Corrosion of Refractories

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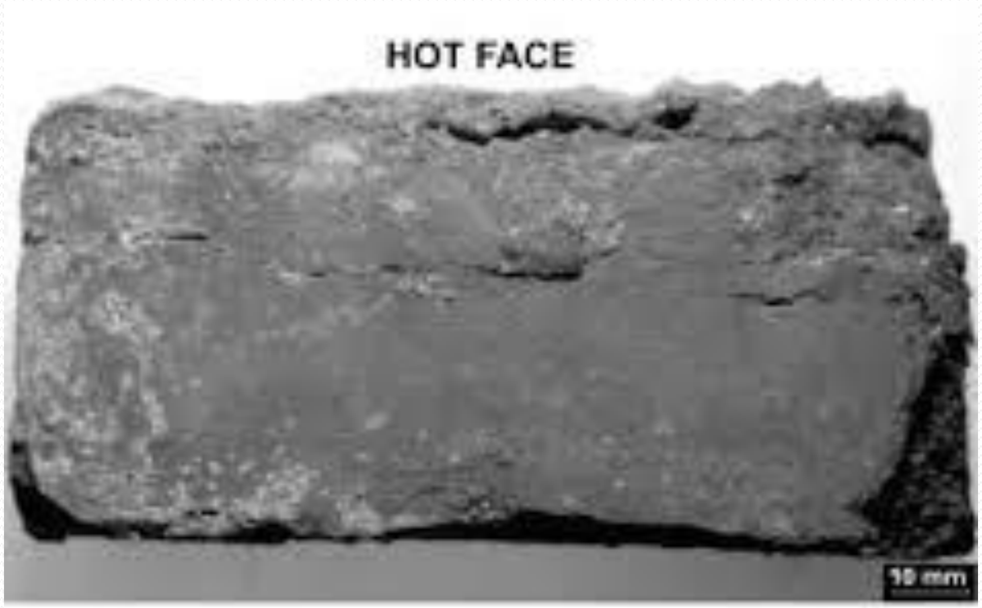
Corrosion of refractories is refractory wear by loss of thickness and mass from the exposed face of the refractory as a consequence of **chemical attack** by a corroding fluid.

The corrosion of refractories at high temperatures is essentially a chemical rather than an electrochemical phenomenon.



In most application, refractory materials are in contact with **solids**, **liquids** or **gases** which can react with them and lead to their modification.

The corrosion is generally complex and includes a lot of parameters:

- chemical composition
- microstructure of the refractory material,
- chemical composition of the product in contact,
- service temperature,
- atmosphere ... etc.

The following are just a few concepts that go a long way in helping one to understand corrosion:

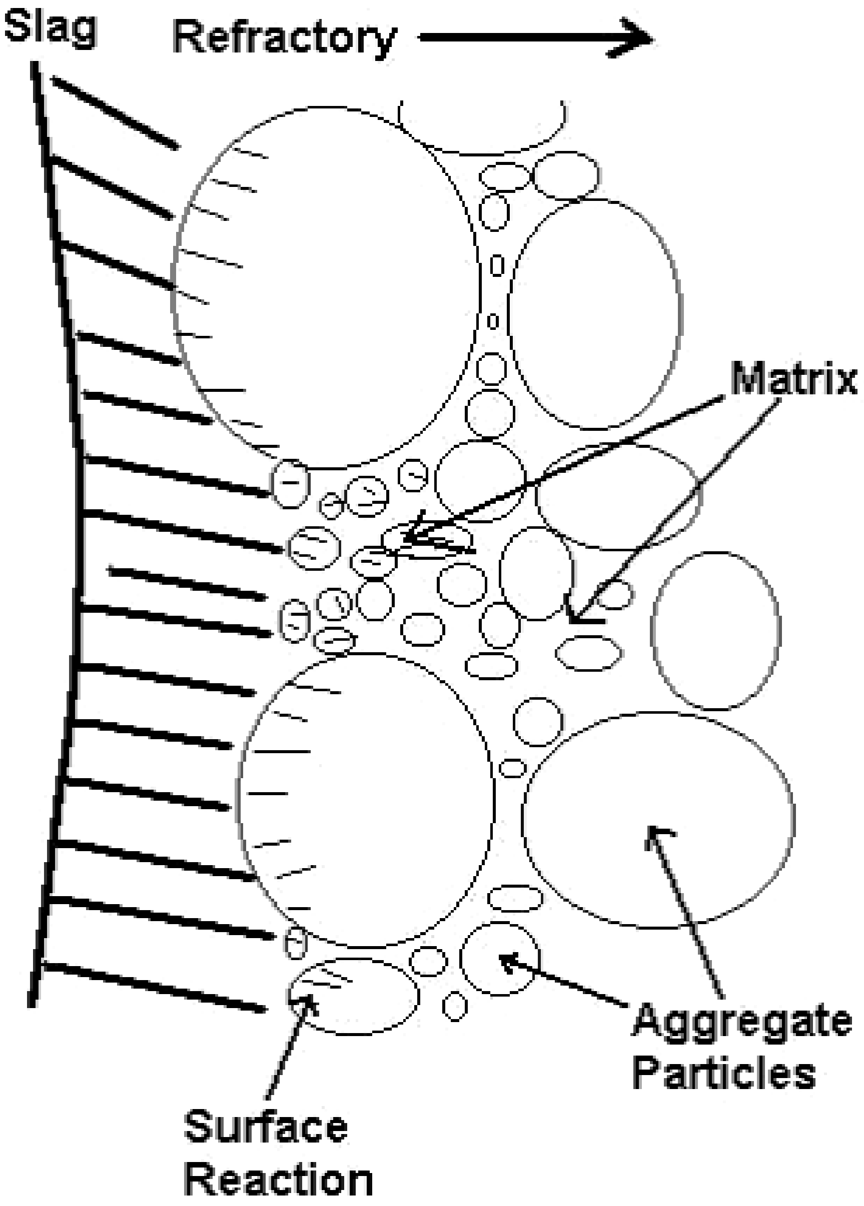
1. Refractories with acidic character tend to be attacked by an environment with a basic character and vice versa.
2. The vapor pressure of covalent materials is generally greater than that of ionic materials and therefore tends to vaporize or sublime more quickly.
3. Ionic materials tend to be soluble in polar solvents (e.g., salt in water) and covalent materials tend to be soluble in nonpolar solvents (e.g., SiC in hexane).
4. The solubility of solids in liquids generally increases with increasing temperature.

Refractories Corrosion Stages:

Stage 1: Inter-diffusional process (Thin Wall)

Here the refractory corrosion reactions occur primarily at **the immediate hot face**, and there is **little or no slag penetration**.

Microscopic examinations usually show that penetration is confined to a depth of **less than 100 microns (0.1 mm)** behind the exposed hot face.


Slag
Refractory
Matrix
Aggregate Particles
Surface Reaction

Stage 2: Matrix dissolution (Thick Wall)

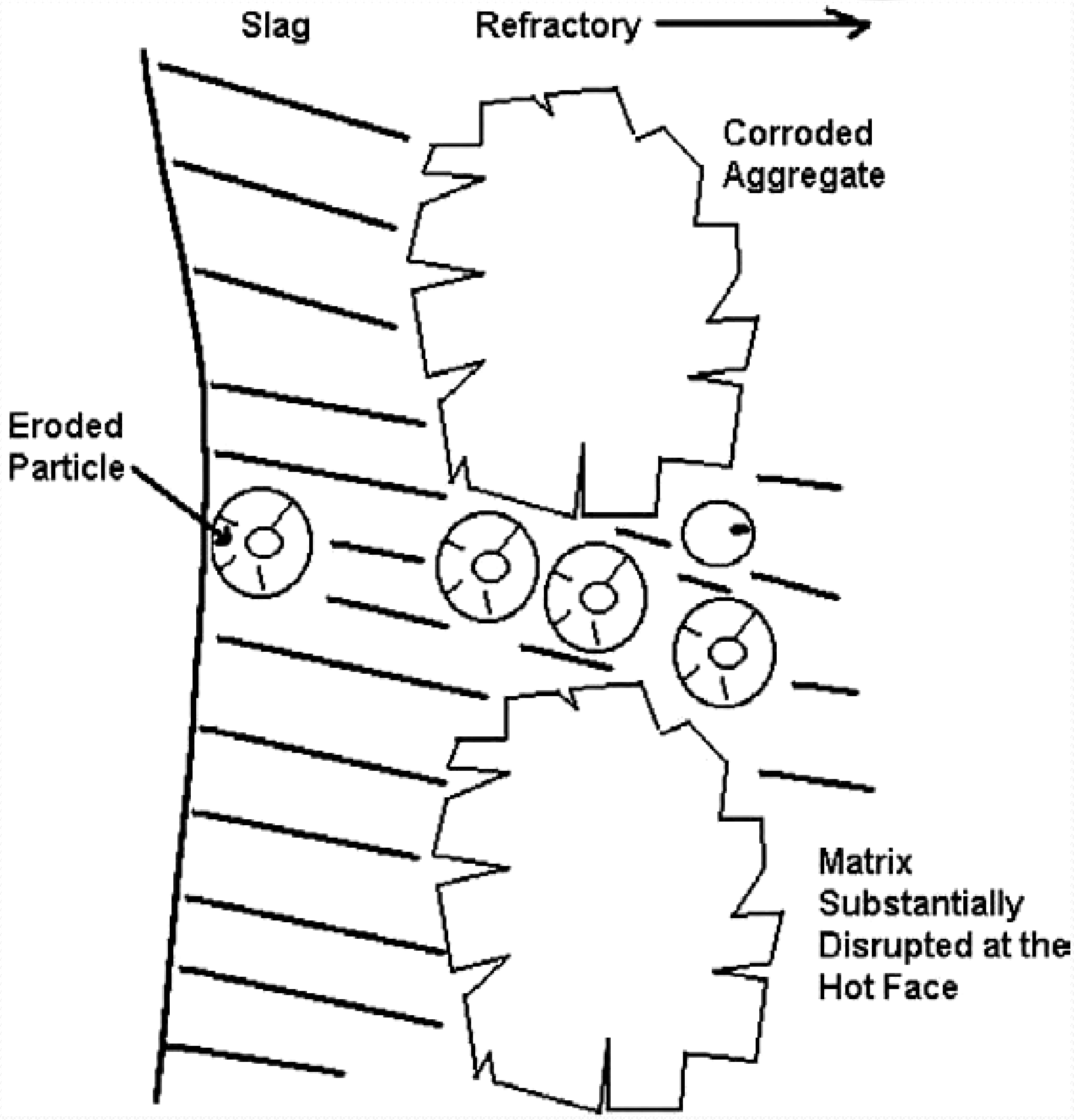
Stage II is characterized by two phenomena:

(1) full penetration of the refractory and

(2) extensive disruption by corrosion of the hot face region.

Stage II follows Stage I only if there is a sufficiently broad temperature gradient to allow penetration.

In Stage II, the coarse aggregate in a bonded refractory exhibits penetration—particularly along grain boundaries (boundaries between crystals making up polycrystalline aggregate particles). The direct bonding between the matrix and the aggregate particles is disrupted, but this bonding still exists.


Slag
Refractory
Corroded Aggregate
Eroded Particle
Matrix Substantially Disrupted at the Hot Face

- Slag penetration in Stage II can result in ***densification spalling***. This type of spalling occurs because the thermal expansion coefficient in the slag penetrated zone is different than that in the un-penetrated cold face region.

- On continued thermal excursions (cooling and heating), spalling can occur at the line of demarcation between penetrated and un-penetrated areas. The residual lining, after spalling, then begins the corrosion process anew, progressing from Stage I to Stage II again.

Stage 3: Surface layer formation

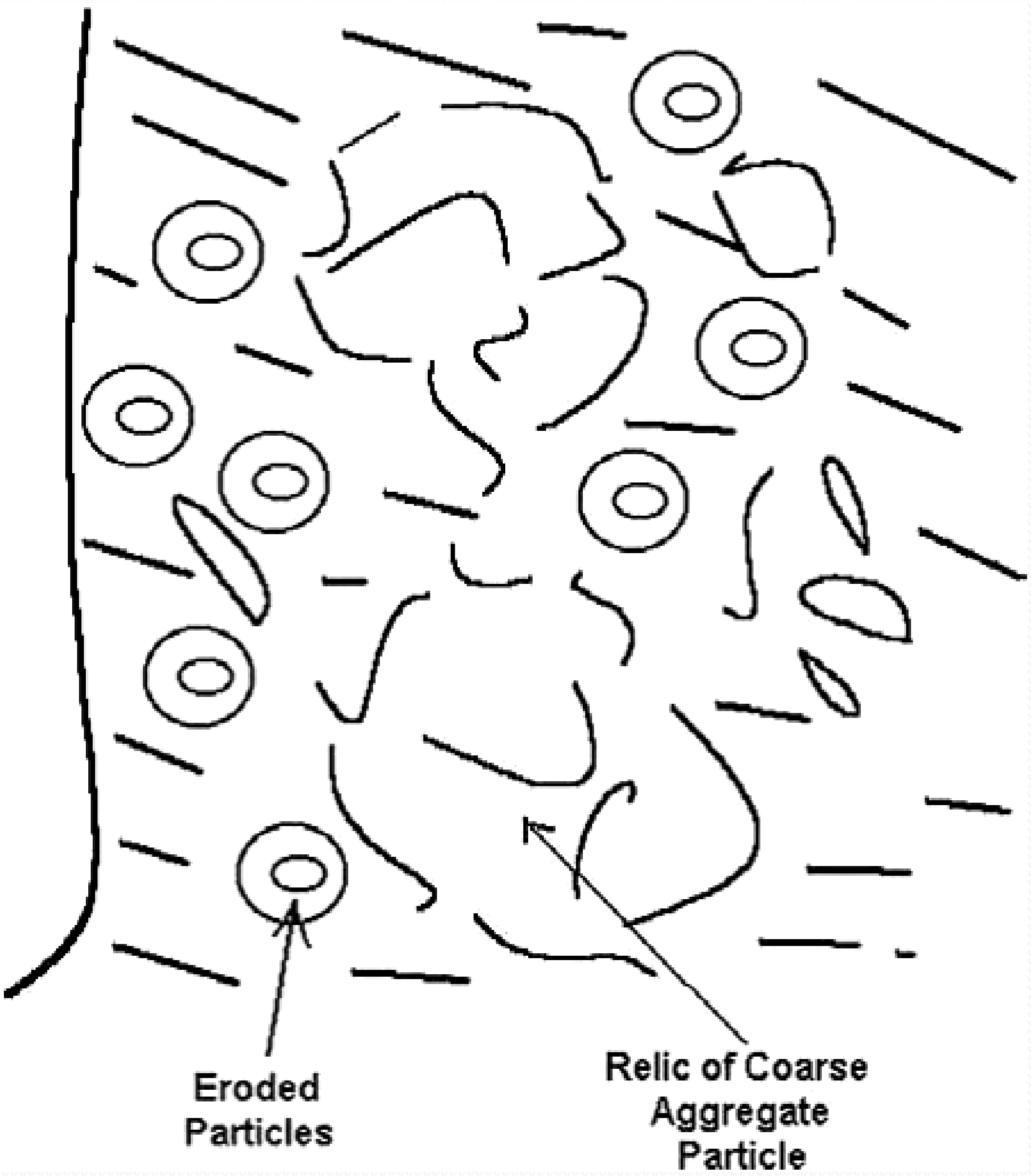
Toward the end of the refractory lining's life, this stage occurs in case of relatively:

(1) **slow corrosion rates** and

(2) **where densification spalling has not taken place,**

The refractory hot face zone may progress to a final stage of corrosion that may be called "Stage III".

In this case, bonding in the hot face region and up to **2 to 4 mm** behind the hot face is minimal.


Eroded Particles
Relic of Coarse Aggregate Particle

The **slag** appears to be the only phase holding the residual aggregate particles in place.

This is probably a result of the higher viscosity of the slag in the hot face region created as a consequence of dissolution of the refractory in the slag.

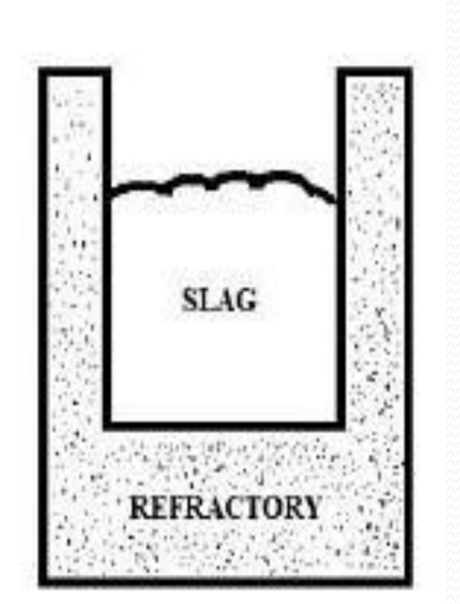
Refractories Corrosion Tests:

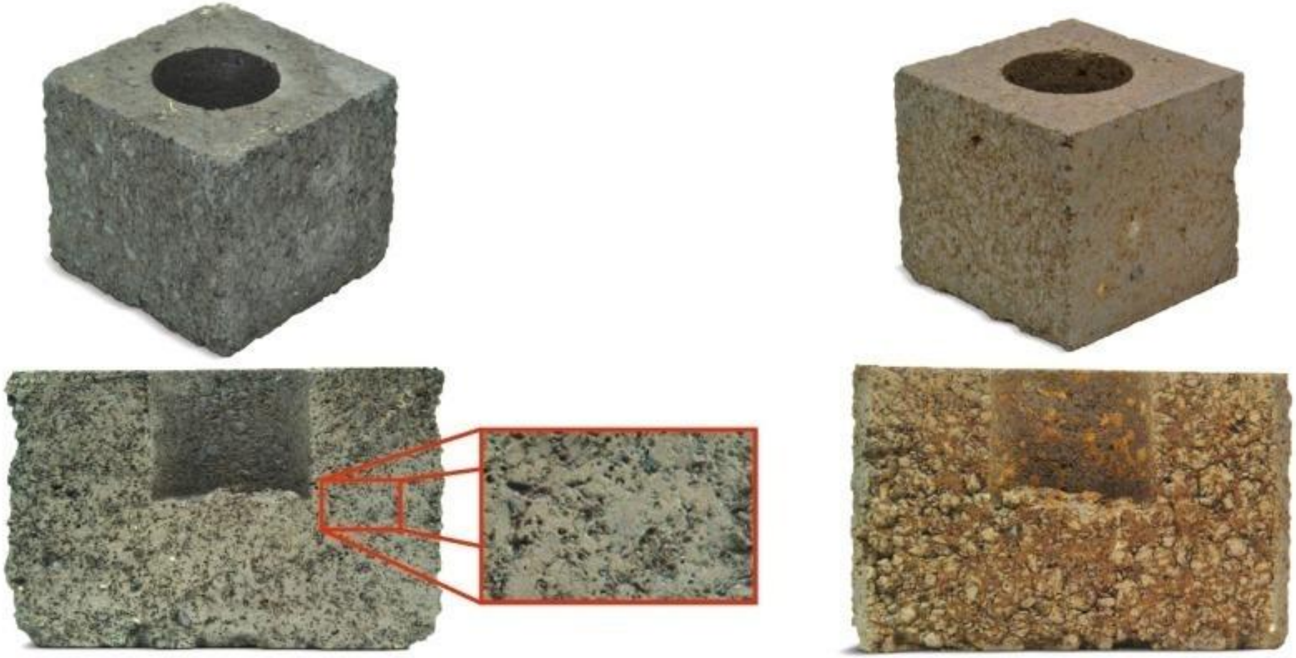
There are few standards concerning the evaluation of refractories corrosion and the existing tests (in laboratory) are often adapted to specific cases due to the corrosion of refractories is generally complex and includes a lot of parameters.

The corrosion properties of refractory materials can be investigated by either **static** or **dynamic** tests. A static test is much simpler to perform but a dynamic test is more similar to realistic conditions. The dynamic test is also more time efficient.

1. Static Test

- The static test is known the **crucible**, **cavity**, **cup** or **brick test**, which consist in a hollow that is filled with slag and exposed to high temperature to promote slag – refractory interaction.



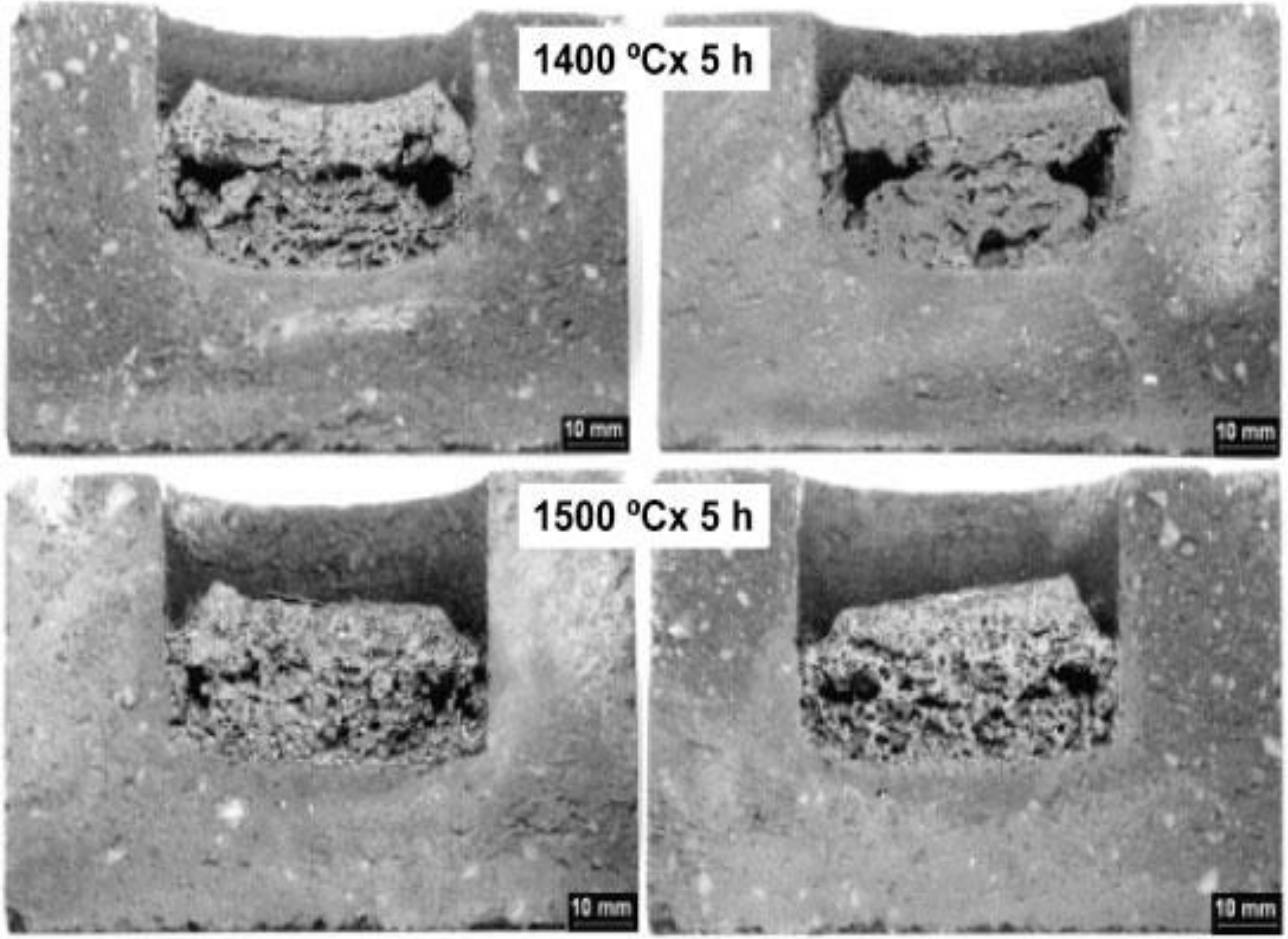


magnesia chromite brick (chrome ore disintegration)

PERILEX® CF (no alkali reaction)

- After cooling the crucible is cut in order to investigate by microscopy and microanalysis methods the interaction between the refractory and the slag.
- The advantages of this method are that it is simple and many samples can be tested quickly.

Croos sections



Mean Slag penetration area

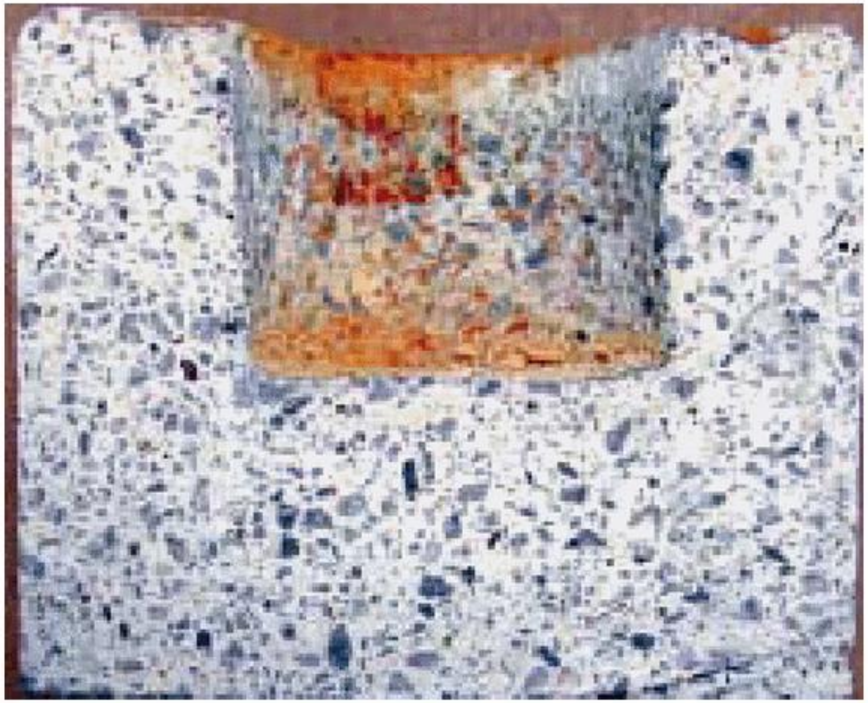
1400 °C x 5 h

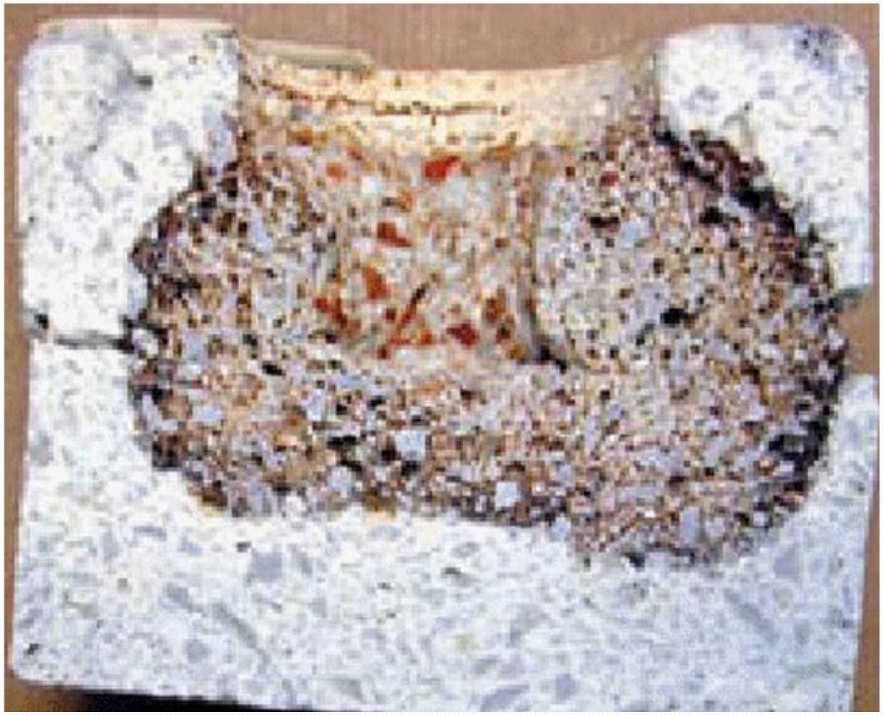
114.1 mm^2

1500 °C x 5 h

247.0 mm^2

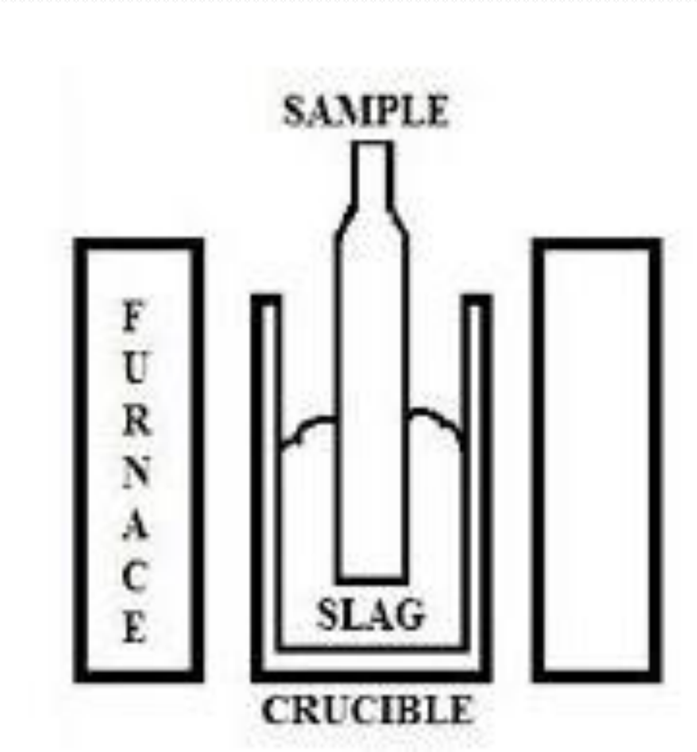
Figure 8: Cross section of used sintered magnesia-chromite brick after the crucible corrosion test.





2. Dynamic Test

- The dynamic test is known as the **dipping**, **immersion** or **finger**, where one or more cylindrical or square pillar shaped refractory samples are held with moving in the corrosive slag at high temperature for a certain period of time. After cooling, the effect of the corrosion is observed on the sample(s).


SAMPLE
FURNACE
SLAG
CRUCIBLE