ISSN 1982-9345

42º Seminário de Aciaria Internacional

42nd Steelmaking Seminar - International

15 a 18 de maio de 2011 / May 15th - 18th, 2011

THE METALURGICAL, FINANCIAL AND ENVIROMENTAL BENEFITS OF THE CLEAN STEEL BLOCK (CSB) [1]

Ashley James Webster[2]
Paulo Leite[3]
Lucio Rey[3]

Abstract

After secondary metallurgy, when casting steel into the tundish or ingot mould from the steel teeming ladle, it is desirable to maximize the quantity of steel poured and to eliminate the carry over of ladle slag. Due to natural formation of a vortex in the ladle well area during casting this ideal is difficult to achieve. The use of the “Clean Steel Block” as a replacement for the conventional refractory wellblock in the ladle bottom inhibits this vortex which allows the Steelmaker to optimize his steel yield from the ladle whilst eliminating "carry over" slag. This paper will demonstrate the practical results of this system and outline the metallurgical, financial and environmental benefits it provides.
Keywords: Refractory; Clean steel; Vortex; Yield; Secondary metallurgy.

OS BENEFÍCIOS METALÚRGICOS, FINANCEIROS E AMBIENTAIS DO CLEAN STEEL BLOCK (CSB)

Resumo

Após a metalurgia secundária, quando do vazamento do aço da panela para os distribuidores ou lingoteiras, é desejável maximizar a quantidade de aço vazado e eliminar a passagem de escória da panela para o lingotamento. Devido a formação de um vórtex na zona do sistema de vávula da panela durante o vazamento, essa situação ideal é dificil de se alcançar. A utilização do Clean Steel Block em substituição às sedes de válvulas refratárias convencionais no fundo da panela inibe a formação desse vórtex o que possibilita ao Aciarista otimizar o rendimento do aço vazado ao mesmo tempo que elimina a passagem de escória para o lingotamento. Esse trabalho irá demonstrar os resultados práticos desse sistema e apontar os benefícios metalúrgicos, financeiros e ambientais que o sistema proporciona.
Palavras-chave: Refratário; Aço limpo; Vórtex; Rendimento metálico; Metalurgia secundária.

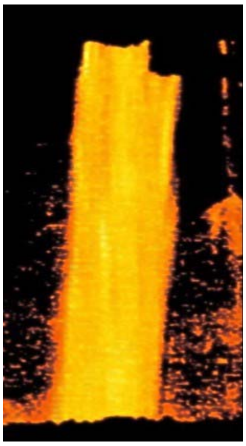
[1] *Contribuição técnica ao 42º Seminário de Aciaria – Internacional, 15 a 18 de maio de 2011, Salvador, BA, Brasil.*
[2] *PAHAGE Feuerfeste Erzeugnisse GmbH & Co.KG, Viersen/Germany*
[3] *Vamtec S.A, Vitoria, Brazil*

1 INTRODUCTION

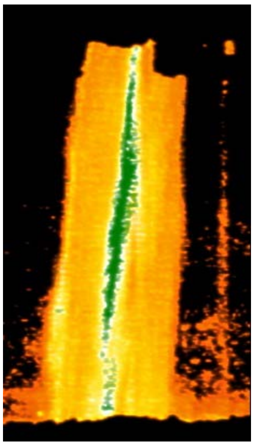
In today's competitive and challenging world market all steelmakers face the same basic question; how can I make improve my steel quality and produce it more efficiently? Much time, effort and cost is invested in steelmaking processes in order to solve these issues. One of the areas that require the most examination is the control and management of steel slag. A "necessary evil" for most steel producers slag is formed in both the primary and secondary steelmaking processes. During the primary melt in either the BOF or EAF "slag free tapping" into the ladle has evolved significantly over recent years by use of a number or techniques, most notably the convertor Slag Dart or the EAF Furnace Gate. The main focus of these two techniques is the maximisation of steel yield into the ladle. Slag carry over may be reduced, or indeed even eliminated, at this point but quickly becomes an issue again as the slag on the steel ladle, often in the form of synthetic slag, is an important component in the secondary metallurgy steel treatment.
Whilst it is therefore understood that slag will be present in the steel teeming ladle after the steel has been treated it is equally clear that from this point onwards it becomes the enemy of the steelmaker and is to be eliminated from all the processes downstream. Ladle slag carryover to the tundish can have a disastrous effect on the finished product quality. Slag in the ladle can also result in significant negative impact on steel yield and production efficiency. The Clean Steel Bock system is an effective solution to resolve these issues harmoniously.

2 THE CAUSE OF LADLE SLAG CARRYOVER

To understand the principles of the Clean Steel Block it is important to first consider the mechanism by which slag is carried into the tundish during casting and the existing methods of minimising this.
Initially as the casting ladle is drained into the tundish the slag is kept on the top surface of the steel for most of the casting duration by way of its relative lower density. During the latter stage of casting as the level of steel in the ladle is reduced a "vortex effect" is experienced. This means that rather than the lowest level of the steel in the ladle passing through the wellblock and inner nozzle and into the tundish, elements from the top surface of the melt are dragged down into the molten liquid flow. This results in ladle slag mixing in with the "clean steel" and being dragged into the tundish in the core of the metal steam (Figure 1).



Steel Stream Before Vortex



Steel Stream During Vortex

Figure 1 – The result of the vortex effect.

At this point the ladle still contains valuable amounts of clean liquid steel but further casting to drain all this steel from the ladle is resulting in the carryover of the unwanted slag.

Now the steelmaker has a decision to make. Do I maximise my ladle steel yield by continuing to cast and accept that I will "drag" slag to the tundish or do I optimise the steel quality and stop the casting now? Whilst the use of sophisticated slag detection devices, often based on electromagnetic or emissivity principles will assist the steelmaker to determine at which time the slag is being carried over they do not help him to solve the dilemma of when to finish the casting process. The sensitivity of the detection unit will offer a maximum amount of slag that the steelmaker deems acceptable but at this shut off point clean steel will be left in the ladle. This steel, along with the residual ladle slag can be scrapped, downgraded, or as often the case, separated and reworked. Effectively this means double treating this already processed steel, with all the associated costs of the procedure needing to be re-invested.

A summary of the choices of when to shut off the steel steam and the resultant consequences are shown below in Table 1. As can clearly be seen either option, early or late shut off, is a compromise.

Table 1 - Implications of decision when to finish ladle casting

Result	Early Shut-Off	Later Shut - Off
Maximised Steel Yield	NO	**YES**
Slag in Tundish Steel	NO	**YES**
Reduction of Steel Quality	NO	**YES**
Increased Tundish Nozzle Clogging	**NO**	**YES**

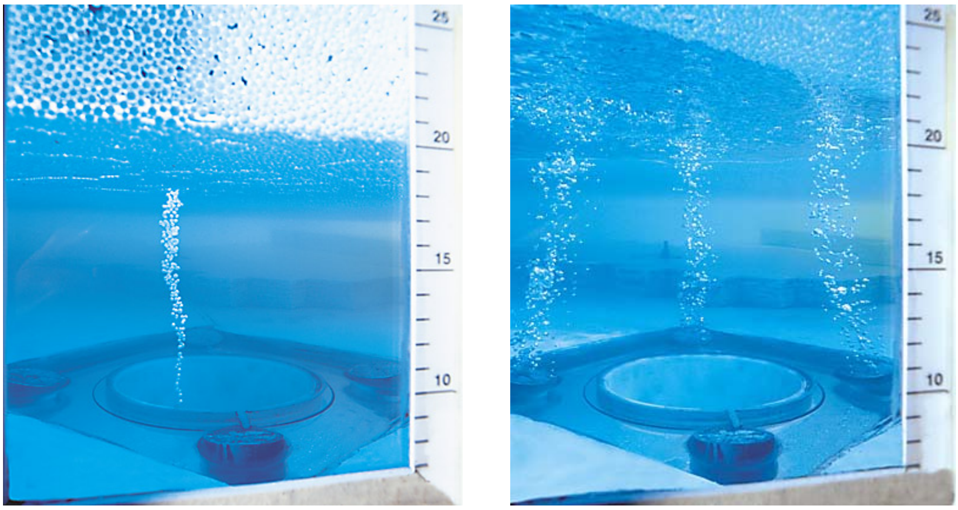
3 THE PRINCIPLE AND DESIGN OF THE CLEAN STEEL BLOCK (CSB)

In simple terms the CSB system uses a specially designed and constructed refractory wellblock that has four purging elements through which argon gas is gently blown upwards into the steel during the casting process (Figure 2).

ISSN 1982-9345

Figure 2 – Design of clean steel block.

This inert argon gas stream disrupts and nullifies the vortex effect in the ladle; see Figure 3 showing a water model demonstrating this effect.



Without Argon Flow With Argon Flow

Figure 3– Water Model showing the effect of CSB argon flow on vortex.

The CSB block is cast around the purging elements with ultra –high quality cement bonded castable based on the latest "Blue Spinel" technology. This castable uses pre-formed sintered Alumina Spinel aggregates which combined with its sophisticated binder system result in a very stable and thermal shock resistant castable that has excellent corrosion and erosion properties when in contact with liquid steel and slag. As the argon gas is passing through the middle of the block during casting it performs a "cooling effect" on the surrounding castable whilst in service, resulting in even further improved erosion resistance. This combination of the latest technology castable coupled with the cooling effect from the argon passing through the block means that the CSB has an extremely low wear rate in comparison with other more traditional ladle wellblocks. The unique "non wetting" properties of the Blue Spinel also ensure that no cleaning of the purging elements is required between casts, the purging elements open first time, every time. Experience has shown that the CSB, with its extremely low wear rate, gives such a high performance

ISSN 1982-9345

that the block does not require changing during the lifetime of the ladle lining and one Clean Steel Block will cover the whole of the one ladle campaign before re-line.

4 INSTALLATION AND USE OF THE CSB

To install the CSB is a simple procedure. As the design of the block can be changed to fit all available sliding gate systems on the market it can be installed in the ladle bottom by the bricklayers in exactly the same method as the existing wellblock, either cast or rammed, and can be used in conjunction with either a monolithic or bricked bottom configuration (Figure 4). The only change is that the flexible hose that connects the argon gas supply to the block must be positioned such that it can be fed through the ladle shell. As this takes place below the level of the ladle working lining it means that the only requirement is a small hole drilled into the ladle shell, which due to its low height in the ladle is well away from any area of the ladle which comes into contact with molten metal (Figure 5). This ensures that the access for the hose is 100% safe.

Figure 4- Installation of CSB in ladle bottom.

The argon is controlled by a specially designed flow meter (Figure 5). This small movable unit is fully automatic and is easily programmed to start the argon flow at whichever pre-determined point in the casting process is calculated as optimum for the specific ladle size and tap weight. The unit is usually placed close to the tundish area or ladle turret. Typical argon flow rates required to disrupt the vortex are extremely low, normally around the level of 10 - 12 litres/minute. The unit operates on a maximum argon line pressure of up to 16 bar. The controller delivers the argon independently from the influence of the ferro-static pressure of the molten steel and also incorporates a shut off valve in the unlikely event of a power supply failure. All parameters of the argon flow are monitored and recorded by the controller to provide full traceability for each heat treated.

ISSN 1982-9345
42º Seminário de Aciaria Internacional
42nd Steelmaking Seminar - International
15 a 18 de maio de 2011 / May 15th - 18th, 2011

Flexible hose from CSB

Flow Controller

Figure 5 – Configuration of argon supply pipe and the flow controller.

To physically operate the CSB the practice is again fundamentally basic. Simply couple the gas hose to the flow controller just prior to the start of casting when the ladle is positioned by the tundish. The pre-programmed flow controller is then started, with one button operation. The argon gas will purge through the CSB at the determined rate sufficient to break up the vortex, allowing optimisation of the steel yield to be successfully discharged into the tundish without the risk of slag carryover.
See Figure 6 for a typical argon flow rate throughout the casting process. Note in this example the argon flow (soft bubbling) is introduced a couple of minutes prior to the start of casting. This is an optional step that can be used to equalise the steel temperature to redress any heat differences that may have occurred after the end of the normal secondary metallurgical treatments. This helps to minimise the occurrence of any non-metallic elements in the melt.

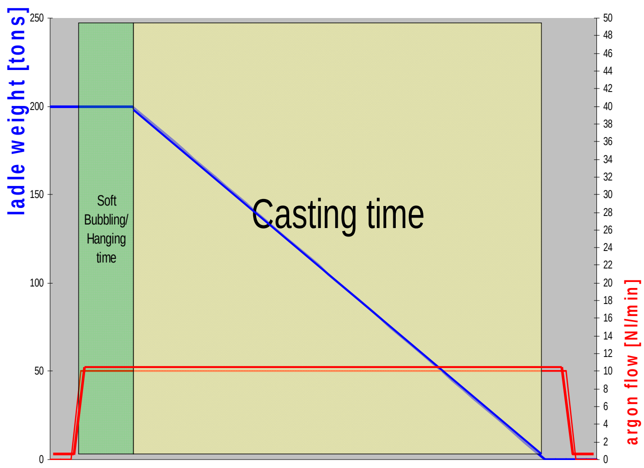
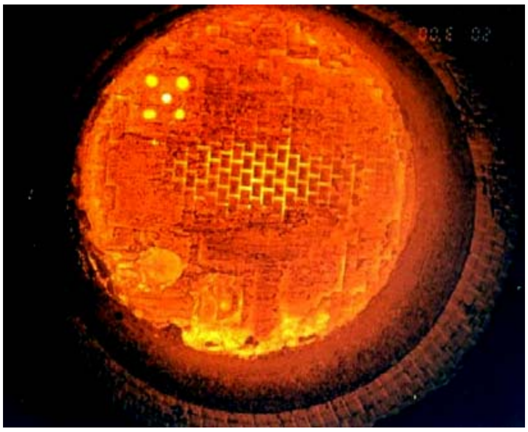


Figure 6 – A typical argon flow rate for the CSB.

At the end of the casting process the CSB hose is disconnected from the flow controller and the ladle continues in the normal circuit for the production process i.e. back to pre-heating.

ISSN 1982-9345



CSB Prior to casting

CSB during final casting

Figure 7 – Clean Steal Block in service.

5 AN EXAMPLE OF ACTUAL RESULTS WITH THE CLEAN STEEL BLOCK

Plant Details:

Annual Production; 2,500,000 Tonnes
Production Process; BOF
Ladle Size; 260 Tonnes
Heats/Annum; 9600
Ladle Life (Heats); 90 (average)

CSB Lifetime:

CSB Life (Heats); 90 (full ladle lifetime)

Steel Yield Comparison:

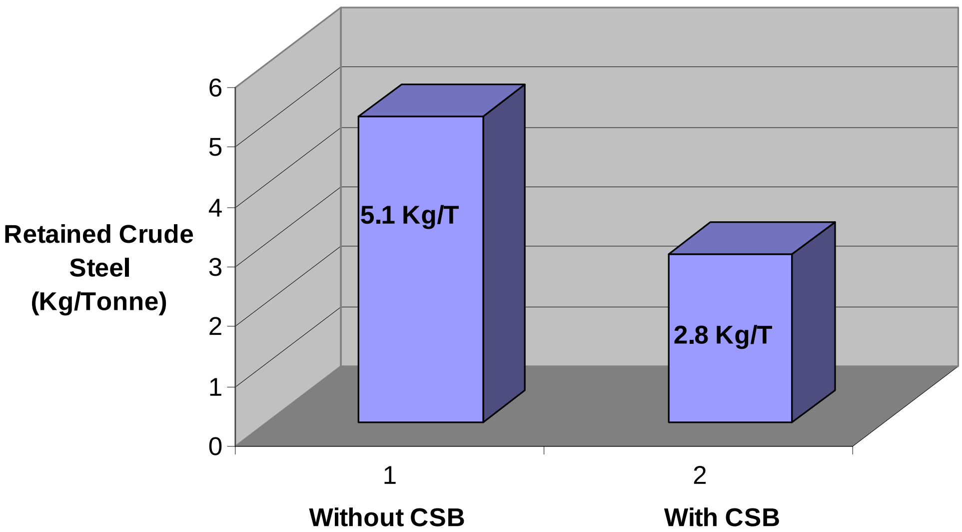


Figure 8 – Actual Result, Residual Steel (per tonne produced).

Based on the above result the plant achieves a weight saving of 2.3Kg per tonne of steel produced (5.1Kg – 2.8Kg=2.3Kg) or *0.23% yield improvement* per tonne of steel. Based on an annual production of 2,500,000 tonnes per annum;

OR:

5,750 tonnes steel per annum increased yield.
(Approximate gain of 22 heats per annum)

Based on actual the plant experiences the other benefits of the CSB are shown as:

- Increased cleanliness of Steel (minimal slag carry over)
- Reduction in Wellblock consumption (and waste disposal)
- Reduction in tundish nozzle clogging (reduction in non-metallic elements)
- Improved secondary metallurgy efficiency from CSB soft bubbling at the ladle turret.

6 THE PHILOSOPHY OF THE CLEAN STEEL BLOCK "SYSTEM"

It is very important to explain and understand the philosophy of the CSB concept. Critically it must be considered a "system", not just a refractory item. For it to succeed and demonstrate the benefits outlined in this paper it needs the cooperation and team working from several departments within the steelplant. This is outlined below in Table 2.

Table 2 – Departmental Responsibilities for the successful CSB System.

Steelplant Department	Responsibility
Maintenance Dept.	**Ladle Preparation**
Refractory Dept.	**CSB Installation/Lining**
Continuous Casting Dept.	**Argon Supply (Connecting /Disconnecting)**
Ladle Station Dept.	**Testing, Preparation for Next Heat**
R&D / Quality Dept.	**Evaluation/Results**

7 SUMMARY AND OUTLOOK

With proper internal steelplant coordination the use of the Clean Steel Block system can realise significant improvements for the user. It is not a simple consumable refractory item but a practical, effective, technical process solution. Its potential impact can be experienced across a wide area of a steelplant's operations, positively assisting quality, raw material, production, refractory and environmental departments. Whilst direct cost savings in the form of increased steel yield and improved steel cleanliness are, on a stand alone basis, attractive and significant the CSB system can also help generate other genuine process improvements and indirect benefits which may further assist the steelmaker to gain advantage in an increasingly competitive world market.