RENO REFRACTORIES
Research Department

Refractory Analysis

Performed by: RAP
Requested by: H. Zinn
Customer: Reno Refractories
Project: Compare Standard Reno Sil 1.0 with Reno ElectroSil™ 1.0

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A slag test of candidate dry vibratables for use in iron contact vessels was performed in the Reno induction furnace. For this test two silica materials were examined to verify the development of the ElectroSil™ product line. The current product Reno Sil 1.0 served as the standard. The newly developed material ElectroSil™ 1.0 was the experimental sample.

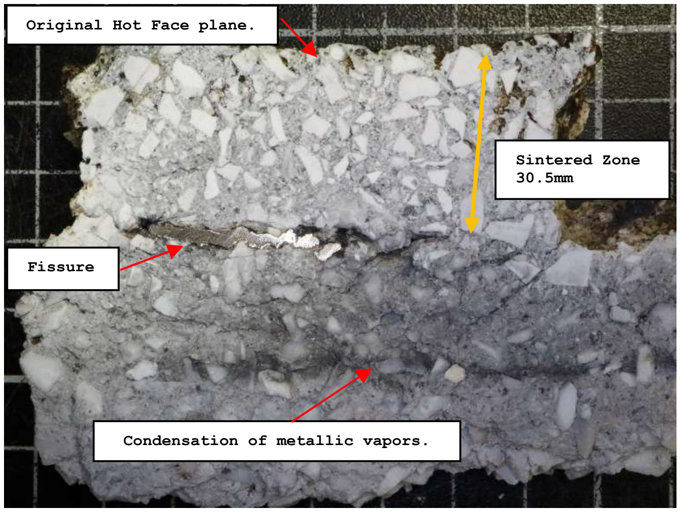

Figure 1(1x)- Reno Sil 1.0 dry vibratable. The slag penetrated the structure and reacted with the bond phase. The material had densified to a depth of 30.5mm due to the sintering agent. The condensation of vapors from the melt is observed to a depth of 47mm.
The sample appeared to have high porosity in the sintered zone. Additionally, the sample had considerable iron ingress into the lining.

Procedure

A crucible was lined with other test castables, for other research purposes. The dry materials were installed between two of the castables in order to contain their structure until high temperatures were achieved. The crucible was then dried and mounted in the induction furnace. The crucible was preheated using a gas burner to 1500F. Next cupola iron ingots were charged and power to the induction furnace applied. After four hours on molten metal, a small amount of corrosion was observed, so the run was terminated. After cooling, the samples were retrieved from the crucible for analysis. The reaction zone (slag line) region was saw cut from the samples and examined by optical microscopy. A small sample was cut from the hot face region of each material for microstructural testing.

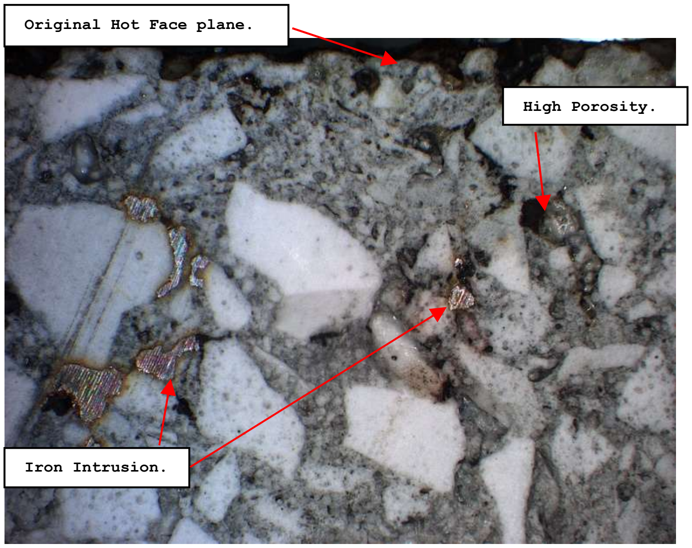

Figure 2(10x)- Reno Sil 1.0 at higher magnification. Very high porosity caused by bridging of coarse aggregate during installation vibration is observed. The fine particles were electrically charged and prevented good compaction.
The penetration of iron into the structure occurred due to the large pores. Thermal cycling has also created fissures through the weak bond (pores). These formed pathways for iron to infiltrate the material.

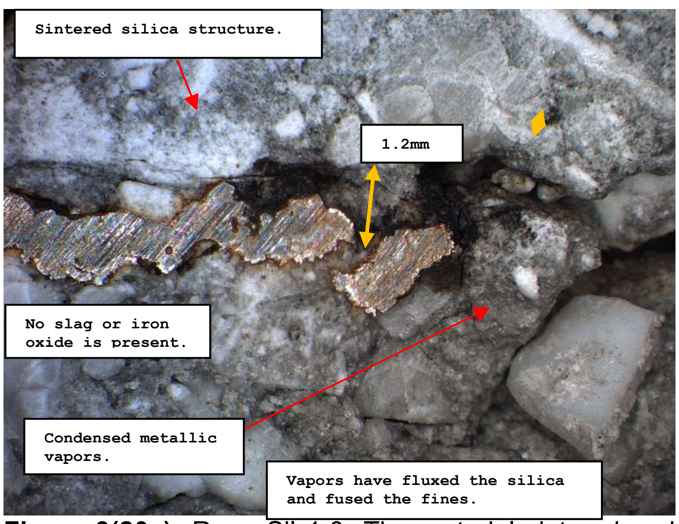

Figure 3(20x)- Reno Sil 1.0- The material sintered and developed fissures below the hot face. The width of the fissure is about 1.2mm which is sufficient to allow intrusion of both iron and slag. The orientation of the fissures was parallel to the hot face. This indicates that the stress direction was circumferential around the circular lining. Likely, the cause was the expansion of the quartz and shrinkage of the lining at a depth where the vapors condensed. Iron entered the fissures and flowed to a depth of 1 inch.

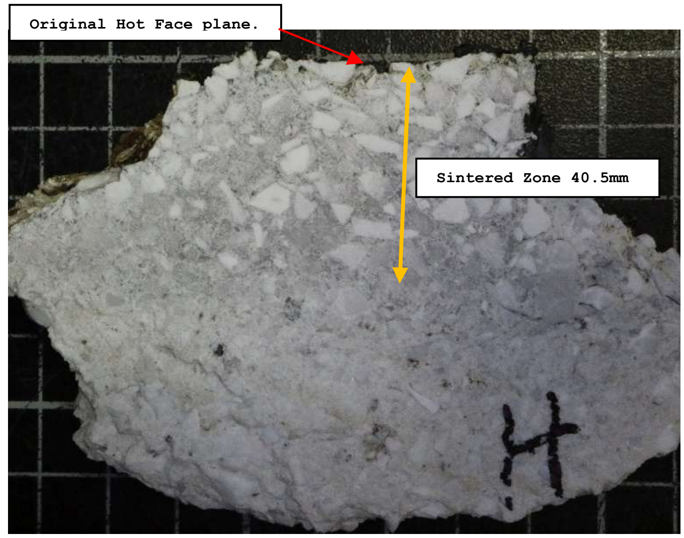

Figure 4(1x)- ElectroSil™ 1.0(mix H)- This material incorporated improvements in the composition to dissipate electrostatic charges on the particles. This allows for better particle packing of the fine bond phase. The structure was very good, with no flaws in the particle packing. The material had little metal infiltration due to the small pore sizes of the bond phase and lack of physical flaws, such as fissures. Corrosion resistance of the material was improved due to the improved microstructure.

Figure 5(10x)- Reno ElectroSil™ 1.0(mix H)- This view shows the effect of the improved particle packing. Visually, there was no iron ingress into the structure.

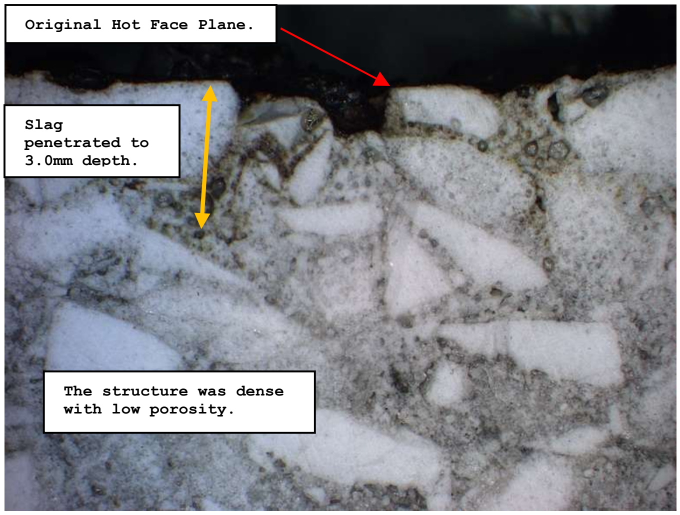

Figure 6 (20x)- ElectroSil™ 1.0 (mix H)- This image shows the hot face region of the sample. The only corrosion that occurred was along grain boundaries on the hot face. Depth of penetration was 3.0 mm.

Observations

1. The corrosion ranking of the materials is as follows:

Rank 1st Run	Material	Corrosion Depth(mm)
1.	ElectroSil™ 1.0	3.0 mm
2.	Reno Sil 1.0	30.5 mm

2. Results from porosimetry testing of the two materials.

Property	Reno Sil 1.0	ElectroSil™ 1.0
Pore Area(m2/g)	5.207	4.435
Pore Dia(μm)	1.1846	0.4705
Bulk Density(g/ml)	1.9778	2.0593
Apparent Density(g/ml)	2.3325	2.2833
Porosity (%)	15.2077	9.8101
Permeability (mdarcy)	125.88	12.18

Summary

1. The ElectroSil™ 1.0 had a greatly improved microstructure over the existing product. The porosity was much lower 9.8% versus 15.2% for the Reno Sil. Lower porosity will decrease the corrosion rate of a material.
2. The median pore size of the ElectroSil™ 1.0 material was substantially reduced. (0.47 microns versus 1.18 microns for the Reno Sil). A small pore size will not allow liquid metal or slag to enter the structure.
3. The Permeability of the ElectroSil™ was much lower than the Reno Sil. (12.18 versus 125.9 mdarcy). The permeability of a material is a measure of resistance to gas flow. In this case, a low permeability will prevent gas vapors from entering the lining. This is shown by the dark layers in the Reno Sil. The ElectroSil™ is all white because of its low permeability.
4. This improved structure resulted in a reduction in the penetration depth of iron and slag into the lining (3.0 versus 30.5mm).
5. The reduction of electrostatic charges results in much improved density and pore size of the installed product. The resulting lining will have enhanced durability due to higher abrasion resistance during charging operations. These improvements should significantly improve campaign life.