THE BLUELINE PURGE PLUG DEVELOPMENT AND THE VIBRO-DENSE-BOTTOM CONCEPT[1]

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Abstract
Our company is a long established European manufacturer of high quality ceramic shapes for use in the steel making process. Due to the ever increasing need for cleaner, higher quality steel grades the R + D focus of the group has been directed towards value in use of refractory solutions to assist the customers in this goal. A significant response has been the development of the purging systems that resulted in the introduction of high technology alumina–spinel based directional plugs and blocks that proved an important step forward from the traditional "top lance" and porous plug routes traditionally used. This paper will outline the history of these developments culminating in the introduction to the market place in 2006 of the new "Blue Line" range of purge plugs and the Vibro-Dense Bottom Concept. This includes the Clean Steel Block (CSB) for improved steel cleanliness, ladle yield and the use of self flow castables for the ladle bottom. Through a close technical and commercial cooperation those products range is now being launched in South and Latin America.
Key words: Purgeplugs; Ladles; Ladle bottom.

O DESENVOLVIMENTO DO PLUG "BLUE LINE" E O CONCEITO DE FUNDO DENDO VIBRADO

Resumo
Nossa empresa é um antigo produtor Europeu de peças cerâmicas de alta qualidade para uso em processos de produção de aço. Devido às necessidades crescentes de limpidez e qualidade do aço, o foco de P + D do grupo tem sido dirigido para soluções de valor do refratário para o usuário atingir seus objetivos. Uma das respostas significativas desenvolvidas foi o sistema de rinsagem que resultou na introdução da alumina - espinélio de alta tecnologia baseado em sedes e plugs direcionais que provaram ser um passo adiante à tradicional "lança de topo" e plug poroso. Este trabalho delineará a história deste desenvolvimento culminando na introdução no mercado em 2006 do novo plug "Blue Line" e do conceito "Vibro-Dense-Bottom". Isto inclui o Clean Steel Block (CSB) para aumento na limpidez do aço e rendimento metálico e o uso de concretos de fluência livre para fundo de panela.. Através de uma cooperação técnica e comercial os produtos estão sendo disponibilizados na América Latina.
Palavras-chave: Plug de rinsagem; Panelas, Fundo de panela.

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1 INTRODUCTION

There is a twenty year history behind the development of dense vibration castables (1985-2005) based on High Alumina and Alumina Spinel. The quality range goes from Low Cement Castables and Ultra LCC to Cement Free Castables.
During this period one of the main driving forces behind the development process was the quest to establish extreme dense vibration masses in order to produce vibrated slide plates without tar, pitch or resin impregnation with the same or even better physical properties as pressed and impregnated slide plates.
This development was the basis for continual improvements in castables that could also be utilised in other existing and new products such as new types of purge plugs. The result of the purge plug development is the introduction of the new “BlueLine Range”
The Clean Steel Block (CSB) is an important new addition to the portfolio. This revolutionary concept helps to increase ladle yield and improve steel cleanliness.
Utilising these recently developed castables and new component products it is now also able to offer the unique “Vibro-Dense-Bottom” concept to improve the ladle bottom performance due to higher bottom life or increased ladle capacities due to reduced bottom thickness.

2 PRODUCT HISTORY AND DEVELOPMENT

Twenty years ago our product range was completely based on MgO formulations. The main refractories produced were nozzles, blocks and skimmer plates. In April 1993 the first production of high alumina, spinel containing castables was started. The “in house” R & D programme on this product range led to the development of cement free variants, self flow mixes and finally, in 2004, the “advanced alumina spinel castable”.
A comparison between a standard alumina spinel castable and the advanced development product can be seen in Table 1.

Table 1 - Chemical properties of conventional and advanced alumina spinel castables.

Castable		Conventional	Advanced
	Al_2O_3	96	95
	MgO %	2.3	2.3
	CaO %	1.5	1.9
	SiO_2 %	< 0.10	< 0.10
	Fe_2O_3 %	< 0.10	< 0.10

Whilst the two types of castable have a relatively similar chemical analysis, the physical properties of the advanced development exhibit greatly improved results, as shown in Table 2 and Figure 1. This is the basis for significant improvements in service applications.

Table 2 - Physical properties of conventional and advanced alumina –spinel castables

Castable		Conventional	Advanced
Bulk Density g/cm³	After Drying	3.11	3.24
CCS N/mm²	500 °C 1600 °C	56 167	142 >200
MOR N/mm²	500 °C 1600 °C	6 29	12 41
Porosity %	1600 °C	18	< 14
HMOR N/mm²	1500 °C	13	>30

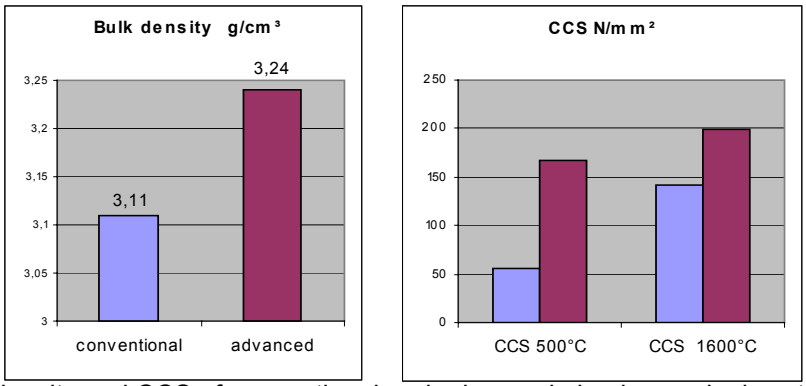

Figure 1 - Bulk density and CCS of conventional and advanced alumina –spinel castables

3 LADLE BOTTOM CONCEPT

The ladle bottom concept covers four principle areas: the purging system, the sliding gate system, pre-shaped parts (impact pads) and self flow bottom castables. Also familiar are lining configurations with bricks in the bottom and sidewall. In this paper, however, we will only focus on the monolithic lining concept and the utilisation of the BlueLine Purge Plugs and the Clean Steel Block (CSB) as seen in Figure 2.

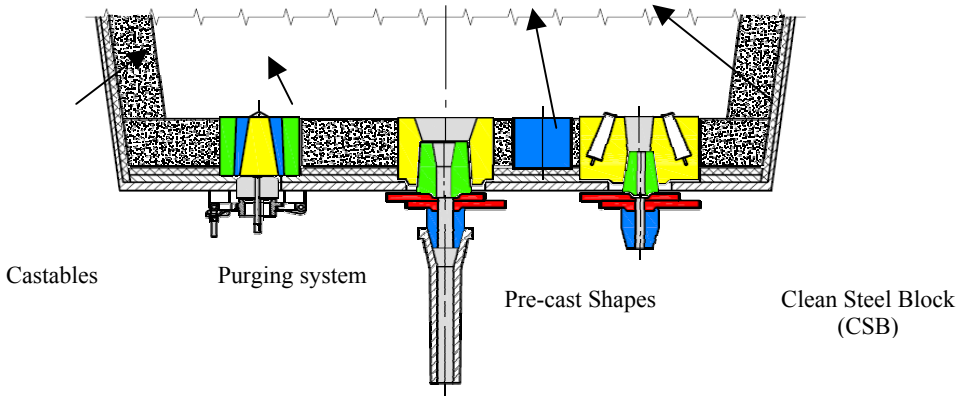

Figure 2 – Ladle Bottom Concept areas

3.1 Purging Systems

For high clean steels such as ultra-low-carbon or IF grades an efficient, reliable purging system with inert gases is absolutely essential. More and more steel plants now use vacuum degassing units without the possibility to use lances for top purging, so the demands on the purge plugs are ever increasing.
The substitution of the conventional spinel castable for the advanced development formulation has given significant performance benefits in the purge plug and housing block area of the ladle bottom. It has been seen in actual plant usage that increases in life in excess of 20% can be experienced when comparing against the results with the original standard castables..
Figure 3 shows the generic development of the purge plug range that has now benefited from the introduction of the advanced spinel castables.
The radial slit configuration in the RS plug can accommodate up to 48 slots. The HP plug is designed with a single round slot whilst the HP – Turbo model combines both previously mentioned techniques.

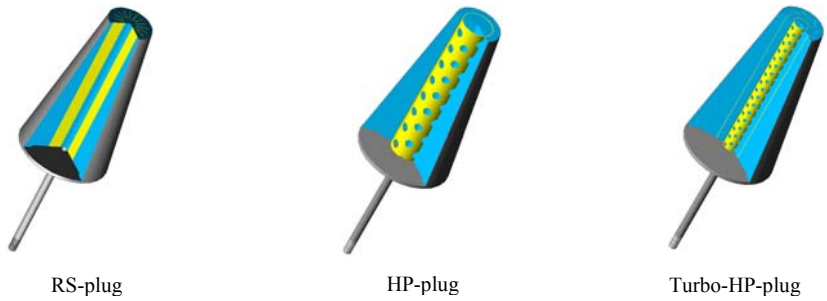

Figure 3 – Different designs of standard purge plugs

3.1.1 The blueline purge plug

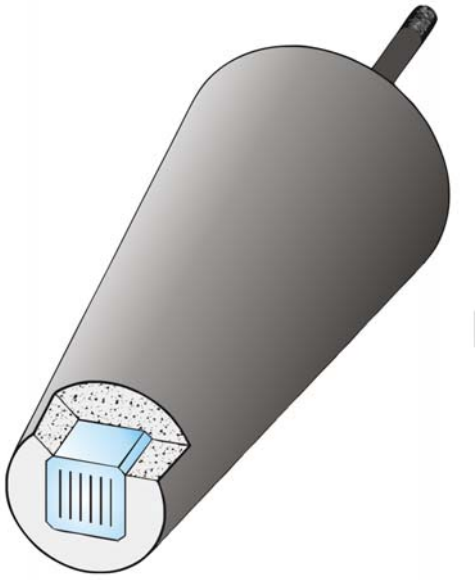

Figure 4 – Design of BlueLine-plug with high fired inner core

The latest development, the BlueLine plug (see Figure 4), has a pre-fired inner core. Just one of the benefits of this design is a lower coefficient of friction that can lead to higher flow rates. Traditional production techniques utilising an outer metal can, as a mould, have limitations when considering the firing temperatures of the plug. With the aid of the advanced alumina-spinel castable range we are now able to “pre-fire” the inner section up to temperatures of 1400 deg C. Due to the ceramic sintering processes experienced in the refractory core this results in an extremely stable and smooth series of channels to allow gas flow. Tests have shown significant increases in flow rates of up to 10% when compared with conventional plugs. The extra volume stability and physical consistency achieved with the higher pre-firing also contribute towards improved slag and steel penetration and crack resistance. Current trials in steel plants are confirming these properties and demonstrating increased plug life and greater purging availability.

The stable fired inner core of the BlueLine plug exhibits an extremely smooth inner surface, this reduces the effect of friction on the gas flow channel considerably and results in the plug having an extremely fast reaction time (see Figure 5) when the argon supply is switched on and off. In comparison with standard conventional slot type plugs the BlueLine plug allows the steelmaker to increase sensitivity and control over the purging gases; this is particularly of benefit when secondary steelmaking treatments such as a tank de-gasser unit are employed.

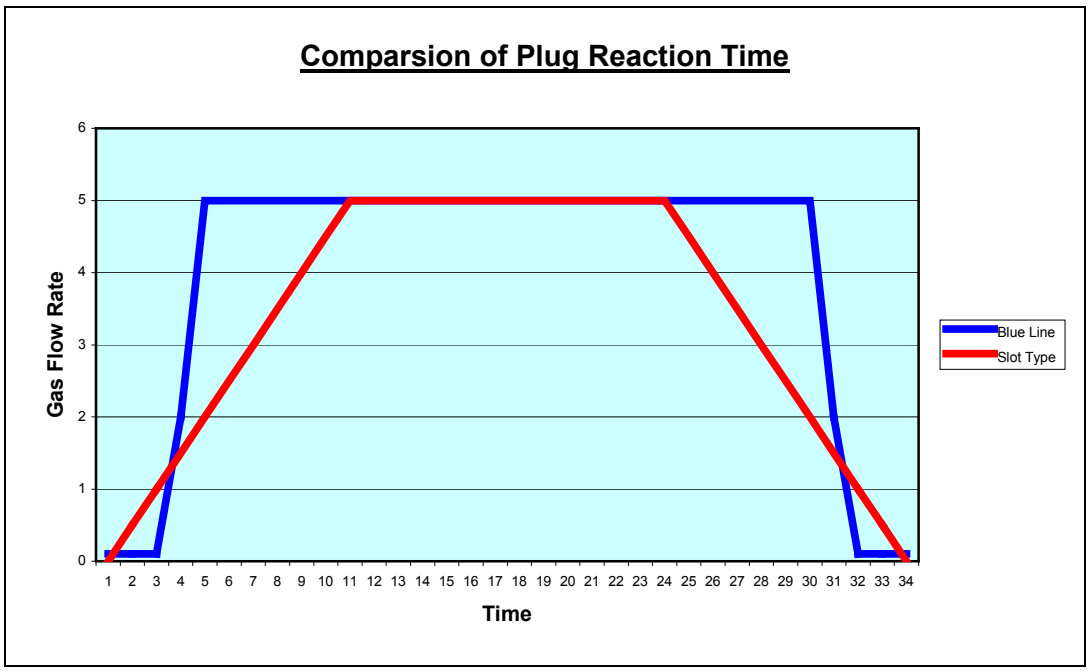

Figure 5 - Reaction Time of the BlueLine Purge Plug

The lifetime of the BlueLine plug is also enhanced by its pre-fired inner core. The non-wetting properties of the sintered inner section helps to prevent the “sticking” of slag and steel to the plug’s top surface. This means that reduced oxygen cleaning of the plug is required to maintain high purging availability. As the process of cleaning with oxygen is one of the major factors in the wear rate of purge plug refractories its reduction will ultimately lead to an increase in the life of the BlueLine plug.

Due to its pre-fired properties the new BlueLine design offers the customer a purge plug with an extremely high security and safety factor, an important issue in this critical area of the ladle.

3.1.2 Steel plant experiences with blueline purge plugs

Table 3 outlines some of the European references for the BlueLine purge plugs. In all cases the BlueLine has replaced the existing slot type plug supplied by the same company.

Table 3 - BlueLine European Reference

Plant Reference	Ladle Size (tonnes)	Production Process	Lifetime Standard Plug (Heats)	Lifetime BlueLine (Heats)
Plant A	125	EAF	20	25
Plant B	150	EAF	45	50
Plant C	85	EAF	35	43
Plant D	120	EAF 30% Stainless	3	5
Plant E	65	EAF	50	55
Plant F	200	EAF 40% Stainless	4	5
Plant G	90	EAF Stainless with AOD	20	25
Plant H	150	EAF Stainless with AOD	45	65
Plant I	80	EAF	25/15/15	32/20/20
Plant J	170	BOF	40	> 45
Plant L	75	EAF Tubes	20	25
Plant M	85	EAF Stainless with AOD	30	40
Plant N	400	BOF	8	15
Plant O	100	EAF Tubes	13/8	15/10

3.2. Clean Steel Block (CSB)

A serious problem in many steel plants is the slag carry over from the ladle into the tundish which can inhibit the ability to achieve the correct quality of steel. Due to the vortex-effect, at the end of casting a slag core appears in the centre of the steel stream resulting in ingress of ladle slag to the tundish. To attempt to reduce this slag carry over many steel makers stop casting early, whilst this will reduce carry over slag it does have a negative effect on efficiency and steel yield. The solution is the Clean Steel Block (CSB), this is a specially designed well-block incorporating small purge plugs in the corners, as can be seen in Figure 6.
By purging with low levels of Argon during the end of the draining process the vortex effect is suppressed allowing more steel to be passed from the ladle. In combination with a slag detection device the resultant advantages of the CSB are higher yield of

steel, less non-metallic inclusions and a reduction of inner nozzle clogging. This combined effect will help provide an over all reduction in costs.
By use of the advanced alumina–spinel castable range, the CSB can be manufactured to last the full ladle campaign without the need for it to be changed. Lives of up to 123 heats have been recorded with this system.

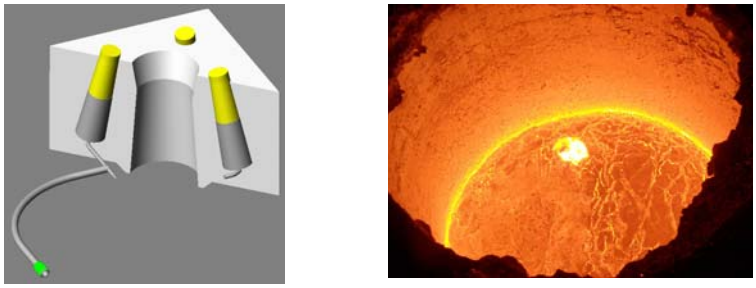

Figure 6 - Design and function of the Clean Steel Block (CSB)

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3.3 Castables & Filling Masses

In the last 10 years more and more steel plants have changed from conventional bricked linings to use a monolithic bottom and sidewall lining. Today, this system is fairly well established. Amongst the advantages of a monolithic lining are less manual work, reduced refractory costs, less waste and cleaner steels. Lifetimes of 120 heats and more per lining are published and well documented.
The work that our company had undertaken to develop its sophisticated range of alumina-spinel castables was expanded to produce self-flow variants of these new products that naturally lent themselves to monolithic ladle linings. Figure 7 shows the diagram of softening under load from 12 different castables for bottom lining measured at Voestalpine, Linz/Austria. This test clearly demonstrates the superior properties of this alumina-spinel castable. After studying the chemical and physical data of this alumina-spinel castable range in his laboratory the customer was convinced to make trials with the advanced alumina-spinel self flowing material in the ladle bottom.

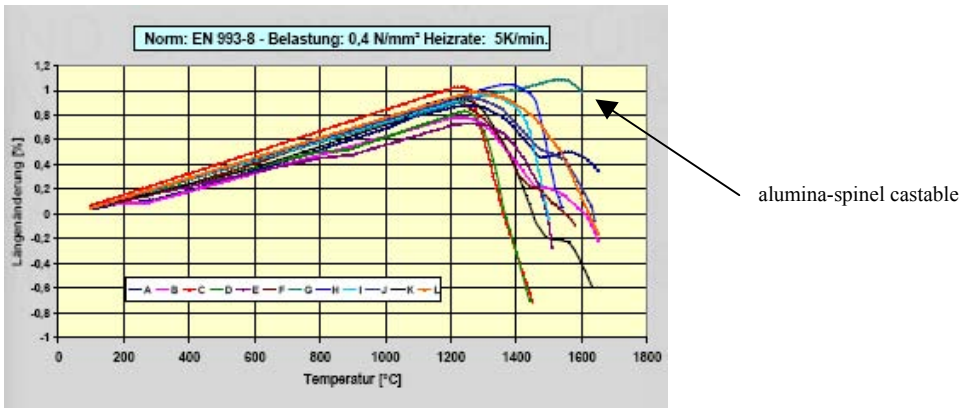

Figure 7– Softening under load of castables (voestalpine[3])

A trial was made with the advanced self-flow castable in the bottom area and bricks were used to form the impact pad. The lifetime of the ladle bottom cast was 131 heats with a residual depth of 35mm in the bricked impact area (see Figure 8).

Compared with standard castable materials and impact pad from magnesia-alumina-carbon bricks, the trial results show the possibility to increase the bottom life or to reduce the lining thickness.

By reducing the bottom lining thickness by 50mm and the sidewall lining by 30mm, the capacity of the ladle at this plant could be increased from 165 to 175 tons of steel.

The next planned step in the programme will be to use both the alumina-spinel castable and a pre-cast impact pad together in the same ladle bottom. The ultimate aim will be to perform cast repairs on the impact pad at the end of the campaign, a procedure that is not possible when using bricks in that area.

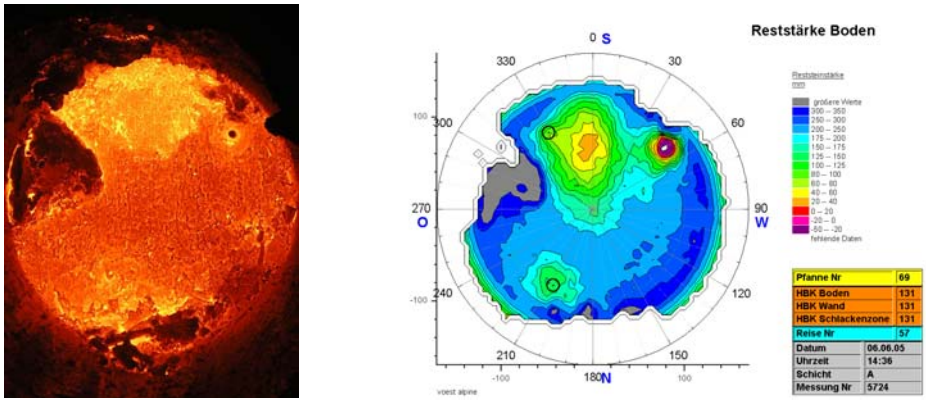

Figure 8 - Bottom at Voest Alpine, Linz/Austria, lined with special castable after 131 heats

Following the successful trials, this product has now become an established material at this plant and is in regular use as the approved castable for ladle bottom lining.

4 SUMMARY AND OUTLOOK

Driven by the customers needs, our company has developed a new refractory concept for the bottom of steel casting ladles. The ”Vibro-Dense-Bottom” is based on the opportunities created by the in house development of the “advanced alumina spinel castable “ range. The exceptional properties of these new materials allow our company to offer the steel maker new solutions for all ladle bottom refractories.

The BlueLine purge plug and the Clean Steel Block represent significant advances in the secondary treatment of steel in the ladle.

This new range of products offers the option to target specific problem areas in the ladle bottom or to provide a full package solution incorporating all new developments.

One commercial and technical co-operation has resulted in a partnership that will enable this concept and associated products to be introduced to the South and Latin American Steel Industry.

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