of the defective castable layer over a minimum area spanning 3–4 anchors. Locate the repair boundary midway between anchors, never at an anchor.
- Remove the material at a small angle to the shell so the cut-out is undercut (keyed) rather than feather-edged – this locks the repair in mechanically and avoids weak feather edges.
- Take care not to damage the surrounding sound lining or, where present, the back-up lining.
- Clean the area of all loose castable and debris, and thoroughly wet the adjacent sound material before installing new castable.
- Cast against forms made of boards propped and fixed against the sound castable surface.



Insulating refractory lining reparation scheme

Random-crack repairs

- Remove the full thickness of the lining for about 120–150 mm each side of the crack and parallel to it, giving a total width across the crack of roughly 240–300 mm.
- Where possible, install auxiliary anchors along the repair to give a new longitudinal and transverse anchor pitch of about 200 mm.

Soft-surface areas after dry-out

- Remove a soft surface only if enough material would become disengaged to affect normal operation.
- If removal is needed, scrape back until sound material is reached.

- If the resulting reduced thickness stays within the limits in Section 7.2, it may be acceptable; if it exceeds them, reinstate the area fully – unless it is confirmed that the reduced thickness still meets the design (insulating) performance. The Inspector or Owner's Engineer may still reject that demonstration and require full repair.

Curing & dry-out of repairs

- Prepare the surface, install, consolidate and finish following the relevant installation section.
- Cure, air dry and heat up the repair as for new work (Sections 4.1, 4.2 and 7.1). For small repairs (less than about 3 m²), accelerated procedures may be agreed with the Linco Baxo Technical Department.
- Re-inspect the repaired area before returning it to service (Section 7.2).

IMPORTANT

A repair is only as durable as its bond to sound material and its correct curing and dry-out. Cut back to a sound, keyed (undercut) edge – never feather repair material over unsound substrate – and never skip the drying stage.

Cross-references

Section 1.3 Ramming Mixes & Patches · Section 2.1 Anchor Systems · Section 3.2 Casting · Section 3.3 Gunning · Section 4.1 Curing · Section 4.2 Air Drying · Section 7.1 Principles of Drying & Heating Up · Section 7.2 Lining Inspection.

8.1 – Sampling & Testing

Purpose & scope

Sampling and testing verify that the material supplied and the lining installed meet the specified properties. The scope, frequency and acceptance criteria should be agreed in the project quality plan; where a recognised standard is required, the principles of API 936 for the inspection and testing of monolithic refractory linings provide a suitable framework.

Categories of test

Testing of monolithic refractories falls into three categories, covered in the following sections:

- **Pre-installation tests** – test-pieces prepared under controlled laboratory conditions from samples representative of the supplied consignment, to confirm the material as delivered (Section 8.2).
- **As-installed tests** – test-pieces prepared on site, under the actual installation conditions, which are often different from and less ideal than the laboratory. These show the quality the lining is likely to achieve in practice (Section 8.3).
- **After-installation tests** – non-destructive inspection of the finished lining, principally visual and hammer (audio) testing (Section 7.2).

Principles

- Samples shall be representative of the material as supplied and as installed, and shall be traceable to the production batch and the area of the lining they represent.
- Test frequency should be defined per material, per batch and per installed volume in the quality plan.
- Retain reference samples where required so that results can be checked or repeated.
- Test methods should follow the relevant ASTM, ISO or EN standard cited in the specification, applied consistently throughout the project. Linco Baxo also operates in-house methods based on ASTM, developed for specific purposes.

Scope is a compromise

The extent of sampling and testing is necessarily a compromise between customer and supplier. The total quantity of castable in the project, the time available to make and test pieces, report, review and grant approval, the throughput of the testing laboratory and the required rate of installation all bound how much testing is practical. For this reason the properties to be tested and the number of tests must be agreed when the material is ordered. Linco Baxo is always ready to discuss and agree a mutually acceptable plan.

> **NOTE**
> The specific properties, test methods and acceptance values for each product are given in the relevant Linco Baxo Technical Data Sheet. Confirm the applicable standards and pass/fail limits with the Linco Baxo Technical Department and the project specification before testing.

Cross-references

Section 7.2 Lining Inspection · Section 8.2 Pre-Installation & Production Testing · Section 8.3 As-Installed Tests · Section 8.4 Manufacturing of Moulded Pieces in Shop · Section 8.5 Laboratory Testing at Levate · Appendix A Research & Technical Basis.

8.2 – Pre-Installation & Production Testing

Purpose & scope

This section covers two things: the production quality control applied at Linco Baxo plants before material is released, and the pre-installation qualification of material, equipment and personnel before lining work begins. It follows the principles of API 936 and the project quality plan.

Production quality control

- All products are manufactured, tested, approved and released for shipment under an ISO 9001:2015 quality system, on the authority of the Quality Control Manager of the plant where the product is made.
- Raw materials are governed by a stringent Linco Baxo Purchase Specification imposed on all suppliers; all incoming materials are tested on arrival before being accepted for production.
- Blending is PLC-monitored with full raw-material tracking by quality and batch against the formula, which prevents blend errors becoming quality failures later.
- Each production shift is routinely checked for sieve analysis, water/mix ratio, cold compressive strength and permanent linear change. Periodic tests cover chemical analysis, thermal conductivity, thermal-shock resistance, modulus of rupture, abrasion resistance, refractoriness under load and, where applicable, resistance to CO disintegration.
- For large projects, pre-delivery testing may be carried out in Linco Baxo laboratories in the presence of the customer's inspector or nominated representative, on samples selected at random from material awaiting shipment. Customers with particular requirements are invited to agree the sampling plan and test procedures with Linco Baxo specialists early in the contract.

Material qualification (pre-installation)

- Confirm product identity, batch number and shelf life against the delivery and the data sheet (see Section 1.7).
- Check working properties relevant to the method: flow/consistency and working time for casting, gunnability for gunning.
- Verify the specified cured/dried properties – which may include bulk density, cold crushing strength and modulus of rupture – by the test methods named in the specification.

Equipment & personnel qualification

- Mixers, gunning machines and instrumentation shall be in good order and, where required, calibrated.
- Key personnel – in particular nozzle operators for gunning – should be qualified, typically by installing and testing a trial panel that is then assessed against the acceptance criteria.
- Where the specification requires trial panels or mock-ups, install them with the same materials, equipment and crew intended for the works, and test them to the agreed criteria before production starts.

Gunned panel test

Panel tests are imperative for gunned applications and are made before actual lining placement. Each operator shall gun at least one panel of each castable to be installed, always with the same gun equipment to be used on site.

- **Panel size:** 900 × 900 mm minimum, depth equal to the lining to be installed.
- **Method:** gunned in the vertical position, nozzle held about 1 m from the panel surface, in accordance with the gunning procedure in Section 3.3.

- **Conditioning:** cure for 24 hours, then dry at 105 °C for a further 24 hours.
- **Assessment:** check integrity by hammer test (Section 7.2) and establish density. A sound panel with density within the acceptable limits qualifies the operator and equipment.
- **Optional:** at the customer's discretion, cut the panel into four pieces to examine internally for inclusions and lamination.

IMPORTANT

Production application shall not begin until the trial panel or mock-up has been installed, tested and formally accepted against the agreed criteria. Nozzle operators, mixing crews and installation procedures that have not been qualified in this way shall not apply refractory material to the works.

Production control

During production, the following parameters should be checked and recorded as applicable:

- Water addition (total %).
- Mixing time.
- Flow / consistency.
- Material temperature (where required).
- Batch identification and traceability.
- Visual appearance of the mixed material.

Results shall be recorded and retained in accordance with the project quality plan.

Cross-references

Section 1.7 Monolithic Shelf Life · Section 2.4 Equipment & Workforce · Section 3.1 Mixing · Section 3.3 Gunning · Section 8.1 Sampling & Testing · Section 8.3 As-Installed Tests.

8.3 – As-Installed Tests

Purpose & scope

As-installed testing confirms that the lining placed on site achieves the specified properties. Test-pieces are produced from the same batched material as the lining, in the same manner as far as possible, so the lining can be assessed without core-drilling or cutting the actual lining. Sampling follows the project quality plan and the principles of API 936.

Sampling principle

Test-pieces are fabricated from material prepared for installation, sampled at times corresponding to the installation of the various lining sections (or, if preferred, by shift worked), and marked accordingly. Each sample is coded, its position marked on the lining drawings, and the castable type for that position recorded.

> **NOTE**
> Where not otherwise specified, a minimum sampling frequency of one sample per installation crew, per material and per shift is a commonly used reference (see API 936).

Sampling by casting

- Take one sample per lining section (or per shift), for each quality and each production batch of castable, during actual installation.
- Each sample comprises three cubes of 50 mm ± 0.4 mm (2″ ± 1/64), cast in approved metal or plastic moulds from the material being installed.
- Where modulus of rupture is specified, bar specimens of 230 × 50 × 50 mm ± 1.0 are prepared from the same material and in the same manner.
- Cure, carefully code and mark the cubes, indicate the codes on the lining drawings, and record the castable type installed in that position.

Sampling by gunning

- Take one sample per lining section (or per shift) for each quality of material, during installation. Each sample comprises three specimens of 114 × 114 × 64 mm ± 1.0 (4½ × 4½ × 2½″ ± 1/32).
- The material is obtained from a panel of 600 × 600 × 75 mm, gunned by each operator working that section (or shift) into a rigid test box (25 mm timber or 3 mm metal plate) mounted vertically, nozzle held about 1 m from the box, in accordance with Section 3.3. Gun slightly over 75 mm and trim back carefully.
- Cut a section about 300 mm square, full depth, from the middle of the panel before the material finally sets; cure it in a plastic bag, coded and recorded for future use.
- When testing is required, cut specimens with a diamond saw, dry at 105 °C and test.

> **IMPORTANT**
> Diamond-saw cutting can introduce micro-cracks and stresses. When comparing sawn 50 mm specimens with cubes cast from the same material, allow an additional variation of about 10 % to account for weaknesses introduced by sawing.

Other checks & records

- Verify installed thickness against the approved drawings.
- Confirm that curing, air drying and dry-out have been carried out and recorded as specified.
- Record all results against the batch and the lining area represented.

Properties tested

The properties tested on cast or gunned specimens – commonly bulk density and cold crushing strength and, where specified, modulus of rupture, permanent linear change and apparent porosity – depend on the equipment, the lining type and the service conditions, and on whether the castable was supplied as a two-component mix. Sampling frequency, specimen preparation, curing and acceptance values shall follow the project specification and the relevant test standards.

NOTE

Results from site specimens depend strongly on correct sampling, specimen preparation and curing. Investigate non-conforming results for sampling or curing error before the lining itself is judged.

IMPORTANT

If a result is non-conforming or disputed, a new sample shall be taken from the same area and retested using the same procedure and acceptance criteria. If the retest also fails, the area represented shall be repaired or replaced in accordance with Section 7.3. The contractor shall keep a record (e.g. a map) of all rejected and repaired areas, showing the reason, the repair method and the material used.

Cross-references

Section 3.1 Mixing · Section 3.2 Casting · Section 3.3 Gunning · Section 7.1 Principles of Drying & Heating Up · Section 7.2 Lining Inspection · Section 8.1 Sampling & Testing · Section 8.2 Pre-Installation & Production Testing.

8.4 – Manufacturing of Moulded Pieces in Shop

Purpose & scope

Pre-cast and, where specified, pre-fired shapes – such as burner blocks, peephole and support blocks, baffles and dampers – are produced in the shop to controlled procedures so that finished pieces arrive on site ready for installation. This section gives general principles; product-specific procedures are held by Linco Baxo, who should be contacted at the start of any shop operation using their castables.

Moulds & shop

- Cast on a vibrating table rather than with an immersion poker. Metal moulds are preferred; wooden moulds with a special internal coating may be used.
- Moulds shall allow easy casting and stripping, be strong enough to withstand repeated vibration cycles, and be securely clamped to obtain maximum vibration.
- At the design stage, confirm each shape can actually be released from the mould – modify the shape if the problem cannot be solved through the mould design.
- For large series, lost/burnable moulds or cores (for example polystyrene) may be used: the piece is cast and cured in the mould, then material and mould are dried and fired together.
- The shop should be equipped with paddle mixers, batteries of vibrating tables, and a curing room, drier and furnace of sufficient capacity; be clean, with potable water, exhaust and controlled temperature; provide mould storage; and be run by skilled labour.

Production sequence

1. Prepare clean, dimensionally correct moulds treated with an approved release agent.
2. Mix and place the castable following the relevant fundamentals and casting guidance (Sections 1.1 and 3.2), consolidating to achieve the specified density.
3. Cure the shapes under controlled temperature and humidity (Section 4.1), then strip without damage.
4. Air dry, and where specified dry out or pre-fire, following a controlled schedule (Sections 4.2 and 7.1).
5. Carry out dimensional and visual quality control, mark each piece for traceability, and package to protect against mechanical damage and water ingress for transport and storage (Section 9.1).
6. Pre-cast shapes still require correct handling, storage and, after installation, the appropriate joint treatment and final dry-out as part of the complete lining.

Mould turnover & planning

After stripping, each mould is cleaned, oiled and prepared for the next casting. Linco Baxo castables normally allow two pieces per mould per day (excluding the night shift). Use this rate to decide how many moulds a contract requires, allowing for curing, drying and – if required – firing time, plus a reasonable margin for production losses. Where a large number of pieces against a short delivery would otherwise demand an uneconomic number of moulds, a Linco Baxo vibrated castable that permits high-frequency stripping can reduce the mould count.

> **IMPORTANT**
> Linco Baxo dense vibrated castables use less than 6 % mixing water, but drying and firing of the pieces still require special care to avoid cracks and explosive spalling – even more so than for normal casting – unless a quick-heating grade is selected. Skilled operators are essential for vibrated pieces.

Cross-references

Section 1.1 Fundamentals of Castables · Section 3.2 Casting · Section 4.1 Curing · Section 4.2 Air Drying · Section 7.1 Principles of Drying & Heating Up · Section 9.1 Storage of Non-Perishable Refractories.

8.5 – Laboratory Testing at Levate

Purpose & scope

Linco Baxo operates a modern central laboratory of 800 m² at the Levate (BG) plant. The laboratory supports all Linco Baxo manufacturing facilities and is equipped for both routine quality control and R&D testing across the full range of refractory products. It is used for new formulation development, performance validation and product certification, and is integrated with an in-house technical training centre for staff and client education.

Laboratory tests performed

The following tests are performed at the Levate central laboratory, in compliance with the applicable ASTM, PRE and EN standards:

Test	Description
True density & bulk density	Size, dimensional measurements and bulk density of refractories.
Water content	Water content of refractory materials.
Sieve analysis	Particle size distribution and water content evaluation.
X-ray fluorescence (XRF)	Chemical composition analysis of the final product.
Cold crushing strength (CCS) & cold modulus of rupture (CMOR)	Mechanical resistance testing at room temperature.
Permanent linear change (PLC)	Dimensional stability after reheating (thermal shrinkage / expansion test).
Porosity	Apparent porosity, liquid absorption, specific gravity and bulk density of refractories.
Refractoriness under load (RUL)	Thermal expansion and structural deformation under load at high temperature.
Creep	Long-term dimensional change under constant stress and elevated temperature.
Thermal conductivity	Measurement of thermal conductivity for insulating and dense refractory materials.
Abrasion resistance	Wear resistance of refractories under mechanical stress at room temperature.
Hot modulus of rupture (HMOR)	Measurement of flexural strength of refractory materials at elevated temperatures.

NOTE

The table above lists the tests available at the Levate central laboratory. The specific test method, testing frequency and acceptance values applicable to a given product or project are defined in the relevant Linco Baxo Technical Data Sheet, the project specification and the project quality plan (see Sections 8.1–8.3 and Appendix A for the principal reference standards). Routine production testing per shift is described in Section 8.2.

Cross-references

Section 8.1 Sampling & Testing · Section 8.2 Pre-Installation & Production Testing · Section 8.3 As-Installed Tests · Appendix A Research & Technical Basis.

9.1 – Storage of Non-Perishable Refractories

Purpose & scope

This section covers the storage of items that do not have the strict shelf life of monolithics – fired bricks, back-up insulation, ancillary items and metallic parts. Although these are less time-sensitive, poor storage still causes damage, contamination and corrosion.

Storage practice

- Store off the ground on pallets, under cover, in a dry and well-drained area, protected from rain and standing water.
- Keep pallets and packs organised by type, quality and batch so that the correct material is used and stock can be rotated.
- Handle fired bricks and shapes carefully to avoid chipping edges and corners; keep packaging intact until use.
- Protect insulation products (boards, blanket, back-up insulation) from moisture, crushing and contamination.
- Protect anchors, fixings and other metallic parts from corrosion; keep them dry and, where specified, retain protective coatings.
- Keep materials in their original packaging until installation whenever practical.
- Store ceramic fibre products in dry conditions and avoid unnecessary compression that may permanently reduce thickness.
- Prevent contamination by oils, chemicals, dust, cement, lime or other foreign materials.
- Inspect stored materials periodically and remove any damaged or contaminated items before installation.

Pre-fired refractory bricks can generally be stored for several years under suitable conditions, in contrast to monolithics (see Section 1.7). Always check material against the specification before use.

Cross-references

Section 1.5 Storage – Castables & Dry Mortars · Section 1.7 Shelf Life · Section 2.1 Anchor Systems · Section 9.4 Ceramic Fibres.

9.2 – Brickwork Installation Guidelines

Purpose & scope

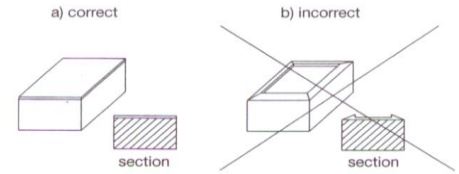
This section gives good-practice guidance for installing refractory brickwork. Bonding patterns, mortar selection, expansion allowances and anchoring are project-specific and shall follow the approved drawings and specification. Acceptance criteria for brick condition and joint tolerances shall follow the specification or be agreed between contractor, manufacturer and purchaser before work starts.

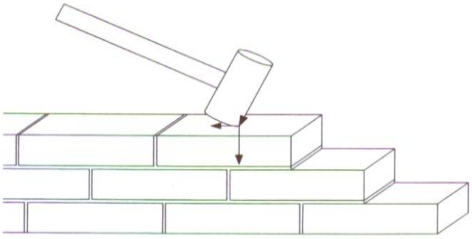
The ten rules of the furnace construction worker

1. Lay refractory bricks horizontally, unless the design requires inclined positions (for example crowns or inclined parts).
2. Observe the construction dimensions on the drawings within the stated tolerances. Install the first course with extreme care – aligned and checked – before giving the go-ahead for further work.
3. Fill all joints with the prescribed joint material, to the specified joint thickness within tolerance.
4. Fill each joint completely over its entire face. This is only achieved by rubbing the brick in firmly as it is laid. Do not apply mortar as a "collar", which leaves hollow spaces in the joint.
5. Where brick size tolerances prevent the specified joint thickness, the refractory designer decides whether the joint thickness may deviate; other measures are sorting, grinding/finishing the bricks, or changing shapes in exceptional cases.
6. Keep the brickwork clean; in particular, do not contaminate the expansion joints.
7. Adjust already-laid bricks only in the direction of the bed or vertical joint.
8. Do not readjust once the mortar has begun to harden. Remove incorrectly placed bricks, clean them, and reset them with fresh mortar.
9. Install bricks with spalls, cracks or minor inclusions only where the damage is insignificant or within the acceptable tolerance – this applies also to the rear brickwork and the brickwork behind. Acceptance follows the specification or a prior agreement between contractor, manufacturer and purchaser.
10. Design and build so that no hollow spaces form. Dust or fly ash can penetrate hollow spaces and cause an uncontrolled build-up of pressure that may destroy the brickwork; roaming gases can do likewise.

Engineering know-how before starting

- Measure, check and compare the construction components against the installation drawings before starting work.
- Install and align the first layers very precisely to avoid unnecessary cutting and to obtain uniform joint thickness; in specific cases, dry-stack a few courses in advance.
- For multi-layer brickwork, work section by section – for example support to support, or between expansion joints – installing one layer at a time. This is especially important where the layers use different refractory grades and different mortars.
- Where multi-layer brickwork is separated by sliding joints, keep everything scrupulously clean: dirt or mortar bridges impair the relative movement and readily cause damage.
- Where the steel casing is not level: for slight, shallow waves, follow the shape of the shell but keep the bed joints absolutely horizontal, so the bricks protrude in steps. Where service requires an absolutely level hot face, fill the casing deformation with monolithics instead.
- When bricks are cut, allow for the joint thickness at the cut edge. Key (fitting) bricks in crowns and rotary kilns always have a minimum thickness requirement of 40 mm, which must be observed.





Good practice reminders

- Set out and dry-lay critical courses and rings first to confirm fit and the position of closures before bedding in mortar.
- Use the mortar specified for the brick quality and service, applying thin, full joints (see Section 9.3); avoid over-thick joints, which weaken the structure.
- Follow the bonding pattern shown on the drawings, breaking vertical joints between courses and avoiding continuous through-joints.
- Provide and keep clear the expansion allowance specified by the designer, using the correct compressible material where called for.
- Install anchors, retainers and back-up insulation as specified, keeping the work clean, plumb and true to line.
- Where possible, use full bricks; position cut bricks (closures) away from high-stress or high-wear zones (e.g. not at the crown of an arch or the throat of a burner block) and keep the cut face away from the hot face where practicable.
- For curved or circular construction (arches, rings, stacks), set out on a template or trammel to confirm the required key / closure width before cutting, and build symmetrically from the springers or a fixed reference point.
- Fully butter both bed and cross joints; avoid furrowing (buttering only the joint edges), which leaves internal voids.
- Where the lining is multi-ring (e.g. working lining plus back-up insulation), stagger the joints of adjacent rings so they do not align radially.
- Before proceeding to the next course or ring, verify bond pattern, joint thickness and fullness, closure position and expansion-joint continuity; record any deviation from the drawings and obtain approval before covering the work.

> **NOTE**
> Bonding arrangements, expansion allowances, mortar types and anchoring details vary by application and are defined by the project drawings and specification. Refer doubtful points to the design engineer and the Linco Baxo Technical Department.

Cross-references

Section 1.4 Fundamentals of Mortars · Section 6.1 Joints · Section 9.1 Storage · Section 9.3 Mortars & Coating Installation.

9.3 – Mortars & Coating Mix Installation Guidelines

Purpose & scope

This section covers the site installation of mortars and coating mixes. It complements the fundamentals and storage guidance for mortars in Sections 1.4 and 1.6.

Mixing – dry mortars

- Use drinking water unless another bonding liquid is indicated, with clean tools and containers.
- Use the whole contents of a bag; if using part of a bag, thoroughly mix the whole bag first, then take the amount required.
- Regulate the working consistency by adding drinking water within ±10 % of the indicated amount.
- A paddle mixer is recommended; smaller amounts can be mixed with a putty knife or trowel.
- Mix hydraulically and highly reactively bonding mortars with water in small portions up to 20 kg, and use them within their pot life of about 30 minutes.
- Let ceramic-bonding mortars stand for about 1 hour after water-mixing before use.

Mixing – wet mortars

Wet mortars are supplied ready-mixed in buckets. If a wet mortar has segregated through ageing, it can usually be restored by remixing with a drill-mounted paddle.

Surface preparation

- The surfaces to be mortared shall be clean and free of dust and loose particles.
- Pre-wetting depends on the bond type: required for hydraulically bonding mortars, permitted for ceramic-bonding mortars, and prohibited for chemically bonding mortars (see Section 1.4).

Processing – mortar

- Work at an ambient temperature of at least 5 °C.
- Joint width shall not exceed 2 mm.
- Spread the mortar evenly over the surfaces to be joined, then place the brick.
- Discard set mortar residues and keep working tools clean.

Processing – coating mix

Coatings and protective layers are used where the untreated base material will not resist the expected service stress. The coating itself is gradually consumed – for example by thermal stress – but in most cases extends the service life of the material beneath.

- Work at an ambient temperature of at least 5 °C.
- Follow the tailored mixing instructions for the specific coating.
- Spread the coating mix evenly over the surface to be protected.
- Discard set residues and keep working tools clean.

First heat-up

- For hydraulically bonding mortars, wait about 24 hours before heat-up.
- The heating-up schedule does not depend on the mortar type, but on the nature of the whole lining (see Section 7.1).

Cross-references

Section 1.4 Fundamentals of Mortars · Section 1.6 Storage · Section 7.1 Principles of Drying & Heating Up · Section 9.2 Brickwork Installation · Section 9.5 Wet Mortars, Glues & Mastics.

9.4 – Ceramic Fibres & Associated Products

Purpose & scope

This section gives installation and handling guidance for ceramic fibre products – blanket, board, felt, modules, veneer and paper – and sets out the health-and-safety controls these materials require. Installation requires expert personnel experienced in the work procedures and the special tools occasionally needed.

Anchoring

- Position metallic anchoring elements with stud-welding equipment, strictly following the construction plans for anchor arrangement and module positioning. Faulty installation opens joints and causes leakages, leading to impermissible overheating of the furnace casing.
- Where holding studs have nubs, ensure the nubs all point in one direction.

Wallpapering / veneering

Wallpapering or veneering is the covering and gluing of ceramic fibre to the hot face of the lining, for new construction or furnaces already in operation. For in-service furnaces, first check that the brickwork can serve as a gluing surface.

- Adhesive is critical on low-strength substrates – for example insulating firebrick below ASTM group 28 and various insulating castables – which usually need supplementary anchoring in addition to gluing.
- The surface must be free of dust, coatings and loose particles; clean by applying liquids or brushing. Blast or chisel off glazed surfaces. Rectify greater unevenness before starting, and do not glue until the equalisation layer has completely dried and hardened.
- Adhesive type and adhesion depend on the substrate condition, the module/fibre type, the temperature of the components, the ambient temperature and the expected service temperature.
- Apply the adhesive at the correct consistency by trowel or spatula to the wall or module; align modules in rows, position precisely and press home by hand or with a board, offsetting or turning each module by 90°.

Layer design (blanket, mat, felt, board)

- Transfer the anchoring plan to the steel casing and fix anchors at right angles to it.
- Install mats, blankets, plates and felts with clips so they do not sag on roofs and sit tight on walls. Run wall fibre horizontally to resist sagging; vacuum-formed products may be horizontal or vertical.
- Fit ceramic caps or heat-resistant metal end-clips only after the final layer is positioned. To ease installation, cut the blanket/mat around the studs (to the ceramic-cap shaft length) or make an x-shaped cut; extend the holding studs with auxiliary studs before positioning the top rolls.
- After installation, check that every holding device and end-clip fits tightly – a correct stud weld is easy to verify visually, and correctly fitted clips and cap markings all lie in the same direction.
- Stagger the vertical joints between layers, and compress or overlap the blanket/mat at roll ends.

Fibre modules

- The common strip module is fixed mechanically or glued; to secure the adhesive embedment, attach temperature-suitable expanded metal to the shell with wire nails or spot welds. Once positioned, modules must not be pulled back out of the embedment.
- Flexible ceramic fibre modules are generally fixed directly to the shell, with anchors welded or screwed per the installation plan (integral to the module or by comb-anchor system). Position all layers pointing the same way, and install the modules in the compressed state according to the set-up and fixings.

- Inspect fibre-lined furnaces before commissioning, as part of preventive maintenance, to keep shrinkage joints closed. Inserting compensation strips of premium-grade aluminium-oxide fibre between module rows helps prevent shrinkage joints.

Coatings

Coatings can protect the surface of ceramic fibre construction. Follow the manufacturer's preparation and use instructions.

SAFETY – CERAMIC FIBRE

Refractory ceramic fibres (RCF / aluminosilicate wools) are classified in the EU under CLP as a Category 1B carcinogen, with an EU binding occupational exposure limit of 0.3 fibres per millilitre (8-hour TWA). After use, fibres can convert to crystalline silica, which carries its own exposure limits (see Section 1.7). Control airborne dust and fibre at source; provide local exhaust ventilation where practicable; wear the respiratory protection, eye protection, gloves and coveralls specified in the product Safety Data Sheet; and manage waste and used fibre in accordance with local regulations; avoid dry sweeping or compressed-air clean-down, using vacuum extraction or damping instead. Low-biopersistence AES (alkaline earth silicate) fibres are not classified as carcinogenic under CLP but shall still be handled under the same dust-control discipline, as they are also respirable fibrous materials, and in accordance with their specific Safety Data Sheets; where AES fibre is specified as a substitute for RCF, confirm with the Linco Baxo Technical Department that the maximum use temperature and mechanical behaviour are equivalent for the intended service condition. Always read the Safety Data Sheet before handling and follow the site occupational-hygiene plan.

Cross-references

Section 1.7 Monolithic Shelf Life & Expired Material · Section 2.1 Anchor Systems · Section 6.1 Joints · Appendix A Research & Technical Basis.

9.5 – Wet Mortars, Glues & Mastics

Purpose & scope

This section covers ready-mixed wet mortars, glues and coating mixes used for firm laying, mortaring, jointing and gluing of refractory and insulating bricks and precast shapes. It complements Sections 1.4, 1.6 and 9.3.

Types

Wet mortars are made from fine-grain aggregates and binders formulated to suit a specific brick or application, and are supplied ready to use in plastic buckets. There are generally two types:

- Mortars that set on heating and harden by a chemical or ceramic bond.
- Mortars that set on contact with air and harden by a chemical bond at room temperature.

Application

- Do not pre-water the bricks when wet mortars are used. The brick surfaces shall be free of dust.
- Use a clean spatula or trowel; take about one third of a trowel-load from the bucket and spread the mortar uniformly as joint material for about one minute.
- Keep joints to the minimum width, maximum 2 mm.
- Work at an ambient temperature of at least 5 °C. Note that temperatures above 45 °C accelerate the hardening of air-setting wet mortars, shortening working time.
- Discard set mortar residues, and clean working tools immediately after use, as removal after bonding is difficult.

Handling & storage

- These products are supplied ready for use in sealed containers; if a product has segregated through ageing, restore it by mixing with a drill-mounted paddle rather than by adding water, unless the data sheet allows it.
- Keep containers closed when not in use to prevent moisture loss and skinning, and observe the storage limits in Section 1.6 (typically about six months for wet mortars).

Associated products & coatings

- These instructions also apply to associated products – coatings, glues and patches – where applicable.
- Some superfine coatings, such as KWG 311, LICOGLUE and BAXOCOAT, can also be applied by brush or spray when used to protect a lining or steel casing.
- Allow the specified drying before heat-up; the schedule depends on the whole lining, not the product alone (see Section 7.1).

> **NOTE**
> Working life, drying behaviour and surface-preparation requirements differ between products. Always follow the relevant Linco Baxo Technical Data Sheet and Safety Data Sheet, and ask a Linco Baxo specialist for detailed instructions.

Cross-references

Section 1.4 Fundamentals of Mortars · Section 1.6 Storage · Section 7.1 Principles of Drying & Heating Up · Section 9.3 Mortars & Coating Installation.

A – Appendix A – Research & Technical Basis

Purpose

This handbook consolidates long-standing Linco Baxo site practice. Where general best-practice or health-and-safety content has been added or expanded in this revision, it draws on the recognised standards and references listed below. These are provided for orientation; the controlling documents for any project remain the relevant Linco Baxo Technical Data Sheets, the project specification and the applicable local regulations.

Installation, inspection & testing

- **API 936** – American Petroleum Institute, Refractory Installation Quality Control – Inspection and Testing of Monolithic Refractory Linings and Materials. Basis for the sampling, testing, qualification and inspection principles in Sections 7.2 and 8.1–8.3.
- API 936, Table 6 and §10.1.2 – indicative dry-out schedules for conventional castables by density class, and the recommendation that complex units (more than one burner, more than two flue-gas exit points, or eight or more thermocouples) have their dry-out plan reviewed by an engineer experienced in dry-out. Cited for general orientation in Section 7.1, subordinate to the applicable Linco Baxo TDS or dedicated dry-out schedule.
- API 936, §9.7.3 and §9.12 – guidance on using external immersion vibrators rather than nozzle-mounted vibration, and on treating extended interruptions as a construction (cold) joint. Basis for the reinforced consolidation and continuity guidance in Section 3.2.
- **ASTM / ISO / EN refractory test methods** – standard methods for properties such as bulk density, cold crushing strength and modulus of rupture, as cited in the applicable project specification and product data sheets.

Occupational health & exposure limits

- **Respirable crystalline silica** – EU Directive (EU) 2017/2398 amending the Carcinogens and Mutagens Directive 2004/37/EC sets a binding occupational exposure limit of 0.1 mg/m³ (8-hour TWA); several member states, including Italy, apply a stricter 0.05 mg/m³. Referenced in Sections 1.7 and 9.4.
- **Refractory ceramic fibres (RCF)** – classified under the EU CLP Regulation as a Category 1B carcinogen, with an EU binding occupational exposure limit of 0.3 fibres/ml (8-hour TWA). This guidance applies specifically to RCF products; biosoluble AES (alkaline earth silicate) fibres are subject to different classifications and should be handled in accordance with their specific Safety Data Sheets. Referenced in Section 9.4.
- **National occupational-hygiene guidance** – the applicable national authority's workplace exposure limits and codes of practice apply on site in addition to the figures above.

Drying, heat-up & material behaviour

- **Calcium-aluminate-cement castable dry-out** – the distinction between free (physical) water released around 100–150 °C and chemically combined water released at higher temperatures, and the associated risk of steam pressure and explosive spalling, follows established refractory dry-out practice and underpins Section 7.1.
- **Alkali hydrolysis / carbonation of alumina-cement castables** – the air-drying and ventilation guidance in Section 4.2 reflects published work on carbonation of alumina-cement-bonded castables (S. Sakamoto and E. Kudo, Journal of the Technical Association of Refractories, Japan, 2000).

Additional references

- ASTM C401 – Classification of Alumina and Alumina-Silicate Castable Refractories.
- ASTM C860 – Determining the Consistency of Refractory Castable Using the Ball-in-Hand Test (basis for the workability check in Sections 1.1 / 3.1).
- ASTM C862 – Preparing Refractory Concrete Specimens by Casting (basis for specimen preparation in Sections 8.2 / 8.3).
- ASTM C133 – Cold Crushing Strength and Modulus of Rupture of Refractories.
- ASTM C134 – Size, Dimensional Measurements, and Bulk Density of Refractory Brick and Insulating Firebrick.
- ASTM C830 – Apparent Porosity, Liquid Absorption, Apparent Specific Gravity, and Bulk Density of Refractory Shapes by Vacuum Pressure.
- ASTM C704 – Abrasion Resistance of Refractory Materials at Room Temperature.
- ASTM C181 – Workability Index of Fireclay and High-Alumina Refractory Plastics.
- ASTM C113 – Reheat Change of Refractory Brick.
- ASTM C16 – Load Testing Refractory Shapes at High Temperatures.
- EN ISO 1927 (Parts 1–8) – Monolithic (unshaped) refractory products: classification, sampling, characterisation, consistency, specimen preparation, physical properties and testing of pre-formed shapes.
- ISO 8895 – Shaped Insulating Refractory Products – Determination of Cold Crushing Strength.
- ISO 10059 – Dense Shaped Refractory Products – Determination of Cold Compressive Strength.
- ISO 12677 – Chemical Analysis of Refractory Products by X-ray Fluorescence (XRF).

> **NOTE**
> Standards are revised periodically. Confirm the current edition of any standard before relying on it for a project, and consult the Linco Baxo Technical Department where a specific value, limit or procedure is required. The additional references above are listed for general orientation and are not necessarily all cited elsewhere in this handbook; confirm relevance and current status before use in a project.