THE ADVANTAGES & DISADVANTAGES OF INCORPORATING A FOURTH STOVE WITHIN AN EXISTING BLAST FURNACE STOVE SYSTEM[1]

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Abstract
There is a growing trend among iron-makers, particularly those operating plant built in the 1970's, or older, to add a fourth stove to the blast furnace hot blast system. The reasons for adding a further stove to the system are usually to provide increased security of operation and to provide more operational flexibility. However, if the fourth stove is correctly specified at the time of ordering and a modern control system is incorporated significant increases in blast duty can be achieved. The paper explores all of the advantages and disadvantages both technically and financially of add a forth stove in the existing system.
Key words: Stoves; Operation; Blast furnace.

AS VANTAGENS E DESVANTAGENS DE INCORPORAR O QUARTO REGENERADOR NO SISTEMA EXISTENTE DE UM ALTO-FORNO

Resumo
Atualmente, no mundo, está aparecendo um aumento da requisição entre os produtores de ferro gusa, particularmente entre os que operam plantas construídas nos anos 70, para se adicionar o quarto regenerador no sistema de aquecimento de ar. A razão para se adicionar um regenerador no sistema é normalmente o aumento da flexibilidade e da segurança de operação. No entanto, se o quarto regenerador é especificado corretamente e um sistema de controle é incorporado um aumento significante na geração de ar quente pode ser atingido. Este trabalho explora as vantagens e desvantagens, tanto técnicas quanto econômicas, de se adicionar o quarto regenerador no sistema existente.
Palavras-chave: Regenerador; Operação; Alto-forno.

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4 Introduction

Siemens VAI has extensive experience in hot blast stove technology covering both internal and external arrangements. Our portfolio includes the Krupp Koppers technology for external combustion chamber stoves following the acquisition of this company in the early 90s.

Fourth Stove Installation

There are a number of reasons for adding a new stove to an existing system. A 4th stove can be added to an existing system designed such that the four operate together to produce the increased the blast duty of a furnace after a rebuild. The smooth operation of the furnace can be guaranteed with the 4th stove acting as a backup whilst repairing or replacing the existing stoves 1 at a time. Four stoves operating in a cyclic mode can improve the combustion performance of the existing stoves due to the 60% increase in the gassing time available when compared with three stoves. This allows higher blast duties to be achieved. This is important where the combustion chambers of the existing stoves are too small for the future duty, yet their chequer chambers are quite adequate. This is quite commonly found in older stoves. Four stoves operating in staggered parallel mode can increase the blast temperature by up to 30°C compared to three stoves operating in cyclic mode thus increasing blast duty.

Reference Projects

Before looking at the benefits of a new stove in more detail, it is considered useful to review data on relevant reference projects.

Firstly, at Mittal SA Vanderbijlpark, a new fourth stove of an internal type was added to three existing external stoves. This project was then followed by the systematic rebuilding of two of the three existing Stoves and ultimately replacing of the Hot Blast Main as part of the blast furnace rebuild. When the project is finally completed in 2007 during the blast furnace rebuild, the stove arrangement will have been modified from three aging and non-performing external stoves to three new and modern internal stoves. Refer to Figure 1.

Figure 1 – Mittal SA Vanderbijlpark BF D – Fourth Stove

In a second project, completed for SSAB in Lulea a range of stove work was carried out commencing with a hot burner replacement on an existing stove, then installation of a new 4th stove and finally a partial rebuild of two of the remaining external chambered stoves. This is a case where the fourth stove always ensured three stoves were available during rebuilding the existing stoves. At the same time the new stove will significantly reduce the waste gas velocities in the combustion chambers of the existing stoves, when operating in a four stove cyclic mode at the future increased blast duty.
On Figure 2, it is possible to see the new internal stove positioned at the end of the three external stoves. In this case, the stove arrangement has been modified from having three aging external stoves to one new internal stove, two repaired external stoves and one aging external stove. This last stove may be repaired at some stage in the future.

Figure 2 – SSAB Lulea BF 2 – Fourth Stove

There is one further point of note relating to the stove arrangement at SSAB Lulea. The new fourth stove on this blast furnace was of an internal type working alongside three external types. The new internal stove has the same heating surface area as the old external stoves. There are therefore no performance issues with regard to the operation of internal and external stoves together. In fact, there is no performance advantage of an internal stove over an external stove if both are of the same heating surface area.

Technical and Economic Cases for the Addition of a Fourth Hot Blast Stove

Figure 3 shows the performance of a typical three stove system and the increase in blast temperature an additional stove can achieve. For an assumed blast duty of 180,000 Nm3/h at a blast temperature of 1250ºC and each stove having a heating surface area of 41,200 m², the graph shows a comparison between different types of operation and the effect on blast temperature. A 400ºC maximum flue gas temperature i.e. the temperature at the end of the gassing cycle, is taken as the constraint which limits increase in blast temperature.

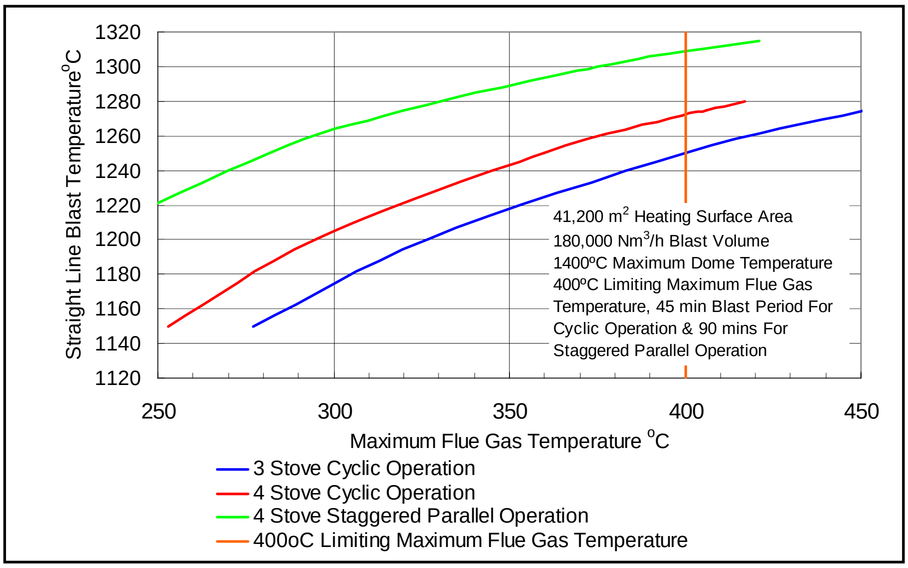

Figure 3 – Stove Performance Comparison – Temperature Improvement

The most common reason for building a fourth stove is to enable hot metal production to continue whilst the existing stoves are sequentially rebuilt one by one. The justification for this case is totally economic as discussed later. However once the fourth stove is built and if all three of the existing stoves are rebuilt, the resulting four stove system has several operational advantages over the original three stove system.

The original 'as built' three stove system is represented by the blue line. For a 45 minute blast period, this system has a limiting duty of 180,000 Nm³/h of blast at a blast temperature of 1250ºC when operating up to the maximum flue gas temperature constraint of 400ºC. Four stove cyclic operation is represented by the red line. This shows a 22ºC increase in blast temperature over the three stove cyclic operation when operating under the same conditions with a 45 minute blast period. Finally, if four stove staggered parallel operation is adopted, as represented by the green line, a 59ºC theoretical increase in blast temperature over the three stove system is possible. In reality, this is more likely to be approximately 30ºC, due to the volume of gas that would need to be burnt exceeding the capabilities of the combustion chamber. This constraint is discussed later.

As an alternative to the increases in blast temperature, as shown above, Figure 4 shows the potential increases in blast volume for the same typical stove system.

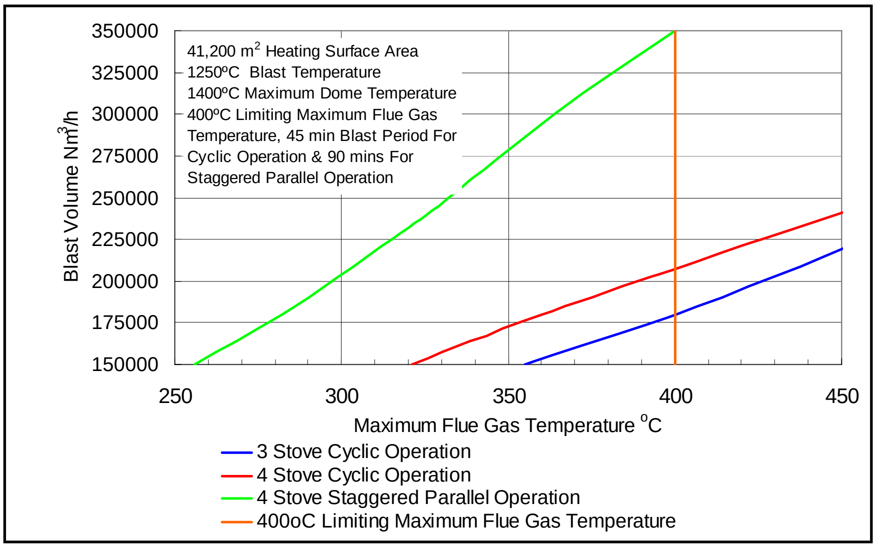

Figure 4 – Stove Performance Comparison – Volume Improvement

The blue line represents the original three stove system which achieves its design maximum blast volume of 180,000 Nm³/h when operating with a blast temperature of 1250ºC and a 45 minute blast period. The limiting constraint is the maximum flue gas temperature of 400ºC, which is shown where the blue line crosses the vertical orange line.

If a fourth stove with the same heating surface area and mass is added to the system, when operating in a four stove cyclic mode, a blast volume of 208,000 Nm3/h can be achieved. This is at the same 1250ºC blast temperature, 45 minute blast period and limiting maximum flue gas temperature of 400ºC. This is represented by the red line.

Similarly for four stove staggered parallel operation, which is represented by the green line, a theoretical blast volume of 350,000 Nm3/h can be achieved. This is unlikely to be achieved due to the increase in the volume of gas that would need to be burnt in relatively small combustion chambers.

Study Investigations

A common investigation carried out by Siemens VAI is to look at the viability of a stove addition, usually to achieve an increase in the blast duty – a so-called study investigation. In a typical analysis, the target duty would be to achieve a blast volume of 265,000 Nm³/h at a temperature of 1250ºC from three existing stoves and one new stove. The easy part is to size the new stove. The difficult part is to find an operating condition which will allow the existing stoves to make their contribution without exceeding any of the many constraints which limit stove performance. The results of this exercise are shown in Figure 5, 6 and 7.

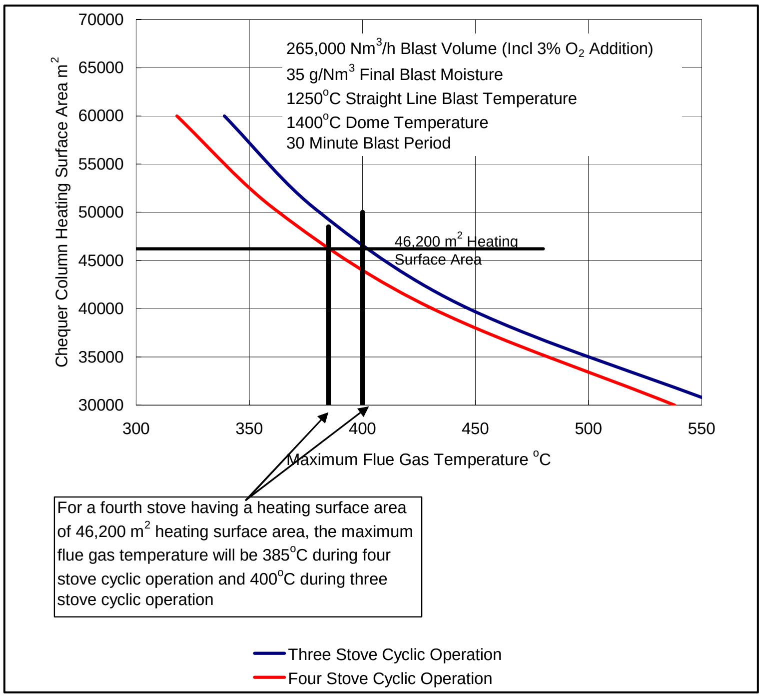

Figure 5 – Stove Performance Comparison – HSA v Flue Gas Temperature

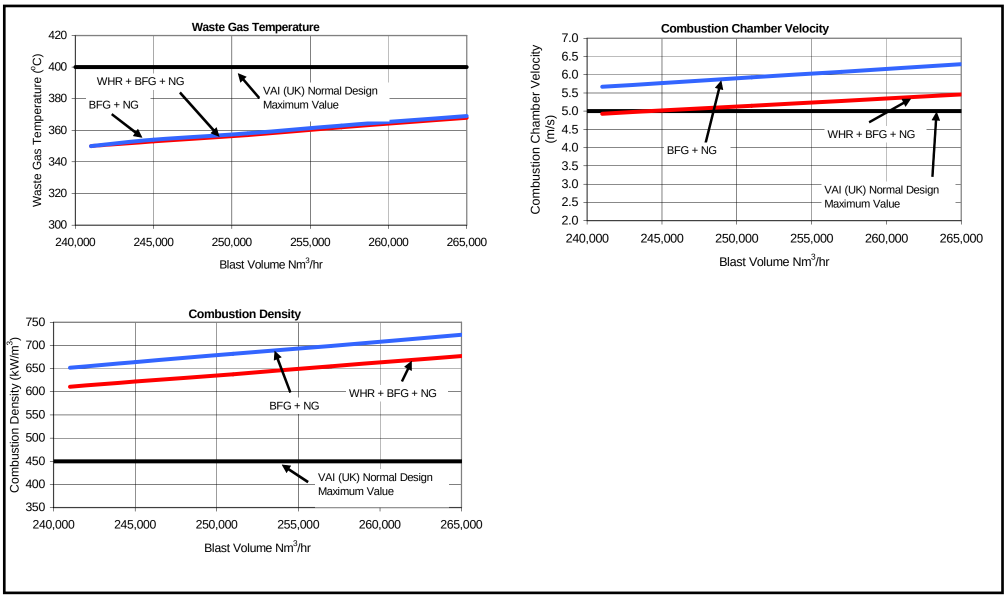

Figure 6 – 3 Stove Cyclic Operation - 30 Minute Blast Period

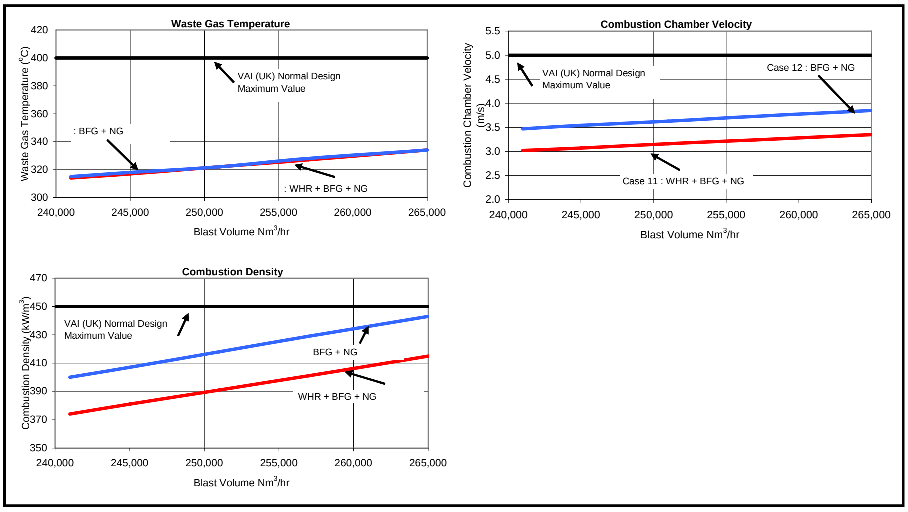

Figure 7 – 4 Stove Cyclic Operation - 30 Minute Blast Period

In Figure 5, it is possible to see a summary of a study analysis relating to the need for a fourth stove in an existing system.

The study considered alternative gassing and waste heat recovery options using an in-house computer model. The model was used to forecast performance using a 3 or 4 stove system as can be seen on the graph –showing a relation between heating surface area and waste gas temperature. Within the analysis, the 4th stove was then sized and performance forecast.

For a fourth stove having a heating surface area of 46,000 m2 the maximum flue gas temperature will be 385 ^{o}C for four stove cyclic operation and 400^{o}C for three stove cyclic operation.

The main constraints which limit stove performance are the maximum waste gas temperature, the flue gas velocity in the combustion chamber and the combustion density.

The maximum waste gas temperature is usually set at 400ºC. This is both a function of the material of the columns, grids and girders and achieving an acceptable efficiency from the stoves.

The waste gas velocity in the combustion chamber is ideally limited to 5 Nm/s in Siemens VAI UK designs. Above this velocity there is an increasing risk of incomplete combustion, or pulsations which in extreme cases can cause damage to the burner, or even the combustion chamber lining. High velocities are a common problem in older stoves operating at higher duties than originally designed for. Their combustion chambers are often too small to cope with their generously sized chequer chambers.

Combustion density is a measure of the heat release rate from the burner applied to the volume of the combustion chamber. Values above 450 kW/m³ can result in the same problems as high waste gas velocity.

Returning to the target duty of 265,000 Nm³/h of blast at 1250ºC previously noted, Figure 6 shows how the existing three stoves would perform when measured against the maximum waste gas temperature, combustion chamber waste gas velocity and combustion density constraints.

The graphs show that the maximum waste gas temperature is below the constraint value, but that the combustion chamber waste gas velocity and the combustion density are both above the acceptable levels and therefore the target duty is unlikely to be achieved.

Figure 7 shows how the existing three stoves would perform when they are working with an additional stove in a four stove cyclic mode. We have not considered staggered parallel operation as each stove receives the same percentage of the total cycle for gassing the stoves as three stove cyclic operation and therefore this type of operation would have the same waste gas velocity and combustion density problems as shown in the previous slide.

Four stove cyclic operation increases the available gassing time for each stove thus lowering the waste gas velocity and the combustion density. This can be seen where all of the constraints are satisfied at the target duty.

Stove Operation Modes

In Figure 8, we can see a comparison of the different gassing periods associated with the different operating cycles for stoves.

The first cases shown are for three stove cyclic and four stove cyclic. In both cases, the blast period is of 30 minutes duration. For the three stove cyclic case, the corresponding gassing time is 50 minutes and for the four stove cyclic case, the corresponding gassing time is 80 minutes. In both cases, the assumed changeover time is of 10 minutes total duration.

Clearly, by changing from three to four stove cyclic, for the same blast period, the gassing period is extended by sixty percent which has an impact on the gassing rate of the stoves. This is particularly helpful for some older stoves, where the rating of their combustion chambers and burners may not match the capability of the chequer chamber during three stove cyclic operation.

The last case shows the arrangement for four stove staggered parallel operation. In this case, the same gassing period as three stove operation is provided for a blast period twice the length of that of comparable three stove operation but at approximately half the blast flow. Again, this feature of the operation has an effect on the stove physical design.

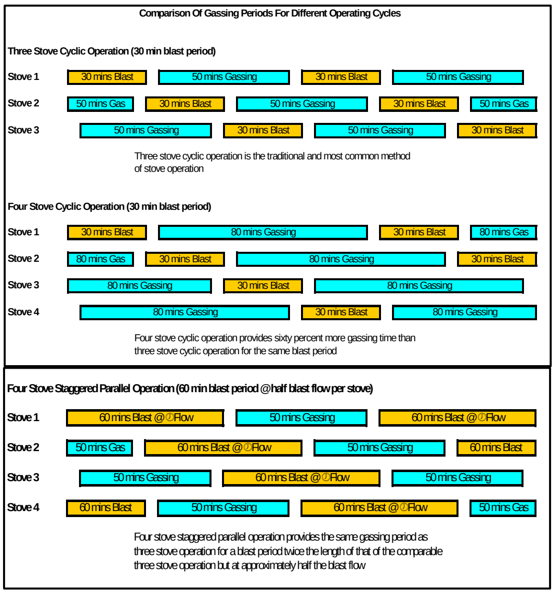

Figure 8 – Stove Operating Modes – Effect on Gassing Time

Cost Implications

In Figure 9, the cost implications of the two key methods of repairing a set of stoves are compared. This cost analysis is simple and makes basic assumptions on various costs, particularly those associated with lost production.

Replacing 3 existing stoves can be done in 2 ways:

Rebuild the existing 3 stoves one by one operating at 2 thirds capacity using only 2 stoves.

■ **Intervention time to rebuild 3 stoves**	**24 months**
■ **Daily iron production**	**7500 tonnes**
■ **Loss of iron production, during 24 months, due to 2 stove operation**	**1.8 million tonnes**
■ **Cost of pig iron per tonne**	**280 US$/ tonne *(IBS Steel Statistics, April 2007, page15)***
■ **Revenue loss due to rebuild of 3 stoves**	**US$ 504 million**
■ **Loss Of Profit, Assume, Say 4%**	**US$ 20 million**

Add a 4th stove and rebuild the existing 3 stoves one by one thus using 3 stoves at any one time and operating at full capacity.

■ **Investment Cost of New Stove**	**€ 20 million**

Figure 9 – Cost Comparison

The first option is to carry out a repair of all three stoves sequentially with associated losses in production. In the calculation, it is assumed that the total project time will be 24 months and during this time, it is estimated that the blast restrictions imposed will result in a loss of 1.8 million tonnes of iron. This loss of iron is based upon an assumed loss in production of around one third with the reduction to two stove operation. With an assumed cost of pig iron of Euros 275 for this iron, the revenue loss with be of the order of US Dollar 500 million and taking a guess at a profit margin of 4% loss of profit will be US Dollar 20 million.
As a comparison, the investment cost for a new fourth stove is around € 20 million.
Cleary, the decision to install a new fourth stove looks attractive. Whilst the investment cost approximately equals the savings, at the end of the program the plant has a four stove system offering more security and if required an increased duty.
It is fully accepted that this analysis is of a simplified nature and the production loss and the iron cost can all be challenged. However, the important point to note is the trend and it is strongly believed that the conclusion noted is reasonable.

Conclusion

Many companies are now opting to add a fourth stove to their existing three stove system and this provides:-
The addition of a fourth stove to an existing three stove system enables the existing stoves to be sequentially rebuilt with no loss of production at the blast furnace, or from any of the downstream production processes.
The cost of a fourth stove approximately equals the losses that would have been incurred if the alternative two stove operation was adopted with reduced iron production whilst rebuilding three existing stoves.
The final rebuilt plant will have four stoves with the potential of blast higher duties.