SEMI-CALCINED MAGNESITE AS INNOVATIVE SLAG FORMER CONCEPT IN STEELMAKING[1]

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Abstract

Semi-calcined or soft-burnt slag formers have existed for some time. This paper deals with a magnesite and foremost with presenting the excellent fit of this in-so-many-ways different material in steelmaking applications. Operational experiences will be shared from the last 2 years of worldwide implementation campaigns. Unique steelmaking characteristics have been accommodated through adapting practices for each individual plant. Originally a raw material of small grain size (0.5mm) found with magnesite mining in Europe it is agglomerated as a briquette. In tailor-made solutions one can incorporate additives in the briquette making as specified by the customer. Reacting to plant needs an additional technology concept was developed for injectable semi calcined magnesite.

Key words: Foaming slag; Synthetic slag; EAF; BOF

O USO DE MAGNESITA SEMI-CALCINADA COMO UM CONCEITO INOVADOR NA FORMAÇÃO DE ESCÓRIAS

Resumo

O uso da Magnesita semi-calcinada ou levemente queimada como formadora de escórias já ocorre há algum tempo. Este trabalho trata de como a Magnesita e acima de tudo, os vários caminhos encontrados para os ajustes desta em diferentes aplicações na fabricação do aço, podem auxiliar ao processo. Serão apresentados resultados de mais de 2 anos de trabalho da implementação desta tecnologia ao redor do mundo. Uma única característica da fabricação do aço foi adaptada para diferentes praticas que são adotadas em cada planta. Originalmente a material prima está num tamanho de grão pequeno (0.5mm), na forma que é encontrada na mineração na Europa, a qual então é aglomerada em briquetes. Numa solução Taylorista, pode-se incorporar ao briquete outros aditivos especificados pelo cliente. Um conceito adicional de tecnologia seria a aplicação do produto por injeção durante o processo de fabricação de aço.

Palavras-chave: Escória espumante; Escória sintética; FEA; LD.

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INTRODUCTION

Semi-calcined or soft-burnt slag formers have existed for some time. This paper deals with a magnesite and foremost with presenting the excellent fit of this in-so-many-ways different material in steelmaking applications. Operational experiences will be shared from the last 2 years of worldwide implementation campaigns. Unique steelmaking characteristics have been accommodated through adapting practices for each individual plant.

The slag former in question is essentially an MgO carrier with the following analysis:

MgO	50 - 63%
CaO	< 4%
Acidic impurities	< 10%
Sulphur	< 0,2%
Volatiles	30 – 35%

Originally a raw material of small grain size (0.5mm) found with magnesite mining in Europe it is agglomerated as a briquette. In tailor-made solutions one can incorporate additives in the briquette making as specified by the customer. Reacting to plant needs an additional technology concept was developed for injectable semi calcined magnetite.

Comparing semi-calcined magnesite with other slag formers it becomes immediately obvious that it is more concentrated in MgO than many traditional MgO carriers. The low CaO content provides further for certain briquette robustness in handling and storage.

After entering furnaces and completing calcination at steelmaking temperatures semi-calcined magnesite is best suited to contributing very effectively to MgO enrichment in slags. Supplied in form of briquettes the disintegration mechanism and rapid grain dissolution is put in motion instantaneously when the volatiles start escaping the material under extremely hot conditions. The same effect of fast increasing the MgO activity in slags can obviously be accomplished with offering the semi-calcined slag former as injectable material. The aim in both cases is to waste no time in neutralising refractory attacking slags.

Before altering existing slag former concepts it pays to first fully recognize the metallurgical needs of the various steelmaking processes. Besides satisfying conventional melting and refining requirements the request was made to further enhance refractory and process performances over and above the traditional expectations.

Correct timing is considered the key to smarter steelmaking. This point is illustrated in showing an effective utilization of this slag former tool when combined with superior process strategies. In areas ranging from Carbon Steel melting in electric arc furnaces to refining in BOF converters and stainless steelmaking applications, semi-calcined magnesite has managed to outperform conventional MgO carriers in many plants.

Carbon Steelmaking processes often have to perform dephoshorisation tasks regardless whether one deals with primary or secondary iron units. As part of the innovative slag former concept one would allocate early steelmaking phases to CaO dominated slag regimes. MgO units are offered initially in moderation until Phosphorus has left the steelmaking system as run-off slag. A dedicated MgO boosting phase follows afterwards aiming predominantly at protecting Magnesia based refractory linings.

In that sense the last couple of minutes of EAF melting are earmarked for slag modification with substantial amounts of MgO units, in this case soft-burnt magnesite. When following a continuous addition practice volatiles are consistently released by calcining reactions. Thick and creamy slag is forming through MgO enrichment while Fe-oxide levels are due to be driven down to lower levels in the final melting stages. When appropriate slag consistency and gas generation are obtained and enhanced by charging semi-calcined magnetite stable foaming is sustained. Especially during flat bath melting slag foaming is highly desirable. The benefits with regard to superior heat transfer of a filly shielded open arc are widely understood among steelmakers. After tapping sticky slag coats the furnace walls for refractory protection. A running start in the subsequent melting cycle is provided with holding back the ready-made MgO rich slag as much as the conventional metallic hot heel.
In a similar strategy one would modify BOF slags in dedicated periods between melts decoupled from the blowing and dephosphorisation metallurgy. Adding concentrated MgO units into liquid refining slag after steel tapping is to secure an MgO enriched mixture. Ideally suited for slag splashing one has to balance the preferred slag viscosity with maximum MgO concentrations. This can be accomplished with semi-calcined magnesite that dissolves rapidly in the available time. An obtained higher MgO content in the slag splash coating enables longer lasting protection and superior compatibility with the Magnesia based refractory lining.
In contrast to Carbon steelmaking foaming of stainless slags is a difficult undertaking in EAF melting. Finding a suitable supply of foaming gas can be combined with controlling Chromium oxidation during processing. Through measures such as improving kinetic bath conditions and effective protection against Oxygen exposure Cr oxide levels must be kept at sufficiently low levels. The delicate balance of slag components for obtaining the correct foaming viscosity is easily corrupted in the presence of excessive Cr oxide concentrations. Semi-calcined magnesite greatly assists in adjusting the slag viscosity and enhancing foaming gas supplies in these complex process conditions.
Even world-class EAF operators that had developed excellent slag foaming practices without assistance from semi calcified magnesite will today not want to return to a melting process without this MgO carrier. The added value from sustaining foam stability by this innovative slag former concept provides for a higher level of process reproducibility. Plants around the world have realised productivity gains and cost savings with turning to semi-calcined magnesite usage. Opportunities are welcomed for fine-tuning and consolidating the general concept. They present themselves with every new customer who will require unique solutions for their particular steelmaking environments.

BACKGROUND

The Customers

With the mother company of Intocast AG residing in Ratingen, Germany the obvious choice for initial market targeting were the German steel plants, then Europe and later also developing countries, as in the Golf Region.
Modern, high productivity plants in Western Europe were typically looking for ways of fully utilizing their high tech equipment to their best advantage. Process strategies as Intocast's innovative concept were expected to assist in stabilizing production performances at highest level. The Intocast product had to become an ideal part of

high productivity processing modes fining in with the most modern, state-of-the art infrastructures of the work stations.
In Eastern Europe many of our customers are lacking investment funds (long term capital) for essential equipment upgrades to reach desired production levels. They are constrained to introducing technology improvements for example through alternative process additives (short term expenses). Intocast's semi-calcined MgO unit is such a material, able to assist their effort even in an environment that is deficient of modern addition facilities.
Steelplants in developing countries often appreciate Intocast's innovative slag former concept as a way to connecting with global players. They often have a great appetite for advancing their steelmaking skills by interfacing with companies experienced in the field. With a great deal of open mindedness towards new technologies they are on their way to establishing practices of world-class standard.
This paper deals with operational experiences gathered while spreading the semi-calcined magnesite process technology to a variety of new customer operations. In an environment of unique steelmaking characteristics and forever changing plant conditions materials and methods had to cope with complex challenges. In reply the slag former concept demonstrates a high degree of adaptability based on high quality products in combination with sound metallurgical principles.

THE INTOCAST SEMI-CALCINED SLAG FORMER - PRODUCT DESCRIPTION

The slag former in question is essentially an MgO carrier WitD the following analysis:

MgO	50 – 63%
CaO	< 4%
Acidic impurities	<10%
Sulphur	< 0,2%
Volatiles	30 – 35%

Originally a raw material of small sprain size (0.5mm) found with rnagnesite mining in Europe it is agglomerated as a briquette. In tailor-made solutions one can incorporate additives in the briquette making as specified by the customer. A standard product chemistry is also available with 15% Carbon content preferred by steelmakers who wish to substitute Carbon carriers. In a joint development project work is currently being conducted towards integrating ferro-alloy fines and waste materials in Intocast slag former briquettes. The motivation for combining several material streams in one agglomerated product is dependent on specific plant requirements. Increasing the briquette weight for superior bath penetration could be a reason, utilising opportunities with low cost raw material fines (off-grade) or disposal of steelmaking by-products and residues, such as dust, mill scale or others. In all cases high material yields arc to be obtained with fast disintegration and dissolution rates once the briquette has entered the bath.
Reacting to plant needs an additional technology concept was developed for injectable semi-calcined magnesite. Where plants have moved away from conveyor belt and bunker addition systems pneumatic feeding has taken over as transportation measure. Dependent on the size of the entry nozzle into the steelmaking unit the Intocast product can be offered in the appropriate size ranges, 0 to 3mm or 2 to l0 mm. The slag former can be blown into melts through conventional injectors in furnace side walls as well as lances. The use of water-cooled lances is entirely feasible for introduction of solids through furnace doors. For converters a new approach has been suggested whereby top blowing lances have been modified to

accommodate solids injection.
Comparing the soft burnt magnesite with other slag formers it becomes immediately obvious that it is highly concentrated in MgO contend This measures up very favorably against many traditional MgO carriers, such as dolomitic lime or crushed bricks. The low CaO content provides further for briquette robustness in handling and storage. Potential degradation of soft burnt magnesite briquettes is less likely since the hydration mechanism via Ca-hydroxide formation is virtually absent.
Alter entering the steelmaking unit and completing calcination at elevated process temperatures the Intocast slag former is best suited to contributing very effectively to MgO enrichment in slags. Supplied in form of briquettes the disintegration mechanism and rapid grain dissolution is put in motion instantaneously when the volatiles start escaping the material under hot bath conditions. The same effect of fast increasing the MgO activity in slags can obviously be accomplished with offering the semi-calcined slag former as injectable material. The aim in both cases is to waste no time in getting MgO in solution and neutralizing refractory attacking slags.

Top Performance Applications

Before altering existing slag former concepts it pays to first fully understand the metallurgical needs of the various steelmaking operations. Besides satisfying conventional melting and refining requirements the expectation is to further enhance refractory and process performances over and above the traditional levels. In the first step of a new project a comprehensive assessment of the standard steelmaking operation is carried out in steel plant visits and discussions with the local process experts. Safe working procedures have to be observed as much as essential metallurgical process tasks performed without compromising final steel quality. Often the plant logistics and infrastructure dictate what addition strategy can be followed.
Correct timing of the MgO addition is considered the key to smarter steelmaking. Effective utilization of the added functionalities of the slag former is much related to correctly applying superior process strategies. The value of the concept of using semi-calcined magnesite is only realized once the optimum time window has been identified in the different steelmaking operations. In areas ranging from Carbon Steel melting in electric arc furnaces to refining in BOF converters and stainless steelmaking applications the Intocast product has managed to outperform conventional MgO carriers in many plants.

Carbon Steelmaking

Carbon Steelmaking processes often have to perform dephoshorisation tasks regardless whether one deals with primary or secondary iron units. Concerns had been raised by steelmakers that this metallurgical step may not be compromised by the innovative MgO concept. As part of the new slag metallurgy approach one would therefore allocate early steelmaking phases to CaO dominated slag regimes. MgO units are offered initially in moderation until Phosphorus has left the steelmaking system through deslagging. A dedicated MgO boosting phase follows afterwards aiming predominantly at protecting Magnesia based refractory linings. The success of this practice is clearly related to a slag former that by design has to be as high in MgO concentration as possible.

EAF Steelmaking

Following this process philosophy the last couple of minutes of EAF melting are earmarked for slag modification with substantial amounts of MgO units, in this case the semi-calcined magnesite. Lifting the MgO concentration in a slag leads to creating a thick and creamy slag. After EAF tapping sticky slag coats the furnace walls for refractory protection. This "home growth" artificial refractory layer is chemically better compatible with Mag-Carbon bricks than MgO deficient slags. With MgO enrichment and lower CaO concentration the coating lasts longer on the refractory hot face than a lime based slag layer.
The reason for the superior sustainability of MgO rich slag coatings is the anticipated CaO demand in dephospborisation slag of subsequent melt cycles. Lower CaO concentration in the protective layer and therefore lower CaO activity retards its dissolution and maintains the integrity of the refractory cover.
A thicker slag has the additional advantage of promoting slag-free tapping. Due to the reduced mobility of sticky slag vortexing and slag entrapment in the steel tapping stream is observed to a lesser degree. A running start in the subsequent melting cycle is provided with holding back the ready-made MgO rich slag together with a metallic hot heel. MgO credits in the carry-over slag will eventually be diluted by lime additions and Fe-oxide formation of the new heat cycle preparing conditions for optimum dephosphorization requirements. There is, however, a lesser appetite for MgO units from the hot face coating or magnesia based bricks than in conventional melts.
The final slag consistency is also more conducive to stable foaming. The modification is therefore not only aiming at altering the chemistry towards superior refractory protection but also at viscosity adjustment. During superheating of a melt directly prior to tapping conventional slag foaming is often becoming unstable. Essential CO generation as foaming gas can be in conflict with finalizing steel and slag chemistries at the very end of a melting cycle. The optimum balance of Fe-oxide level in the slag and C in the steel is to be obtained. While Fe-oxide values are typically due to be driven down same as injection rates of Carbon carriers slag floatability suffers.
This is where the Intocast product is able to much assist foam stability. When following a continuous addition practice with this slag former volatiles are consistently released by calcining reactions. Appropriate slag consistency and gas generation are obtained simultaneously and stable foaming is sustained throughout the final energy input phase when it counts the most.
As part of this innovative process strategy inert gas stirring is considered a vital element in supporting the slag foaming process. Superior kinetic conditions promote reactions in the bath such as a Carbon boil with CO generation. The resulting gas bubbles are utilized for slag foaming. Carbon and Oxygen concentrations in the melt move closer to equilibrium and the decarburization product (Carbon Monoxide) enhances foam stability. Effective Oxygen removal from the steel with inert gas stirring prior to tapping increases reductant yields. Lowering metallic oxides values in the slag via the same tool supports the drive towards thicker slags and marginally increased metallic yields.

BOF Steelmaking

In a similar strategy one would enrich BOF slags with MgO in dedicated periods outside dephosphorisation slag regimes. Between melts one can introduce refractory protection steps decoupled from the conventional refining metallurgy. Adding concentrated MgO units into liquid refining slag after steel tapping is to secure an MgO enriched mixture. For optimum slag splashing results one has to balance the preferred slag viscosity with maximum MgO concentrations. This can be accomplished with soft burnt magnesite that dissolves rapidly in the available time. A maximum MgO content in the slag splash coating enables longer lasting protection and superior compatibility with the Magnesia based refractory lining.

Where BOF shops lack slag splashing equipment or find the practice too complex or time consuming they may follow a reduced version of a refractory maintenance practice. The distribution of a sticky MgO enriched slag is facilitated through rocking the converter forwards and backwards. A slag coat covers a wide band mainly confined to the front and back wall of the converter. The most important lining part that is supposed to receive protection in this way is the high wear zone of the impact area. Given a time constraint and minimum effort that goes into this slag coating method the benefits can be substantial. Similar to slag splashing the Intocast magnesite slag former is the preferred choice of material to modify refining slag to obtain ideal chemistry and viscosity. It is clearly understood that refractory issues in the trunnion areas are not addressed with the vessel rocking technique. Those are open regions that also demonstrate premature wear since they are the spots of permanent slag contact.

Stainless Steelmaking

In contrast to Carbon steelmaking foaming of stainless slags is a difficult undertaking in EAF melting. Not only are Chromium (Cr) containing melts easily corrupted by solid slags but also does the foaming gas supply mechanism not function as readily as with unalloyed steels. A holistic concept for obtaining the correct foaming viscosity has been developed by Intocast AG to control the delicate balance of slag components

Slag poisoning with Cr oxides resulting in high liquidus temperatures occur at levels above 5% Cr203. The slags usually turn hard so that foaming becomes virtually impossible. Offering sufficiently strong reductants can return slag viscosities back into foaming range. Ideally one should never incur process conditions that lead to such excessive Cr losses to the slag in the first place.

One aspect of preventing uncontrolled Cr oxidation is restraining the air intake into the furnace. The gas pressure inside the EAF should always be positive with flames and small dust puffs escaping through gaps. This serves as an indicator that as little false air as possible is sucked through the furnace with minimum Cr oxidation risk.

Cr oxidation during EAF melting can never be avoided entirely. In the presence of elements in the melt that can act as sufficiently strong reductants (for example Si) the slags will, however, never accumulate concentrations that will turn it into a solid crust. In actual fact the Si content in the steel should at all times remain at suitable levels to act as a protective barrier against the Cr oxidation.

Finding a suitable supply of foaming gas is another challenge. Intocast AG proposes an inert gas stirring technique as applied with Carbon steelmaking. During melting kinetic bath conditions are to be improved away from a more likely heterogeneous state. Carbon removal in the steel is promoted through the reduction of the partial pressure of CO. This way available Oxygen in the melt is preferentially getting involved in decarburization reactions than Chromium oxidation. One could say that this tool had been borrowed from the AOD process where such practice is common

place in the low range of the Carbon removal process. Carbon has become another instrument engaged in protecting Chromium against oxidation during EAF melting The formation of resulting bubbles of gas mixtures is obviously utilized as foaming gas similar to the Carbon steel scenario.
The soft-burnt magnesite greatly helps in enhancing foaming gas supplies in these complex process conditions. Since no attempt towards dephosphorisation in stainless steelmaking is made the MgO carrier can be added over a long time span starting earlier than in Carbon steelmaking. For the full benefit of utilizing the escaping volatiles as foaming gases the slag has to be liquid at the time of addition. The briquettes obviously have to be able to penetrate under the slag surface.

RESULTS

From 8 to 320 ton Steelmaking Units

Early work with Intocsst's innovative slag former was conducted in Carbon steelmaking environment. In a melting operation with an 80t EAF the new slag concept matured into an innovative and stable metallurgy that delivered convincing operational results.
Refractory lining lives were extended up to 25%. The consumption of graphite electrodes was reduced by up to 10% and energy usage decreased by up to 7%. These highly favorable process improvements had been accomplished in a world-class EAF melting operation (45 heats a day) and demonstrate the concept potential. Excellent slag foaming practices had been developed by the operator already prior to consuming the Intocast product. But today there is no talk of returning to a melting process without semi-calcined magnesite. The added value through maintained foam stability by this innovative slag former concept provides for superior levels of process reproducibility at maximum production rate.
Obviously not all EAF melting operations are geared up to these high productivity performances. Production requirements, equipment constraints and input materials dictate among others to what degree the Intocast product is able to assist process improvements. Merits can be expected with almost all applications, furnace sizes and plant characteristics since sound fundamental process principles are practiced. More effective usage of process tools, consumables and metallurgical mechanisms has produced superior furnace parameters.
The issue in some furnaces is that the energy input system may have become so powerful that without appropriate measures the work station could destroy itself in the melting process. Without proper energy distribution mechanisms localized high heat input can cause damage to the equipment. Where hot spots form energy input rates have to be throttled back, a step that often affects the total melting speed. Effective slag foaming is one way of overcoming problems where certain furnace areas have to be shielded from excessive thermal exposure. In cases steelmakers are able to create an un-balanced electrical energy input to account for hot spots. Where this cannot be accomplished cooling methods for the critical areas have to be found.
The Intocast technology concept provides solutions since it lends itself to feeding the slag former in specific furnace areas where undesirably high energy load could lead to problems. With localized cooling from calcination and through the concentrated supply of MgO units one follows a strategy of creating a non-metallic built-up. Such a scenario has been successfully implemented where an operator injected Intocast's specially formulated magnesite fines through furnace side walls into a hot zone. As a

result the steelmaker could continue following an aggressive and fast power input program without damaging the furnace shell.

In a shaft furnace operation similar issues with uneven thermal loads on furnace walls have been encountered. The nature of the process entails that the pre-heated scrap is often asymmetrically discharged into the furnace hearth with some areas remaining relatively bare. This is where hot spots will typically develop when melting progresses. Through localized feeding of Intocast semi-calcined magnesite briquettes and pneumatic conveying of fines into the critical area the overall high melting speed can be maintained. Dependent on furnace design and available equipment it may be more desirable to give preference to injectable MgO carriers to affect localized cooling of problem zones.

In conventional EAF melting operations it is often the super-heat phase in an open-bath situation when effective heat transfer is most difficult. This is the melting stage when most of the scrap has been transformed into liquid. From the centre outwards all solids have melted or collapsed into a pool of liquid until the furnace walls become exposed. This is when it becomes essential that the open arc is covered with slag. Slag foaming is the preferred shielding method since lower slag mass can be modified into thick layers through volume increases. The thicker the slag layer the longer one can select the arc. Long arc operations provide for more efficient energy input given that the heat reports to where the desired temperature increase is needed. When slag foam stability cannot be guaranteed the melter cuts back on maximum power input to avoid the risk of causing damage. The arc length is typically reduced since collapsing slag foam covers only shorter arcs.

In intelligent furnaces the foaming success is carefully monitored. Sensors, such as audiometers (noise meters), electrode tracking devices or hot spot control systems give feedback to the energy input control system to establish healthy heat conditions in the EAF. When such schemes report back proper arc shielding and low thermal impact on furnace side walls power input is opportunistically raised. Through such optimization melting speed and productivity is increased.

When the Intocast soft burnt magnetite product is used in furnaces that make use of such power input optimization tools the indicators clearly give evidence of the superior performance of the slag former. While adding this MgO carrier highest energy input rates can be kept, the furnace typically turns all quiet and hot-spot alarms are absent.

Another application where semi-calcined magnesite excelled as the preferred slag former is the CONSteel melting process. By design the operation relies on continuous adding of pre-heated scrap at relatively low feed rates. In a permanent open bath melting scenario the thermal equilibrium of cooling and heating is kept fairly constant throughout the entire process cycle. Furnace walls are covered with scrap to a lesser degree than with batch feeding (scrap basket charging) processes. The demand on effective protection of the EAF side panels against heat from the arc is much more pronounced in CONSteel furnaces. Periods of open bath melting are a lot more extended than in conventional EAF melting processes. The contribution of Intocast magnesite with high MgO concentration and LOI value in maintaining stable slag foaming is seen as significantly adding value to this particular melting process.

The CONSteel process further makes use of an extensive hot heel offer tapping, 30% residual steel mass and in cases even more metal is kept back as against more conventional 10%. This process feature is a key characteristic of the continuous melting approach. At the same time it presents a certain limitation in the sense that the furnace floor can be inspected for refractory wear only a less frequent intervals.

The integrity of the furnace lining has to be maintained with a higher degree of confidence than in furnaces where the refractory hearth and banks can be examined more easily and more often. A sound refractory scheme is of greater importance to the CONSteel system than to other processes. In a way Intocast product technology becomes the effective refractory protection tool to enable healthy continuous melting with over-size hot heels.

Operational experience has been gathered in both EAF modes, AC and DC arc furnaces. A difference in behavior of the soft burnt slag former is not noticeable. A positive effect on melting performances is equally evident regardless of the furnace mode. A direct comparison is not possible to determine whether it is more advisable to use the semi-calcined magnesite with AC or DC furnaces. In evaluations other plant parameters and operational characteristics have been so dominant that up to now a certain slag former priority for a specific electrical system could not be found.

Only when introducing our innovative slag concept to steelmakers in the Gulf Region Intocast magnesite product had to discover that it could not add the same value as in traditional melting operations. When high rates of sponge iron (HBI or DRI) are used as Fe units instead of scrap slag foaming almost automatically occurs in abundance. The high intake of metallic oxides (limited degree of Fe metallization in sponge iron), excess Carbon and slag forming non-metallics provide for excellent slag foam generation. 'When EAF melters charge well over 50% of their Fe requirements as sponge iron there is no need for semi calcified magnesite to sustain adequate slag foaming.

The use of sponge iron is often governed by raw material availability reasons in a region and has draw-backs. The ability to foam slag is not among Mom as we had confirmed also with the only melting shop in Germany that consumes major quantities of DRI and HBI in EAF melting.

On the other end of the EAF melting spectrum Intocast had to prove its slag former technology in low productivity mode and with small size furnaces. Here the melting process can be the front end of a foundry for example or an ingot casting operation. In this business melting speed is not necessarily the important excellence criteria. Cycle times can run into several hours when the entire list of metallurgical tasks from scrap melting to reaming, alloying and chemistry fine trimming all has to be performed in a single EAF process. In such production scenarios Intocast's slag former product convinces through its ability to be used as a user-friendly MgO carrier that manages to provide effective refractory protection during prolonged processing times.

Whether it is an 8 ton foundry furnace or a battery of 10 to 20 ton EAF melting stations as encountered in Eastern Europe it is common to feed soft burnt magnesite briquettes manually through furnace doors. From the most sophisticated solids injection system to "the man with the shuffle" the slag former concept with the innovative MgO carrier has provided solutions. Superior refractory performances have presented sufficient motivation and cost savings in steelmaking operations where productivity gains have not been allocated highest priority.

Since individual furnaces demonstrate unique behavior and react differently towards alterations in slag metallurgy the Intocast slag former technology concept had to be adapted with every new customer. In introduction phases the quantities and timing of the slag former additions have to be tested and optimized. In cases we have been too successful with forming slag coatings and growing built-up eventually restricted available furnace volume. Through proper balancing of MgO carrier additions with prevailing EAF process parameters the best strategy is found in cooperation with the

local experts. Intocast AG provides full supervision when such learning curve has to be completed with every new customer that wants to introduce the novel MgO concept.
The use of Intocast's semi-calcined magnesite in stainless steel operations is still fairly much in its infant stages. The above mentioned complexity of slag foaming in Cr containing melts has prompted customers to take a more critical position towards development proposals. Previously a great number of suppliers have promised a variety of slag foaming solutions for stainless EAF processes. In the end none of the products and methods has succeeded in becoming a regular tool in stainless steel melting,
Intocast's modified slag metallurgy certainly makes valuable contribution towards superior long-term refractory performances, also in stainless furnaces. In a joint project with our customers we are furthermore looking for opportunities to trial our proposed methods aiming at more effective protection against excessive Cr oxidation. This is considered the pre-requisite for enabling slag foaming in stainless EAF operations.
At present a development project with a German stainless steelmaker is in progress wanting to establish a briquette system that promotes slag foaming. A combination of Fe-alloy fines, slag former, easily reducible metal oxide, reductant and binder is to be agglomerated to create an additive that is able to perform multiple metallurgical functions. The briquette is expected to be sufficiently heavy to penetrate well below the bath surface. At the same time it needs to break up easily into its components to dissolve at rapid rates. Further the request is made that through reduction of the available oxides with the co-supplied reductant sufficient foaming gas can be generated while Cr is effectively protected from oxidation. Results from plant trials are expected only later in this year.
The application of the Intocast semi-calcined magnesite products in BOF steelmaking presents a picture with many options dependent on dephosphorization needs and practices for enhancing refractory performances.
Most of our customers have to deal with significant P removal work during refining. This particular slag metallurgy tolerates only moderate MgO levels and refractory protection measures have limitations during the blowing cycle. Without being able to go near MgO saturation levels slags will inevitably attack the converter lining since the dephosphorization metallurgy has to be given preference. In such scenario the Intocast concept is targeting superior slag splashing practices decoupled from the refining stages.
The local specialists and converter operators play a major role in obtaining optimum results in modifying the existing refining slag to get the best suitable slag chemistry and viscosity for slag splashing. Prevailing operational conditions have to be assessed correctly since the consistency of refining slags can vary from heat to heat in some plants. Another parameter in the preparation phase is the determination of the residual slag mass that is deliberately held back after steel tapping and partial deslagging. According to the operator's judgment the kept refining slag has to be modified with the appropriate Intocast slag former quantities to balance slag stickiness with maximum MgO content. In liquid refining slags the semi-calcined magnesite briquettes have shown to dissolve readily. Effective breaking up of the material is noticeable from a crackling sound that can be heard at the converter mouth of the tilted vessel (almost as if throwing rice crispies in milk).
After splashing the slag coating is expected to cover all lining areas especially those below metal and slag line. With converter scan measurements a successful building

of a protective layer is confirmed. Its sustainability is monitored in subsequent scans while in simple visual inspections one determines its lasting effect until brick joints are clearly visible again. Dependent on the maximum MgO level one can obtain in the splashing slag the coating will last for 4 to 6 heats, sometimes even longer. The key to successful splashing is to create a slag that is not too hard (risk of peeling off alter splashing) while optimizing the MgO concentration. Compared to other slag formers the high MgO concentration in the Intocast product assists in driving the splashing slag composition into the preferred range. CaO dominated slag layers dissolve more readily in subsequent blowing cycles (Fe oxide formation) due to the high thermodynamic demand. A splashing slag that remains too liquid is also of lesser benefit because major quantities will run down the converter walls without sticking. For this reason it cannot be over emphasized to what significant extend the correct slag preparation and assessment of the converter operator is important in getting the concept right.
An entirely different BOF scenario was met in Northern Europe. There the Scandinavian iron ores permit producing a hot metal that in cases results in low P intake into the converter process. In this situation the steelmaker can afford running refining slags at unconventionally high MgO levels. A specially developed Intocast practice was successfully tested that involved additions of the semi-calcined magnesite three quarter through the blowing cycle. Since the steelmaker puts a lot of emphasis in creating a viscous slag at tapping stage to promote slag-free steel taps the Intocast soft burnt magnesite product replaces portions of lime additions that were originally used for slag stiffening. The effective coating of the refractory lining was observed similar to the splashing scenario. With the layer lasting for a minimum of 4 heats the procedure does not need to be repeated with every refining cycle but only when the refractory lining has lost its protective slag coating.

FUTURE DEVELOPMENT

Opportunities are welcomed for fine-tuning consolidating the general concept. They present themselves with every new customer who will require unique solutions for their particular steelmaking environments.
In several plants the implementation of the innovative Intocast soft burnt slag former has not yet gone passed the introduction and test phase. After additional trials the steelmakers plan to take decisions on running the semi-calcined magnesite practice as standard operational feature.
Especially the option with injecting Intocast slag former fines has some way to go before full maturity is reached at plant level. Some of our current customers that have started with consuming briquettes on a regular base contemplate converting to pneumatic feeding of magnesite solids. Injection points and equipment can vary in the different plants from entry ports in the EAF roof, injector nozzles in furnace side walls as much as water-cooled lances located in EAF slag doors.
Intocast semi calcified magnesite briquette applications are to be extended to Ladle Furnace (LF) processes. Similar to EAF melting superior protection of the refractory walls are anticipated through slag foaming. Often ladle slag lines suffer from high thermal loads when heat distribution is insufficiently managed. Some of the conceptual solutions that were found in the bigger furnaces can be scaled down to ladle size. Intocast AG offers ladle slag metallurgy that integrates synthetic slags with superior refractory performances. The request for liquid, double saturated slags (CaO and MgO saturated) modified with Calcium Aluminates for high reactivity and with

sufficient Sulfur capacity can be combined perfectly with the Intocast magnesite concept.
Especially on the stainless steelmaking side Intocast AG hopes to test slag foaming practices supported by semi-calcined magnesite additions. The briquette project with the material mixtures as mentioned earlier could be the entry point into gaining a stainless steelmaker's confidence for Intocast's innovative slag metallurgy trial works

SUMMARY

Intocast AG presents this new soft burnt slag former to the steelmaking industry as an Innovative consumable with an entirely new range of process enhancing capabilities. The product characteristics of this semi-calcined magnesite satisfy highest standards. Numerous opportunities for productivity increases in cost saving scenarios have been demonstrated. Although the Intocast product is a mass-produced consumable options exist to adapt material and application method to individual customer requirements.
As a holistic metallurgical system it provides a highly valuable service concept. Beside the supply of high quality MgO units customers can consult with Intocast's metallurgical experts to optimize the use of the soft burnt magnesite product. Present development progress suggests great optimization potential that Intocast AG wishes to explore in future work together with their customers. While the current low order book in most plants understandably presents a serious problem one should also consider the fact that presently there is time and opportunity to try novel steelmaking techniques as the innovative slag former concept. Intocast AG is committed to making contributions towards improving the long-term competitiveness of steelmaking operations.