HOT OXYGEN INJECTION – INCREASING PCI (POWDER COAL INJECTION) RATE IN BLAST-FURNACES [1]

HOT OXYGEN INJECTION FOR BLAST FURNACES

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Abstract

PRAXAIR is one of the largest industrial gases producers in the World, present in more than 40 countries. The Company's sales are largely destined to the steel industry. PRAXAIR has the experience of supplying products and services to all kinds of steel mills. Several technologies developed by the Company, such as *CoJet*® (a system of coherent oxygen jet injection in EAF and BOF furnaces), *Slag Splashing* (splashing slag to cover BOF furnaces' walls increasing refractory wear campaign life), AOD (a process for special steel production) and others, are currently in commercial operation in different parts of the world. In Brazil, PRAXAIR is the owner of White Martins, the largest industrial gases company in South America, present in nine countries of the continent. Company's portfolio includes atmospheric gases, carbonic gas production, acetylene, hydrogen, special and health care gases, welding mixtures, gas seamless steel cylinders, applications equipment, and gases storage and transportation. Recently the Company has started the operation of a natural gas liquefaction unit. The present work has the objective to show the potential benefits of the Hot Oxygen Injection, a system for coal or coke fines injection in blast furnaces, developed by PRAXAIR, that is able to inject fines in rates higher than the observed in conventional injection systems. The Hot Oxygen Injection is able to increase the firing rate of the injected fines, making this increase possible.

Key words: Fines injection; Blast furnace; Coal; Charcoal; Coke.

Resumo

A PRAXAIR é uma das três maiores empresas de gases industriais do mundo, com atuação em mais de 40 países. Grande parte das vendas da Companhia é destinada à indústria siderúrgica. A PRAXAIR possui experiência para fornecer produtos e serviços para todos os tipos de siderúrgica. Diversas tecnologias desenvolvidas pela Empresa, como o *CoJet*® (sistema para injeção de jato coerente de oxigênio em fornos elétricos e conversores), *Slag Splashing* (espalhamento de escória nas paredes de conversores, aumentando a vida útil dos refratários), *AOD* (processo para produção de aços especiais) e outros, encontram-se em operação comercial atualmente em diferentes partes do mundo. No Brasil, a PRAXAIR é a controladora da White Martins, maior empresa de gases industriais da América do Sul, presente em nove países do continente. Seu portfólio de produtos inclui os gases atmosféricos produção de gás carbônico, acetileno, hidrogênio, gases especiais e medicinais, misturas para soldagem, cilindros de aço sem costura, equipamentos para aplicação, transporte e armazenamento de gases. Recentemente a empresa iniciou a operação de uma unidade para liquefação de gás natural. O presente trabalho tem por objetivo mostrar os potenciais benefícios do *Hot Oxygen Injection*, um sistema para injeção de finos de coque ou de carvão em altos-fornos desenvolvido pela PRAXAIR, capaz de realizar a injeção de finos em taxas superiores a dos sistemas atualmente conhecidos. O *Hot Oxygen* Injection é capaz de aumentar a capacidade de queima dos finos injetados, tornando este incremento viável.

Palavras-chave: Injeção de finos; Alto-forno; Carvão; Carvão vegetal; Coque.

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1 INTRODUCTION

Coal fines, always generated during product's handling and transportation, represent losses and environmental issues for the steel industry. Even charcoal and mineral coal fines must be adequately stored to avoid environmental hazards.
Another aspect that should be emphasized is the coke production in the steel mills that uses this product in its blast furnaces: it normally represents high costs and high emission levels to the atmosphere, requiring an adequate treatment.
Coke consumption reduction is always an issue carefully studied by the steel industry.
Fines injection in blast furnaces means the creation of value to a product, that before was a waste, and an environmental liability, substituting another product of higher acquisition cost.
Coal fines injections in charcoal or conventional blast furnaces is a useful and well known procedure in commercial operation in several steel mills around the world. PRAXAIR technology Hot Oxygen Injection represents an evolution on fines injection, making it possible for it to be done in higher injection rates, optimizing even more blast furnaces raw material costs.

2 DESCRIPTION OF THE TECHNOLOGY

Charcoal or coal fines injection in blast furnaces is a well known procedure in the steel industry. PRAXAIR has a PCI (Powder Coal Injection) System that is already in commercial operation in many pig iron producers with successful results. For each 1 kg of fines injected, 1 kg of charcoal can be replaced.
The Hot Oxygen Injection technology, developed by PRAXAIR, is able to increase the amount of fines injected (kg of fines injected per ton of pig iron), creating even more value to the industry. In the conventional systems, high injection rates can represent operational problems, such as the presence of carbon in the blast furnace gas and the increase of the pressure drop inside the furnace. To make the coal fines injection possible in higher rates, a more efficient combustion of the fines is necessary and can be achieved with the Hot Oxygen. Table 1 shows a comparison of the different injection modes.

Table 1. Comparison of the Different Injection Modes

Ambient Injection	Hot Injection

• **Turbulence**
  • Sonic velocity 300 m/s
	• **Turbulence**
	  • Sonic velocity 800 m/s

• **Cold Oxygen / Cold Coal**
  • Slow heating
  • Low volatile release
  • Need blast mixing for ignition
	• **Hot Oxygen / Cold Coal**
	  • Rapid heating
	  • High volatile release
	  • Ignition without dilution

• **Position Near Raceway for Radiant Ignition or Low Oxygen Concentration at Ignition**	• **Flexible Position and Oxygen Concentration ~80% at Ignition**

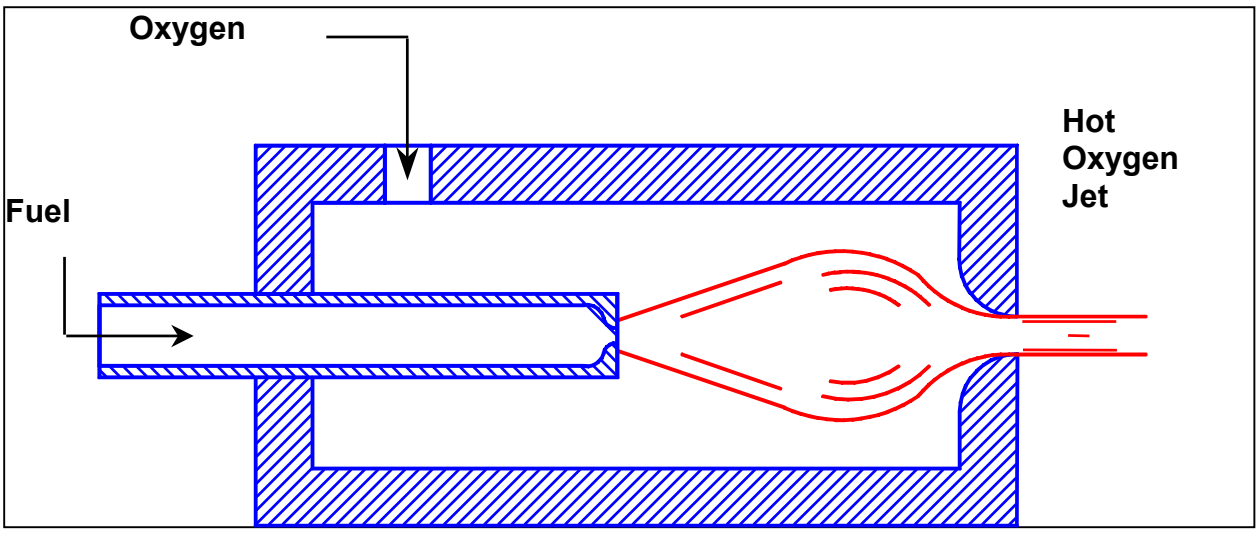
Source: Praxair Technology Center.

The Hot Oxygen Injection lance makes a combined blow of oxygen and natural gas, using an amount of oxygen than stoichiometric for combustion (Hot Oxygen chemistry is shown in Table 2). Not all the injected oxygen is consumed during combustion, making it possible for the excess of oxygen leaving the lance to be available, allowing a more efficient burning of the fines injected. Figure 1 shows a schematic drawing of a Hot Oxygen Injection lance.

Table 2. Hot Oxygen Injection Chemistry

Oxygen Temperature	Reactant		Product		Sonic Velocity
°C			Composition	Percent	m/s
1350	Oxygen	100 m³	Oxygen	81.9	745
			Carbon Dioxide	6	
	Natural Gas	6.4 m³	Water Vapor	12.1	
1650	Oxygen	100m³	Oxygen	77.1	800
			Carbon Dioxide	7.6	
	Natural Gas	8.2 m³	Water Vapor	15	

Source: Praxair Technology Center

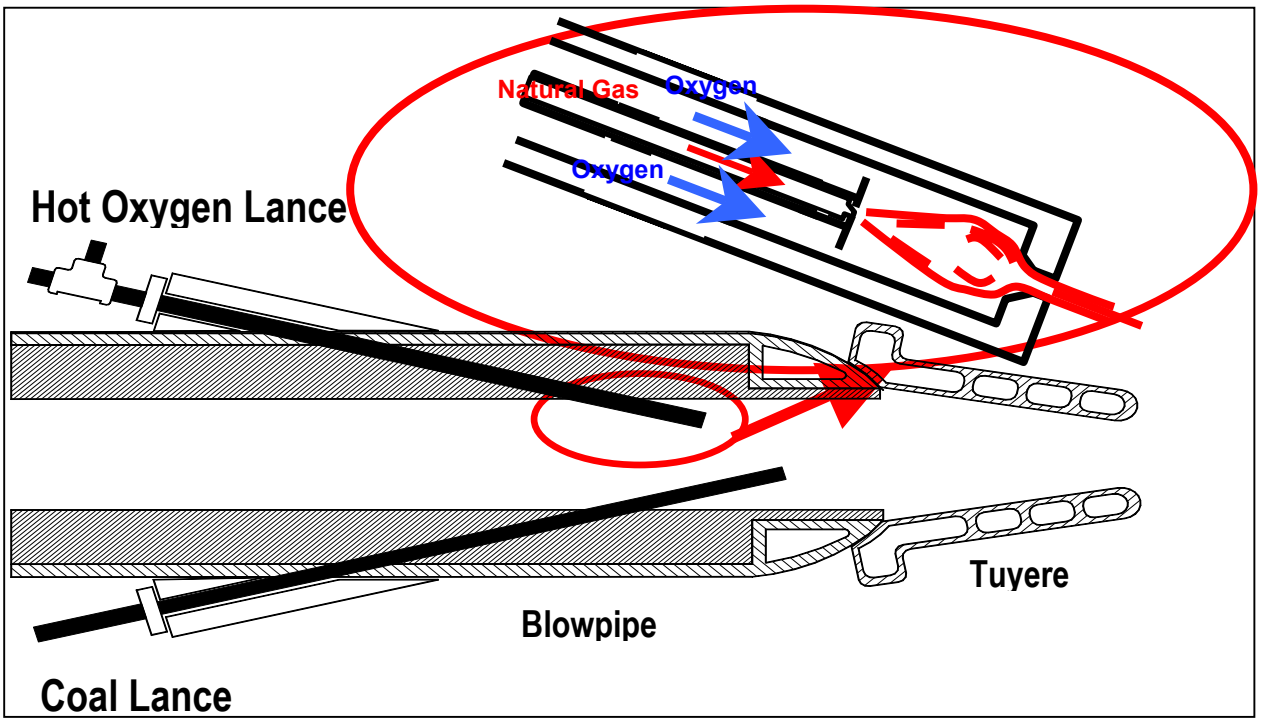


Source: Praxair Technology Center

Figure 1. Hot Oxygen Injection Lance Schematic Draw

3 INJECTION SYSTEM AND FINES COMBUSTION EFFICIENCY

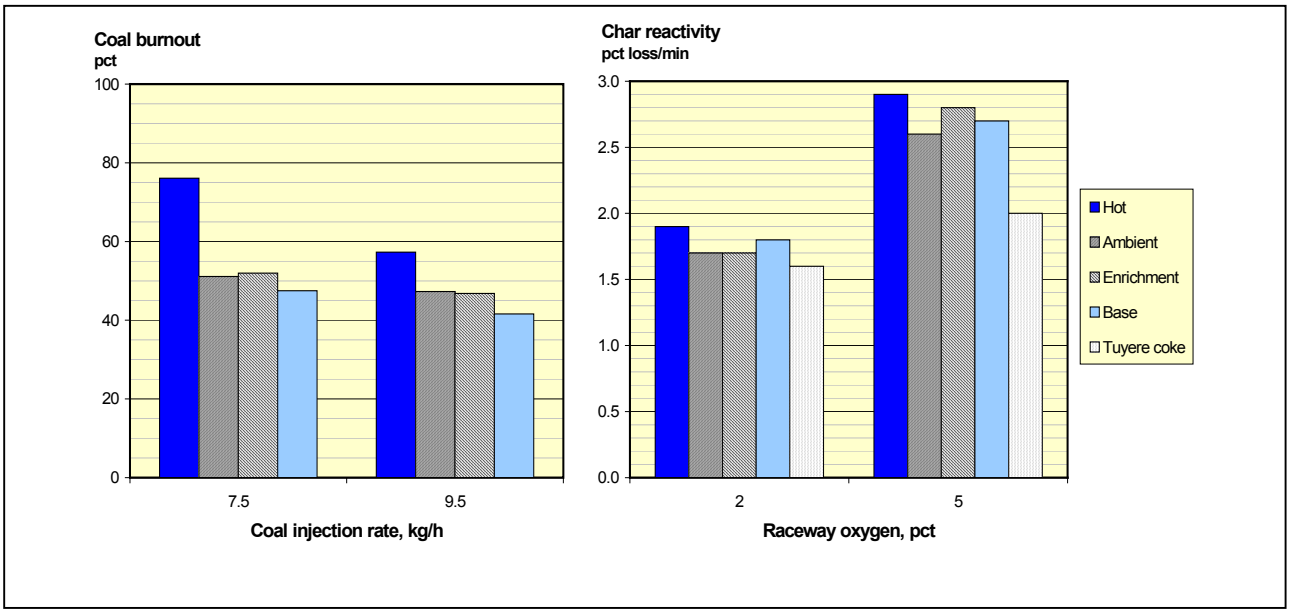
The injection system is composed of two lances (one for the hot oxygen and another for coal fines) assembled in the blow-pipe where the different flows are mixed, before entering in a blast furnace tuyere. The burning of the coal fines starts in the blow pipe, before the tuyere, as shown in Figure 2.



Source: Praxair Technology Center

Figure 2. Injection System in Blast Furnaces

The use of hot oxygen maximizes the combustion of the coal fines. Figure 3 shows the increase in coal burning rates and in coal reactivity brought by the Hot Oxygen technology.



Source: Praxair Technology Center

Figure 3. Additional efficiency of the combustion brought by Hot Oxygen technology. Resultados dos testes em escala piloto – comparação entre enriquecimento com oxigênio, injeção de oxigênio a temperatura ambiente, e injeção do oxigênio quente. A queima do carvão com o oxigênio quente é entre 20% e 50% superior em relação às outras rotas.

For good operation, and to reach the expected results, the Hot Oxygen Injection system requires individual controls for oxygen, natural gas and purge nitrogen for each lance. In this way, the accurate control of the relation natural gas/oxygen assures the correct temperature of the hot oxygen to be injected. There are also equipments for control/diagnostic and safety mechanisms to stop the operation in case of any problem.

4 HOT OXYGEN TESTS

With the objective of demonstrating the potential economical benefits, listed on Table 3, the tests planning for Hot Oxygen Injection has been divided in two stages: Phase 1 and Phase 2, developed in a conventional blast furnace in USA.

Table 3. Potential Benefits – Increase the amount of fines injected in comparison to the amount of coke or charcoal consumed

Injection System	Blast Furnace Charge Composition	
	Fines	Coke
Hot Oxygen Injection	38%	62%
Conventional PCI	31%	69%
Base Case - Only Coke	0%	100%

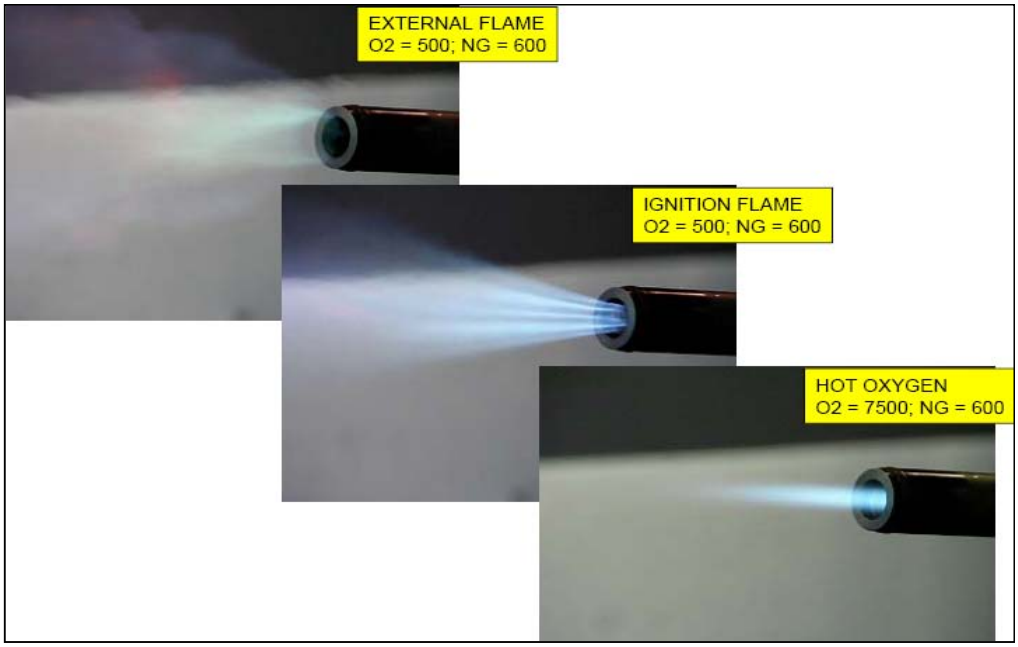
Fonte: Praxair Technology Center

- Phase 1 Main Goals:

    - Demonstrate the hot oxygen injection in two tuyeres of a commercial blast furnace
    - Monitor the life time of the lance, energy costs and effects on the fines combustion
- Phase 2 Main Goals
    - Demonstrate the hot oxygen injection in all the tuyeres of a commercial blast furnace
    - Increase the fines injection rate in 35 kg per ton of pig iron
    - Demonstrate the potential benefit that might be between US$ 0.84 and US$ 2.90 per ton of pig iron depending on the prices of blast furnace raw materials.

Phase 1 has already been concluded and Phase 2 is already being negotiated to be developed in Brazil. Following, the results of Phase 1 are listed:

- Any adverse effect has been observed in the equipment during the operation
    - Any change in the surface of the blow pipe has been detected
    - The heat supplied by the tuyeres has increased in 10%
    - The control f the ash deposits has been done adjusting lance position
- Increase in coal burning rate
    - Measurements of pressure in the blow-pipe and tuyeres suggest that the Hot Oxygen increases the burning rate by 30%.
    - It is very important to assure that the ignition will occur inside the lance combustion chamber as show in Picture 4.
- Lance performance
    - The durability of the lance has increased by 85% with the modification of the construction materials and the learning and practice of the ignition
    - Any significant hazard has been detected in 30 days of operation.



Source: Praxair Technology Center

Figure 4. Sequence of the Operation. It is important to assure the ignition of the burner before the start of the fines injection. To make it possible, the heat from furnace gases is used. After the ignition, the tip is positioned more inside the lance and the hot oxygen and fines start to be injected.

All Phase 1 goals have been achieved, proving that:

- Lance performance is trustable;
- Any hazards to the furnace have been detected;
- Improvement in coal burning rates was possible.

4 CONCLUSIONS

Phase 2 has been negotiated with a steel producer with operations in Brazil and the preparations have already started.

There is a great potential that the objective of increasing fines injection rates will be achieved and reduce charcoal or coke consumption. Regarding Phase 1 results, the most important aspect has been reached: coal fines burning rate was higher while using the Hot Oxygen Injection.

Regarding the operational aspects, no damage to the furnace components has been detected and the lance showed a trustable performance. Mixture ignition, another very important issue, has been well understood and the mechanism to make it successfully is now under control. An adequate control of the amount of fuel and oxygen injected will be able to assure the efficiency and the successful operation of the process.

Hot Oxygen Injection is showing itself to be an alternative with great potential to increase the productivity of the integrated steel mills.