HEAT TREATMENT FURNACES – REFRACTORY OPTIMIZATION – CARBON FOOTPRINT REDUCTION

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1. Introduction:

What is heat treatment?

Heat treatment is a controlled process that modifies the internal structure of metals through heating and cooling cycles. Unlike forging, its primary objective is not to alter the geometric shape of the part, but rather to optimize mechanical properties such as hardness, toughness, and wear resistance.

Main types of heat treatments

- **Hardening (Quenching)**: Rapid heating and cooling to maximize hardness.
- **Tempering**: Subsequent reheating to reduce the metal's brittleness.
- **Annealing**: Heating and slow cooling to relieve internal stresses.
- **Normalizing**: Heating to refine and homogenize the steel's grain structure.

Key process benefits
- **Extreme durability**: Extends the service life of critical mechanical components.
- **Stress relief**: Prevents deformation and cracking during subsequent machining.
- **Controlled malleability**: Temporarily softens the metal to facilitate machining.

Classification of heat treatment furnaces

- A. •**By operating system**:
    - •**Batch furnaces**: Process trays or fixed groups of parts. They offer tremendous metallurgical flexibility.
    - •**Continuous furnaces**: Parts move along belts or rollers through different thermal zones. Ideal for mass production.
- B. **By working atmosphere**:
    - •**Controlled-atmosphere / Vacuum furnaces**: Use protective gases (nitrogen or argon) to prevent metal decarburization and oxidation.
    - •**Salt bath furnaces**: Submerge parts in molten salts to achieve uniform, rapid heat transfer.

- C. **By heating technology**:
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    - **Electric furnaces (Resistive):** Highly precise and clean, utilizing PID controllers.
    - **Combustion furnaces (Gas):** Equipped with modulating burners for high thermal capacities.
    - **Forced-convection furnaces**: Use internal fans to recirculate air. Essential for light alloys such as aluminum.

3. Energy Management

Energy efficiency in this equipment presents a critical challenge: unlike in forging, parts must be kept hot for hours at stabilized thermal plateaus. Optimizing operating costs relies on three pillars (p. 2):

- ✓ **Highly specialized layered insulation**: In controlled-atmosphere or vacuum furnaces, heat leakage destabilizes the process. Using hybrid systems (low-porosity insulating bricks and microporous boards) minimizes conductive heat loss to the outer shell (p. 3).
- ✓ **Minimizing thermal bridges and sealing joints**: Furnace doors and hatches are major sources of heat loss (p. 3). Using pre-compressed ceramic fiber modules and elastic joint seals prevents leakage caused by convection and radiation.
- ✓ **Low thermal inertia in batch furnaces**: Reducing lining mass through the use of state-of-the-art ceramic fibers prevents the furnace from absorbing heat intended for the metal, resulting in much faster heating and cooling cycles (p. 3).

1. Cálculo de Ahorro de Energía (Caso Práctico)

We compare a traditional batch furnace made of dense brick with one retrofitted with an ultra-lightweight ceramic fiber lining and microporous blocks.

Energy Savings Calculation (Case Study)

- **Process**: Stress relief (annealing) at 650°C.
- **Daily production**: 2,000 kg of steel parts per day.
- **Fuel:** Natural gas (9.3 kWh/m^3).
- **Operating days**: 250 days per year (p. 4).

Step 1: Theoretical energy required by the metal

- Formula: $Q = m \times Cp \times \Delta T$ (p. 4)

- Net energy in the metal = 2,000 kg × 0.000186 kWh/kg°C × (650°C - 20°C) = approx. 234.3 kWh/day

Step 2: Comparison of consumption based on efficiency

- **Furnace 1: Traditional (Overall efficiency of 20%)**
  - Energy consumed: 234.3 kWh / 0.20 = 1,171.5 kWh/day (p. 4)
  - Daily gas consumption: 1,171.5 kWh / 9.3 kWh/m^3 = 126 m^3/day

- **Furnace 2: Modern Optimized (Overall efficiency of 45%)**
  - Energy consumed: 234.3 kWh / 0.45 = 520.6 kWh/day
  - Daily gas consumption: 520.6 kWh / 9.3 kWh/m^3 = 56 m^3/day

Step 3: Annual savings balance

- **Annual gas savings**: (126 m^3 - 56 m^3) × 250 days = 17,500 m^3/year
- **Economic savings**: At a cost of USD 0.40 per m^3, this represents **USD 7,000 in annual savings**
- **Carbon footprint reduction:** 17,500 m^3 × 1.9 kg CO_2 = **33,250 kg of CO_2** saved per year

2. Redesign of the Cladding and Material:

The success of a heat treatment process depends on strict temperature control and a clean internal atmosphere. A degraded or poorly designed lining contaminates the parts with loose particles and causes a sharp increase in gas or electricity consumption.

At **Soluciones Refractarias SRL** we provide state-of-the-art materials to optimize every critical zone of the furnace :

1. **Base plates, load supports, and conveyor rollers:**
   - **The chanllenge:** They withstand the weight of the components, mechanical wear due to friction, and direct thermal shock.
   - **Our Solution:** Linings made of **low-cement (LCC), low-porosity refractory concretes**, which offer extremely high mechanical strength. For areas subject to less mechanical wear but requiring backup insulation, we supply **Group K**

insulating bricks (K-23, K-26) and calcium silicate blocks, which cut off heat flow toward the base.

2. **Walls, Ceilings, and Doors (High Heat Loss Areas):**
   - **The challenge:** The doors open and close constantly, subjecting them to thermal shock. The walls absorb excessive heat if the material is dense, slowing down cooling and heating cycles (thermal inertia).
   - **Our solution:**
     - **Pre-compressed Ceramic Fiber Modules (1260°C and 1430°C):** They install quickly and withstand thermal shock without cracking. They completely eliminate open expansion joints, preventing convective heat loss
     - **High density Ceramic fiber blankets:** Ideal for multi-layer backup insulation, drastically reducing the temperature of the furnace's outer casing.
3. **Sealing of Doors and Resistor/Burner Pass-throughs:**
   - **The challenge :** Gas or air leaks ruin the furnace's controlled atmosphere (causing oxidation on steel parts) and burn the metal casings.
   - **Our solution:** **Ceramic fiber paper, fabrics, and braided cords**. These flexible materials ensure an airtight, elastic seal on the gates, maintaining stable pressure and internal atmosphere.
4. **High-Efficiency Barriers (Ultralight Backing Insulation):**
   - **The challenge:** Confined spaces within the furnace design where maximum possible insulation is required.
   - **Our solution :** **Last generation Microporous boards**. They have a thermal conductivity lower than that of still air, which allows for a reduction in the total thickness of the lining without sacrificing insulating performance, thereby gaining usable loading space inside the furnace.
5. **Attack by reducing gases (controlled atmosphere) on the furnace's internal components:**
   - **The challenge:** Prevent the decomposition of refractories in contact with this atmosphere, where their oxides are attacked and the refractory structure breaks down.
   - **Our solution :** **Rails, skids, and refractory parts made of silicon carbide or silicon nitride.** They possess greater chemical stability in strongly reducing atmospheres and prevent the destruction of these components.

3. Technical Comparison of Refractory Linings

The following table compares a traditional heavy lining (dense brick) with a modern ultra-lightweight system (ceramic fiber modules and microporous boards) operating at an internal temperature of **950°**C in a heat treatment furnace.

Technical Parameter	Traditional lining (Heavy)	Moder Lining Soluciones Refractarias (Ultra-light)	Real impact on operations
Typical wall composition	114 mm Dense brick + 114 mm Insulating brick	150 mm Ceramic fiber Module + 25 mm Microporous board	Structure that is 40% thinner and **more compact**.
Heat Loss by Conduction	aprox 1250 W/m2	aprox 480 W/m2	**61% direct saving** on maintenance fuel or electricity.
Accumulated Heat (Thermal Inertia)	aprox 145000 kJ/m2	aprox 8500 kJ/m2	**Reduction of 94%** of heat taken by walls . heating/cooling ultra-fast cicles.
External Cold-Face Temperature	aprox 105 °C	approx 62 °C	Safe working environment; complies with safety standards and prevents sheet metal deformation..
Cold-Side Emissivity Coefficient	0.85 (Rusty/hot sheet metal)	aprox 0.30 (Optimized finish/low radiation)	Drastically reduces heat radiation into the shed or workshop.
Total Coating Weight	aprox 280 kg/m2	aprox 22 kg/m2	Reduces the structural load on the oven. Allows for smaller motors and door actuators..

Puntos a tener en cuenta partiendo de estos cálculos:

- **Goodbye to "stolen heat" :** In batch heat treatment processes, the furnace undergoes constant heating and cooling cycles. Traditional heavy lining acts like a sponge, absorbing 145,000 kJ/m² per cycle. By switching to **ceramic fiber modules**, the walls store almost no energy (8,500 kJ/m²), allowing 94% of the heat to be transferred directly to the metal parts
- **The Magic of the Microporous Plate:** By combining the module with a **microporous backing board**, we are able to cut off heat flow so efficiently that the external casing temperature drops from 105°C to a completely safe 62°C, thereby reducing thermal fatigue on the furnace structure.
- **Controlled Emissitivy :** A cool surface closer to ambient temperature radiates significantly less energy into the workshop, drastically improving thermal comfort for operators and reducing industrial ventilation costs.

4. Summary:

Heat treatment requires extremely rigorous temperature control. An obsolete lining compromises metallurgical quality and drives up energy costs. Redesigning with modern refractory engineering is the key to profitability and reducing the industrial carbon footprint.

This is where we believe **Soluciones Refractarias SRL** is positioned to anticipate, resolve, and install these materials.
Our company possesses all the resources needed to address these matters**:**

- Premium level technical advice.
- Latest generation Materials. Specifs for this problem.
- Lining Design, Heat flow calculations.
- Installation of different materials with the suitable procedures.
- Convective Dry-Out of Hot-air.

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Note: This report aims to present all aspects and complexities of the subject matter. It should not be interpreted literally for making decisions regarding values or absolute final results concerning the report's scope. We recommend seeking specific consultation for particular calculations or decisions. Sources: Internal data, information published by manufacturers, universities, and other sources.

Links relacionados:

Tipes of treatment furnaces and their processes

Different types of heat treatment furnaces

Insulating materials for hat treatment furnaces.

Use of Silicon carbide for skid rails for TT furnaces.

Carbon Footprint reduction in thermal furnaces

All aspects brought together in one place
Our space!!!!

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