

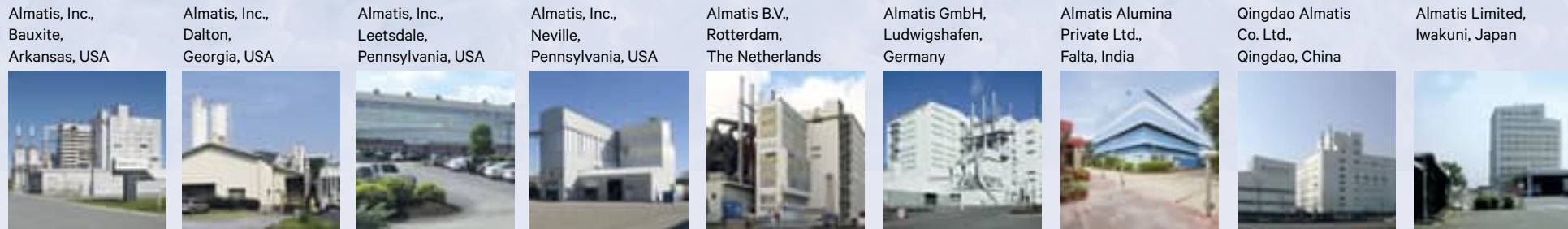


ALMATIS

PREMIUM ALUMINA

# PREMIUM ALUMINA FOR REFRACTORY APPLICATIONS

- ▲ Sales Office
- ▲ Application Lab
- ▲ Plant
- ▲ Refinery



## Almatris – The Premium Alumina Company

With more than 100 years of alumina expertise, Almatris is the world's leader in the development, manufacture and supply of premium alumina and alumina-based products.

Almatris is both a global and fully integrated producer, serving our customers from sixteen strategically located sales, research and manufacturing sites. Our employees strive to exceed customers' expectations through industry leading customer service, technical support and manufacturing excellence. We implement leading technologies and continuous improvement programs, which have established Almatris products as the benchmark for quality and consistency. Our commitment to strong partnerships with our customers creates innovative solutions that support and enhance their growth in all regions of the world.

Almatris offers the most comprehensive alumina product portfolio in the industry. Our broad product line includes:

- Tabular aluminas
- Calcined and reactive aluminas
- Polishing aluminas
- Calcium aluminate cements
- Alphabond 300
- Dispersing aluminas
- Brown sintered alumina, BSA 96
- Alumina and magnesia-rich spinels
- Calcium hexa-aluminates, Bonite and SLA 92

Across our core markets—refractories, ceramics and polishing—we deliver one-stop shopping, always expanding our portfolio to meet customer and market requirements.

- QUICK FACTS:**
- Global specialty alumina producer with over 100 years of expertise*
  - Most comprehensive alumina portfolio*
  - Closer to our customers with highest quality products*
  - Reliable and secure supply from our refinery and 9 world-class production facilities*
  - Excellent global and local service with leading-edge technical support*
  - Continuous development of innovative solutions and applications know-how*



## Refractories: Heat and Wear Resistance

### ALMATIS ALUMINAS FOR REFRACTORIES:

- *High-alumina dense aggregates*
- *Lightweight aggregates*
- *Calcined and reactive aluminas*
- *Calcium aluminate cements and binders*
- *Dispersing aluminas*

### *Broadest alumina portfolio worldwide*

Refractories are formulated for the harsh conditions they will face in service. These include applications in the production of iron and steel, cement, petrochemicals, non-ferrous metal, glass and others.

The Almatris range of premium aluminas is designed for use in advanced refractories such as:

- *monolithics*
- *prefabricated pieces*
- *bricks*
- *isostatic pressed products*

Almatris products ensure the design of higher performance refractories where heat tolerance, creep resistance and corrosion resistance are of crucial importance.

### *High-alumina aggregates*

Almatris offers multiple aggregates in a wide range of crushed and milled sizes to optimize refractory formulations.

Aggregates are the backbone of a refractory formulation and provide dimensional stability to the refractory products. The coarser fractions add thermal shock and corrosion resistance.

All Almatris alumina-based aggregates are manufactured from high purity raw materials. The well-controlled production processes result in very homogeneous, pure products for producing high quality refractories.

### *High performance matrix products*

The aggregate fines and matrix products, such as calcined and reactive alumina, optimize the particle size distribution and increase the refractoriness of the product.

The use of ultrafine aluminas with high sinter reactivity provides mechanical strength and abrasion resistance to bricks and functional products. In monolithic formulations, engineered reactive aluminas define the rheology and allow, in combination with dispersing aluminas, the formulation of castables with extremely low water demand.

High temperature calcium aluminate cements and binders bring stability to monolithic products and complete the Almatris product range for our refractory customers.



## Tabular Alumina T60/T64

### High-purity aggregate

Almatis Tabular Alumina T60/T64 is widely used for various high temperature applications.

The purity and unique microstructure of tabular alumina offer considerable advantages over other high alumina aggregates used for the formulation of unshaped and shaped refractories.

The high purity of Almatis Tabular Alumina T60/T64 ensures excellent thermomechanical properties of the refractory products. In combination with carefully selected, high performance binding systems, refractory products based on Almatis Tabular Alumina T60/T64 can be applied at temperatures up to 1800 °C.

Tabular alumina exhibits excellent chemical resistance against basic and acidic corrosive media and exhibits a high abrasion resistance with a Mohs hardness of 9 for corundum.

Refractories made of tabular alumina are used in many applications in various industries:

- Iron and Steel
- Cement
- Petrochemical
- Foundry
- Non-ferrous metallurgy
- Glass
- Incineration

### Tabular Alumina T60/T64

Chemical Composition [%]	All Sizes <sup>1</sup>	-45 micron LI	-45 micron STD	-20 micron
Al <sub>2</sub> O <sub>3</sub> by difference (typical)	99.5	99.5	99.1	99.3
Na <sub>2</sub> O	≤0.40	≤0.40	≤0.60	≤0.40
SiO <sub>2</sub>	≤0.09	≤0.09	≤0.12	≤0.15
Fe Magnetic	≤0.02	≤0.02	≤0.30	≤0.02
Physical Properties				
Bulk Specific Gravity [g/cm <sup>3</sup> ]	≥ 3.50			
Apparent Porosity [%]	≤ 5			
Water Absorption [%]	≤ 1.5			

<sup>1</sup>) All sizes excluding -45 micron LI, -45 micron STD and -20 micron



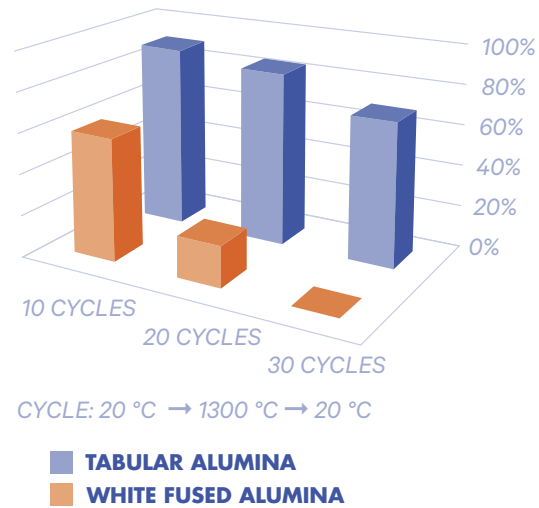
Almatis Tabular Alumina T60/T64 converter discharge



Almatis Tabular Alumina T60/T64 sized

# Tabular Alumina T60/T64

Comparison of thermal shock test resistance: 60% of tabular alumina grains survive a thermal shock whereas all fused grains get damaged.



## Volume stability

The consistent quality of Almatris Tabular Alumina T60/T64 is the result of a well-controlled sinter process with firing temperatures above 1800 °C. The use of high temperature furnaces with state-of-the-art technology permits densification of selected raw materials without sintering aids that would negatively impact the high temperature properties of the refractories. Refractories made of Almatris Tabular Alumina T60/T64 show, therefore, high volume stability.

## Unique microstructure

The particular production process is controlled to achieve the special microstructure of tabular alumina.

Almatris Tabular Alumina T60/T64 is characterized by its large, well-developed hexagonal tablet-shaped alumina crystals of up to 200 µm

length with closed spherical pores. Because of this unique microstructure, tabular alumina exhibits an excellent thermal shock resistance when compared to fused aggregates.

Parts under severe thermal shock conditions, such as burner blocks or steelmaking’s sliding gate plates and sub-entry nozzles, achieve a stable and long service life when formulated with Almatris Tabular Alumina T60/T64.

Tabular alumina-based monolithic ladle linings lower the specific refractory consumption and offer chemical inertness for the production of clean steel.

## Stable PSD and chemistry

Almatris offers various tabular alumina sizings from very coarse fractions to fine-ground sizes of <45 µm and <20 µm.

The controlled particle size distribution (PSD) and low batch-to-batch variation make Almatris Tabular Alumina T60/T64 the material of choice for critical applications such as isostatic pressing or recipes for dry vibrating mixes.

Crushing and milling are followed by intensive de-ironing steps that result in very low free iron within the various tabular alumina fractions, thus providing a high resistance in reducing atmospheres.

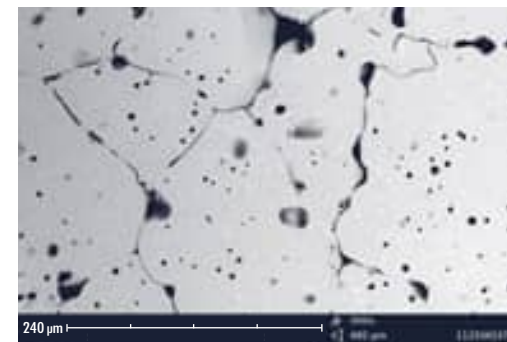
As a result of the sinter process, tabular alumina exhibits the same mineralogical and chemical composition for all fractions. Contrary to fused products where impurities accumulate in the fines, the use of tabular alumina in refractory formulation guarantees stable and reliable behavior.

## Global product specifications

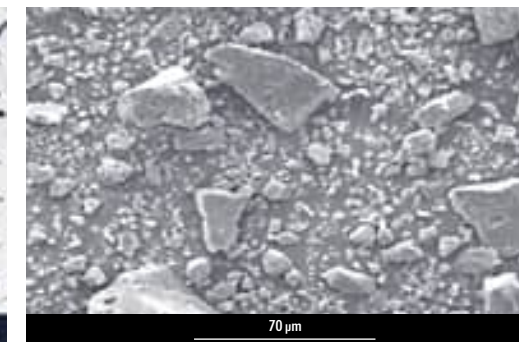
Almatris Tabular Alumina T60/T64 is available in various sizes and the majority are global products. Identical product specifications, regardless of where they are produced, facilitate the transfer of formulations and production from one geographic region to another.

## BENEFITS OF ALMATIS TABULAR ALUMINA T60/T64:

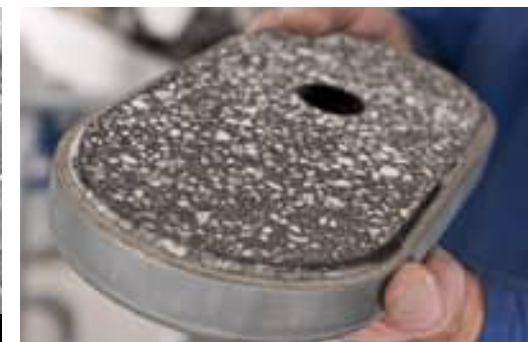
- Excellent thermomechanical properties
- High volume stability
- High thermal shock resistance
- High chemical resistance
- High purity
- High mechanical stability
- High wear resistance



Almatris Tabular Alumina T60/T64 microstructure (SEM)



Almatris Tabular Alumina T60/T64 <45 µm (SEM)



APPLICATION: Sliding gate plate



## Magnesium Aluminate Spinel

Magnesium aluminate spinel has excellent refractory properties with a melting point of stoichiometric spinel of 2135 °C. All spinels have the ability to substitute large percentages of one or both of the cationic site components ( $\text{Al}^{3+}$  or  $\text{Mg}^{2+}$ ) with other elements with the same charge and similar atom size. These specific interactions with corrosive media, especially steel slag, explain the use of magnesium aluminate spinels in refractory products designed for high corrosion resistance.

Furthermore, the thermal-shock resistance of refractories can be improved by the addition of high purity, sintered spinel.

### High purity

The purity and homogeneous microstructure of Almatix sintered spinels offer considerable advantages over other high purity fused spinels used for the formulation of unshaped and shaped refractories. Low grade spinel materials made of bauxite or diaspore cannot be compared with the premium sintered spinels and do not match the excellent thermomechanical properties, especially creep resistance, of high purity sintered spinel.

The Almatix magnesium aluminate spinel product line includes both alumina-rich and magnesia-rich spinels, which are increasingly used in refractories for demanding applications in these industries:

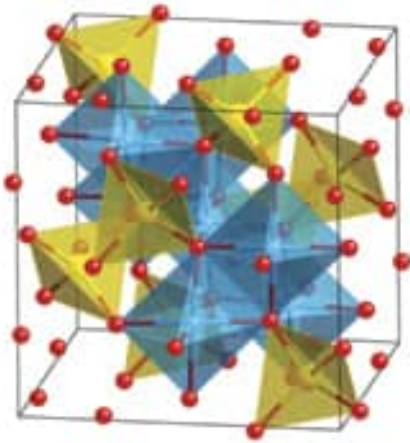
- Steel
- Cement
- Foundry

### Sintered Spinel

Chemical Composition [%]	MR 66	AR 78	AR 90
$\text{Al}_2\text{O}_3$	> 63.0	> 74.0	> 87.0
MgO	33.0	22.5	9.5
CaO	0.39	0.24	0.15
$\text{SiO}_2$	0.09	0.10	0.06
$\text{Na}_2\text{O}$	0.03	0.09	0.15
$\text{Fe}_2\text{O}_3$	0.20	0.15	0.06
Phase Composition (X-ray diffraction peaks)			
Spinel	main phase	main phase	main phase
Corundum ( $\text{Al}_2\text{O}_3$ )	none	trace	minor phase
Periclase (MgO)	minor phase	none	none

# Alumina-Rich Spinel AR 78 and AR 90

MgAl<sub>2</sub>O<sub>4</sub> – Spinel Structure\*



● **Al** – atoms on octahedral sites

Can be replaced by Fe(III), Cr, Mn(III),...

● **Mg** – atoms on tetrahedral sites

Can be replaced by Fe(II), Ni, Mn(II), Zn,...

● **Oxygen**

\*The Structure of Materials, by Marc De Graef & Michael McHenry, published by Cambridge University Press

Alumina-rich spinels AR 78 and AR 90 are distinguished by their chemistries (78% and 90% alumina respectively).

AR 78 and AR 90 are mainly used in high-alumina refractory bricks, monolithics and pre-fired shapes in the iron and steel industry. Latest research shows the superiority of these spinel-containing materials when in contact with magnesium-containing aluminum alloys.

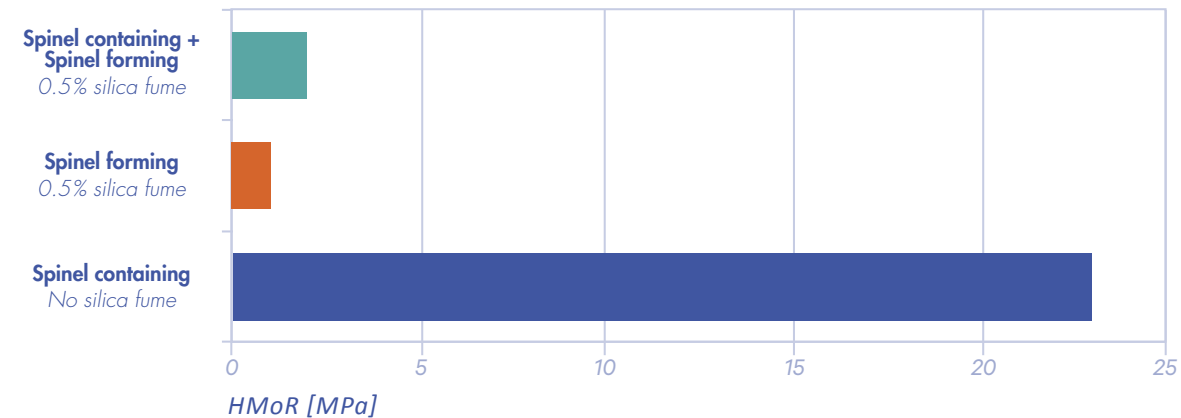
### Mechanism of spinel

When compared to stoichiometric spinel, the alumina-rich spinels have additional vacant

lattice sites with the capability to absorb low-melting, low-viscosity components of the attacking slag, such as Fe (FeO) and Mn (MnO). As the slag composition becomes deficient in FeO and MnO, the slag viscosity increases and has much lower tendency for penetration and erosion.

Superstoichiometric spinel AR 90 precipitates alpha alumina at working temperatures, which reacts with calcium oxide in the slag forming the refractory CA<sub>6</sub> phase at the edge of the spinel grains that protect the spinel grains against further corrosion.

Impact of Silica content on HMoR of ladle castables



### Volume stability

Established practice sets a total spinel content of 15-30% for alumina refractories in contact with steel slag.

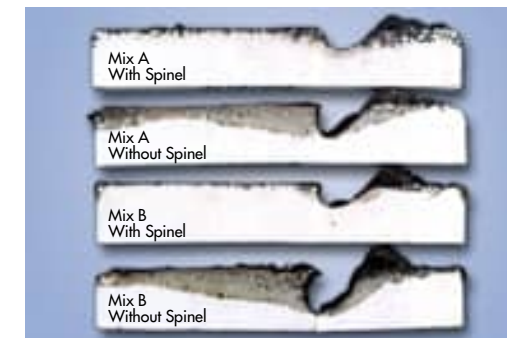
High quality pre-reacted spinels ensure volume stability during firing and are therefore less prone to the spalling of refractory linings, which is sometimes experienced with in situ spinel forming solutions. Pre-reacted spinel is inert and does not react with water. The use of Almatix AR 78 and AR 90 is therefore recommended for the production of prefabricated shapes like impact pads, purging plugs, well blocks and EAF-roofs. With spinel-containing formulations, crack-free pieces can easily be achieved.

### Without silica fume

Although spinel-forming solutions require the addition of some microsilica for expansion control, the optimum performance of pre-reacted sintered spinels can only be achieved when formulated with high purity aggregates and a silica-free matrix.

### BENEFITS OF ALMATIX ALUMINA-RICH SPINELS AR 78 / AR 90:

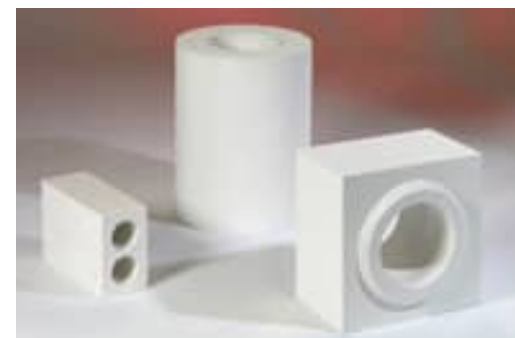
- High refractoriness
- High corrosion resistance against steel slag
- Excellent thermomechanical properties
- High volume stability
- High thermal shock resistance



Improved corrosion resistance due to spinel addition



APPLICATION: Steel ladles



APPLICATION: Steel well blocks

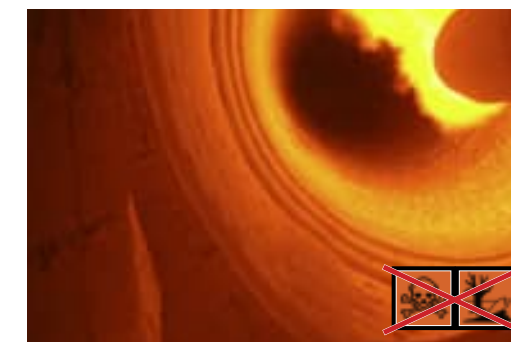
## Magnesia-Rich Spinel MR 66

### *Stress relief through microcracks*

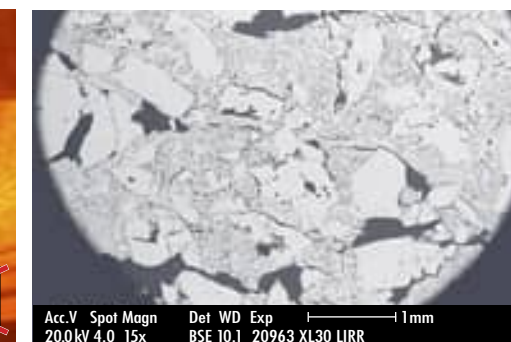
Almatis magnesia-rich spinel MR 66 is used in basic refractory bricks for cement rotary kilns. It imparts the improved thermal shock resistance normally associated with chrome additions, but without the potential problem of hazardous waste disposal.

Because MR 66 spinel has a lower thermal expansion coefficient than periclase, micro-pores and microcracks form around the spinel grains during heating and firing. This inhibits crack propagation from thermally or mechanically induced stress.

Magnesia-rich spinel MR 66 contains free magnesium oxide. The free magnesia easily hydrates with water, which is accompanied by volume expansion and potential crack formation. The MR 66 spinel is, therefore, not recommended for use in castables, especially for large structural parts.



APPLICATION: Cement rotary kiln



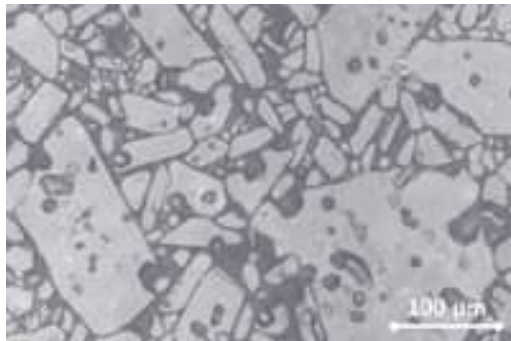
Microcracks around MR 66 grains



## BSA 96



Almatis BSA 96



BSA 96 microstructure

### High-alumina sinter aggregate

BSA 96 is a highly refractory, dense aggregate with an  $\text{Al}_2\text{O}_3$  content greater than 96%. The major phase of the BSA 96 aggregate is corundum with traces of tialite ( $\text{Al}_2\text{TiO}_5$ ).

The sintered aggregate BSA 96 is produced in Germany and provides a technical and strategic alternative to brown fused alumina and refractory bauxite used in refractory products for various industries:

- Iron and Steel
- Aluminum
- Foundry
- Petrochemical
- Incineration

### BSA 96

Chemical Composition [%]	Typical	Physical Properties	Typical
$\text{Al}_2\text{O}_3$	96.5	Bulk Specific Gravity [ $\text{g}/\text{cm}^3$ ]	3.5
$\text{TiO}_2$	1.5	Apparent Porosity [%]	4.5
$\text{SiO}_2$	1.0	Water Absorption [%]	1.3
$\text{MgO}$	0.4		
$\text{Na}_2\text{O}$	0.3		
$\text{Fe}_2\text{O}_3$	0.15		

### Carbide and metallic free

BSA 96 is a homogeneous sintered product with identical chemical composition across all size fractions. It is free of the carbide or metallic contaminants which disturb the performance of fused high-alumina aggregates in monolithic and brick applications.

Refractory bricks based on BSA 96 are consequently free from any blisters or brown spots. Refractory castables formulated with BSA 96 show a stable flow and setting behavior and do not release any gases.

BSA 96 is de-ironed and is inert with liquid phosphate binder for mortars and ramming mixes, providing a longer shelf life for these special type of refractory materials.



## BSA 96

### *Economic advantage*

BSA 96 has intergranular closed pores similar to tabular alumina. Therefore, the bulk density of refractory products based on BSA 96 is 5 to 8% lower when compared to brown fused alumina. The open porosity, which is important for corrosion resistance, is in the same range or lower. BSA 96-based monolithic formulations have a lower material demand and thus a lower specific cost at the same or even better corrosion resistance than brown fused alumina-based products.

### *Higher sinter reactivity*

When compared to fused aggregates, BSA 96 exhibits a higher sinter reactivity resulting in high

mechanical strength and abrasion resistance of the refractory products. Low-cement castables with BSA 96 showed, according to ASTM, abrasion values below 3 cm<sup>3</sup> at room temperature and even lower when tested in hot conditions (1200 °C).

The higher sinter reactivity of BSA 96 can also be noticed when used in AluMagCarbon (AMC) bricks. The spinel formation rate is increased and expansion is seen at lower temperatures than with fused aggregates.

The slag resistance of an AMC brick based on BSA 96 was found to be comparable to fused high alumina aggregate.



*APPLICATION: Delta section of electric arc furnace roof*



*BSA 96 (middle) shows no melt-outs compared to BFA (right); tabular alumina (left) for comparison*



## Calcium Hexa-aluminate (CA<sub>6</sub>)

### Unique sinter aggregates

Almatis offers an exclusive range of aggregates based on high purity calcium hexa-aluminate.

Calcium hexa-aluminate (CA<sub>6</sub>) is a highly refractory mineral that exhibits a particular combination of properties:

- Low thermal conductivity when compared to other aggregates of comparable density
- High chemical resistance in an alkali environment
- Low wettability by molten metals and slag (ferrous and non-ferrous)
- Low solubility in iron containing slag
- High stability in reducing atmospheres, e.g., CO

Almatis CA<sub>6</sub> products are composed of about 90% calcium hexa-aluminate with only a minor content of corundum and traces of CA<sub>2</sub>. The Almatis CA<sub>6</sub> products are differentiated mainly by their densities and porosities.

The dense CA<sub>6</sub> aggregate Bonite is the material of choice in applications where high corrosion resistance is the major focus. Bonite LD (low density) offers reduced thermal conductivity but still a sufficient level of corrosion resistance.

The super lightweight aggregate SLA 92 offers ultimate heat insulation at high temperatures and outperforms even ceramic fibers.

### INDUSTRIES USING ALMATIS CA<sub>6</sub> PRODUCTS:

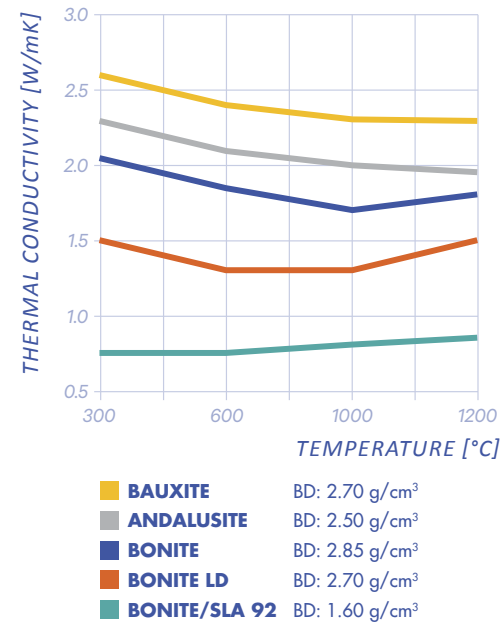
- Steel
- Aluminum
- Glass
- Foundry
- Cement
- Petrochemical

### Calcium Hexa-aluminate

Chemical Composition [%]	SLA 92	Bonite	Bonite LD
Al <sub>2</sub> O <sub>3</sub>	91.0	91.0	91.0
CaO	8.5	7.6	7.7
Na <sub>2</sub> O	0.40		
SiO <sub>2</sub>	0.07	0.9	0.5
Fe <sub>2</sub> O <sub>3</sub>	0.04	0.09	0.08
Physical Properties			
Bulk Specific Gravity [g/cm <sup>3</sup> ]	0.8	3.0	2.8
Apparent Porosity [vol. %]	70 – 75	9.8	24
Phase Composition (X-ray diffraction peaks)			
Calcium Hexa-aluminate (CA <sub>6</sub> )	main phase	main phase	main phase
Corundum (Al <sub>2</sub> O <sub>3</sub> )	minor phase	minor phase	minor phase
CA <sub>2</sub>	trace	none	none

# Bonite / Bonite LD (CA<sub>6</sub>)

Thermal conductivity of refractory materials used for steel ladle permanent lining



### Low thermal conductivity

Low thermal conductivity is inherent to calcium hexa-aluminate (CA<sub>6</sub>) based aggregates and can be transferred to refractory products, monolithics and bricks.

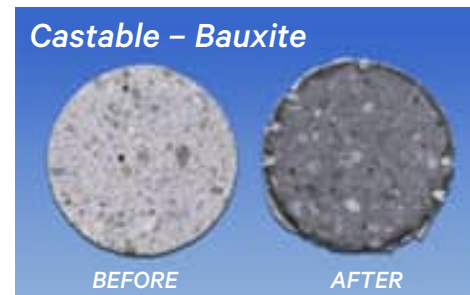
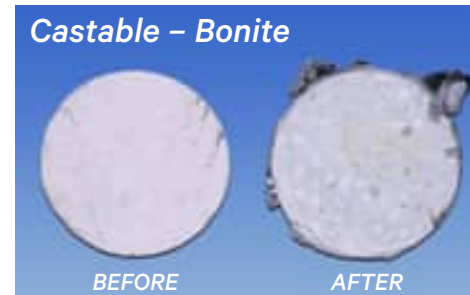
The combination of the three commercially available products, Bonite/Bonite LD as dense aggregates and SLA 92 as a super lightweight material, allows the developer of refractory products to create tailor-made solutions taking into account density, strength and thermal insulation.

### Energy saving and safety

High-alumina aggregates, like bauxite and andalusite, have widespread use in various industries, including materials for steel ladle safety linings.

In comparison with these standard materials, the corrosion resistance of bonite-based castables shows superior performance against steel slag at comparable porosity levels. The thermal conductivity of a bonite-based castable is 30-40% lower than for the typical bauxite-based material.

Reduced heat loss combined with high resistance against slag make bonite-based refractory materials the ideal choice when energy reduction is desired while keeping high safety levels.



Bonite corrosion resistance against aluminum; comparison with bauxite-based castable with anti-wetting additive

### Aluminum resistance at >1200 °C

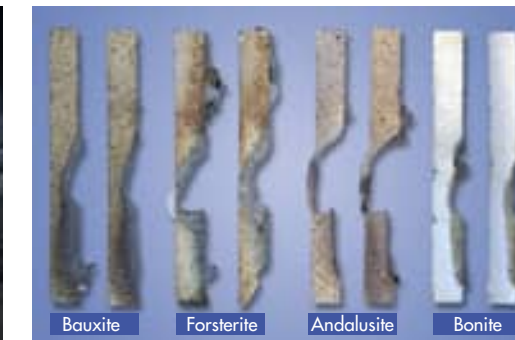
For aluminum applications, bonite provides an anti-wetting effect at temperatures >1200 °C where commonly used anti-wetting additives decompose. Corundum formation and build-up in aluminum melting furnaces are significantly reduced. At the same time, heat losses are reduced due to the lower thermal conductivity of bonite-based refractory materials in the wear lining. The relocation of the Al-liquidus line to the front of the refractory lining is an additional safety aspect.



APPLICATION: Aluminum melting furnace

### Alkali resistance

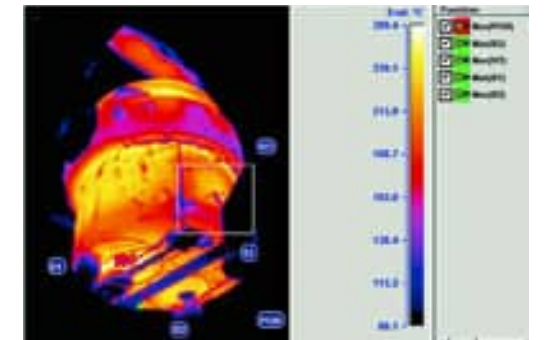
Applications such as glass and cement require a refractory material that is resistant to attack by alkalis. The destructive effect, called alkali-bursting, is caused by the formation of new mineral phases combined with high volume expansion within the lining. Because of its special mineralogical structure, bonite exhibits a high resistance against alkali attack. Alkali ions like Na<sup>+</sup> and K<sup>+</sup> can be incorporated into the crystal structure without significant change of volume. Therefore, calcium hexa-aluminate based refractories show much higher volume stability under alkali attack compared to other high-alumina refractories, providing that the matrix is designed accordingly.



Bonite corrosion resistance against steel slag

### BENEFITS OF ALMATIS BONITE:

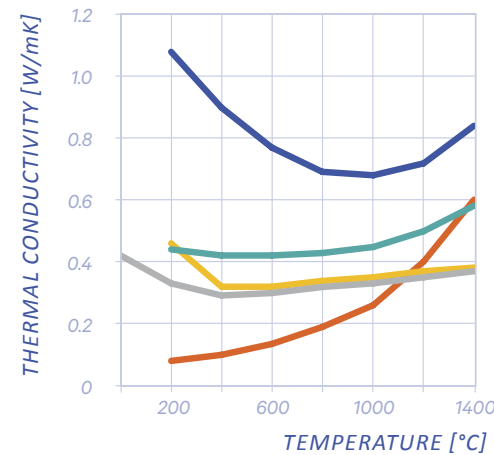
- High refractoriness
- Low thermal conductivity
- Low solubility in iron containing slag
- High stability in reducing atmospheres, e.g., CO
- High chemical resistance in alkali environment
- Low wettability by molten metals and slag (ferrous and non-ferrous)



APPLICATION: Steel ladle / heat loss

## SLA 92 – Super Lightweight Aggregate (CA<sub>6</sub>)

Thermal conductivity of high temperature, lightweight aggregates



- BUBBLE ALUMINA CASTABLE
- HIGH ALUMINA INSULATING FIREBRICK
- SLA 92 CASTABLE (1.1 g/cm<sup>3</sup>)
- SLA 92 BRICK (1.3 g/cm<sup>3</sup>)
- CERAMIC FIBER MODULE

### High-purity insulation

SLA 92 is a non-fibrous, high-purity insulating aggregate based on calcium hexa-aluminate (CA<sub>6</sub>).

Due to a special production process, SLA 92 has a high microporosity that hampers the heat transfer by radiation at temperatures > 1200 °C. The pore structure remains stable up to 1500 °C, which makes SLA 92 perform even better than ceramic fiber at high temperature.

SLA 92 can be used throughout all high temperature industries where increased process temperatures, along with the need for energy savings due to new environmental laws, require efficient high temperature refractory insulation material. The main use of SLA 92-based refractory products is in applications for the following industries:

- Steel
- Aluminum
- Foundry
- Petrochemical



ALMATIS SLA 92 microstructure (SEM)



APPLICATION: Liquid aluminum transport

### Fiber-free linings

The use of SLA 92-based insulating castables and gunning mixes overcomes concerns about potential health hazards.

The change from traditional fiber linings to a monolithic lining with SLA 92-based castable requires, in most cases, some re-engineering work. Nevertheless, high-insulating SLA 92 castables have successfully replaced hazardous fiber linings in various applications.

Prefabricated shapes made of SLA 92 are used in steel reheating furnaces, significantly improving the energy performance of the units.

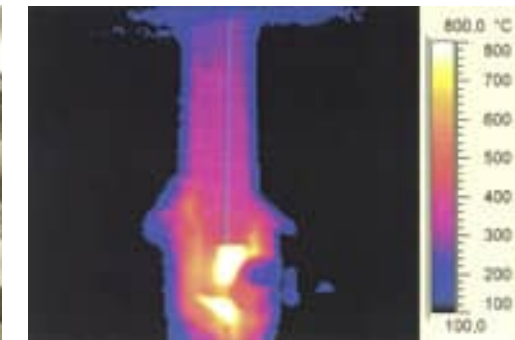
Aluminum transport ladles are lined with this highly insulating material. It is also used in petrochemical applications due to its high resistance in reducing atmospheres. Even under severe conditions, for example exposure to harsh thermal shock conditions or alkali attack, SLA 92-based refractory products have proven their high performance.

### BENEFITS OF ALMATIS SUPER LIGHTWEIGHT AGGREGATE SLA 92:

- Constant low thermal conductivity
- Very good insulation, even at high temperatures
- High open porosity
- Very good thermal stability
- Excellent thermal shock resistance
- High refractoriness
- High purity



APPLICATION: Walking beam furnace



APPLICATION: Steel, fiber-free insulation for sub-entry nozzles



APPLICATION: Insulation of ducts



## Calcium Aluminate Cements

High-purity calcium aluminate cements contain a minimum of 70%  $\text{Al}_2\text{O}_3$  and are used as binders in monolithic refractories.

Almatis produces high purity calcium aluminate cements with 70% and 80%  $\text{Al}_2\text{O}_3$  content.

70%  $\text{Al}_2\text{O}_3$ : CA-14 / CA-270 / CA-470 Ti / CA-670

80%  $\text{Al}_2\text{O}_3$ : CA-25

### *Broad CAC portfolio*

Depending on the type of cement, the curing and setting behavior varies significantly, impacting hardening and strength development. This allows the developer to choose from a wide range of calcium aluminate cements to find the right one to meet the desired properties.

### *Consistent setting*

Almatis calcium aluminate cements are tested to reflect customers' needs. Consistency in chemical and mineralogical composition, particle size distribution, and in flow, setting, and strength

are all essential for good and reliable cement performance. Intensive quality control is carried out to ensure high product consistency, which results in the high performance and reliability of monolithic refractory products made with Almatis calcium aluminate cements.

### *Long shelf life*

All Almatis cements are packed in sealed plastic bags that prevent reaction with humidity in the environment. Therefore Almatis cements have a long shelf life, with 24 months guaranteed when stored under adequate conditions, even when climatic conditions are challenging.

CA-14 M

CA-14 S

CA-14 W

CA-25 C

CA-25 M

CA-25 R

CA-270

CA-470 Ti

CA-670

## Calcium Aluminate Cements 70% Al<sub>2</sub>O<sub>3</sub>

The CAC 70 family of products includes:

### CA-14

CA-14 is a well-established product line with three distinct setting time ranges:

- CA-14 W short
- CA-14 M medium
- CA-14 S long

CA-14 type cements are used especially in low and ultra-low cement castables and gunning mixes for various purposes.

The cements are additive-free and for optimum flow properties require the addition of deflocculating additives. The use of Almatris dispersing aluminas is highly recommended, but CA-14 cements also work well with common deflocculating additives like phosphates or acrylates.

### CA-270

CA-270 is characterized by very low water demand, excellent flowability and high strength development. In established highly sophisticated formulations, CA-270 can give that extra 10% of water reduction to provide ultimate performance.

Like all Almatris 70% alumina cements, CA-270 does not contain any additives, providing full flexibility in product design without any potential chemical mismatches.

### CA-470 Ti

The latest Almatris development is the temperature-independent cement CA-470 Ti that shows clear advantages when compared to standard 70% Al<sub>2</sub>O<sub>3</sub> cements. CA-470 Ti improves the setting behavior of castables at low temperature whether or not they contain silica fume. Castables with CA-470 Ti exhibit a much more robust setting and avoid the setting time variation and uncertainty that are especially apparent at low ambient temperatures.

The flow of silica fume-containing mixes is improved when using CA-470 Ti instead of CA-14 M.

### 70% Cements

	CA-14 W	CA-14 M	CA-14 S	CA-270
Setting	short	medium	long	long
<b>Cement Properties in Nortab Mortar</b>				
Water Addition [%]	10	10	10	9
Vicat Setting Time [min] (Final setting)	220	300	400	370
Exothermic Reaction Time [min] (EXO max)	360	400	480	450
Cold Crushing Strength [MPa] (24h cured 20 °C)	48	48	48	52



# Calcium Aluminate Cements 80% Al<sub>2</sub>O<sub>3</sub>



QUALITY CONTROL: Manufacturing excellence



QUALITY CONTROL: X-ray diffraction testing

The CAC 80 family of products includes:

### CA-25

The 80% alumina cements are represented by:  
 CA-25 R regular grade  
 CA-25 M medium grade  
 CA-25 C casting grade

They are used in conventional and medium cement castables, which require fast setting, high early strength development and good strength at intermediate temperatures.

CA-25 type cements contain deflocculating additives. Any further addition of additives can lead to undesired effects due to unpredictable interaction between the additives used.

### 80% Cements

	CA-25 R	CA-25 M	CA-25 C
Setting	short	medium	long
<b>Cement Properties in Nortab Mortar</b>			
Water Addition [%]	10	10	9
Vicat Setting Time [min] (Final setting)	70	110	140
Vibration Flow [cm]			
F10	18	18	18
F30	13	17	17
Cold Crushing Strength [MPa] (24h cured 20 °C)	35	30	38

### BENEFITS OF ALMATIS CALCIUM ALUMINATE CEMENTS:

- High product consistency
- Very low mixing-water requirement
- Good flowability and setting consistency
- Very high purity
- High cured and sintered strength
- High thermomechanical properties
- Temperature independent product eases on-site application

# Alphabond 300

### High purity CaO-free hydratable binder

Alphabond 300 is a calcium-free hydratable alumina binder for use in no-cement refractory castable compositions. Alphabond has been developed for applications where the chemistry of the refractory matrix is critical to product performance.

### Calcium-free

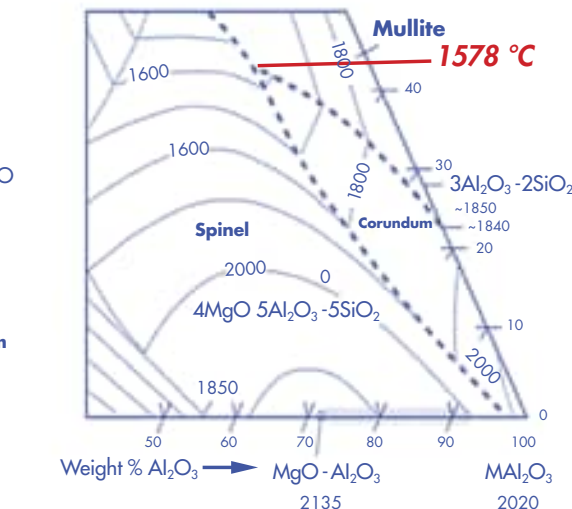
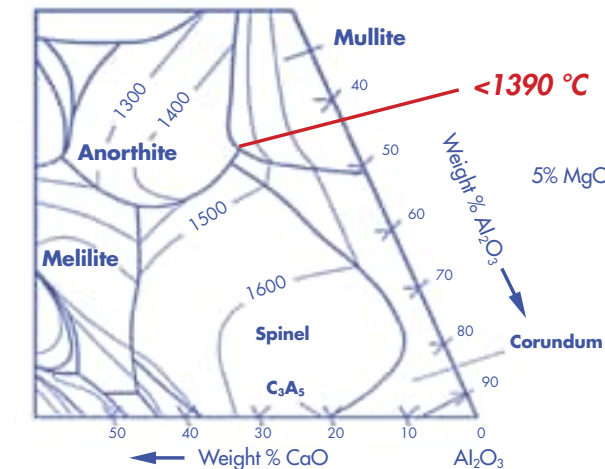
Alphabond 300 contains less than 0.1% CaO and thus avoids the formation of low melting point silicates in the matrix. Such calcium-aluminum silicates can have a significant harmful

impact on high temperature properties, notably strength (particularly creep) and resistance to slag attack.

Castables using Alphabond 300 require additional time to wet out after water addition to achieve optimum flow properties at lowest water content. The use of high force compulsory mixers is highly recommended. Apart from that, they act similar to a typical 80% calcium aluminate cement bonded mix with respect to working time, and initial and final setting time.

### BENEFITS OF ALPHABOND:

- Low water demand
- Reliable setting behavior
- Improved slag resistance
- Increased refractoriness for silica fume mixes





## Calcined Aluminas

### Competence in alumina conversion

Almatis offers a large product range of calcined aluminas that are produced with the latest state-of-the-art production technology. Calcined aluminas are alpha-aluminas that consist primarily of sintered agglomerates of individual alumina crystals. The size of these primary crystals depends upon the degree of calcination and the agglomerate size on the subsequent grinding steps. The majority of calcined aluminas are supplied ground ( $<63\ \mu\text{m}$ ) or fine-ground ( $<45\ \mu\text{m}$ ). The agglomerates are not fully broken down during the grinding, which is a significant difference from reactive aluminas that are fully ground by a batch grinding process.

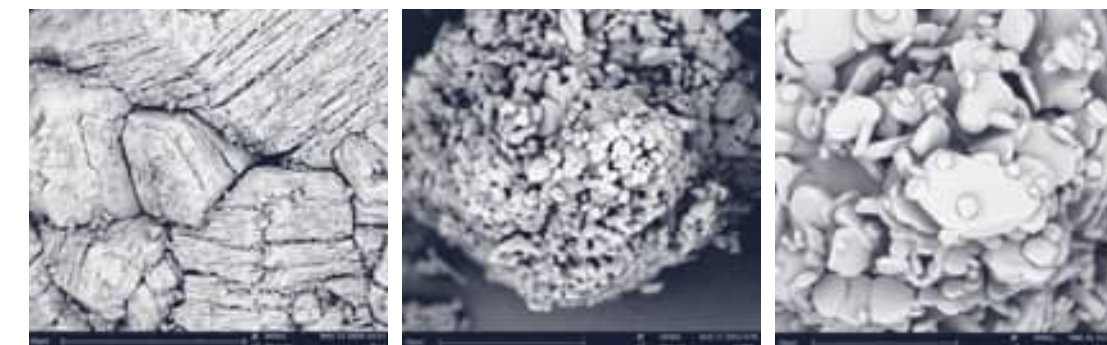
Calcined aluminas are classified by soda content, particle size and degree of calcination and are widely used in the matrix of:

- Refractory bricks
- Castables
- Gunning and shotcrete mixes
- Isostatically pressed pieces
- Sliding gate plates

All Almatis aluminas are produced to tight product specifications for chemistry, particle size distribution and specific surface area/BET. Many years of experience guarantee high lot-to-lot consistency supporting the production of highly reliable refractory products.

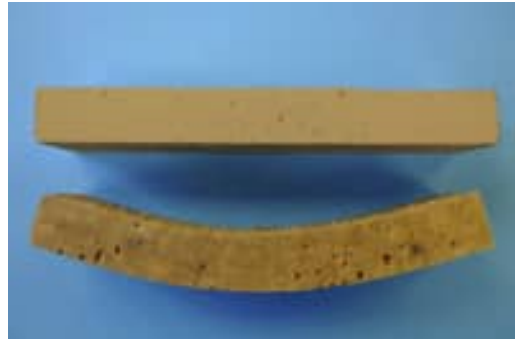
### BENEFITS OF CALCINED ALUMINAS:

- Enhanced refractoriness and performance
- Improved mechanical strength
- Abrasion resistance
- Thermal shock resistance
- Reduced water demand



Calcined aluminas with different degrees of calcination: low - medium - hard (SEM X4000)

## Calcined Aluminas



Sagging behavior of castable with (upper) and without (lower) calcined alumina addition

### Reliable matrix enhancer

Ground and fine-ground calcined aluminas are used as a matrix filler to upgrade the product performance of formulations predominantly based on natural raw materials. Calcined aluminas have a particle size similar to ground mineral aggregates and can therefore easily replace aggregates with lower purity. By increasing the overall alumina content of the mixes and improving their particle packing through the addition of fine alumina, the refractoriness and mechanical properties, such as hot modulus of rupture and abrasion resistance, are improved.

The water demand of calcined aluminas is defined by the amount of residual agglomerates and the surface area. Therefore, calcined aluminas with low surface area are preferred as fillers in bricks and castables. Special calcined aluminas with higher surface area, such as CT 10 SG and A 13 -325 mesh, can successfully replace clay as the plasticizer in gunning and ramming mixes. Refractory products modified by these products keep their good installation characteristics but show significantly reduced shrinkage after drying and firing.

### Calcined Aluminas

Physical Properties	A 10 -325	A 35 -325	CT 800 FG	CT 9 FG	A 2 -325	A 13 -325	CT 10 SG
Surface Area	low	low	low	low	low	medium	medium
BET/Specific Surface Area [m <sup>2</sup> /gm]	0.5	0.7	0.9	0.8	0.6	11.0	13.0
Particle Size D <sub>50</sub> Cilas [µm]	8.3	6.0	3.5	5.0	5.3	4.3	3.0
<b>Chemical Composition</b>							
Na <sub>2</sub> O [%]	0.08	0.11	0.12	0.15	0.25	0.12	0.4



# Reactive Aluminas

## High performance matrix components

Reactive aluminas are specially designed for the production of high performance refractories where defined particle packing, rheology and consistent placement characteristics are as important as the superior physical properties of the final product.

Reactive aluminas are applied in:

- Low and ultra-low cement castables
- No cement castables
- High performance gunning and shotcrete mixes
- High performance bricks and sliding gate plates

## High performance bricks and sliding gate plates

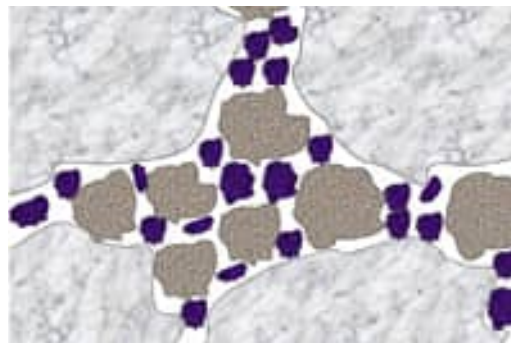
With the use of reactive aluminas, high performance bricks and sliding gate plates benefit in water reduction and improved ceramic sintering when compared to ground calcined aluminas.

The agglomerates in calcined aluminas have significant open porosity that absorbs water during mixing and casting. During firing, the porosity limits crystal growth at ceramic sintering temperatures leading to reduced thermo-mechanical properties.

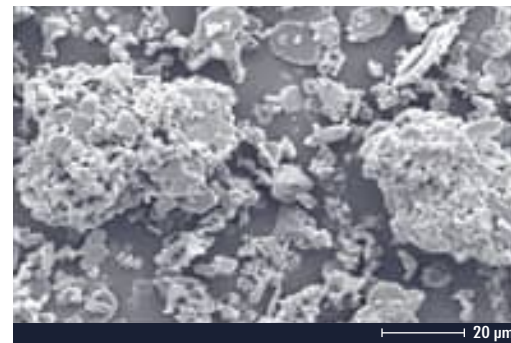
Reactive aluminas are fully ground down to the primary (single) crystals by highly

efficient grinding processes. The average particle size,  $D_{50}$ , of mono-modal reactive aluminas, is therefore nearly equal to the diameter of their single crystals.

The combination of reactive aluminas with other matrix components, such as tabular alumina 20  $\mu\text{m}$  or spinel 20  $\mu\text{m}$ , allows the control of the particle size distribution to achieve the desired placement rheology. Otherwise, high mixing water may be required and the product may suffer from inadequate physical properties or water and aggregate separation after casting.



Model for optimized particle packing



Calcined alumina CT 9 FG with residual agglomerates >20 microns



Reactive alumina RG 4000 fully ground to primary crystal

## Broad portfolio

Almatis has the broadest reactive alumina product portfolio available around the globe, with products from sub-micron to 3 micron particle size. Particle size distributions, ranging from mono-modal to bi-modal and multi-modal, allow full flexibility in formulation design and provide the convenience of co-milled engineered reactive aluminas.

Specially designed multi-modal aluminas, such as CTC 50 and CTC 55, are the optimized solution to achieve reliable self-flowing properties.

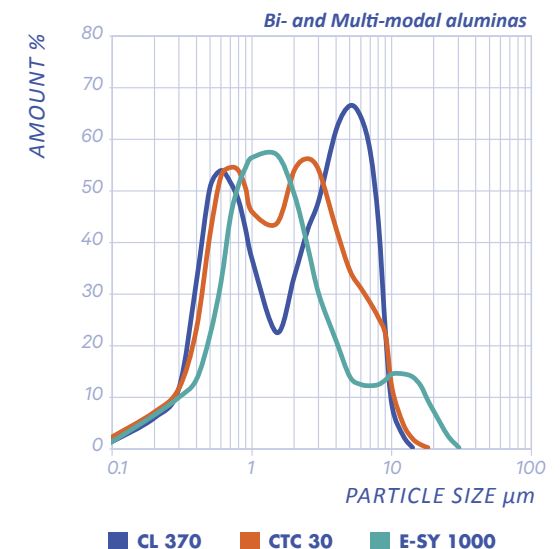
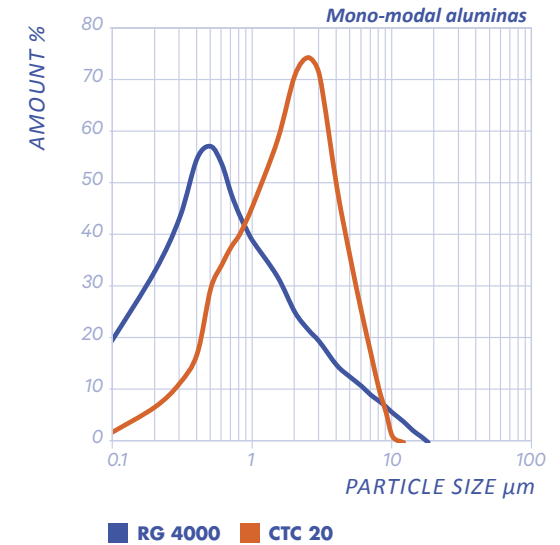
### Mono-Modal Reactive Aluminas

Physical Properties	A 1000 SG	RG 4000	A 152 SG	CTC 20	A 20 SG
BET/Specific Surface Area [ $\text{m}^2/\text{gm}$ ]	8.2	7.2	4.3	2.0	1.3
Particle Size $D_{50}$ Cilas [ $\mu\text{m}$ ]	0.6	0.6	1.2	1.8	3.3
Chemical Composition					
$\text{Na}_2\text{O}$ [%]	0.07	0.08	0.06	0.12	0.23

### Bi-Modal and Multi-Modal Reactive Aluminas

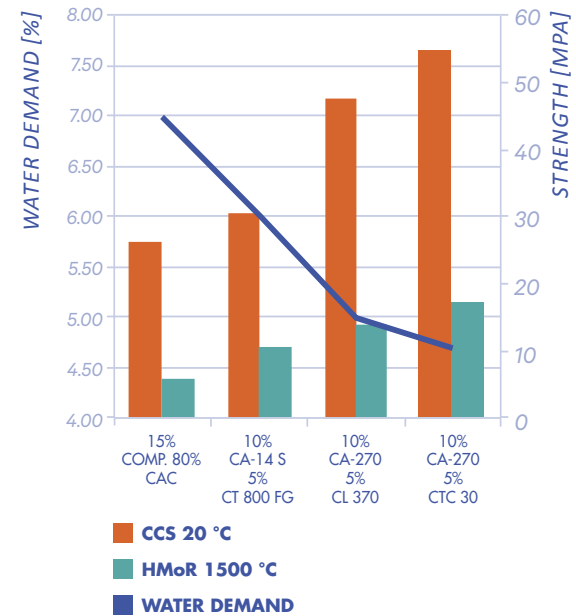
Physical Properties	CTC 40	CL 370	A 3000 FL	E-SY 1000	CTC 30	CTC 50
BET/Specific Surface Area [ $\text{m}^2/\text{gm}$ ]	4.8	3.0	2.5	2.0	3.8	4.1
Particle Size $D_{50}$ Cilas [ $\mu\text{m}$ ]	1.2	2.5	2.7	1.7	1.5	1.5
Chemical Composition						
$\text{Na}_2\text{O}$ [%]	0.08	0.10	0.07	0.2	0.08	0.16

Typical particle size distributions of selected reactive aluminas



## Reactive Aluminas

Impact of reactive alumina on water demand and cold crushing strength



### Mono-modal aluminas

Mono-modal reactive aluminas provide full flexibility to the refractory designer. Aluminas such as CTC 20 or A 20 SG, with a low surface area and water demand, are designed to be utilized in combination with silica fume and calcium aluminate cement to achieve the overall particle size distribution required for optimal particle packing and good flow behavior.

For high demanding applications like spinel-containing steel ladle materials, the ultrafine mono-modal reactive aluminas RG 4000 and A 1000 SG can replace microsilica in the formulation to increase thermomechanical stability.

### Bi-modal aluminas

The use of bi-modal aluminas, such as CL 370 or A 3000 FL, optimizes the packing density of the matrix and further reduces the water demand of the castables. They are typically used in high purity alumina matrix systems, but also work well with mixes containing lower amounts of microsilica.

### Multi-modal aluminas

The multi-modal reactive aluminas exhibit an extremely broad particle size range that has been optimized to reduce the number of matrix components needed. Their use minimizes formulation design time and the effort necessary to achieve extremely good physical and rheological properties. With the use of CTC 30, CTC 50 or spinel-containing CTC 55, self-flowing castables with high thermomechanical performance can be achieved.

### Soft consistency

The bi-modal reactive aluminas E-SY 1000 and E-SY 2000 (which contains spinel) offer a solution to overcoming dilatant rheological behavior, often observed for high alumina-containing castables, and for achieving a soft working consistency. E-SY-containing castables can be handled by shovel but can also be successfully pumped. The soft consistency of E-SY-based castables permits installations of difficult geometries, such as small gaps or linings with a high density of anchors.



## Reactive Aluminas

### Spinel-containing aluminas

Spinel-containing castables are typically used for steel ladle linings and prefabricated pieces such as purging plugs and well blocks. The resistance of these castables against steel slag corrosion depends largely on the amount and the fineness of the spinel. Experience shows that fine-ground spinel in the formulation is essential to achieve best performance.

Almatis offers reactive aluminas containing super-fine spinel for highly efficient matrix components for demanding applications.

Spinel-containing aluminas can be used in the same way as all other bi- and multi-modal aluminas, and allow the formulation of vibrating and self-flowing low cement, ultra-low cement and no cement castables with low water demand and good thermomechanical properties.

### BENEFITS OF ALMATIS REACTIVE ALUMINAS:

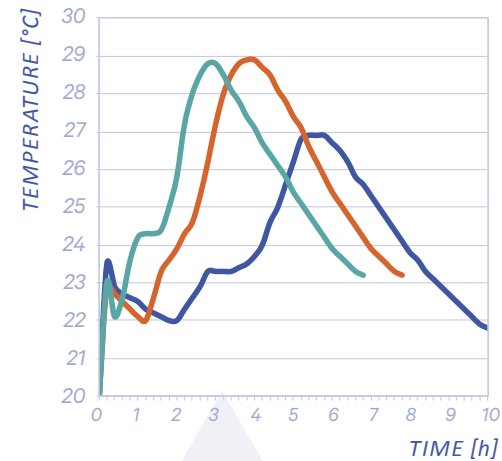
- *Very low water demand*
- *Low open porosity*
- *Excellent sinter reactivity*
- *Excellent wear resistance and mechanical strength*
- *Excellent high temperature performance*
- *Broad range to support individual preferences in formulation*
- *Improved flowability with E-SY products*
- *Ultimate corrosion resistance with spinel-containing reactives*

### Reactive Aluminas

Chemical Composition [%]	E-SY 2000	CTC 55
Spinel Content	50.0	35.0
Na <sub>2</sub> O	0.1	0.1
MgO	11.0	8.0
Physical Properties		
Grain Size Distribution	bi-modal	multi-modal
BET/Specific Surface Area [m <sup>2</sup> /gm]	2.3	3.8
Particle Size D <sub>50</sub> Cilas [µm]	1.4	1.6

# Dispersing Aluminas

Set control by varying dosage of ADS and ADW versions; measured in a low-cement castable.



EXOTHERMIC REACTION 20 °C: ADW 1 – ADS 3

- 0.6% ADW 1; 0.4% ADS 3
- 0.7% ADW 1; 0.3% ADS 3
- 0.8% ADW 1; 0.2% ADS 3

## Efficient deflocculation

The matrix of refractory low cement castables contains fine and ultra-fine particles such as calcium aluminate cement, reactive aluminas and silica fume. It is essential that all the matrix components are homogeneously distributed during mixing with water to take full advantage of the optimized particle size distribution, and achieve the lowest water demand and desired rheological behavior. Dispersing agents are commonly used to de-agglomerate the fine particles of the matrix.

Almatis dispersing aluminas are widely used in castable manufacturing. The combination of organic dispersants with alumina and other inorganic materials decreases the castable water demand and allows excellent setting control.

## Dispersing Aluminas

	ADS 1	ADS 3	ADW 1	M-ADS 1	M-ADS 3	M-ADW 1
FOR USE IN	CASTABLES WITH SILICA FUME <2%			CASTABLES WITH SILICA FUME >2%		
Effect	Retarding	Strong retarding	Accelerating	Retarding	Strong retarding	Accelerating
Chemical Composition [%]						
Al <sub>2</sub> O <sub>3</sub>	80	76	80	91	95	96
Na <sub>2</sub> O	0.10	0.10	0.10	1.40	1.40	0.10
B <sub>2</sub> O <sub>3</sub>	0.80	2.80	0.03	1.30	2.50	0.55
CaO	1.80	1.80	1.80	0.02	0.02	0.02

There are two different product lines of dispersing aluminas available for individual castable concepts:

- ADS 1 / ADS 3 / ADW 1 for high performance silica-free castables with alumina fines, and
- M-ADS 1 / M-ADS 3 / M-ADW 1 for fumed silica-containing castables using alumina fines.

Almatis dispersing aluminas are very efficient additives for optimizing properties of castables. When compared to traditional dispersing agents such as phosphates, the water demand can be significantly reduced to provide improved mechanical properties and better corrosion resistance.

## Set control

A unique feature of Almatis dispersing aluminas is the possibility of adjusting the setting time of castables, according to specific placement requirements and climatic conditions, without sacrificing the final strength development as is the case for other common additives for set control. The ratio of the retarding "S" type to the accelerating "W" type is varied to achieve set control.

The total amount of dispersing aluminas is recommended to be about 1% by weight in the castable. When keeping the total amount unchanged, the dispersing capability of dispersing aluminas remains stable no matter which ratio of S/W is used.

When compared to the classical phosphate-based deflocculating systems, the dispersing aluminas exhibit various advantages:

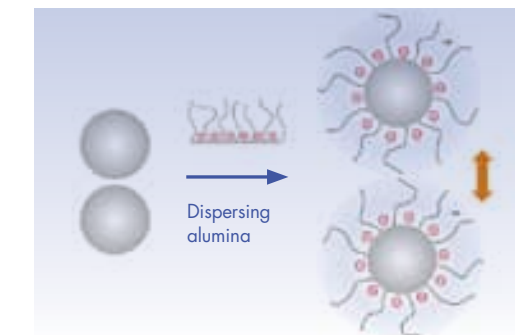
- Lower water demand and, therefore, higher mechanical strength and abrasion resistance
- Control of working time with low impact on the start of setting
- Aging resistance, for longer shelf life of the castables

## Robust dosage lowers risk

The recommended dosage for the dispersing aluminas is typically 1wt% in total, which guarantees a robust dosing for the production of refractory castables.

## BENEFITS OF ALMATIS DISPERSING ALUMINAS:

- Reduced water demand of refractory castable through optimized dispersion of finest particles
- Improved flowability
- Adjustable setting times (accelerating or retarding) in accordance with placement requirements and temperature conditions
- Increased homogeneity of dry castable, due to easy dosage of additives in production



Principle of electrosteric dispersion



Adjustable setting times

## *Alumina Expertise Starts in our Research Labs*

Innovation is the driving force for growth. Almatís' leading position in the industry is the result of ten decades of research and development of alumina-based materials. Today, many refractory applications would not be possible without Almatís innovations such as tabular alumina, sintered alumina magnesia spinel or reactive aluminas.

To maintain this level of innovation, Almatís has increased the staffing of its Product and Market Development organization while also investing in new application laboratories. An ambitious development program has been initiated and basic research work with research centers and universities has been reinforced.

Dedicated applications and market development managers and engineers provide our customers tailor-made technical support to help them optimize formulations and resolve application problems. New product developments pro-

vide the opportunity for our customers to further upgrade their own portfolio to stay ahead of their competition. Almatís engineers and market development managers are continually enhancing their application know-how to better support our customers' growth strategies.

An important part of the service that Almatís offers its customers is the application laboratories that are located in all major geographical regions. These labs have the latest technical equipment for enabling us to study the influence of Almatís products on the performance of our customers' products. In addition, Almatís offers its customers the opportunity to join us in our laboratories for training sessions or joint development work.







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