

# **Comparative Analysis of Dolomitic Lime and Chinese Magnesite Practices in Electric Arc Furnace Steelmaking Slags**

By

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## **Abstract**

This paper will present comparative analytical data from North Star BHP Steel LTD. utilizing both dolomitic lime and Chinese magnesite. The conclusion of this trial resulted in a practice change and cost savings to the plant. Steel mills that have converted from the Chinese magnesite practice to dolomitic lime practice have shown the same benefits through their understanding of key parameters in producing the correct foamy slag properties, while at the same time achieving flux cost savings.

## **Introduction**

Key to improved performance for electric arc furnace steel producers have been the optimization of foamy slag practices that provides benefits of saving electrical energy, improved arc stability, reduced noise, improved productivity, lower nitrogen levels and increased refractory life in the furnace. In addition optimized slag practices satisfying MgO solubility requirements and basicity control have improved clean steel practices and refractory consumption.

In Figure 1, key changes in the electric arc furnace steelmaking process are highlighted and shows how they have impacted heat times and lowered energy consumption.<sup>8</sup> In the mid 1980's efforts to produce foamy slag resulted from plants using DRI which inherently caused the slag to foam. This introduced the concept for foamy slag practice in EAF operations. However, in the mid 1990's work continued by several noted steel industry experts and universities for optimization of foamy slag practice through control of slag chemistry and use of magnesia to influence increased duration of foamy slag during the melting as well as refractory protection. This has resulted in gunning consumption performance of less than 2 lbs per ton and continued energy benefits with the higher powered furnaces.

Knowledge gained by steelmakers of the key factors that influence EAF slags has surged in the last few years. An increase in technical studies by Albany Research Center, Dr. Fruehan, Carnegie Mellon University, Dr. Eugene Pretorius, LWB Refractories, and many others have presented information about the chemistry requirements of slags and their influence on slag characteristics. This has influenced the increased usage of dolomitic lime as well as Chinese magnesite. Studies relating to the use of recyclable material that can be blended and injected into the slag have also recently been issued in efforts to utilize other sources of magnesia units for slag chemistry.

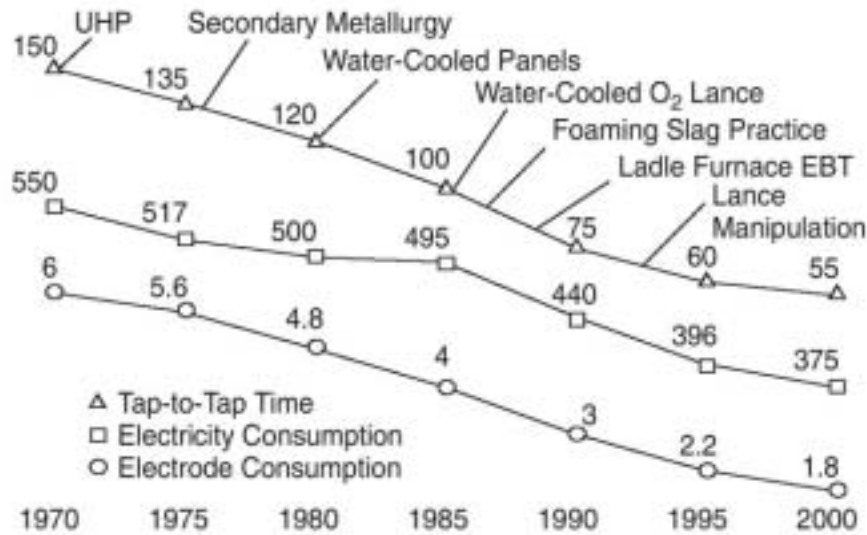


Figure 1: Historical overview of improvements in the EAF Tap to Tap time and Energy Consumption. JOM, 53 (10) (2001) page 3. C.P.Manning and R. J. Fruehan

Material handling systems have had an impact on the ability of steel plants to efficiently utilize the most economical approach to improving performance in the electric arc furnace. Storage bins and methods of transferring lime ranges from a single silo to multiple silos with additions of dolomitic lime, blended lime and magnesite being batch charged in buckets, injected via 4<sup>th</sup> hole or in the case of Consteel placed on the scrap conveyor.

The effort to maximize the foamy slag benefits through chemistry modification during the heat has possible limitations in obtaining the lowest cost related to the following factors:

- Flux handling systems
- Materials utilized for slag requirements
- Possible variations related to various steel grades that may be produced in a steel plant.

Recent studies have shown that there is no difference in the dissolution rates of dolomitic lime and magnesite in electric furnace slags when similar conditions are present.<sup>3</sup> In this case, it is possible to reduce the impact of flux cost by selecting the best combination of factors for the slag practice being utilized.

### Technical Review

#### Key elements impacting performance to electric furnace slags:

Key elements impacting performance have been well documented and it should be noted that these are important aspects when considering the cost impact of flux selection. Work done by the Albany Research Center and Eugene Pretorius has shown that the reaction of FeO with carbon to generate CO gas bubbles requires an optimum slag chemistry to maintain the foamy slag during the refining stage in the EAF.<sup>5,11,14</sup> One of the main aspects of controlling the slag relates to this relationship of FeO and C. The main parameters that affect this relationship were stated by Helmut Oltmann and Eugene Pretorius in “Simulation of Refining Stage of the EAF Process” presented at the 2002 AISE conference:

## 1. Proper control of oxygen / carbon relationship<sup>5</sup>

- The final % C and % FeO at tap are impacted by the balance of oxygen and carbon during melt-in and during the refine stage.
- The injection of carbon is both for foaming and control of FeO content.
- Over blowing with oxygen without regards to carbon requirement will result in yield losses and decrease in foaming before tap related to loss of gas formation due to high FeO content and watery slag condition that is not able to support bubble retention.
- Multiple oxygen injection points reduces local over oxidation of the steel.
- Adjustments can be done either by controlling the oxygen injection rate or by controlling the carbon injection rate. Considerations to cost need to be weighed affecting production and materials.

An example can be seen in Figure 2 from Helmut Oltmann and Eugene Pretorius showing the FeO in the slag can be affected by changes in compositions of oxygen and carbon content from melt-in to tapping:

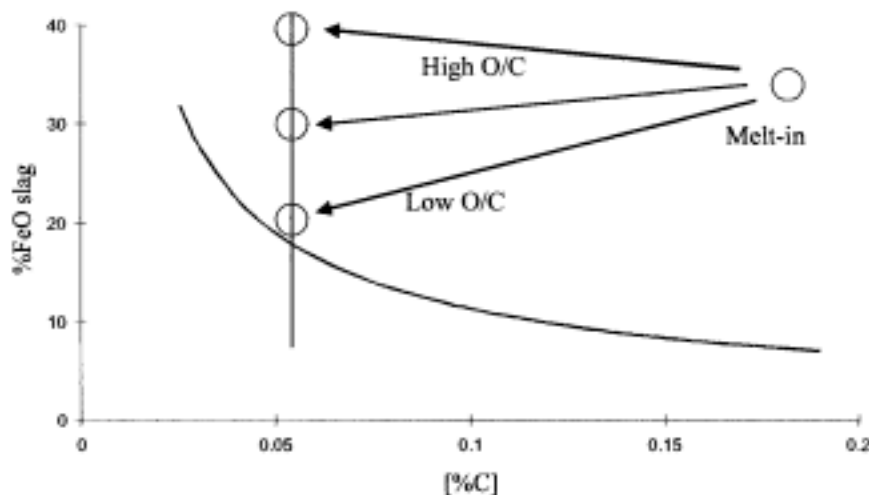


Figure 2: Change in compositions from melt-in to tap for injection profiles of different oxygen to carbon ratios, relative to equilibrium curve for specific conditions. H.Oltmann & E. Pretorius, AISE Conference 2002

In essence, even when starting at the same melt-in carbon in the bath and the same tap carbon, the FeO content of the slag will be impacted by the ratio of oxygen and carbon injection. When using high oxygen and low carbon ratio, the FeO content of 40% is observed as compared to using a low oxygen and higher carbon ratio injection, the FeO content of 20% is observed. Perhaps the ideal solution is the one indicated in the middle with considerations for yield, operating cost and material cost.

## 2. Considerations of mass balance for designing flux practices:<sup>1, 16</sup>

- The impact of metallics and non-metallics input to the furnace is important to the slag characteristics achieved for foaming and steelmaking cost.
- Types of metallic charge quality related to silicon, aluminum, carbon, iron oxide and dirt content impacts flux cost and yield losses related to FeO formation.
- Slag volume derived from the proper flux additions and FeO formation is important for arc coverage, yield and energy efficiency. Too little slag volume is more damaging than too much slag volume. However, cost is impacted by both extremes.

### 3. Slag characteristics required for foamy slag in the EAF:<sup>1, 2,4,13,15</sup>

- Slag chemistry as determined by the basicity ratio is required to retain CO gas bubbles. Sufficient FeO is required to react with carbon to produce bubbles.
- If slag viscosity is too thin, bubbles cannot be retained. (Watery)
- If slag viscosity is too thick, the gas bubbles are hard to form. (Crusty)
- The “Optimum” slag is molten and a saturated MgO slag with presence of suspended secondary phase particles, magnesio-wustite and di-calcium silicates. Usually 1% to 1.5% MgO above saturation value is targeted. (Creamy or Fluffy) Too many solids will make the slag crusty and have poor foaming qualities.

Additional work done on relationships of slag chemistry and improved performance in the electric arc furnace has been shown in the area of MgO solubility for refractory protection related to basicity, FeO content of the slag and temperature impacts.<sup>4, 13</sup> An example of this relationship can simply be seen in Figure 3 from “Magnesia Dissolution in Steelmaking Slags: by J.D. Smith and K.D. Peaslee of the University of Missouri-Rolla:

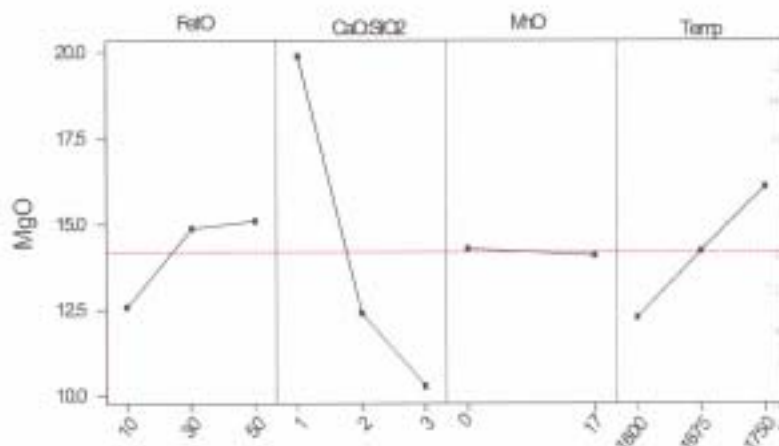


Figure 3: Graphical representation of the main effect (in wt% MgO) of factors. K.D. Peaslee, Magnesia Dissolution in Steelmaking Slags, 2002

### Metallurgical concepts for slag characteristics

Further efforts to translate this information was achieved by J. Kwong, J. Bennett, R. Krabbe of the Albany Research Center and Eugene Pretorius of LWB Refractories that helped to establish guidance for steelmakers in making significant improvements in productivity and cost effective steel production. Below is a quick review of key points from their findings done in the last few years:<sup>1, 4, 14</sup>

- Five oxides typically are monitored in the EAF slag, CaO, SiO<sub>2</sub>, MgO, FeO and Al<sub>2</sub>O<sub>3</sub>. These are used to determine slag basicity.
- The ratio between acid and basic oxides can be related by the following:
  - B ratio (Vratio) – CaO % / SiO<sub>2</sub> % - historical approach
  - B3 ratio – CaO % / (SiO<sub>2</sub> % + Al<sub>2</sub>O<sub>3</sub> %) - typically utilized
  - B4 ratio – (CaO % + MgO %) / (SiO<sub>2</sub> % + Al<sub>2</sub>O<sub>3</sub> %) - best approach
- The lower the basicity ratio the earlier the slag can be foamed. Typical in the EAF, B3 values between 1.5 and 2.0 are seen. Too low of basicity can affect phosphorous removal.

- MgO dissolution is based on basicity, FeO content and temperature. The lower the basicity, MgO requirement is higher for refractory protection. Higher FeO content, MgO requirement is higher for refractory protection. (see figure 3)
- Early addition of MgO is needed when slag is first forming and basicity is lowest. Final adjustments are needed near tapping to account for temperature increases and changes in FeO contents. Typical MgO values in EAF slags range from 10% to 14% based on slag chemistry.

Models and slag calculators were developed under the auspices of the SMA and various suppliers to the steel industry as an aid to steelmakers for a scientific approach in slagmaking and monitoring of foamy slag performance instead of the “sight and sound” only that was used by operators. These models allows the steelmaker to consider the changes in the steelmaking process by input of data relating to mass balance concepts, utilizing real time slag analysis, and scientific recommended changes in flux to achieve optimum foamy slag conditions. Examples of these efforts can be seen in work achieved by the Albany Research Center, Dr. David Schroeder of Schroeder and Associates, and LWB Refractories efforts through Helmut Oltmann and Eugene Pretorius. Instruments and software to monitor foamy slag in real time have been offered by electrode manufacturers and several steel industry equipment suppliers.<sup>5,10,12,16</sup>

### **Dolomitic lime vs Magnesite properties**

What are the differences in dolomitic lime and Chinese magnesite? Magnesite ( $MgCO_3$ ), the naturally occurring carbonate of magnesium is one of the key natural sources for the production of magnesia and usually occurs in a macro crystalline form. When it is calcined it forms a higher magnesia content product called Periclase.<sup>6,17</sup> Primarily dead burned magnesite is utilized for refractory brick production.

Dolomite is a common sedimentary rock forming mineral that contains alternating layers of carbonate ions which have magnesium and calcium ions associated with it. When it is calcined it forms a product called quicklime and contains particles of CaO and MgO in a finely dispersed mixture and not as a binary compound.<sup>7,17</sup>

### **Chemical and Physical Testing**

Comparative testing of dolomitic lime from locations in Ohio and Pennsylvania and samples of Chinese magnesite were analyzed. Chemical analysis was done using ICP analysis, mineral species identification of magnesite using x-ray diffraction analysis, melting points were attempted by using a Kopita furnace and a scanning electron microscope analyzing structures and chemical analysis of dolomitic lime and magnesite.

Chemical analysis of three different magnesite samples were obtained at three different steel plants and compared with that of dolomitic lime analysis in Table 1. The chemical analysis of dolomitic lime comes from two different locations, Ohio and Pennsylvania.

It can be observed that there is a possibility of variability in the material coming from China and could be related to processing of different mineral strata during mining or blending. In each case the steel plant was expecting the 90% minimum MgO content and in one of them it was received as expected. It would appear that sample “C” has been blended with either crushed dolomitic brick or dolomitic limestone to increase the MgO content because of the higher CaO content noted.

Even though both samples of dolomitic lime came from two different locations, one can see the degree of consistency in chemical analysis.

Table 1: Comparison of chemical analysis and melting points for magnesite and dolomitic lime

Comparative Chemical Analysis and Melting Points of Chinese Magnesite and Dolomitic Lime							
	MgO	CaO	SiO <sub>2</sub>	Fe <sub>2</sub> O <sub>3</sub>	Al <sub>2</sub> O <sub>3</sub>	LOI 1100 °C	Melting Pt ° C
<b>Chinese Magnesite</b>	Literature Data*						
A	93.6	2.01	1.74	0.76	0.67	0.82	2900
B	81.4	5.2	9.1	3.5	0.81	0.2	NA
C	72.11	9.53	3.25	0.89	0.73	13.06	NA
<b>Dolomitic Lime</b>							
Ohio	40.7	58	0.29	0.33	0.13	0.58	NA
PA	39.4	58	0.2	0.89	0.08	1.02	2400

\* Kopita Furnace could not attain these higher temperatures, therefore literature data was used.

Magnesite sample “B” was prepared for X-Ray Diffraction Phase Analysis. The sample had to be pulverized to -325 mesh in order to achieve the analysis. XRD Phase Analysis of the magnesite sample was identified and quantified using Rietveld whole pattern refinement. This indicated the following minerals in the sample:

Periclase – MgO	91.5 %
Forsterite Ferroan – (Mg <sub>1.8</sub> Fe <sub>0.2</sub> )SiO <sub>4</sub>	5.7 %
Monticellite – CaMgSiO <sub>4</sub>	2.8 %

The following picture is a photograph of the various components that were observed in the Chinese magnesite sample and selected visually for Scanning Electron Microscope analysis. The pieces are labeled A through K. It may be noted that sample “F” is a piece of coal and is a result of some contamination most likely associated with the ship when the material was loaded.



Figure 4: Multiple components observed in Chinese magnesite sample “B”.

Each component was analyzed in the Scanning Electron Microscope for structure and chemical analysis. Below are SEM photos showing typical structure and chemical analysis related to the picture above. MgO particles can be observed with the dense structure that is associated with these minerals. Corresponding chemical analysis of the photo is shown:

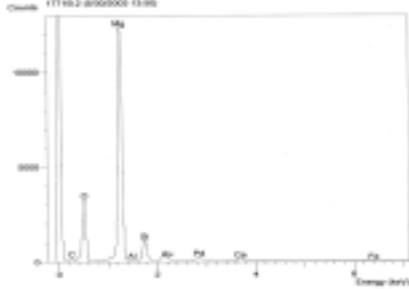
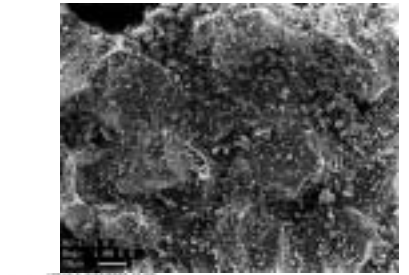


Figure 5: Sample B Mag=1.00 KX

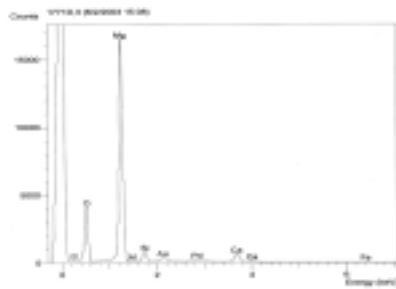
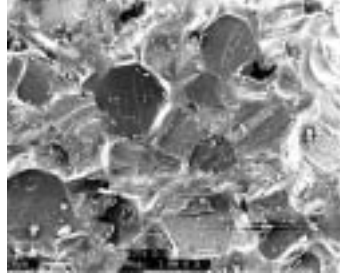


Figure 6: Sample D Mag=1.00 KX

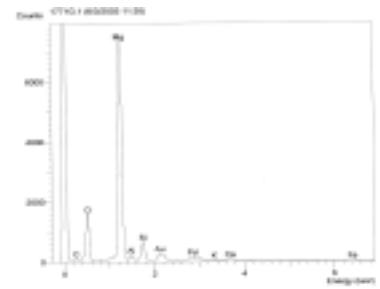
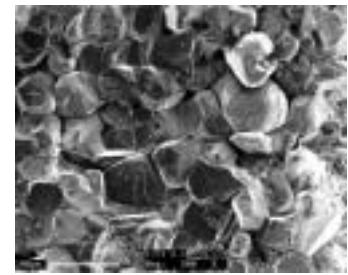


Figure 7: Sample G Mag= 500X

Dolomitic pebble lime which is commonly utilized, was assessed in the scanning electron microscope showing a structure which was more porous and showing the nature of dolomitic lime as a finely dispersed mixture of CaO and MgO particles. This porosity would allow a penetration mechanism of slag for dissolution whereby the magnesite has solid layers eroded during dissolution.

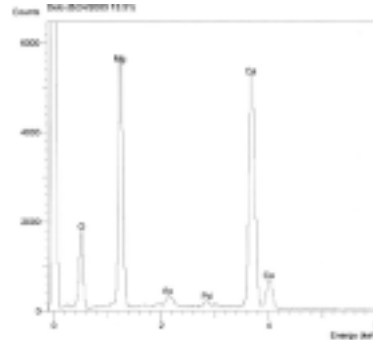
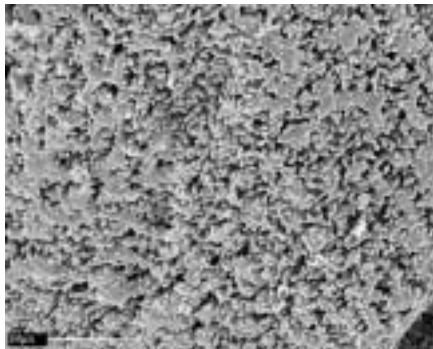


Figure 8: SEM image of dolomitic quicklime Mag = 5.0 KX

### Comparative dissolution of magnesite and dolomitic lime in electric furnace slags

Arguments have been raging about what dissolves faster in electric furnace slags, magnesite or dolomitic lime. A lot has been said about this subject without scientific evidence until recently. Work done by R.J. Fruehan, Y.Li and L. Brabie “Dissolution of Magnesite and Dolomite in Simulated EAF Slags” Carnegie Mellon University, ISS Tech 2003 showed that “for similar conditions, the rates of dissolution of the two materials are similar.”

A key point offered in this study shows that the dissolution of MgO is greater when the basicity is lower.<sup>3,4,13</sup> It is therefore important to introduce a flux into the metal heel prior to charging to counter the negative effects of these acidic oxides.<sup>13</sup> Failure to do so can result in erosion to the lower slag line area.

If only magnesite is introduced, the MgO unit amount required is greater than if dolomitic lime is introduced due to the relationship of MgO solubility and basicity. If the basicity ratio early in the heat is around 1, then the corresponding solubility of MgO is around 14%. If the basicity ratio is around 2, then the corresponding solubility of MgO is around 8%. (Figure 9)

The advantage of dolomitic lime in the first charge is the CaO units available with the MgO units and this will impact the early basicity and MgO requirement. Eugene Pretorius also noted in “Fundamentals of EAF and Ladle Slags and Ladle Refining Principles”, Baker Refractories, “...significant increase in MgO solubility (with decreasing basicity) for slags with basicity levels less than 2.0.” He further went on to show that the initial slag formed may have a low basicity which increases the MgO solubility even more. The recommendation to steelmakers in the paper stated, “The addition of dolomite with the first scrap bucket will provide the necessary MgO units for saturation, minimizing refractory wear on the bottom and lower banks of the furnace.” Figure 9 shows this relationship from this study:

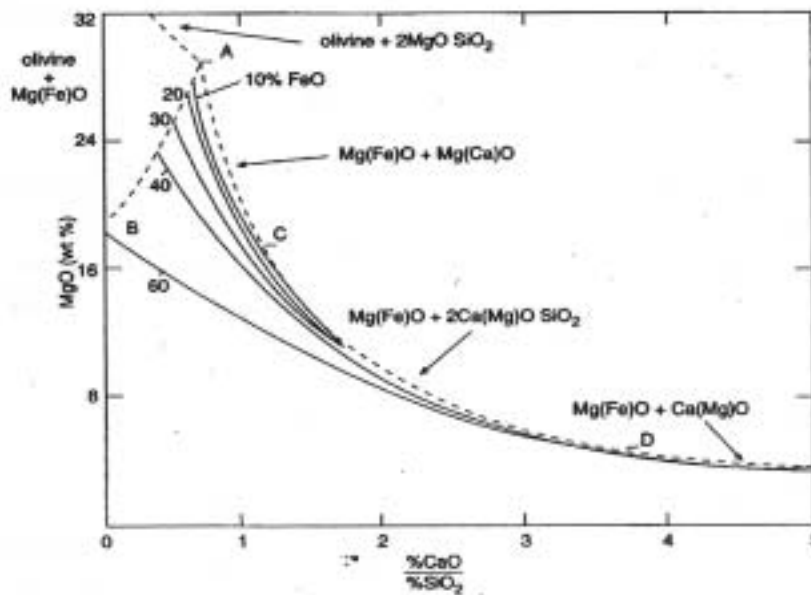


Figure 9: The solubility of MgO in CaO-SiO<sub>2</sub>-FeO slags. Dr. Fruehan, “Dissolution of Magnesite and Dolomite in Simulated EAF Slags” ISS Tech 2003 , Reproduced by permission of the National Lime Association

Dr. Fruehan further states that since in the steelmaking process, lime is always added the comparison of magnesia plus burnt lime vs burnt dolomite is more useful than just magnesite by itself. This shows that the rates of dissolution for a flux using equal amount of MgO and CaO and dolomite are similar.<sup>3</sup>

Figure 10 shows the comparison of magnesite, burnt dolomite and magnesite with lime in regards to the solids dissolved with time. In the experiment, Dr. Fruehan showed that for the rotating cylinders in the slag, “the rate in terms of mass dissolved per unit time is slightly faster than for magnesite.

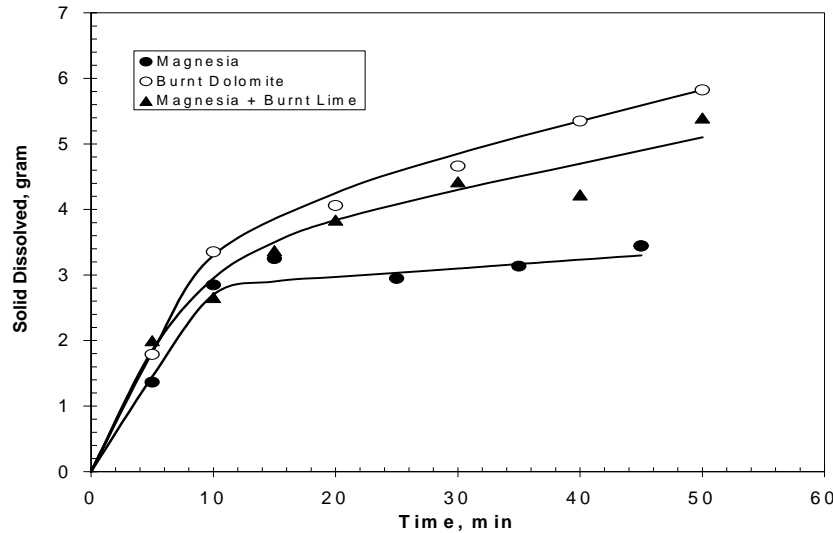


Figure 10: Amount of material dissolved for additions of magnesite(6.06g), dolomite (12.12g) and Magnesite plus lime(12.59g). Dr. Fruehan, “Dissolution of Magnesite and Dolomite in Simulated EAF Slags” ISS Tech 2003, Reproduced by permission of the National Lime Association

In regards to the industrial application, Dr. Fruehan points out that in the electric arc furnace “where temperatures are relatively high and basicity is less than two, the CaO in the dolomite should dissolve rapidly and the MgO grains will enter the slag where they dissolve.” “Magnesite should also dissolve easily unless the slag is close to saturation with MgO.” In this study, evidence of the mechanism for dissolution of dolomite and magnesite concluded the following key points as stated in the paper:<sup>3</sup>

- “For dolomite, it appears that the CaO is dissolved away first and the MgO grains enter the slag where they dissolve. No solid layers of calcium silicate were found for EAF conditions.”
- “For magnesite, the slag penetrates into the particle and solid layers of FeO · MgO form on the MgO grains.”
- “For EAF conditions and the particle sizes of magnesite and dolomite commonly used the rate of dissolution of both materials are essentially the same. As long as the basicity is below about two, dolomite should go into solution rapidly. For magnesite the MgO content must also be significantly below saturation for rapid dissolution.”

A real time trial to demonstrate the hypotheses developed by Fruehan and Pretorius was developed at NSBHP, Delta, OH and is presented in the following case study.

### Flux Practice Case Study

#### North Star BHP Steel – Magnesite Practice vs Dolomitic Lime Practice

##### Mill Background

North Star BHP Steel (NSBHP), located in Delta, OH, is a 50-50 joint venture between BHP Steel Limited and North Star Steel Company. BHP Steel Limited is the leading steel company in Australia and New Zealand. It has an extensive network of operations throughout Asia. BHP Steel Limited specializes in the production and marketing of flat steel products, including slab, hot rolled coil, cold rolled coil, plate, tin plate, and value-added metallic coated and painted steel products. It employs around 12,000 people in over 20 countries.

North Star Steel is a fully owned subsidiary of Cargill, Inc. Cargill is America's largest private company, the world's largest grain trader and food processing company. North Star Steel operates seven mini-mills, is the fifth largest mini-mill steel company in the U.S.A. and is the twelfth largest steel company overall.

The partnership brings together expertise in electric furnace steel making, slab casting and hot rolling technology in a synchronous flat rolled mini-mill. The steel mill is designed with a unique combination of proven technology to provide superior hot rolled coils.

### The Melt Shop

NSBHP produces approximately 1.9 million tons of hot metal annually. The electric arc furnace is a twin shell, twin shaft AC design. Scrap is fed into the furnace through a preheated shaft. The furnace produces 195 tons of fluid steel every 48 minutes tap to tap time.

Typical operating parameters are as follows:

- Heats/Day 28
- Heat Size, Tons 190 to 195
- Pig Iron Charge 20% to 22%
- Tap Temperature, C 1665
- Tap O<sub>2</sub> 860
- Tap Carbon 0.036%

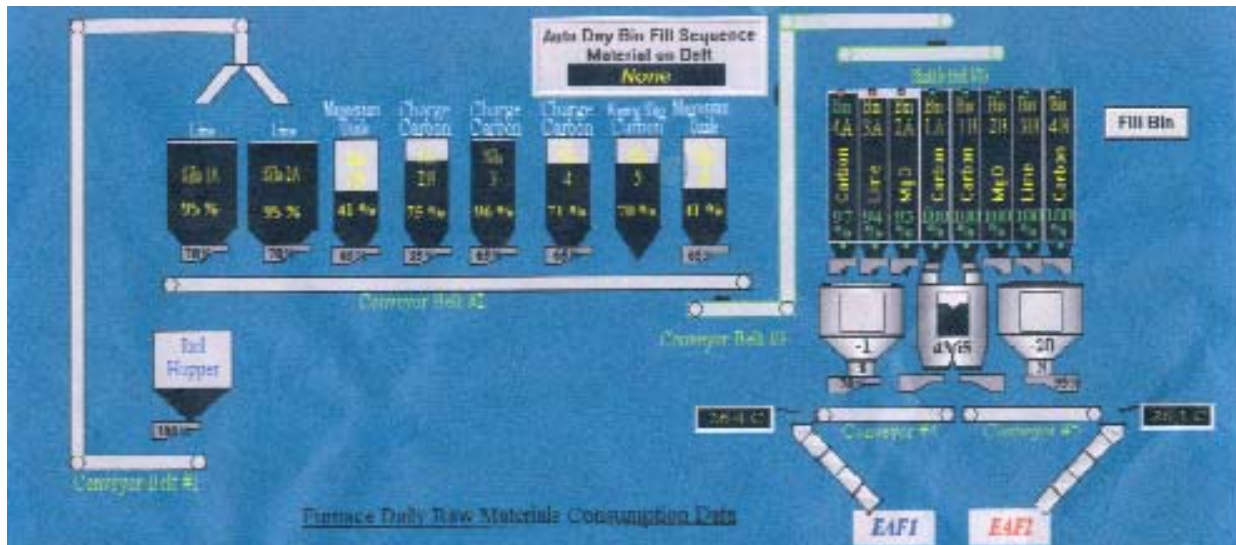


Figure 11 – North Star BHP Melt Shop Schematic

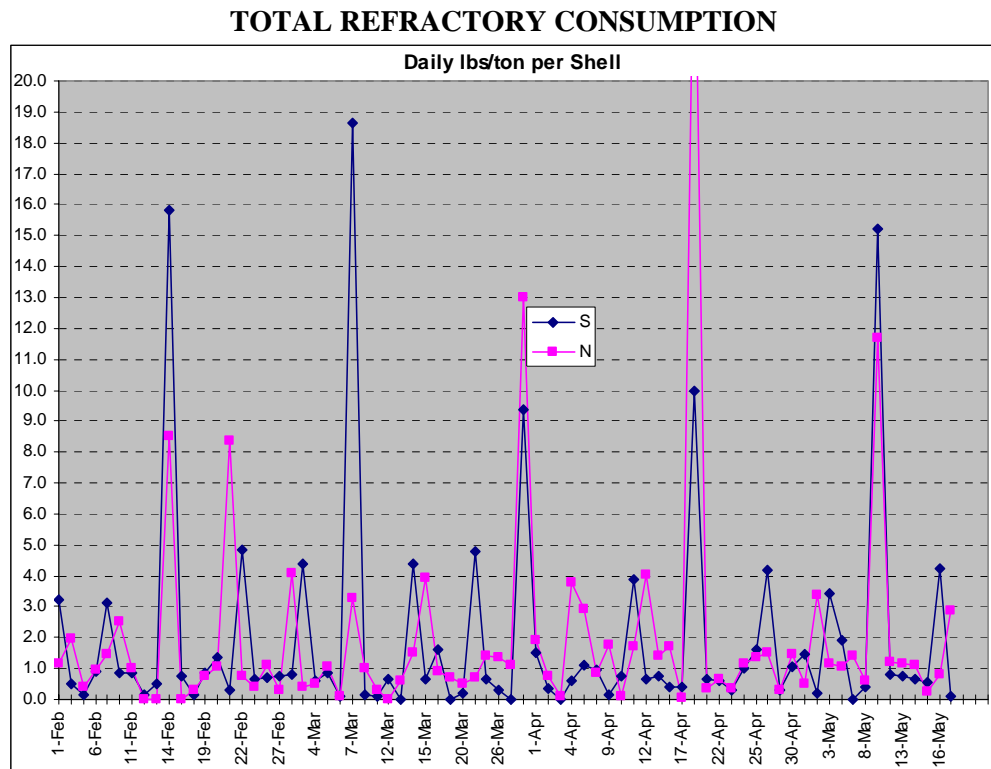
### Flux Background and History

NSBHP started up in June 1997 using a pre-blending flux containing 80% high calcium 20% dolomitic lime. This presented a 8% MgO addition on each charge in the heat. The flux charge model shows that the blended lime was added in increments well into the heat, and no lime was added to the heel. In October 1998, a trial using Chinese magnesite and high calcium lime was accomplished. A practice was established providing significant refractory savings and overall flux reduction. A practice change also occurred as the magnesite was added to the heel and first charge after power on. The contention was that magnesite went into solution faster than dolomitic lime. The practice change of front of heat additions of high percentage MgO was not considered.

In the first quarter of 2002 the Dissolution of Magnesite and Dolomite in Simulated EAF Slags study (Dr. R.J. Fruehan) was reviewed. This study determined in laboratory conditions that the dissolution rates of dolomitic lime and magnesite were similar. Under these conditions it appeared that magnesite did not go into solution faster and in that case the price per point of MgO should be the determining factor for MgO source.

A mass balance analysis was accomplished on the magnesite practice. A dolomitic lime substitution practice was designed to accomplish similar mass balance. A cost analysis comparison indicated a potential \$186.00/heat or \$1.00/NT of steel savings. The decision to run a trial was made.

The trial was conducted from May 6, 2002 through May 15, 2002, and was designed as a side by side trial with dolomitic lime and high calcium lime being designated in the south shell (No.1) and the magnesite and high calcium lime practice continued in the north shell (No.2) (see Figure 11). The run model for both shells was designed (Table 2) to charge equivalent amounts of MgO and high calcium lime in both furnaces based on the current magnesite practice.



S = South Shell No.1

N = North Shell No.2

Figure 12 – Refractory Consumption for the Magnesite vs. Dolomitic Lime Comparison

The trial results indicated that the V-ratio maintenance was consistent, KWH/NT of steel produced was consistent and refractory consumption was consistent (Figure 12). Flux cost savings was in excess of \$200.00/heat. An extended trial/practice change was scheduled for the first quarter 2003 at depletion of magnesite inventory.

In February 2003, the dolomitic lime practice replaced the magnesite practice, and has continued to present. A summary of the flux charge model for each of the practices at North Star BHP is shown in Table 2:

Table 2 –Flux Charge Model by Practice Shown as Percentage of Total Flux Added per Heat

Heat Duration	Dolomitic Lime Practice		Magnesite Practice		Blended Lime Practice
	Dolomitic Lime	High Calcium Lime	Magnesite	High Calcium Lime	80% High Calcium Lime / 20% Dolomitic Lime Blend
Heel	40%	0%	50%	0%	0%
5% Melt in	25%	60%	25%	50%	25%
25% Melt in	35%	40%	25%	50%	25%
50% Melt in	0%	0%	0%	0%	25%
75% Melt in	0%	0%	0%	0%	25%
Tap	0%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%

### Flux Practice Additions

In the magnesite practice, Chinese magnesite is added to the heel and early in the heat. High calcium lime was added throughout the heat to maintain a B3 ratio of 1.6 to 2.0 (V ratio of 2.3 to 2.7).

In the dolomitic lime practice, dolomitic lime (40% MgO) is added to the heel and early in the heat. Since the dolomitic lime also contains CaO (57%), the high calcium lime additions are lower to maintain the B3 ratio target. In addition, the CaO in the dolomitic lime added to the heel increases the basicity and improves the neutralization of the acidic oxides early in the heat.

Table 3 shows the flux charge model and Table 4 shows the summary of flux practice additions. In the magnesite and dolomitic lime practices, MgO and CaO units added are approximately the same. The past blended lime practice additions shown are estimated but reflect the lower amount of MgO added to each heat.

Table 3 - Flux Practice Additions

Flux Practice	Flux Oxide Lbs/Ton of Hot Metal		
	MgO	CaO	Total
Dolomitic Lime	15.6	31.7	47.3
Magnesite	16.5	31.5	48.0
Blended Lime	4.0	48.0	52.0

### Flux Practice Results

#### Slag

Since operating conditions and flux oxide additions were consistent with the magnesite and dolomitic practices, resulting slag chemistries are similar as shown in Table 4.

Table 4 - Typical Slag Chemistry of the Magnesite and Dolomitic Lime Practices

FeO	MgO	CaO	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	V Ratio	B3 Ratio
32 – 35%	11 - 14%	26 - 30%	9 - 13%	4 - 6%	2.3 - 2.7	1.6 - 2.0

## **Energy Consumption**

Typical energy consumption at NSBHP was similar for both dolomitic and magnesite practices at 330 KWH/ton of steel.

## **Refractory Consumption**

Gunning consumption during the dolomitic lime practice reduced significantly to less than 1lb/ton. Total refractory consumption was 2.46 lbs/ton for the dolomitic lime practice and 2.99lbs/ton for the magnesite practice.

## **Cost Savings**

Total cost savings of the dolomitic lime practice over the magnesite practice is \$1.22/ton of steel produced, and **\$2.3 million annually**.

## **Flux Practice Summary**

The evolution of the flux practice change from the high calcium lime/dolomitic lime blend to magnesite and high calcium lime to dolomitic and high calcium lime fed separately, has provided continued cost benefit to NSBHP.

NSBHP achieved significant improvement in refractory consumption after converting from the blended lime practice to the magnesite and high calcium lime practice. These improvements resulted from the flux charge practice change of adding the, magnesite (MgO) to the heel prior to power on. These results support the technical view that the higher MgO reduces refractory consumption early in the heat as the concentration of acidic oxide are at higher levels.

The benefits of converting to the dolomitic lime practice occurred two fold. First, the flux comparative results support the technical view that the dissolution of MgO in magnesite and dolomitic lime are similar under similar conditions. The decision of choosing magnesite or dolomitic lime becomes a matter of flux economics. At NSBHP, Delta, OH the dolomitic lime practice is the low cost option. Second, the flux practice change also supports the technical view that higher MgO levels and higher basicity added to the heel prior to power on improves the ability of the flux to neutralize acidic oxides and further reduce refractory consumption. Since the dolomitic lime contains CaO as well as MgO, the addition of dolomitic lime to the heel provides MgO and basicity at the beginning of the heat. This advantage at NSBHP resulted in a gunning consumption reduction of greater than 0.5 lbs/ton of steel compared to magnesite.

## **Conclusion**

A well managed foamy slag practice based on key steelmaking parameters decreases KWH/ton of steel, reduces tap to tap time, reduces refractory consumption by reducing arcing on refractories during power up time and provides medium for flux building for good clean steel practice

Recent scientific studies have shown for EAF conditions, the rate of dissolution of magnesite and dolomite are essentially the same for similar conditions.

Introduction of 65% to 80% of MgO units in the heel and in the first five minutes of power on time decreases total refractory consumption.

The mass balance requirements of MgO in slag with declining solubility as basicity increases is most cost effectively satisfied by utilizing dolomitic lime.

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