REFRACTORY LINING IN PELLETIZING FURNACES MAINTENANCE PHILOSOPHY[1]

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Abstract

Presented here are the different philosophies concerning refractory linings for pelletizing furnaces, including materials, routines and maintenance cycles. This work discusses a recent case history of the profile of lining in actual use, chronic problems and their associated causes, and blocking actions taken. Emphasis is placed on principal developments and improvements, gains, the trends in linings and the necessity of future improvements.

Key words: Pelletizing; Refractory / Refractory Lining

REFRATÁRIOS EM FORNOS DE PELOTIZACAO FILOSOFIA DE MANUTENÇÃO

Resumo

Apresentar as diversas filosofias de revestimento refratários de fornos de pelotizacao, materiais, rotina e ciclos de manutenção. O trabalho aborda um histórico recente do perfil de revestimento em uso, problemas crônicos e causas associadas, ações de bloqueio adotadas, enfatizando os principais desenvolvimentos e melhorias realizadas, ganhos obtidos, tendências de revestimento e necessidades de melhorias futuras.

Palavras-chave: Pelotizacao; Refratários/ Revestimento Refratário.

1 *Technical contribution to the 3rd International Meeting on Ironmaking, September 22 – 26, 2008, São Luís City – Maranhão State – Brazil*

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1 INTRODUCTION

This work evaluates the present situation of pelletizing furnace linings, focusing on the principle needs, typical problems, description of refractory linings, projects and materials used, recent developments and future trends.

1.1 Principal Characteristics of Pelletizing Furnaces

- Gas and air flow, with return and recuperation of heat.

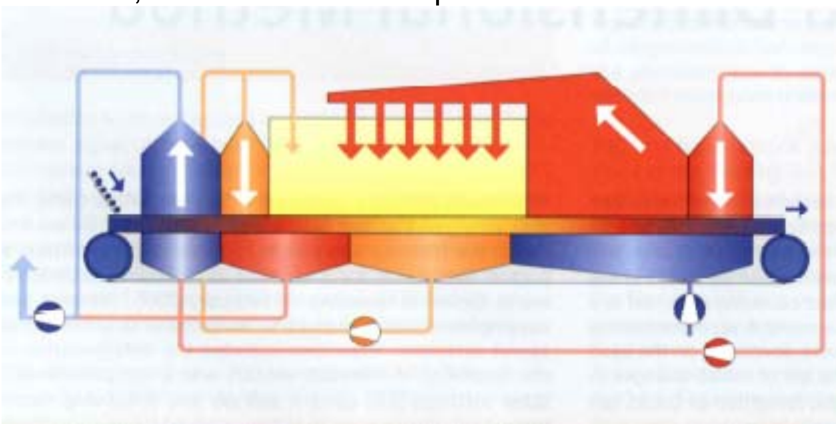


Figure 1 - Gas flow, Traveling Grate Furnace

- Pellet processing, over traveling grate, under temperature gradient.
- Operation temperature in the range of 1350 °C.

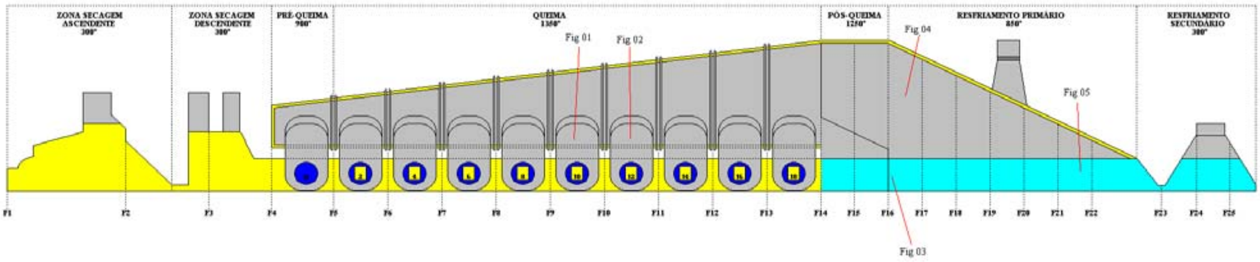


Figure 2 - Cross section, longitudinal - Pelletizing Furnace

2 DISCUSSION AND ANALYSIS

The pelletizing furnace linings are subject to many types of demands:

2.1 Thermal shock

The successive heating and cooling of the refractory lining causes it to undergo a continuous process of expansion and contraction, creating traction and compression tensions that result in cracks, splintering and the consequent reduction of the durability of the lining.

2.2 Abrasion

Wear of the refractory lining due to contact with iron ore fines in suspension that circulate at high velocities in the interior of the furnace.

2.3 Corrosion

Chemical attack due to the interaction of the ore fines with the binders and fuel (ash with the presence of vanadium), creating low fusion-point eutectics on the refractory lining.

Figure 3 - Formation of "scab" in combustion chambers

2.4 High Temperatures

Direct contact of the flame on the refractory lining elevating it to theoretical temperatures in the range of 1800°C, causing the liquefaction phase and thus thinning of the thickness of the lining.

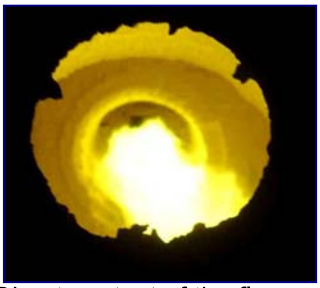


Figure 4 - Direct contact of the flame on the lining

2.5 Thermal-mechanical Tensions

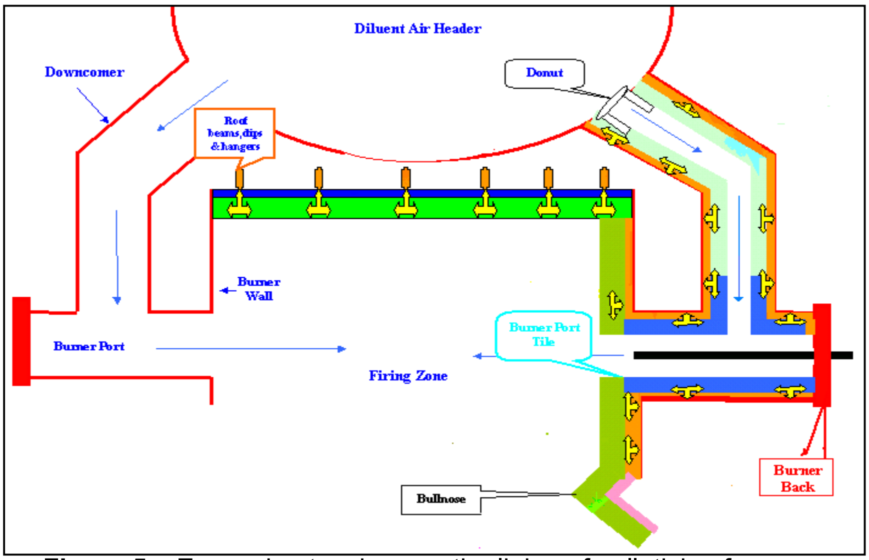


Figure 5 – Expansion tensions on the lining of pelletizing furnaces

2.5.1 Structural spalling

Increased surface density of the refractory material due to penetration of slag and ore fines, altering the microstructure and creating regions with differing densities and expansion coefficients.

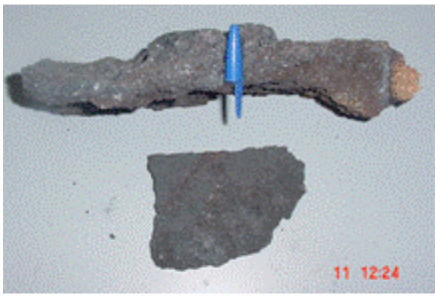


Figure 6 – Splintering of the refractory lining due to structural spalling

2.5.2 Mechanical spalling

Compression tension created by errors in assembly, inadequate projects, inadequate joints and shapes, creating a dislocation of the combustion chamber lining and causing it to fall. The effects are aggravated by the high temperatures generated by the direct contact of the flame.

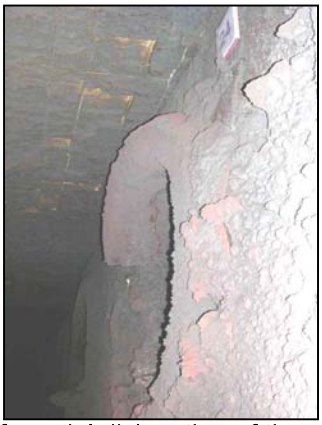


Figure 7 - Differential dislocation of the chamber lining

Figure 8 - Falling off of the chamber's refractory lining

Dislocation is proportionate to temperature:

- The greater the expansion, the greater the dislocation of the parts;
- Differential dislocation of the lining parts, that is, at the region of impact of the flames; the dislocation is greater than in other regions.

Dislocation can cause and/or increase peripheral cracks (longitudinal force). The ring assembly can also dislocate towards the hot face. And due to the differential heating caused by the impact of the flames, the ring assembly contracts even further, causing a greater differential dislocation over a greater extension where the temperature was higher. It should be noted that there also occurs expansion at the perimeter of cylinder of the chamber/burner port.

2.5.3 Thermal spalling

Operational temperature variations, with successive heating and cooling (expansions x contractions, penetration of fines, cracking, splintering, dislocations).

$$\text{Tension } (\sigma) = E \times \alpha \times \Delta T$$

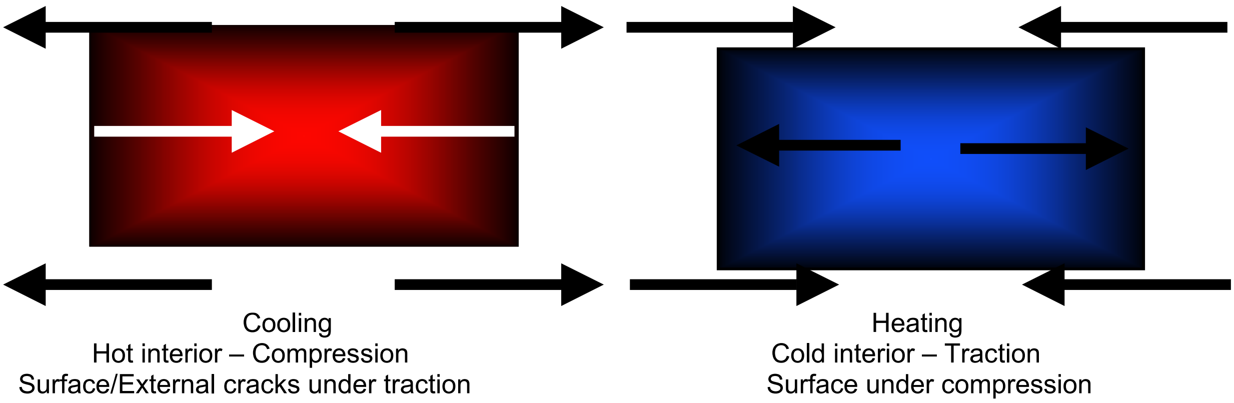


Figure 9 – Effect on refractories of abrupt heating and cooling

The cooling and subsequent contraction of the lining permits the penetration of fines in joints and cracks, limiting the complete expansion of the lining at the next heating. This causes fracturing of the refractory lining, bringing about an ongoing process of deterioration.

2.6 Frequency of Stops for Maintenance

The periodicity of maintenance cycles of pelletizing furnaces refractories is specific to each plant, taking into account regional characteristics, integration of equipment, seasonal characteristics, expenditure involved, budget aspects, performance of peripheral equipment; that is, the periodicity depends on the correct identification of possible performance bottlenecks and targets.
Maintenance cycles here evaluated take into account those that require cooling of the furnace, that is, maintenance where the equipment is cold. In this situation, two types of cycles deserve emphasis:

2.6.1 Short-to-medium maintenance cycles

Short cycles are classified by annual stops, or stops of up to every three years. The main reasons for short cycles are related to low maintenance costs, smaller intervention periods and smaller repair areas of the furnace. They present the disadvantage of the lack of performance foreseeability of the refractory lining due to the difficulty in defining exactly in which areas the lining should be repaired or not. It also generates a mixed history of materials, projects, suppliers and performance of different areas of the refractory lining.

2.6.2 Long maintenance cycles

Long cycles are classified as stops every five or more years when needed. This permits better planning for changing the lining as well as bigger maintenance of critical areas of the furnaces, where the lining should be totally replaced.

2.7 Hot Maintenance

Gunning to restore the linning and injection of insulating material to restore areas of damaged insulation and to sealing of cracks in the lining are the principals procedures. Another points are the cleaning of fines deposited in the external shell (to favor the exchange of heat with the environment and the maintenance of the thermal profile projected) and constant cleaning of slag and fines accumulated in the interior of the combustion chambers. All these contribute to improving the performance of the refractory lining.

2.8 Refractory Lining Profile

Basically two lining concepts have been adopted as lining standards for combustion chambers and/or walls. These are low cement castable (by casting, shotcrete or pumpable (monolithic linings)) and precast shapes. Some variations use ramming plastic material. The principle characteristics of each type are as follows:

Table 1 - Lining Characteristics: Precast Shapes x Monolithic

Precast Shapes Lining	Monolithic Lining
1. Small fired shapes depend upon each other to maintain stability of the whole structure. 2. Numerous joints containing sharp corners subject to structural spalling. 3. Penetration of fines in joints from successive heating and cooling cycles. 4. Heat loss between joints. 5. An excessive amount of special sized shapes are required. 6. Difficulty in adjusting shapes and dimensioning joints to adapt the lining to the deformations of the shell.	1. One solid mass of concrete, containing an internal ceramic anchorage system for additional support from structural steel work of the furnace. 2. Reduced number of joints, reducing the risk of thermal spalling. 3. Faster installation. 4. Long drying out and heating times. 5. Better control of thickness and joints, and of adaptation of the lining to deformations of the shell.

2.8.1 Monolithic lining

A great advantage is gained by the forming of the final shape only at the end of the application of the material: the possibility of separating the walls from the chambers, thus being able to create a “lip lock”, as shown below. The material used in this type of application is free flowing concrete with a low proportion of cement.

Figure 10 – Furnace with monolithic lining

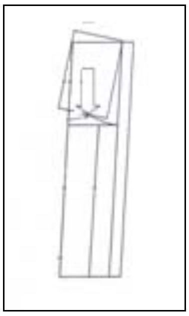


Figure 11 - Lip *Lock* Effect

2.8.2 Precast lining

Aspects related to joint dimensions, inadequate shape sizes and difficulty in assembly are principle factors contributing to lack of success with this type of lining.

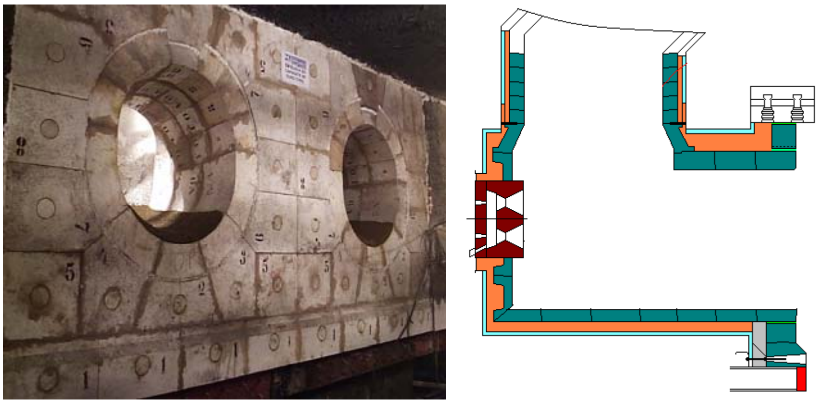
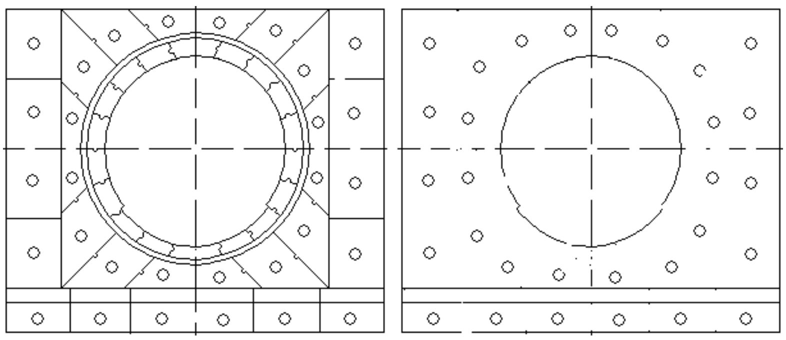


Figure 12 – Chamber and wall lining with precast shapes

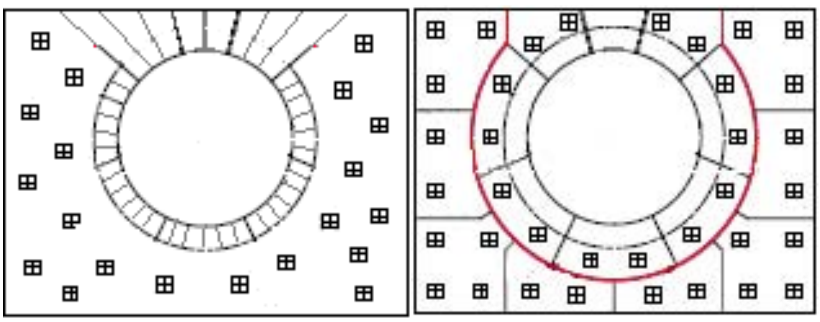
This type of lining demands a perfect dimensioning of expansion joints. The lack of enough joints will cause the dislocation of the shapes towards the interior of the furnace, and the excess will cause the cylinder, composed of the shapes, to be poorly adjusted to the chamber/wall assembly.

The project of the refractory shapes for the chambers must have the premise of arranging the shapes with smaller volume and the most adequate geometry, be it in the traditional formats or a combination of wedges, for example, with the added advantage of alleviating thermo-mechanical problems.



(a) (b)

Figure 13 – Chamber and wall in precast shapes (a) x Chamber in especial shapes and wall in monolithic linning (b)



(c) (d)

Figure 14 – Chamber in especial shapes and wall in ramming (Plastic material) (c) x Chamber in precast shapes and wall in castable/casting (d)

In the above configurations (b) and (d) feature the front ring separate from the wall, acting as a limiter to chamber dislocation.

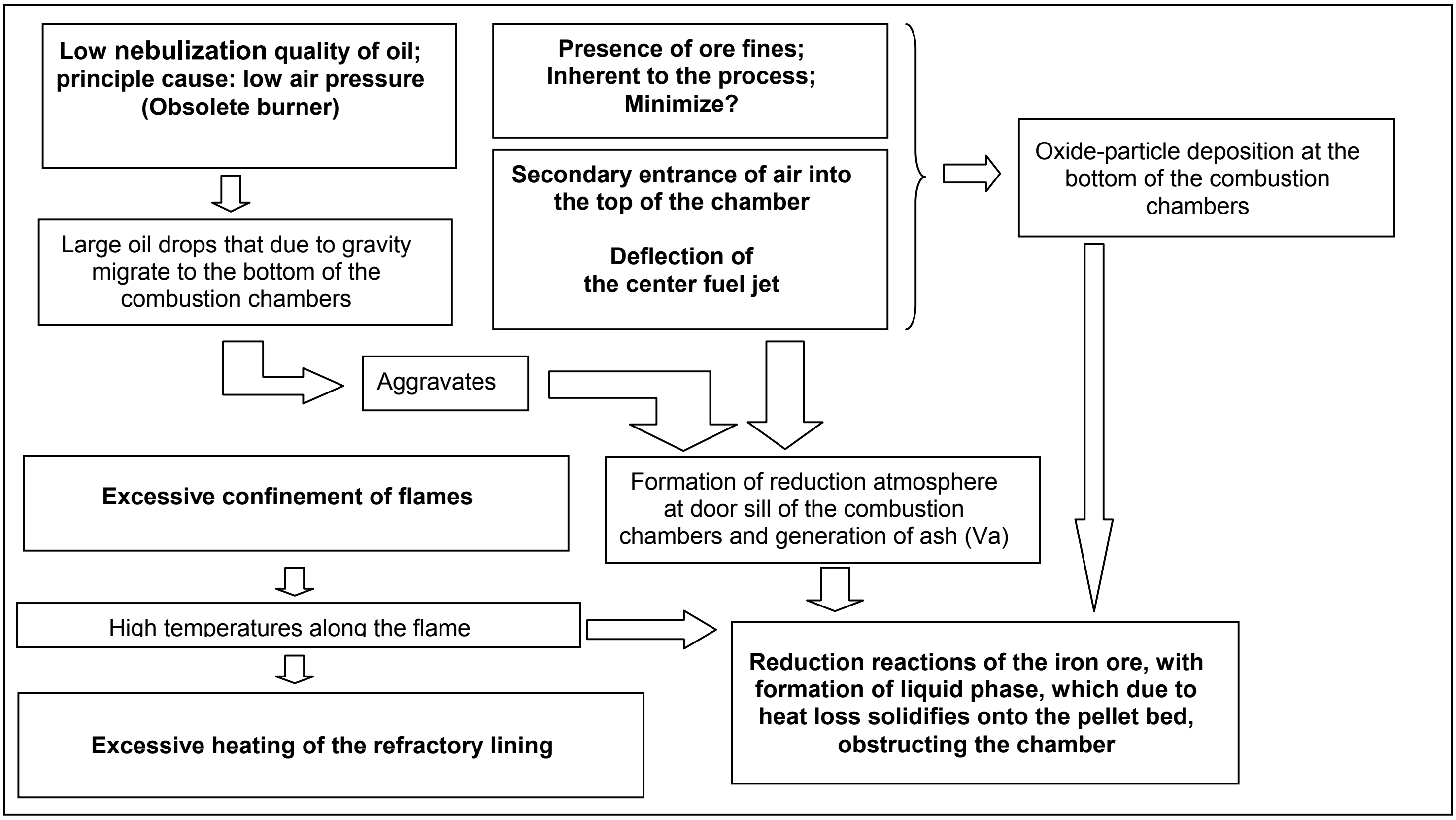
2.9 Refractory Materials

The refractory materials used in furnaces are usually of very high refractoriness with the objective of bettering their stability, in view of the extremely high temperatures they are subject to. This, though, is also a negative characteristic as it increases the material's susceptibility to fractures and generation of cracks.
Chromium alumina or chromium magnesium refractories fired at high temperatures, as well as high alumina content refractories with added magnesia-alumina spinel in the areas of the chamber where there is direct contact with the flames: greater refractoriness and greater chemical compatibility with the powders are actions that can be taken to adjust the refractory to the process requirements. Some products may be cast, pumped, or shotcrete into place making them very versatile to install.

2.10 Operational Vonditions

The main operational condition that affects the furnace's performance is associated with the type of fuel and the combustion system/burner used.

Figure 15 – Effect of fuel oil on the refractory



Other factors associated to operational conditions:

- Reduction of gas circulation when stopping for maintenance
- Complete mapping of pressure and temperature inside the furnace
- Temperature monitoring to avoid overheating
- Better control of pellet size to optimize use of ventilators

2.11 Inspection Routine

Establishment of a inspection routine contributes to the performance of the refractory in a predictive manner:

- Verify conditions of the flame;
- Identify small local areas of wear;
- Minimize the necessity of large time-consuming, “hot” interventions, thus reducing consumption and cost.

Establish inspection routine:

- Daily visual inspection – Lining and flame
- Monthly thermographic inspection to evaluate: heat increase trends on the cool face of the lining; localized problems of wear on the lining and unfavorable operational conditions (high operational temperature).
- Verification of the lining temperature for certain conditions calling for adjustment of the flame.

3 DEVELOPMENTS

3.1 Dry Boxes

The lining of the pelletizing furnaces have refrigerated metal boxes in the longitudinal direction, that in some pelletizing plants have been substituted for special refractory shapes (Figura 17). The principle functions of the refrigerated boxes are:

- To limit longitudinal expansion of the wall base of the furnace.
- To cool the support console of the side wall.
- To minimize the temperature at the edge of the grate car.

3.1.1 Advantages of dry boxes

- Reduction of water consumption – environmental aspect.
- In some configurations, the possibility of “hot” maintenance.
- Energy consumption reduction due to the elimination of cooling elements.
- Minimization of pellet quality problems due to water falling on the bed, when holes in the water tanks occur (Figura 16).

Figure 16 - Leak from a longitudinal water tank

3.1.2 Disadvantages of dry boxes

- The necessity of adjusting the wall’s metal structure, due to higher temperatures at the base of the wall; or rather, of the wall’s support console, to minimize the risk of deformation, falling off of the refractories and danger to the furnace’s metal structure.

- The necessity of a perfect dimensioning of joints in the longitudinal direction to avoid expansion tensions that cause shapes to fall and even may deform the metal structure.

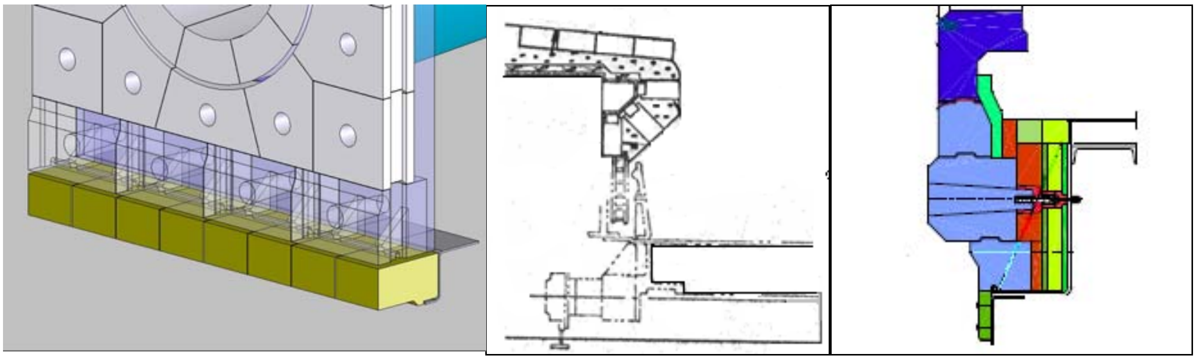


Figure 17 - Configurations of dry boxes

3.2 Partition Walls

These walls have the purpose of dividing the furnace into distinct areas, enabling each area to be treated differently. Each area can then be treated as if it were an individual furnace, essential to aspects of energy consumption, quality, productivity and process control.

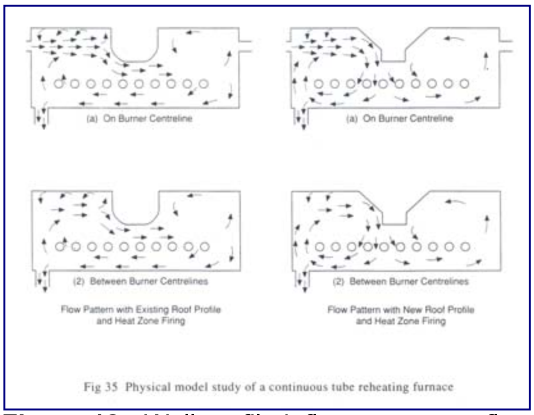


Figure 18 - Wall profile influence on gas flow

Some alternatives being developed and in use are self supporting walls, principally in the transition “pre-firing zone x firing zone”, “firing zone x post-firing zone”, and for mechanically anchored walls in the other transition areas of the furnace (Figure 19).

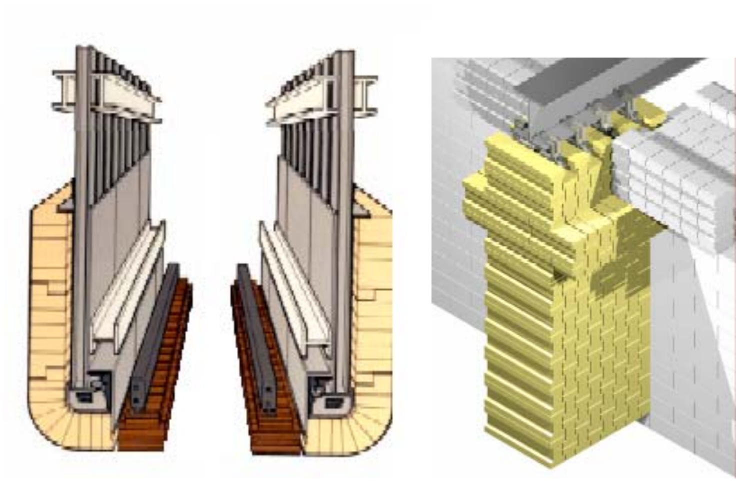


Figure 19 - Baffle walls

4 RESULTS

Refractory Lining Campaigns/Maintenance Cycles
Maintenance Cycles of 01,02,03 e 04 years
Benchmark - 10 Years

5 TRENDS AND NEEDS

The ever increasing demand for iron ore and pellets leads to ever increasing levels of productivity and the availability of larger and larger equipment, with the necessity of constant improvement for the following items:

5.1 Castables without Cement

Reduction of drying time and heating of furnaces.

5.2 Modular Assemblies

Replacement, either “hot” or cold, of specific areas of the furnace with modular assemblies.

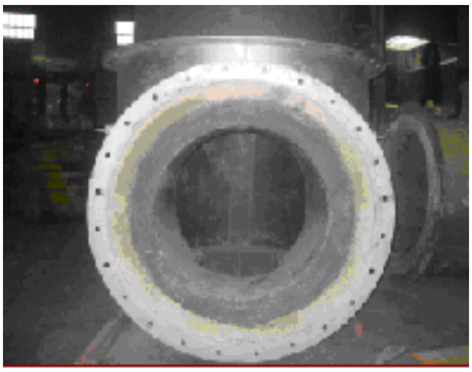


Figure 20 - Modular combustion chamber assembly

5.3 Shotcrete

Further development of the technique and applicable range of materials (chemical compositions) to reduce application time. Mechanization of application.

5.4 Reduction of Heat Loss

Large scale use of high capacity insulation even for small thicknesses, without compromising the equipment safety. Reduction of fuel consumption.

5.5 Improvements to the combustion systems and further development of burners.

5.6 Video monitoring of the flame, with temperature measurement.

6 CONCLUSION

The constant integration between users and manufacturers of refractory material makes possible the refinement of control variables of furnace use and better identification of the causes of problems associated with the performance of refractory material. Improvements to refractory lining projects and development of new products and application techniques will result in reduction of costs and specific consumption, as well as increasing the equipment availability.