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DEVELOPMENT OF INSULATING DRY VIBRATABLE REFRACTORIES

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SUMMARY:

Dry insulating vibratable refractories have been designed for use behind bricks and precast shapes. These products provide insulation, molten metal containment and thermal shock resistance at elevated temperatures.

Initially developed for primary aluminum plants as insulating backup in anode carbon baking furnaces and aluminum launder precast shapes, more products were developed for other applications in copper, iron and steel production.

Other applications include copper shaft furnaces, teeming ladles, launder shapes, crucible furnaces and safety linings behind bricks in steel transfer ladles.

The benefits of this type of material are: excellent insulating characteristics, completely dry material with a heat set bond, compatibility with a wide range of temperatures and metals, resistance to thermal shock and reduced operating cost by minimizing heat loss.

1.0 DESIGN

A dry vibratable is composed of carefully sized aggregates. Controlled amounts of bonding agents are added for development of mechanical strength; inhibiting agents are added for molten metal resistance.

Dry vibratables are manufactured in a dry granular form, are totally dry and are installed by vibration. They will develop mechanical strength upon being heated. Once sintered at high temperature, dry vibratables will function similar to other dense monolithic refractories. (i.e. castables, plastics, etc.)

Dry vibratables are designed to maintain loose backup, providing stress relief planes that allow the development of self-curing properties to inhibit the penetration of metal or slag.

As the temperature increase progresses through the lining, the sintering of the refractory will go deeper, always offering a new work surface.

Insulating dry vibratables also contain graded dry refractory aggregates with bonding agents. Contrary to the majority of dry vibratables, insulating dry vibratables utilize refractory aggregates that exhibit insulating characteristics and low density.

The following table compares density and alumina content for various refractory aggregates normally used:

Similar to the dense vibratables, the insulating vibratables develop a sintered working face and maintain a loose backup. The loose backup performs the same function of stress relief and will sinter as the temperature increases.

2.0 PROPERTIES

Contrary to the majority of dry vibratables, insulating dry vibratables present density and insulating values similar to insulating castable and insulating firebrick.

Insulating firebrick and insulating castables utilize lightweight refractory aggregates that present relatively high porosity but, while providing good thermal insulation, usually have poor molten metal containment capability. On the other hand, the insulating dry vibratables exhibit excellent molten metal containment properties.

As with conventional dry vibratables, insulating dry vibratables develop mechanical strength upon heating and once sintered, will function similar to other dense monolithic refractories in service.

Table I and II compares the physical, chemical and thermal properties of an insulating castable, an insulating brick and an insulating dry vibratable. All three products are used in similar applications.

As illustrated in the following Figure 1, a dry insulating vibratable product was designed to be utilized in molten aluminum handling equipment. The product provides both safety (due to molten aluminum containment properties) and reduced heat loss (due to its low thermal conductivity).

The test was conducted at 800 °C for four hours. There is no observable penetration or saturation by molten metal in the refractory. This shows the ability of the refractory to contain molten metal and still reduce heat losses.

3.0 ADVANTAGES

Dry vibratables are delivered completely dry; there is no need to add water for installation purposes. Because they are completely dry, extensive dryout is not required, allowing shorter repair downtime and quicker turn-around time during furnace construction, increasing productivity. It is installed by conventional dry ramming techniques, avoiding the need for a skilled mason.

Insulating dry vibratables are lightweight, similar to insulating castables and insulating bricks. Due to this characteristic, insulating dry vibratables show high insulating values.

Insulating dry vibratables exhibit excellent molten metal containment capability for aluminum, copper, iron and steel.

The loose backup allows the elimination of stress and the sealing of cracks. This is what we call the self-healing property.

Insulating dry vibratables minimize heat loss through the lining, utilizing the energy input more efficiently to melt the metal.

A typical design for a furnace includes a dense refractory as the working lining with an insulating backup (castable or brick). Depending on the operating temperatures, the thickness of the lining and the backup is determined by the freeze plane of the molten metal. This freeze plane cannot be located inside the backup lining because it means that molten metal will reach the insulating backup and will not be contained inside the vessel.

By using dry vibratables, the freeze plane can be located within the insulating dry vibratable without safety concerns. The thickness of the working lining can be reduced with increased thickness of the insulating backup. This means less heat loss.

A thinner lining reduces thermal stress on the working lining.

Reduction of furnace lining thickness is also a result of the better insulation properties of an insulating dry vibratable lining.

4.0 MOLTEN METAL CONTACT TESTING

To evaluate the behavior of the insulating dry vibratables, cup tests were conducted with several types of metals.

For each case, a cup was pressed using the insulating dry vibratable. Cups were sintered and thermal conductivity was determined during the sintering stage.

Metal was added to the cups and fired at different temperatures to melt the metal. Maximum temperature was held for at least 4 hours.

After being fired, the cups were cut in order to observe the cross section and evaluate the degree of penetration of the molten metal in the cup.

Following are pictures of each test and the tabulated data on the alloy used, the maximum temperature, the type of insulating dry vibratable used, the conductivity values and a description of the status of the cup section.

4.1 ALUMINUM

- Alloy used: aluminum 7075
- Temperature: 820°C (1508°F) for 4 hours.
- Chemistry of the insulating dry vibratable:
  - Al_2O_3 ……….43%
  - SiO_2………..41%
- Density of the insulating dry vibratable: 1.31 gr/cc (82 pcf)
- Thermal Conductivity (W/mK):
  - At 205°C (400°F)……..0.32
  - At 425°C (800°F)….….0.39
  - At 870°C (1600°F)…....0.45
- Cup section: Figure 2, no observable penetration into the insulating dry vibratable material.

4.2 COPPER

- Alloy used: copper alloy 110
- Temperature: 1200°C (2200°F) for 4 hours.
- Chemistry of the insulating dry vibratable:
  - Al_2O_3 ……….50%
  - SiO_2………..31%
  - SiC……....…15%
- Density of the insulating dry vibratable: 1.63 gr/cc (102 pcf)
- Thermal Conductivity (W/mK):
  - At 205°C (400°F)…….0.34
  - At 425°C (800°F)…..…0.46
  - At 870°C (1600°F)..….0.89
- Cup section: Figure 3, the penetration observed at the top of the cup is due to fracture of the cup during handling. At the bottom of the cup, penetration is minimal.

4.3 IRON-STEEL

- Alloy used: gray iron
- Temperature: 980°C (1800°F) for 8 hours.

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Table I. Density and Alumina Content

Refractory Aggregate	Density (g/cc)	% Al_2O_3
White fused alumina	3.45	99
Brown fused alumina	3.86	96
Bauxite	3.10	87
Tabular alumina	3.50	99
Calcined alumina	2.50	42
Insulating aggregate	0.64	40

Table II. Properties of Insulating Products

	Concrete	Brick	Vibratable
Maximum service temperature (°C)	1205	1260	1400
Density (g/cc)	0.88	0.66	0.96
Water required (%)	50	None	None
% alumina	40	37	37.8
% silica	34	57	59.0
Permanent Lineal Change (%)			
After firing at 760 °C	0.5		Nil
After firing at 980 °C	0.9		0.3
After firing at 1315 °C	---		0.1
Thermal Conductivity (W/mK)			
After firing at 205 °C	0.21	0.20	0.22
After firing at 425 °C	0.22	0.29	0.26
After firing at 650 °C	0.25	0.33	0.29
After firing at 816 °C	0.27	0.35	0.32
After firing at 982 °C			0.46

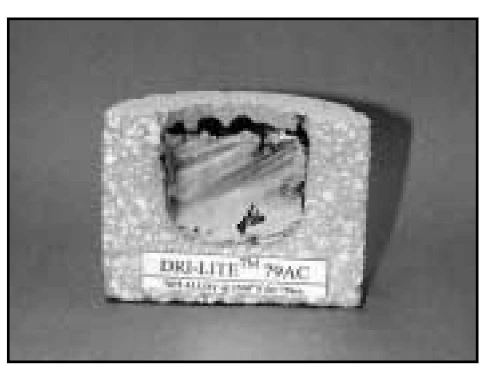

Figure 1. Molten aluminum attack of an insulating dry-vibratable

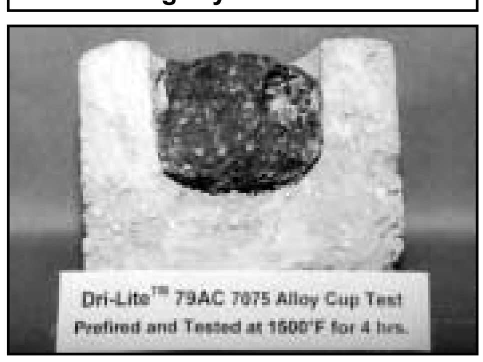

Figure 2. Aluminum attack

Figure 3. Copper attack

Figure 4. Iron attack

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- Chemistry of the insulating dry vibratable:
  - ♦ Al_2O_3 ……….74%
  - ♦ SiO_2………18%
- Density of the insulating dry vibratable: 2.00 gr/cc (125 pcf)
- Thermal Conductivity (W/mK):
  - ♦ At 205°C (400°F)…….0.52
  - ♦ At 425°C (800°F)…..…0.69
  - ♦ At 870°C (1600°F)…...0.79
  - ♦ At 1200°C (2200°F)….0.95
- Cup section: Figure 4, slight penetration of molten metal in the insulating dry vibratable cup.

5.0 CONCLUSIONS.

Insulating dry vibratables exhibit the same characteristics as a conventional dry vibratable with respect to ease of installation, no need for extensive dry-out, self-healing and development of mechanical strength after sintering.

Additionally, insulating dry vibratables exhibit insulating properties that reduce heat losses, achieve higher efficiency in the use of the energy supplied, have the capability to contain molten metal and allow the reduction of the thickness of the refractory lining.

Cup testing with molten aluminum, copper and iron confirm the ability of the insulating dry vibratables to contain molten metal while providing low thermal conductivity.

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at the Society's 103rd Annual Meeting in Indianapolis.

Superior Graphite Company, Chicago, Illinois, was awarded a Technology Challenge Grant as one of 18 Illinois businesses, universities and research centers that are on the cutting edge of 21st Century technology. The company received the grant for the Electroconsolidation® process.

Allied Mineral Products, Columbus, Ohio, major promotions include: John L. Turner to President and Chief Operating Officer, and Jon K. Tabor retaining the position of Chairman of the Board and Chief Executive Officer; Jon R. Tabor promoted to Senior Vice President, Sales & Marketing; Douglas K. Doza to Senior Vice President, Manufacturing & Research; Dana G. Goski to Manager, Research & Development; John S. Halsted to Business Manager, International Foundry Industry. In addition, recent employee hires include William N. Porter, Senior Sales Representative & Product Manager, Steel; Robert J. Harkel, sales representative for the Matrix Refractories Division; and Steven O.Young, Manager, Manufacturing.