

CONTROLLED DRYING OF REFRACTORIES:

A CRITICAL STEP TO PREVENT FAILURES AND IMPROVE THE AVAILABILITY OF THERMAL EQUIPMENT TIPOS TÉRMICOS

(Courtesy of Hotwork Internacional South America SA, Author: Martín Donadío)

SUMMARY

Drying the refractory lining is a critical stage in the commissioning of furnaces, ladles, casting channels, and other thermal equipment. Although often considered a preliminary step, it determines safety, lining service life, and production availability.

This paper explains why controlled drying is essential and compares available methodologies based on the equipment, refractory design, thermal curve, and operational risks.

1. INTRODUCTION

Monolithic refractories consist of aggregates, fines, binders, additives, and installation water. Following installation, they require curing and subsequent controlled drying—stages that determine strength development and moisture removal.

Final quality also depends on the initial heat-up. A prescribed heating curve loses effectiveness when the actual temperature deviates from the specified heating rates and hold periods, particularly due to localized heating or instability at low firing rates.

Comparing process burners with convective systems involves considering temperature control, moisture removal, thermal uniformity, and operating conditions.

2.- CURING, DRYING, AND WATER STATE

2.1 Curing and development of resistance

Curing precedes drying in hydraulically bonded materials. During this stage, hydrated phases form and the strength required to withstand the initial heating develops; insufficient curing results in a brittle matrix.

Calcium aluminate binders, hydratable alumina, phosphates, and other systems undergo different transformations. Therefore, the schedule must follow the manufacturer's recommendations.

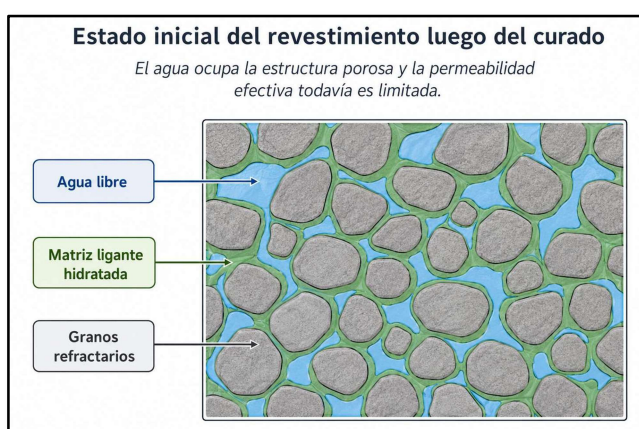


Figure 1. Initial state of the lining after curing.

Conceptual diagram of the porous system, identifying free water, the hydrated binder matrix, and refractory grains .

2.2 Free water and water associated with hydrated phases.

After curing, water remains within the porous structure. As drying begins, free water evaporates; the vapor migrates toward the hot face, while the liquid may move toward cooler zones. At higher temperatures, water associated with hydrated phases is released. Castables can contain a significant fraction of mixing water. In massive linings, this moisture must migrate, evaporate, and leave the system without compromising the material..

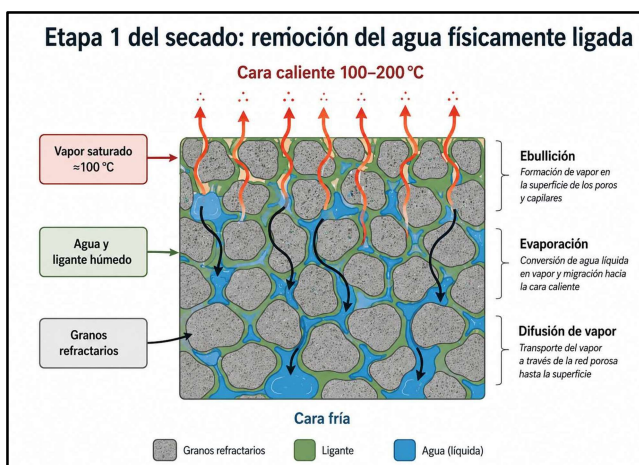


Figure 2. Initial removal of physically bound water. Vapor migration toward the hot face and displacement of liquid water toward relatively cooler zones.

3. WHICH DRYING METHOD IS SUITABLE FOR REMOVING WATER AND MOISTURE ?

The appropriate method must combine controlled temperature, gas circulation, and effective exhaust paths. This limits the thermal gradient and prevents vapor generation from exceeding the material's venting capacity.

The selection must take into account damage mechanisms, heat distribution, and the burners' ability to operate stably at the low end of the curve.

3.1 Heat transfer and control transferencia de calor y control

A localized flame can overheat one area while others remain cool. A well-designed convective distribution reduces gradients and improves uniformity; therefore, the heat source and internal circulation must be evaluated.



Figure 3. Heat transfer mechanisms during drying. Conduction, convection, and radiation act simultaneously, although convective circulation is essential for distributing heat and removing moisture.

3.2 Damage mechanisms during drying

3.2.1 Pore pressure, permeability, and drying front

During heating, heat transfer, water migration, evaporation, vapor flow, and binder transformations occur simultaneously. Internal pressure rises when vapor is generated faster than it can escape through the porous structure.

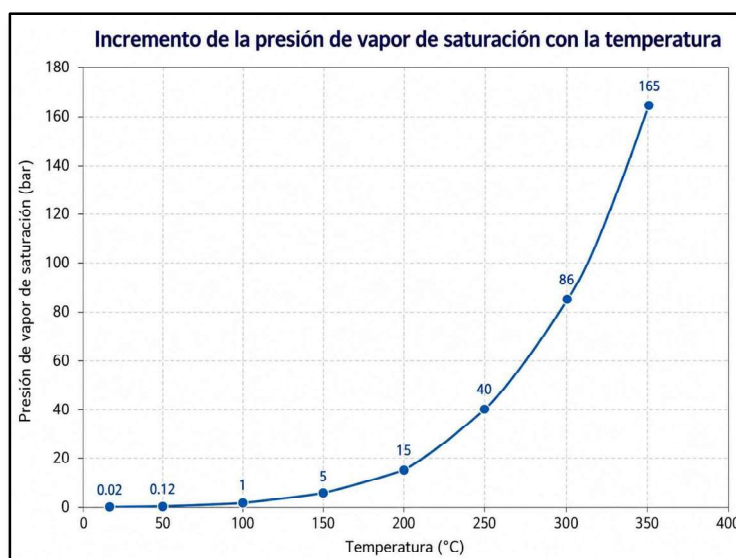


*Figure 4.
Increase in
saturation vapor
pressure with
temperature.*

Saturation vapor pressure increases non-linearly with temperature. Figure 4 does not represent the actual pressure within the refractory, but it illustrates the potential of the phenomenon when the vapor is confined.

3.2.2 Consequences for the lining

If pore pressure and thermal stresses exceed the material's strength, microcracking, delamination, spalling, or explosive spalling may occur. Even without immediate failure, microcracking accelerates erosion, infiltration, and wear.

The risk increases with greater thickness, low permeability, excess water, poor curing, insufficient ventilation, one-sided heating, and temperature differences between the surface and the interior.

3.3 Process burners

Process burners are designed to meet production requirements. They can be used for drying applications provided they offer modulation, an appropriate flame, good distribution, and representative instrumentation; these conditions must be verified.

The main limitations arise when airflow and power output are reduced simultaneously, when the burner operates near its minimum stability limit, or when the flame impinges directly on the lining. Under these conditions, hot spots and combustion oscillations may occur, and measurements may fail to accurately reflect the system's thermal behavior.

3.4 Convective system

The convective system utilizes forced convection: a controlled, high-flow stream of hot gas. Its main advantage is maintaining intense circulation even at low temperatures, when control is most sensitive.

The gas velocity enhances heat exchange, reduces stagnant zones, and directs moisture toward the outlets. In complex geometries, multiple injection points and thermocouples are used to balance the distribution.

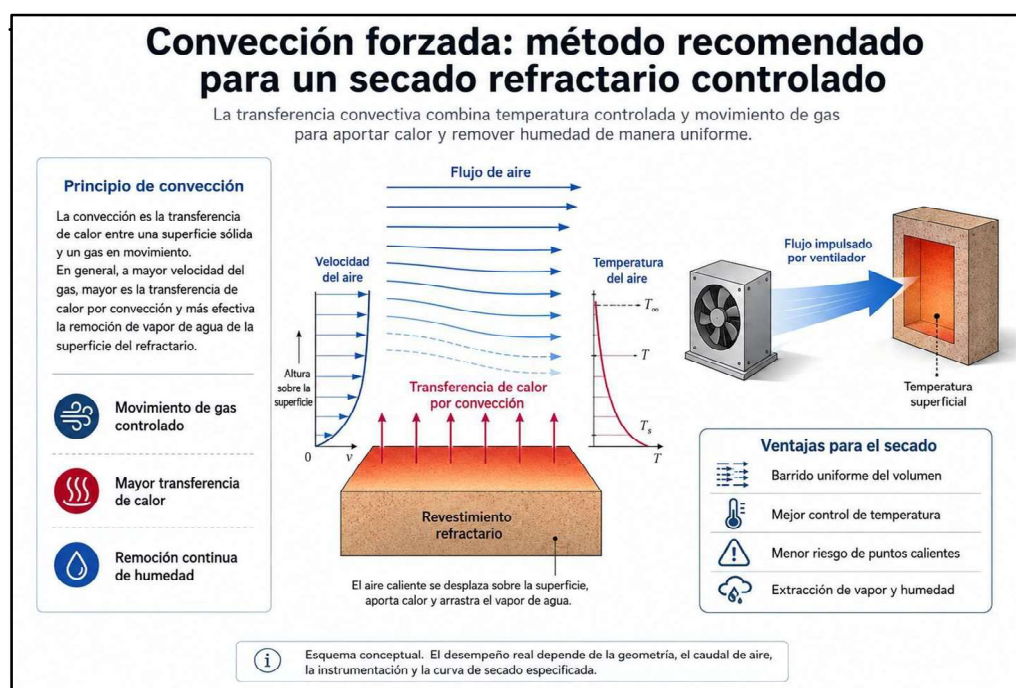


Figure 5. Convective system applied to refractory drying. Forced convection and gas movement over the surface enhance heat transfer and facilitate the continuous removal of moisture and vapor.

After moisture removal, gradual heating promotes binder transformations and homogeneous sintering, consolidating the matrix without creating excessive differences between the surface and the interior.

Nor does the convection system guarantee uniformity on its own; the placement of inlets and exhausts, airtightness, flow rate balance, and thermocouple positioning remain critical factors.

4. CASE STUDY: EXTENDING LINING SERVICE LIFE IN A GRATE-KILN ROTARY KILN

In a major Swedish company engaged in the production of iron ore pellets, the thermal hardening process was carried out using rotary kilns integrated into a Grate-Kiln type line,

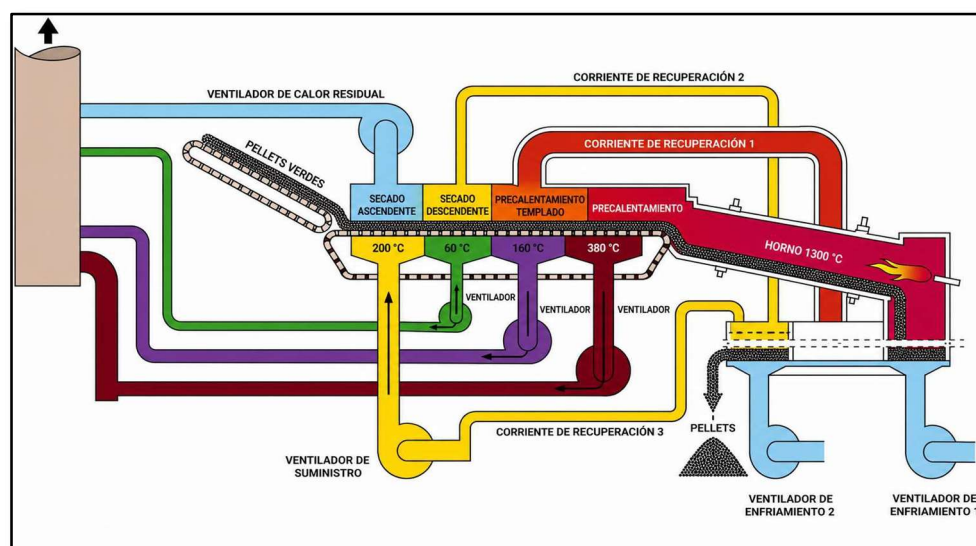


Figure 6. General schematic of the Grate-Kiln process. Green pellets pass through the drying, preheating, rotary kiln induration, and cooling stages, with hot gas recovery and recirculation.

A service life of approximately two years was expected for the rotary kiln's refractory lining. In practice, however, the client was forced to halt operations after about six months to carry out repairs on the refractory bricks.

Faced with this situation, various hypotheses were evaluated, and corrective actions were implemented. Initially, the refractory material supplier was replaced, yet the problem persisted. Subsequently, the supplier responsible for the lining installation was also changed, but no significant improvements were achieved. Consequently, it became evident that neither the quality of the material nor the quality of the installation could account for the premature failure on its own.

The constant factor throughout was the initial heating method. The drying and heating of the lining were performed using the kiln's own process burner—a lance fueled by liquid fuel. To follow the heating curve, the system operated using an on/off control logic, progressively increasing the temperature.

However, the system's actual behavior differed substantially from the theoretical curve. During the evaluation, it was found that temperatures approaching 900°C were rapidly reached in the first section of the furnace, particularly in the upper area. In other words, while the system's average temperature still indicated an initial heating stage, there were already zones subjected to severe overheating.

This localized heating caused uncontrolled, non-uniform expansion of the refractory bricks, generating excessive stress, loss of fit, displacement, and premature failure. Consequently, the observed damage was not due to an intrinsic defect in the refractory material itself, but rather to the way heat was applied during the initial heating phase.

Based on this diagnosis, a controlled drying and heating service using a convective system was scheduled, at an approximate cost of USD 150,000.

The proposal involved replacing the direct, localized heat input from the process burner with a controlled circulation of hot gases capable of distributing heat more evenly, limiting thermal gradients, and accommodating the expansion of the lining in a gradual, controlled manner.

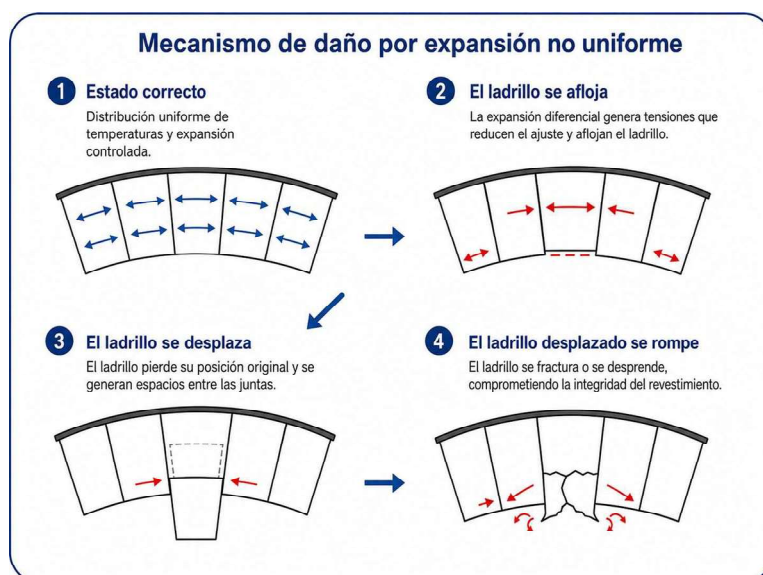


Figure 7.

Mechanism of damage due to non-uniform expansion. Differential expansion reduces the fit of the bricks, promotes their displacement, and can result in fracture or detachment.

The economic impact of the service was clearly favorable: considering the production value involved and the cost associated with a premature shutdown, the return on investment (ROI) was equivalent to just 15 minutes of operation.

Following the implementation of the convective system, the refractory lining achieved its expected two-year service life, eliminating the premature repairs that previously had to be performed at the six-month mark.

5.- CONCLUSIONS

Controlled drying preserves the integrity of the lining. Its effectiveness depends on how heat is supplied and distributed and how water and steam are removed, not merely on the final temperature.

1. The primary risk arises when steam is generated faster than it can migrate and escape; therefore, heating ramps, hold periods, and manufacturer recommendations must be strictly followed.
2. Thermal uniformity is just as important as temperature; hot spots and gradients can lead to micro-cracking, delamination, or spalling.
3. Process burners are suitable only if they demonstrate modulation capabilities, low-temperature stability, sufficient circulation, and representative instrumentation.
4. The convective system combines high gas movement with controlled temperature, enhancing heat exchange and facilitating continuous moisture removal.
5. Proper design minimizes hot spots, improves adherence to the heating curve, and ensures consistent response across measurement points.
6. Application engineering—regarding injection points, outlets, flow rates, seals, and thermocouple placement—is critical.
7. By minimizing early-stage damage, the drying process enhances safety, reliability, and service life; it also promotes proper binder transformation and uniform sintering.

In summary, the appropriate method must simultaneously control temperature, thermal distribution, and gas circulation. When process burners cannot guarantee these conditions, a convective system offers the most robust alternative for achieving complete, uniform, and controlled drying.

REFERENCES

1. *Internal technical material used as a comparative reference for refractory drying and heating, Hotwok International – Egnach, Switzerland, 2026.*
2. *HarbisonWalker International. Curing and Dryout of Refractories. Technical guidance, 2020.*
3. *HarbisonWalker International. Curing and Dryout General Guidelines – Field Use – One-Sided Dryout. Technical schedule and safety notes, rev. 2013.*