Almatis: Complete Alumina Expertise

global world class operations | continuous development of innovative solutions | applications know how

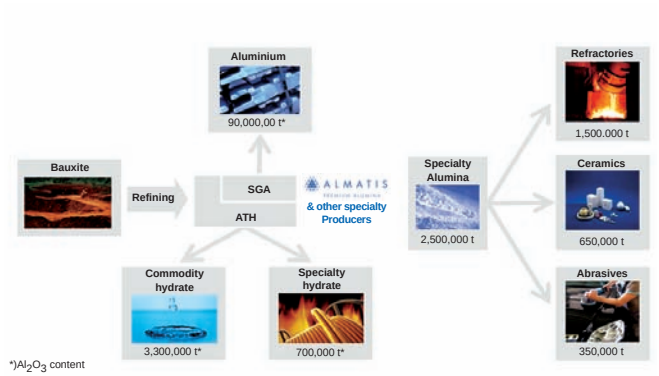
Almatis is the largest global producer of specialty aluminas with nine production plants around the world. Almatis started the specialty alumina business when it made the first sale of a calcined alumina to the abrasives industry in 1910. Almatis today provides premium aluminas globally to the refractory, ceramics and polishing markets. Products include tabular alumina, calcined alumina, reactive alumina, calcium aluminate cement, various spinels, alumina bonding agents and specialty aggregates - most recently introducing a brown sintered alumina of 96% Al_2O_3.*

Almatis Global Footprint - offering a complete product portfolio closer to the customer

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

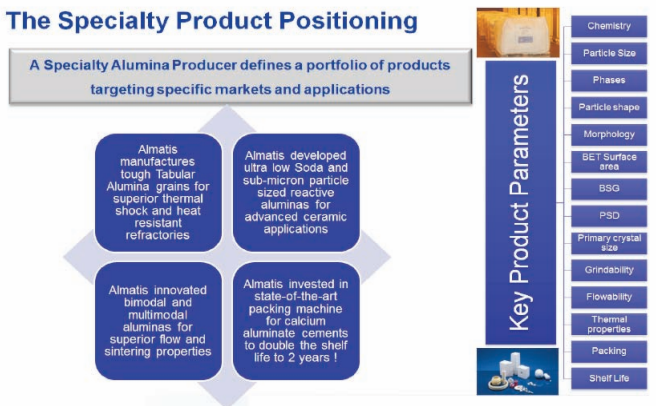
Specialty Aluminas - a distinct class away from smelters

In various forums in India, Almatis recently promoted the core business model associated with Specialty producers and described how this group of products is differentiated from more commonly known standard grade or smelter grade aluminas. The below chart shows the global market niche of Specialty Alumina, where Almatis is the market leader with a wide range of products and services.



Special Alumina Industry (2011 basis)

The key parameters and factors - like optimal size, footprint, technological edge, brand equity, customer service, technical service and innovations - are the essential ingredients for such a niche, specialty segment. The application and market dynamics in the user industries of refractories, ceramics and polishing generate many opportunities for the business to differentiate, innovate, maintain position in the market and add value. Accordingly, alumina products are engineered for quality, consistency and on-time logistics, which are ensured through best practices, lean management systems and technology support practiced at Almatis locations globally. A Specialty Alumina player, like Almatis, thus needs to invest in material science and research to a greater degree to remain competitive and profitable in the industry. The entire value chain thus becomes critical for being a leader, starting from feedstock sourcing and quality control, to application support to end users.



Almatis innovates and focusses on key engineering parameters, offerings solutions that secure a leadership position in the Specialty markets

Our Products: enhancing the 'life' under the most stringent conditions

Almatis offers the most comprehensive alumina-based product line to our customers globally. Across our core markets in refractories, ceramics and polishing, we can deliver one-stop-

** BSA 96 is a high temperature aggregate produced in Europe as a new, innovative refractory raw material alternative for >90%Al_2O_3 applications.*

shopping-always expanding our portfolio to meet customer and market requirements. Our products are essential ingredients in the manufacturing of refractories for the production of steel and cement, in ceramics, for producing polishing media, and in many other manufacturing processes.

The key products used in applications for refractories, ceramics and polishing markets are listed in Table 1.

Table 1: Almatis Products and Applications

Across our entire range of products, Almaits never compromise on quality. We strive for the zero-defect tolerance our customers expect. Having a clear understanding and detailed knowledge of our customers' production processes and technologies is a critical factor in meeting their needs and driving product innovation.

Reliability - supplying premium alumina products, anywhere, every time, on time

Our reliability is based on the operational excellence we achieve through a robust system framework. Premium aluminas by Almatis perform consistently. As part of this commitment to premium quality and service, we use state-of-the-art business tools such as Six Sigma, the Kanban system and the Almatis Business System (ABS), which we developed and refined specifically to improve our response to our customer needs. All Almatis locations are ISO-certified and are striving for ultimate efficiency and quality. The well-established reputation of excellent quality, consistent performance and timely availability stems from such a robust system framework, together with the capability of our people, technology and 100 years of specialty alumina experience.

Our worldwide technical sales network of experienced specialists is supported by the unrivaled expertise of Almatis - built through ten decades of alumina research and investment.

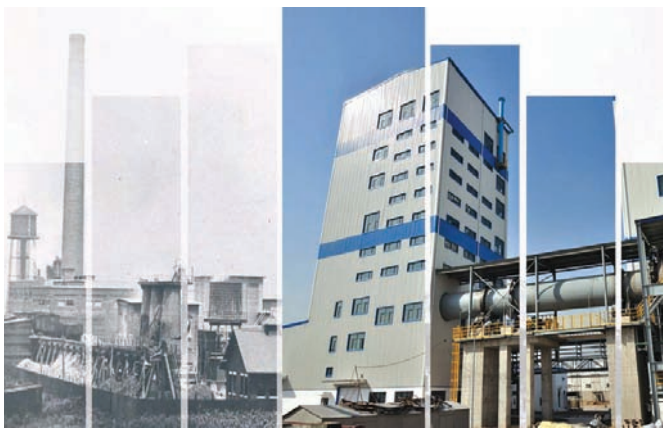
Customer Focus - supporting and enhancing our customers' business with quality products, excellent local service and technical support

To live our value of Customer Focus, Almatis has invested more than $100 million over the last five years in new capacities around the globe, located to support our customers' growth.

- In 2011, the company invested $6 million in a new crushing and sizing line at the Ludwigshafen, Germany plant, which enables crushing and sizing of different aggregates without the risk of cross contamination.

- In 2011, the group broke ground on its tenth alumina production plant, in Huangdao, China, adjacent to the current Huangdao tabular facility. This calcines kiln investment of over $40 million was commissioned in 2012. One of the biggest investments in our company's history, the resulting increase in our calcines capacity has a very large impact on our current business. This is the most modern calcination plant in both Almatis and Asia. All major ranges of calcined and reactive aluminas are being manufactured and supplied to Asian markets with this new state-of-the-art facility - utilizing the best practices of our global units. This investment also supports our strategy to invest in the growth regions for our business.

Bringing quality and consistency to our customer in everything we do



Almatis plant around 1905 vs. new calcines plant in Huangdao, China

- In India, we opened in February 2012 our new state-of-the-art application laboratory at the Falta plant. Its capabilities include cutting-edge equipment for castable preparation and testing, a Hobart mixer for preparing mixes, vibrating tables for flowability determination, exothermic equipment and a climate cabinet for monitoring castable setting, cold crushing strength and cold modulus of rupture testing equipments, as well as high temperature laboratory furnaces. This lab will enable us to enhance our capabilities by offering optimized custom solutions as leading-edge technical support. This is our commitment to the Indian market and the growth it offers.

Almatis 1948 Lab vs. New Falta Lab

- All Almatis plants and locations are ERP enabled (using SAP) and adopts lean management tools and systems like APO (Advanced Planner and Optimizer), the latest roll outs done in India in 2010, Japan in 2011 and Brazil in 2012. This helps Almatis to manage bulk volumes and enhance supply reliability and customer satisfaction.

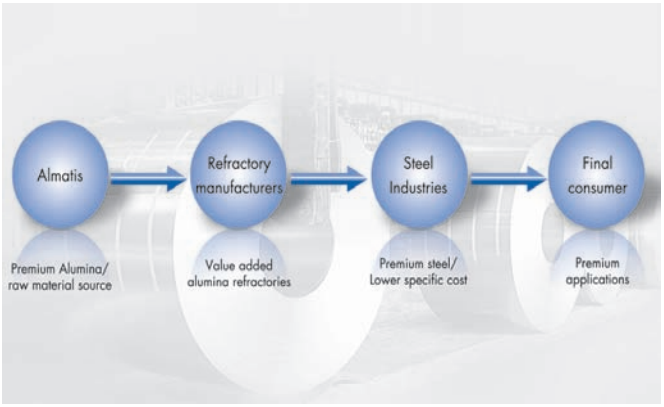
Almatis in India

Almatis' business activities in India trace back to 1995 when the Falta tabular processing plant was established. Now, the Falta plant processes both tabular alumina and calcined aluminas. Almatis Alumina Private Ltd., the Indian arm of the company, consists of the Falta manufacturing site, Falta warehouse and the regional office in Kolkata, ensuring quick response to the rising market demand in India. We offer the full Almatis specialty alumina product portfolio in India. As part of the global Almatis policy, the Falta site has established a management system in conformity with ISO 9001, ISO14001 and OHSAS 18001. We are a leading refractory and ceramic raw material supplier in India.

The drive of higher steel production in India, together with a strong emphasis on high quality steel, is challenging the already stringent demand on refractory quality and performance.

We believe our premium alumina material will add value to our refractory customers' business, and eventually assist in the production of premium steels.

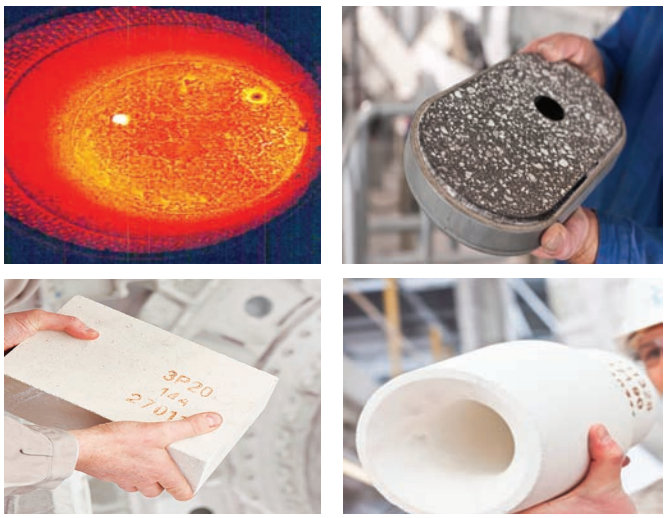
Almatis Premium Aluminas and their role in the premium steel value chain:



Value chain: premium alumina for premium steel

The modern trend of clean steel technology in the Indian iron and steel industry has given birth to a new generation of refractory raw materials. This originated with the iron and steel industry's demand for producing higher volumes of ultra-low carbon or specialty steel-with less pick-ups of carbon, sulphur, oxygen, hydrogen, nitrogen and other non-metallic inclusions-- and thus led to the need for severe operational parameters such as high casting temperatures and purging pressures. To cater to this steel operational demand as well as requirements for higher refractory service life, the Indian refractory industry needed to utilize synthetic raw materials such as tabular alumina which are more consistent in quality than natural or mined and fused raw materials such as bauxite or fused alumina. The local and secured availability of tabular alumina has already proved its significance as a high-quality synthetic raw material over imported alternatives, primarily from China. The current volumes of synthetic high alumina materials consumption show India still remains far behind compared to the developed countries (1.3-1.6 kg of synthetic aluminas per mt of crude steel production in Japan, Americas and EU19 against 0.5-0.9 kg of synthetic alumina consumption per mt of steel in India, China and Asia). Advanced vessel relining techniques using monolithic refractories and repair techniques such as gunning or shotcreting has already become very popular in developed countries and we are now expecting these same breakthroughs to trend in India.

Almatis, with its series of specialty aluminas available in India, offers significant solutions to the refractory industry that



Some typical applications using Almatis products: a) Monolithic ladle bottom; b) Slide gate plate; c) Alumina bricks; d) Precast nozzle

meet the stringent needs of modern-day steelmaking in India. The following sections evaluate selected Almatis value-added synthetic alumina products and share their relevant roles and functions in the manufacture of high performance refractories.

1. Tabular Alumina and its advantages over alternative raw materials

The performance advantage of tabular alumina lies primarily in its thermal spalling resistance, abrasion resistance and erosion resistance over alternative options. Table 2 shows

Table 2: Advantage of Tabular Alumina over other aggregates in Thermal Spalling Resistance

Grain (5 mm) Physical Properties of Al_2O_3 Aggregates								
Al_2O_3 Aggregate	Thermal spalling resistance % undamaged, Cycles 20°C - 1300°C - 20°C			Grain crushing strength after thermal shocking [kg], Cycles 20°C - 1300°C - 20°C			Grain strength breaking load [kg]	Apparent specific gravity [g/cm³]
	10 cycyles	20 cycles	30 cycles	10 cycyles	20 cycles	30 cycles		
Tabular Alumina	95	87	73	170	118	80	296	3.66
White Fused	68	19	0	21	4	0	105	3.89
Brown Fused	62	10	0	38	5	0	195	3.97
Spinel	82	53	20	43	30	12	242	3.26

(Method of evaluation: 5mm grains of each product are subjected to thermal cycles and the percentage of undamaged particles is calculated by sieving in 5mm screens. Grain strength is measured by impact load on a single grain and the load required to disintegrate the same is also measured.)

tabular alumina grains as a synthetic raw material produced in a continuous sintering process, and bearing comparatively lower apparent specific gravity, thus resulting in significantly higher thermal spalling resistance than white and brown fused aluminas.

This characteristic of tabular alumina is attributed to its typical microstructure. Figure 1 shows lower number of pores but larger pore size in the microstructure of WFA, resulting in 2% water absorption in the body-whereas optimal pore size and adequate closed pore distribution in the microstructure of tabular alumina results in 0.5% water penetration (or lower open porosity). Such distribution of tabular alumina crystallography helps to prevent slag infiltration in the application and provides better erosion resistance. In addition to this, lower amounts of impurity such as SiO_2, TiO_2 and Fe_2O_3, help retain higher hot strength in tabular alumina bodies. The very high bulk density and relatively dense large crystals of WFA impart brittleness in the white fused alumina bodies and thus are displaced in continuous surface contact resulting in lower abrasion resistance. But tabular alumina grains with unique crystal structure and comparatively lower bulk density tolerate increased toughness and thus exhibit higher abrasion index, even at elevated temperature. The lower abrasion resistance characteristic of a fused grain is utilized in designing an abrasive wheel where brittle behavior and generation of new surfaces are desired for superior cutting effect. Table 3 explains the physiochemical differences of various aluminous aggregates compared to tabular alumina.

Table 3: Characteristics of various aluminous aggregate

Characteristics	Unit	Bauxite	Brown Fused Alumina	White Fused Alumina	Tabular Alumina
Al_2O_3	%	85-90	**94-97**	**99.5**	**99.6**
SiO_2	%	5-10	**0.8-1.5**	0.02-0.05	**0.01**
TiO_2	%	3-4	**1.5-2.5**	0.01-0.05	**0**
Fe_2O_3	%	1-2	**0.15-0.5**	0.08-0.10	**0.04**
Alkaline Earths	%	0.4-0.8	**0.4-0.6**	0.03-0.05	0.02
Alkalies	%	0.2-0.8	0.2-0.4	0.3-0.4	0.33
Bulk Density	g/cm³	3.1-3.4	**3.8-3.9**	**3.5-3.9**	**3.55**
Apparent Porosity	%	10%	1.5	**8**	**1.5**
Water Absorption	%	4%	0.5	**2**	**0.5**

Figure 1: Microstructure of White Fused Alumina

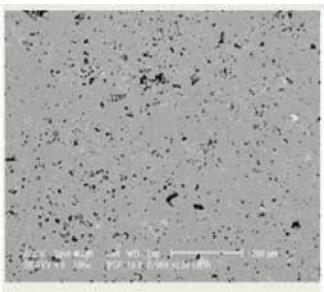


Figure 2: Microstructure of Tabular Alumina

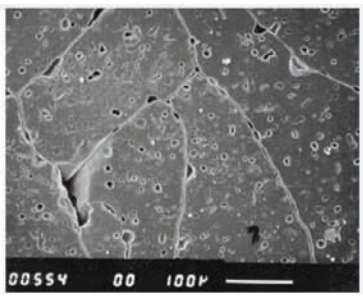


Figure 2a: SEM of thermally etched and polished section of Tabular

2. Application advantages of Tabular alumina

a) In Monolithics

The rheological behavior of tabular alumina containing castable differs significantly from a fused alumina body due to the inherent porosity distribution and grain shape differences. With a 4.2% water addition, it is possible to get a 240 mm vibration flow in a tabular alumina containing LC castable, whereas the same castable with WFA provides only 185 mm vibration flow with the same water addition owing to its variations in AP%. Or, in other words, around 1% more water is required to be added to a fused alumina containing castable than a tabular alumina containing one to achieve similar flow. This ultimately results in 2-3% lower apparent porosity in cast bodies with tabular alumina resulting in higher cold and hot strengths.

b) In High Alumina Bodies

100% tabular alumina-containing bodies (T100) show much higher compressive and tensile strengths than 100% white fused alumina (T0) containing bodies or their combinations. This is due to the higher thermal reactivity of tabular alumina at high temperatures and provides the opportunity for slightly reduced temperature firing (fuel saving) to achieve similar porosity, density and strength patterns for a good quality high alumina shape. The excellent abrasion resistance exhibited by a 100% tabular-based corundum brick is shown in Figure 3.

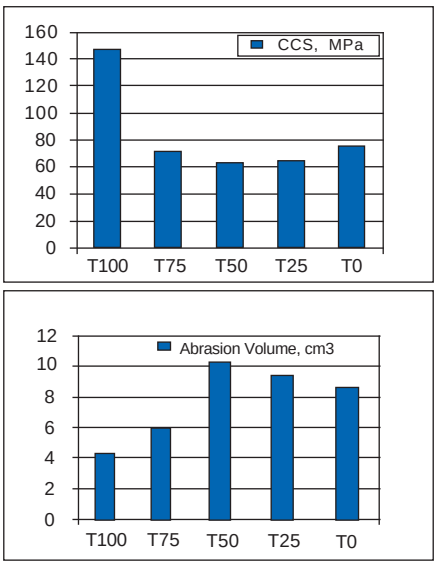


Figure 3: Mechanical strength and abrasion resistance differences among Tabular Alumina and White Fused Based Alumina brick (Ref: Testing at Luoyang Institute of Refractory Research, China)

(Note: T100 means 100% tabular, 0% WFA; T0 means 0% tabular, 100% WFA; T75, T50 and T25 are corresponding mixes)

c) In Alumina Magnesia Carbon Bricks

Alumina magnesia carbon brick with tabular alumina proves its suitability over fused alumina in steel ladle due to chemical consistency of different fractions. Since tabular alumina is more reactive in nature than WFA, proper selection of fractions and amounts are needed to obtain only the required expansions for joint tightening. An uncontrolled expansion may lead to structural spalling and low performance. A proper material designing with less MgO is sufficient to develop the required spinel formation to provide higher slag corrosion resistance. This spinel formation also results in densification at the hot brick surface and "seals" the bricks against low viscosity slag (containing CaF_2 and/or MnO). Properly designed AMC bricks with tabular alumina and ground calcined alumina such as CT9FG give predicted and uniform service life in steel ladle bottoms without the joint opening or slag penetration that is normally seen in WFA containing AMC bricks

d) In Blast furnace Trough Castable

Tabular alumina is of lower bulk specific gravity than brown fused alumina. A castable designed with tabular alumina requires lower quantity by weight than that of a BFA aggregate, thus demonstrating significant cost advantage owing to the bulk volume of a trough castable. Brown fused alumina containing castable shows poorer high temperature properties due to locally-occurring, low-melting phases at application temperature. The superior quality consistency of tabular alumina justifies its value in trough and runner castables compared to other alumina ingredients.

Figure 4: Pre-fired trough castable bars with tabular alumina and brown fused alumina; Almatis coarse Tabular Alumina 10-25mm

3. Matrix Aluminas from Almatis

Almatis provides a series of calcined and reactive aluminas tailor-made for specific value added applications in refractories. Table 4 shows the basic differences in characteristics for calcined and reactive aluminas, which are the significant performing

Table 4: Difference between Calcined and Reactive Aluminas

Parameters	Calcined Ground	Reactive Alumina	Examples
Alpha content or LOI%	May vary 70-95%	Always >95%	Not measured, as anything fired at high temp and pure (low soda) >95% Alpha
Particle Size	3-10 microns d50	0.5-2.5 microns d50	PS is not the sole property to be reactive
Particle Size Distribution	Mono and could be narrow	Mono and wider or multimodal	Multimodal may have higher d50, but better sinterability and flow behavior
BET Surface Area	Generally <2.5 m^2/gm	Varies 1.5-7 m^2/gm	High SSA with high Alpha most desirable
Purity	Soda 0.2-0.4%	Soda usually <0.15%	Higher soda will deteriorate thermal properties and flow

Table 5: Comparative analysis of Almatis aluminas and other standard available aluminas

Properties	Standard available Calcine	Standard available Reactive	CT9FG, Calcine	CT800SG, Calcine	CTC20, Reactive	CL370, Reactive	CTC40, Reactive	RG4000, Reactive
Alpha %	+++	+++	+++	+++	+++	+++	+++	+++
d50 µm	3.0-6.0	1.5-3.0	5	3.5	2	2.5*	1.2*	0.5
PSD	Narrow, Mono	Wide, Mono	Wide, Mono	Wide, Mono	Mono	Bi-modal	Bi-modal	Mono
BET m2/g	0.7-1.5	5-8	0.8	1	2	3	5.5	7
Na2O %	High	High	Low	Low	Low	Very low	Very low	Very low
WD %	Very high	High	Low	Low	Low	Very low	Very low	Very low
Vib. LCC -4.5% H2O, Flow	Very low	Low	High	High	High	Very high	Superior	Superior

(Note: The flow values above are aided by a microsilica based matrix for calcined alumina LCC and silica- free corundum matrix for reactive alumina based LCC)

components of a matrix. Table 5 gives the relative effectiveness of Almatis calcined and reactive aluminas compared to other calcined aluminas. For any aluminas to be used in a matrix, a tradeoff must be made between higher reactivity but lower shrinkage or a better flow but lower water demand. Combined properties of performing matrix aluminas and high alumina cements of Almatis (see Table 5) ensure these attributes in a castable.

From Table 5, it is evident that Almatis' series of calcine and reactive aluminas offer a wide range of choices for a refractory specialist to design the best quality matrix system. The lower particle size, wider or multimodal distribution, lower soda content and optimal (not too low or excessively high) BET surface area manifest in a castable as excellent flow with lower water demand. These aluminas are complemented by aggregate fines, like tabular or spinel -325# and calcium aluminate cements to form a robust, high performing matrix.

4. Calcined Alumina: CT9FG enhancing the performance like never before

Almatis' fine ground calcined alumina CT9FG is the "workhorse" for a good quality LC castable. It is characterized with a wider than standard PSD of ground calcines, low soda content and excellent rheological properties resulting from its low water demand characteristics. Figure 5 shows how a typical CT9FG PSD differs from commonly available ground calcines.

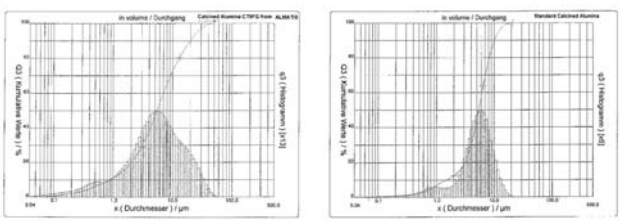


Figure 5: Wider PSD of CT9FG compared to a standard ground calcine

Figure 6 shows the rheological pattern of a standard tabular alumina-based LC castable with silica fume and 10% addition of fine ground calcined and reactive aluminas from different sources as the matrix. First, it can be seen that the water demand of the castables for similar mixing consistency varied for different aluminas, primarily due to the presence of monosized agglomerates. CT9FG-based composition remarkably shows the least water demand, even lower than some of the reactives. Second, for all other aluminas used in the experiment, flow decay was observed after 30 minutes and flow completely ceased within 60 minutes of casting. However, the CT9FG-based recipe revealed consistent flow - with only 20% decay after 60 minutes of casting. Both the compressive and tensile strengths after firing at 1500 ˚C for 5 hours are higher for CT9FG-containing castable. HMOR of CT9FG containing castable is notably more than double that of the others, due to low Na2O (below 0.1%) content. Today, Almatis in India successfully manufactures and supplies CT9FG with controlled BET surface area and strict quality parameters, ensuring our customers a guaranteed castable performance compared to other alternatives.

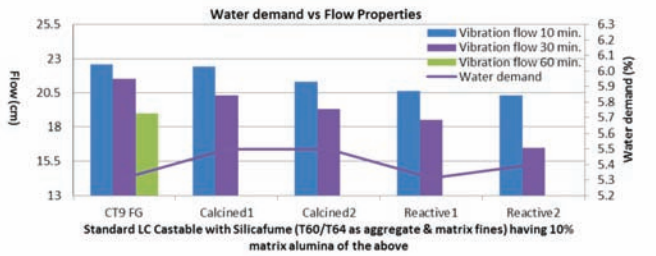


Figure 6: Rheological pattern of the LC castables with different aluminas

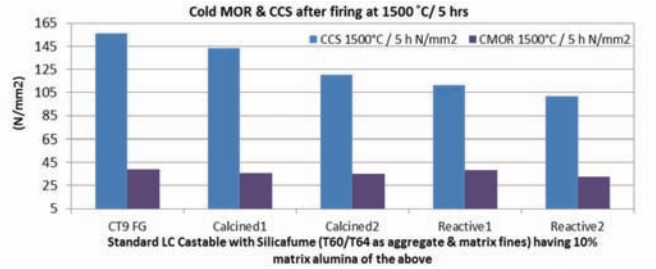


Figure 7a: Strength after firing at 1500°C of the LC castables with different aluminas

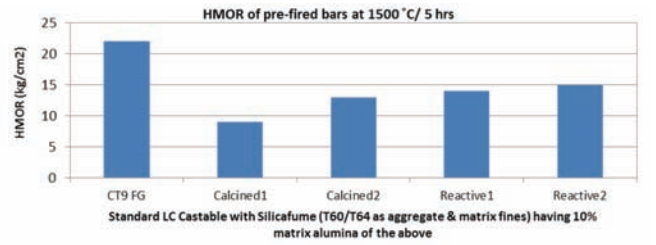


Figure 7b: HMOR at 1400°C/ 30 mins of the LC castables with different aluminas

5. Reactive Aluminas: Almatis dominates the +1550°C segment with a wide range of choice for customers

Almatis positions its performance enhancing reactives in the Indian market based on application needs of the customer. While application ease and comfort becomes one of the prime drivers of refractory design in the western world, we witness more emphasis on cost and performance for selecting a premium reactive alumina in India. The role of reactives is to impart excellent flow and hot strengths in premium castables where standard flow enhancers like microsilica could not be used due to > 1500°C application temperatures and presence of lime (from cementitious binders) and magnesia (from spinels). Further, reactive aluminas help to create a stronger, more robust corundum matrix and aid in attaining adequate strengths at relatively lower temperatures. In this section, we will review the unique solutions Almatis offers to design high performing ladle bottom blocks with some of our reactive products. In India, the reactive grade CL370 is the leading product-- an excellent bimodal alumina with high flowability in castables, but imparting controlled shrinkage characteristics in cast shapes. Tabular T60/T64 -20 microns, a super-fine ground crystalline tabular, further enhances the rheological effect and helps in casting and strengthening larger precast shapes with a low water requirement.

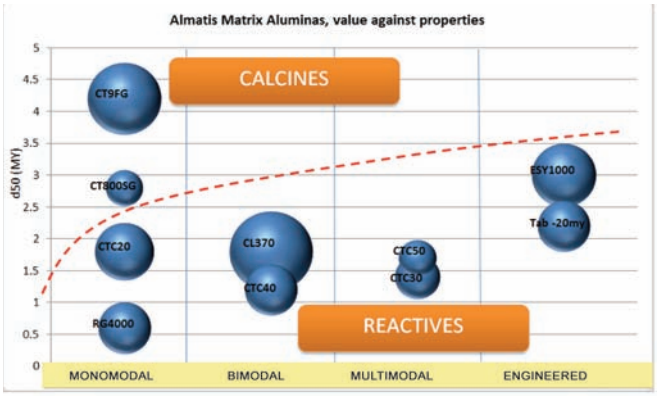


Figure 8: Positioning against market needs in India (sizes of the bubbles indicate relative value in the applications)

CTC20 and RG4000 are relatively strong reactive aluminas with close to 1 micron particle distribution range. Monomodal in nature, CTC20 can impart greater effectiveness to microsilica-based, low-cement castable and is a good flow enhancer, especially for alumina-SiC-based recipes. E-SY 1000 and E-SY2000 (reactive with Mg-Al spinel fines) are typical of new

Table 6: Reactive Alumina-based precast shape recipe, with and without spinels

Standard recipes for precast shapes		Tabular Alumina and Spinel-based LCC	Tabular Alumina-based LCC
Aggregate		%	%
T60/T64	Diff fractions	46	62
AR78	0 - 0,5 mm	15	
Matrix Alumina			
T60/T64	- 45 MY	7	10
T60/T64	- 20 MY	10	10
AR78	- 45 MY	7	
CL 370		10	13
Cement			
CA-14 M		5	5
Additives			
ADS 3		0,5	0,5
ADW 1		0,5	0,5
Properties			
H_2O demand [%]		4,5	4,5
wet out [s]		70	80
VIB-Flow [cm]	10 min	23,8	23,5
	30 min	22,5	22,7
	60 min	21,7	21,9

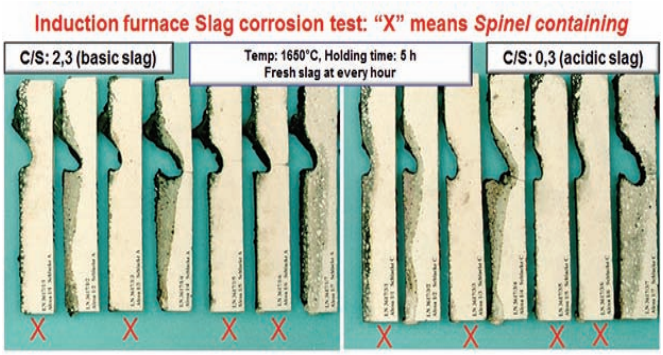


Figure 9 a: Slag corrosion test results of spinel containing castables

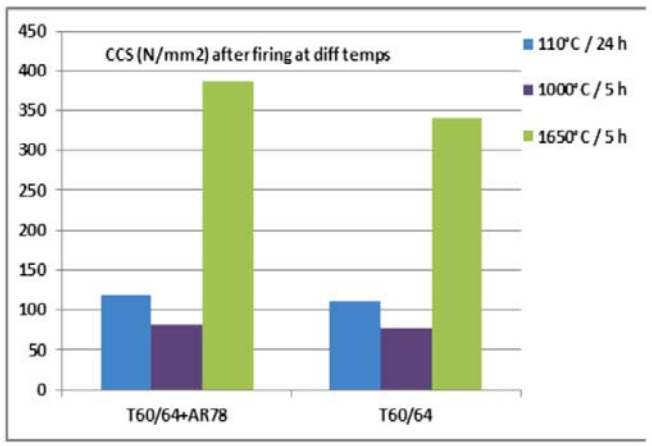


Figure 9 b: Properties of a silica free castable used for ladle bottom applications

generation reactive aluminas, where, the same product can be used for vibration flow, self-flow and pumpables by adjusting the dosage and aggregate design. Figures 10 depicts typical PSDs of some most popular reactive aluminas.

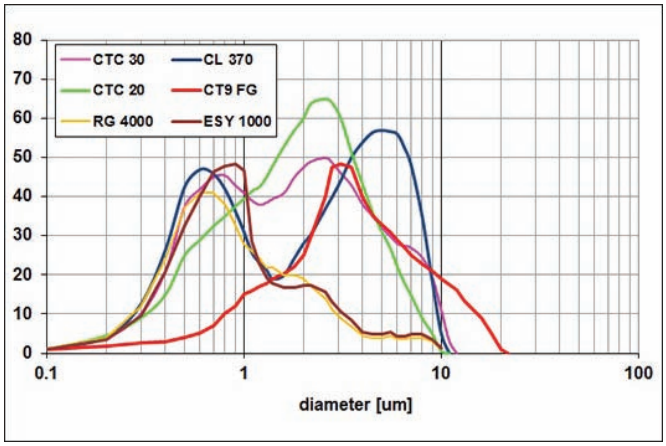


Figure 10: Typical PSD curves of some reactive aluminas

6. Magnesium Aluminate Spinels: the solution to clean steel production

High quality steel production requires extended treatment of the steel in the steel ladle. This has a remarkable impact on the steel ladle refractories, e.g. the need for high performance functional refractories like purging plugs. Operational changes such as increasing tapping temperatures, longer hold times and more aggressive secondary metallurgy are countered by the need for thinner refractory linings and longer refractories life. These combined factors were the prime drivers in developing engineered sintered-magnesium aluminate spinel raw materials- as a non-toxic alternative to MgO-Cr_2O_3.

The advantage of sintered spinel is that it is a continuous ceramic process, with controlled feed-rate and uniform temperature distribution in the kiln, leading to a very homogeneous product with crystal sizes of 30-80 µm and low porosity (<3%). Production of spinel by fusion, on the other hand, is typically a batch process. The large ingots require extended cooling time, which leads to inhomogenities in the microstructure as the poured ingot cools. Homogeneous fused-spinel materials can only be achieved by careful selection of processed material. Spinels based on bauxite and diaspore exhibit high, steady-state creep rates when compared to synthetic alumina-based spinel and hence the applications are limited to areas where low resistance to erosion or low hot strength is not a concern.

Magnesium aluminate spinels are increasingly being used in refractories for steel-making due to their particular

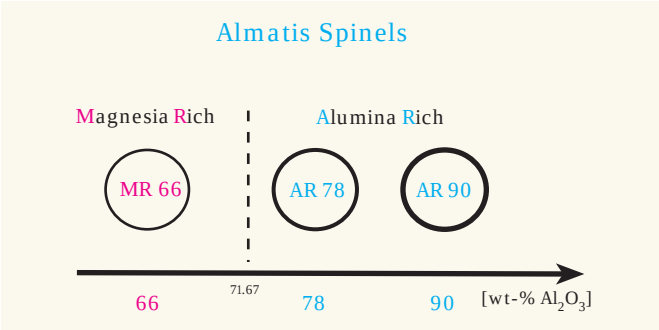


Figure: 11: Almatis Spinels composition scale

Important characteristics of Almatis Spinel

- Low impurity level [e.g. CaO, SiO_2] leads to high hot strength
- Synthetic and sintered spinel (not fused)
- No free Al_2O_3 in MR 66
- No free MgO in AR Spinel
- Low open porosity
- Large crystal size

combination of resistance to steel-making slag corrosion, thermal shock resistance and excellent hot strength. Also, Almatis' spinels are available in a various sizes, including AR78 -45 microns and -20 microns, providing the users many choices to design refractories targeting a specific solution.

a) Mechanism of Almatis spinel

- AR 78 and AR 90 with alumina contents of 78 and 90 mass percentage, respectively, incorporate into the spinel crystal structure (either at vacant lattice sizes or in substitution for MgO) low-melting, low-viscosity components like MnO and FeO in the infiltrated slag. As the slag composition becomes deficient in FeO and MnO, the slag viscosity increases and has a much lower tendency for penetration and erosion. AR78 finer fractions exhibit these characteristics better.
- AR 90, the Al_2O_3 rich, spinel solid solution becomes thermodynamically instable at steel-making temperatures and alumina is released from the spinel. The alumina reacts with CaO from the slag to form an inter-granular phase, calcium hexaluminate (CA6). CA6 is a very refractory phase (onset of melting at 1875°C) and the reaction exhibits, in addition, a volume expansion, causing a reduction in refractory surface porosity and reducing the tendency for slag penetration.
- In MR66, when added to magnesia bricks (cement kilns for

example), significantly enhances the thermal shock resistance due to the lower thermal expansion of spinel versus periclase, which leads to the formation of microcracks, acting as crack arrestors. Its main uses are in lime kilns, cement kilns and Mag-C bricks.

b) Almatis spinels and the requirements in steel ladle

The physical characteristics of a typical steel ladle refractory needed across the ladle design are tabulated in Table 7. It is common that the impact area and ladle bottom (lining and blocks) undergo the most severe abuse during steel refining, and even commonly used magnesia carbon and dolomite/AMC shapes are not able to reliably exceed the user's expectations. Moreover, the carbon pick-up due to higher consumption of lining material is a concern.

Table 7: Refractory requirements in a steel ladle

	Ladle side wall	Ladle botton	Impact area (pad)	Well block/ Purging
Thermal stability	++	++	++	+++
Thermo-mechanical	+	+++	+++	+++
Erosion resistance	+	++	+++	+++
Corrosion resistance	++	++	+++	++
Potential f. stress relaxation (thermal shock resistance)	+++	++	+++	+++

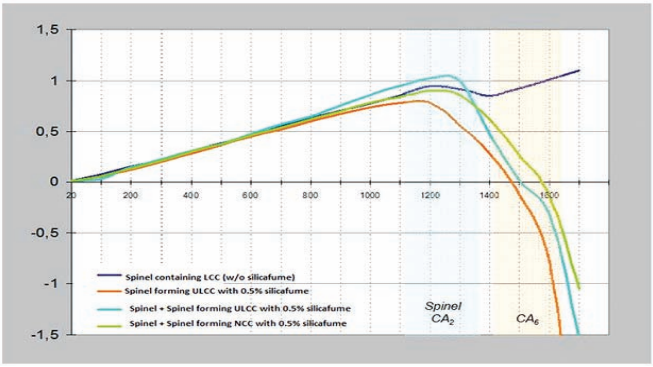


Figure 12: Typical pre-formed AR78-based castable showing improved RUL compared to in-situ spinel based castable

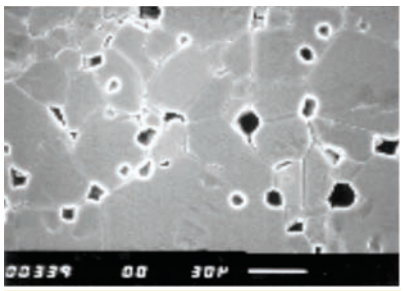


Figure 13: SEM of Almatis AR78 Spinels: polished sections, thermally etched at 1680°C showing crystal size [mm]: 60-80

Table 8 provides the optimal solution with Almatis' pre-formed spinel products when suitably designed with Tabular Alumina aggregates for different parts of the Ladle lining. It is evident that owing to varied thermo-mechanical characteristics undergone in a steel ladle during operation, a combination and trade-off between the properties will give the user an optimal result and performance

Table 8: Refractory requirements catered by different Alumina Spinel products

	Spinel	Alumina-magnesia	Alumina-magnesia + Spinel	Alumna-magnesia + Spinel /NC
Thermal stability	+++	+	+	++
Thermo-mechanical	+++	+	+	++
Erosion resistance	+++	+	+	+
Corrosion resistance	++	++	+++	++
Potential f. stress relaxation (thermal shock resistance)	++	+++	+++	++

As the Indian refractory sector is poised to face the ever-increasing challenges of modern steel making in the new decade, Almatis is further strengthening its product and technical base in India. Through the effective utilization of the application laboratory, customized solutions, joint development projects and specific products for target applications, Almatis provides the much needed alumina expertise for the industry to gain significant competitive advantage. Customers and end users can together attain the ultimate value while using Almatis specialty aluminas available at their doorstep with a complete techno-commercial solution.

"There will be an increasing demand for synthetic high-alumina-based-materials in India's refractory market."

Almatis eyes the country of India as most pivotal which is rearing to pave ahead with optimum growth. With the country's refractory market demanding synthetic high_alumina_based_materials, Leslie Power, Vice President - Commercial Refractories, Almatis discusses company planning, technology norms and the outlook of Indian refractory industry with Iron & Steel Review Magazine.

Leslie Power, VP Commercial Refractories of Almatis

Iron & Steel Review : What is Almatis strategy in India? As you've just invested a new lab in Falta, will there be more investment from Almatis?

Leslie Power : Almatis considers India a strategic market with significant growth potential. We strive to be the premium alumina supplier of choice in servicing the rapidly growing needs of our customers in the Indian market.

Reliable supply of high-quality products and exceptional service are key components that Almatis brings to the market. By investing in the application lab in Falta, we are able to work closely with our customers on optimizing their formulations by suggesting refractory solutions in the end applications. New product solutions that focus on the Indian market needs are being developed locally now. In the future, our target is to expand our production capacity to support the growth of our customers and ensure a secure supply of material.

ISR : What do you think is the technology trend for the steel industry, and will that bring some new requirements on the refractory industry?

LP : Today, automotive and higher-end steel applications require clean steel. Clean Steel Practices drive the need for increased usage of synthetic aluminas such as Almatis materials in both ladle linings and higher performance flow control devices.

Ladle Metallurgy is also a strong driver for the shift towards increased usage of synthetics. Ladle metallurgy conditions are becoming more severe for the production of clean steel and thus require higher quality materials in the steel ladle. Due to their superior performance, such higher quality materials can achieve lower specific cost in spite of higher material prices when compared to conventional refractory solutions. Advantages include a longer lining life and relining technologies instead of complete replacements. This reduces the specific refractory consumption.

ISR : What are the major advantages synthetic materials enjoy over nature material for refractories?

LP : We continue to see a shift from natural minerals to synthetic materials due to the consistency and quality that comes with further processing. Due to Almatis' process technology and operational know-how, our products offer the best quality and consistency in the market place. In addition, the production of clean steel requires thermodynamically stable refractory, which is a clear advantage of synthetic alumina-based materials when compared to natural minerals such as bauxite or alumino-silicate minerals.

ISR : For the refractory industry, what's the gap between the Indian market and the Western/mature market? How does Almatis see the Indian refractory market evolving?

LP : The chart below shows very well the gap between India and Western markets in the use of synthetic materials.

Synthetic High Alumina Materials Consumption Estimated range: kg/mt Crude Steel Production	
Japan	1.4-1.6
Europe (EU 15)	1.3-1.5
Americas	1.3-1.5
Russia, Eastern Europe	0.7-0.9
China, India, Other Asia	0.5-0.9

Within Almatis, we see the Indian refractory market still relying on bricks and shapes while monolithic and application technology is yet to attain mature market status. Mag-carbon and other basic bricks still dominate the secondary refining/ladle linings in almost all steel plants in India compared to the Western world and Japan, where cleaner steel solutions are met with carbon free, alumina-spinel monolithic ladle linings. This, we feel, is primarily due to lack of proper application technology as well as limited market pull from steel plants. This is likely to change soon as the need for cleaner steel, higher energy conservation and operational ease is developed, and we can see that happening with our higher spinel sales in steel ladle applications in India.

ISR : Finally, as the global economy is still fraught with uncertainty, what's the prospect for Indian refractory in 2013?

LP : India has shown its strength during the 2008-2009 global slowdown. Due to growing internal demand, high consumer population and much lower per capita consumption of steel compared to other regions, India is poised for a phenomenal growth curve. What we see today is that investment sentiment is low due to economic uncertainty, but we at Almatis feel this is very short term. Although big projects are being delayed, the steel demand and production is still growing. We are cautiously optimistic about an economic recovery in 2013 as delayed projects need to pick up quickly enough to catch up with the infrastructure, power and construction growth targets. We believe the Indian market will rebound and show steady growth over the next few years.