TECHNOLOGICAL EVOLUTION OF THE TECNORED PROCESS[1]

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Abstract

The Tecnored process is a new ironmaking technology that has been developed on a unique approach of combining the application of both empirical and theoretical fundamentals, backed by extensive tests carried out in a dedicated pilot-plant with close support of universities and research centers. The campaigns in the pilot-plant focused on understand, simulate and operate the furnace using different reactor sizes, including a full size modular slice of the industrial furnace, which provided real-life conditions to develop the main features of the process such as internal dimensions, ultimate flame engineering, raceway pattern, thermal and gaseous profiles and melting zone formation, shape and maintenance. This approach has proven to be an extraordinary tool to abate the risk of scale-up and for the designing of the industrial-scale furnace. This paper describes the different phases of the technology development with respective goals and achievements.

Key-words: Alternative ironmaking; Self-reduction; Coal; Tecnored.

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[1] Technical contribution for the 60th Annual Congress of ABM, 3rd Seminar on "Self-reduction and cold bonded agglomeration", July 25 to 28, 2005 – Belo Horizonte – MG – Brazil
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1 THE TECNORED PROCESS

Tecnored Ironmaking is a quantum leap technology that uses a moving bed shaft furnace served by classical peripherals and featured by two innovations: the side feeders of solid fuels and the secondary combustion (Figure 1). Tecnored technology has been conceived and developed in Brazil in four versions on a unique approach combining experiments on a full size slice of the industrial reactor, mathematical modeling and exhaustive bench scale tests [1].

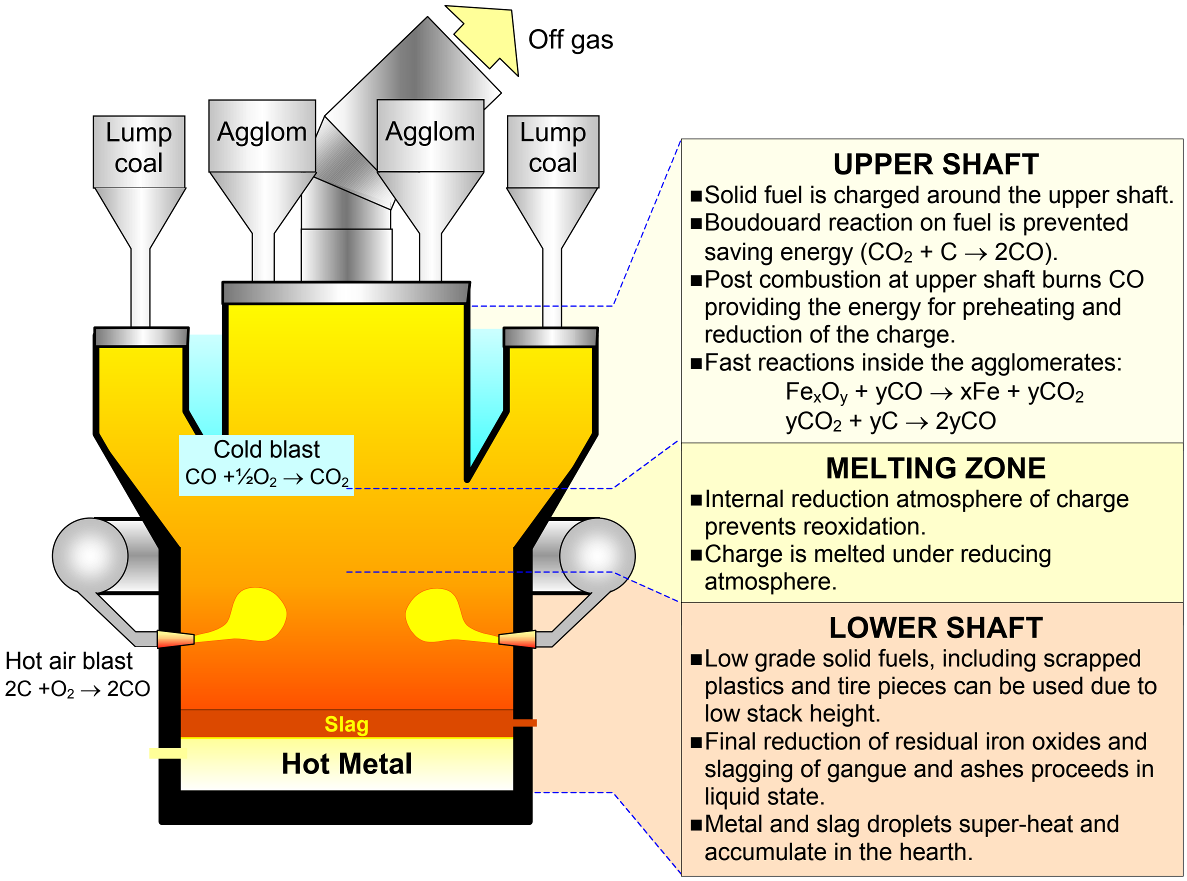

Figure 1. Cross sectional of the Tecnored Furnace

Tecnored is a carbon-based iron making process, using self-reducing agglomerates, in a reactor that is much smaller than a blast furnace but shares many of its technologies. The Tecnored process does not require coke, nor oxygen and can use low-grade raw materials, including fines, dusts and sludges.

Tecnored is the only emergent iron reduction technology that offers a complete range of benefits for the modern heavy demands of a global industry:

- uses low-cost iron ore fines/concentrate and waste oxides as sources of iron units;
- uses lower-cost conventional grades of coal as sources of reducing gas and energy, therefore, completely dismissing the use of coke;

- produces fully reduced / metallized liquid hot metal that can be used in both steel production routes;
- environmentally friendly process;
- very competitive low capital costs with the ability to widely utilize existing infrastructure and facilities in certain applications such as blast furnace replacement;
- modular nature of the process (furnace is of rectangular section) means that the technology can be either efficiently operated over a wide range of production capacities and implemented in a phased manner;

The Tecnored technology was gradually developed during more than 20 years and four pilot plants were constructed meanwhile. An industrial size demonstration plant is under construction and will start operations by the end of 2005.

2 HISTORIC OF THE DEVELOPMENT

The driving force of the origin of the Tecnored technology development was the attempt of the company Tupy[5] in the early 80's, on searching for alternative metallic charges for its operations, which led a consulting company named Setepla-Tecnometal to propose the use of self-reducing pellets in the existing cupolas of Tupy instead of conventional charge.

Coincidently, a state owned company, also located in Santa Catarina (city of Imbituba), called ICC (Indústria Carboquímica Catarinense) was generating a considerable amount of a Fe2O3 rich material (pyrite cinder), as a by-product of sulfuric acid production. This residue was found to be suitable in chemistry and size for use in self-reduction applications besides to be an environmental concern, leading ICC to join the development sought by Tupy (use of self-reducing agglomerates as metallic charge in cupolas).

Figure 2 shows the operational flow-sheet of ICC, while Table 1 shows the characteristics of the Fe bearing by-product.

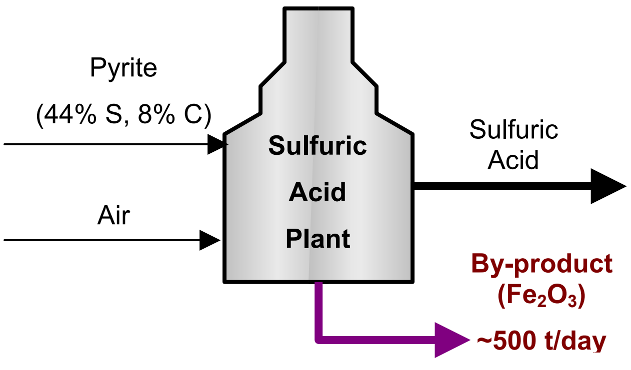

Figure 2. ICC operational flow-sheet.

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[5] Tupy is the largest foundry in Brazil, based in Joinville state of Santa Catarina,

Table 1. Typical analysis of the pyrite cinder (ICC).

Fe_2O_3	83.00%
SiO_2	8.80%
Al_2O_3	3.00%
P_2O_5	0.30%
S	1.20%
Others	3.70%
Size range	*500 – 900 g/cm²*

Therefore, the first ideas that later resulted on both the Tecnored process and the enterprise, were actually related to find an alternative source of raw material to feed cupola furnaces rather than to develop a new ironmaking process. Nonetheless, a few years after the beginning of the development, the existing partners concluded that the potential on the use of self-reducing agglomerates could (and should) extrapolate the initial perspectives [2]. In 1988 a company was formed to develop and market this very auspicious technology, the Tecnored process.

2.1 Phases of the Development

The development of the technology has been made assisted by a solid methodology of empirical and theoretical understandings and problem solving techniques, backed by the various tests in the pilot-plant (Figure 3), in close cooperation with universities and research centers.

This cooperation had resulted in a series of databanks (thermodynamic and kinetic coefficients), thesis and publications in Brazil and abroad, mathematical and physical modeling of the Tecnored furnace, alternative binders development, in-loco observation of relevant reactions, learning of the phenomenology and mechanisms of the process among other achievements, extensively used in the development.

Figure 3. Tecnored pilot plant.

In short, the history of the development comprises different phases with different goals, testing a wide range of raw materials and using distinct sizes and concepts of the reactor, as follows:

a) 1979 to 1985

Description: Development and use of pyrite cinder containing self-reducing pellets as metallic burden in cupola furnaces (preliminary phase, prior to the formation of the company).

Outcome: Good results though with high fuel rates and unable to operate the cupolas with a 100% self-reducing pellets based charge.

Decision: Rather than to adapt the self-reduction to an existing equipment it has been decided that a new furnace should be devised to fit in to the process, in order to get the best possible benefits from the technology. In 1985 the concept of the Tecnored furnace has been formulated at last, already including the side feeders for the solid fuel and the post combustion in the upper shaft, the two main features of the technology.

b) 1985 to 1990

Description: Process development in a small circular furnace of 400 mm dia., aiming at to demonstrate the feasibility of the concept of the new furnace besides to establish the first operational and geometrical parameters.

Outcome: Good continuous feeding and tapping (up to 24 hr continuous heats), hence corroborating the adequacy of the concept of the Tecnored furnace.

Decision: Although the results achieved in this phase were expressive, more than the empirical method of development a better fundamental understanding of the process was required to decide on the next steps on the development. Therefore, for the design and construction of larger pilot furnaces, a very comprehensive mathematical modeling of the behavior of a self-reducing pellet in the Tecnored furnace was built [3].

c) 1990 to 1993

Description: Process development in a larger circular furnace of 600 mm dia., aiming at to achieve longer campaigns, higher operational stability, geometrical and operational adjustment based on the mathematical modeling and higher yield of the post combustion.

Outcome: Longer periods of smooth operational stability, control and maintenance of the charge feeding rate, control of slag and hot metal tapping procedure, improvements on the fluid-dynamics of the process, and close assessment of the thermal and gaseous profile inside the furnace.

Decision: The 600 mm pilot furnace approached its limit to assist the experimental development of the technology; therefore, after 3 years of experiments a new larger pilot furnace with 1000 mm diameter, was decided then.

Also, the mathematical modeling of the process indicated in this period that to achieve higher production i.e. larger furnaces, while keeping a suitable raceway and flame engineering on the Tecnored furnace, the geometry of the reactor had to be changed from circular to rectangular cross-section, thus the decision to built the 1000 mm furnace to confirm this limitation.

d) 1994 to 1995

Description: Process development in the largest circular furnace built (1000 mm dia.), aiming at to confirm the geometrical and operational parameters in a large furnace, besides to check the growing limitation of circular furnaces as indicated by the modeling.

Outcome: Best results achieved on the operation of circular pilot furnaces (high operational stability, good furnace control, long campaign duration, good hot metal and slag quality, etc).

Moreover, this pilot furnace confirmed the prediction of the mathematical modeling that the furnace could not increase while being circular, paving the way for the creation of the modular concept, i.e. having a rectangular furnace it would be possible to increase the production by adding extra modules while keeping a fix cross section (Figure 4).

Decision: To build a full size modular slice of the industrial furnace of rectangular cross-section.

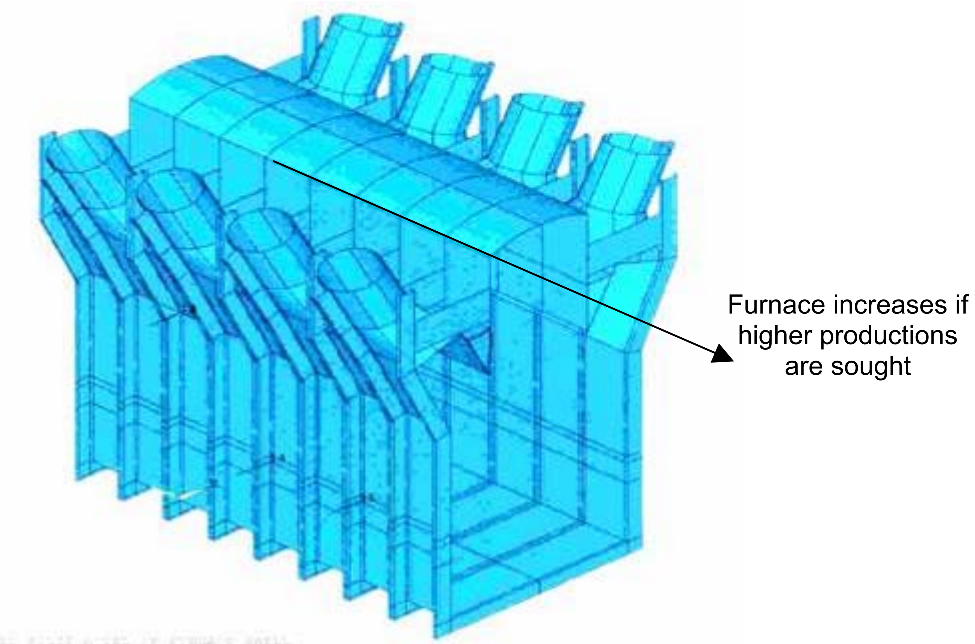

Figure 4. Tecnored modular furnace.

e) 1996

Description: Test of the new furnace concept using a small pilot furnace with one tuyere only.

Outcome: Adequate operational results and corroboration of the adequacy of the new concept for ironmaking based on the use of self-reducing agglomerates.

Decision: Construction of a full size modular slice of the industrial furnace

f) 1997 to 2000

Description: Risk abatement procedure and test assisted design of the industrial furnace using a full size slice (Figure 5).

Outcome: Based on this new design (rectangular), the modularity of the furnace could be exploited by the successful construction and testing of the preliminary cellular furnace.

In this phase, continuous test runs in week long campaigns in the full scale modular slice have been performed in over 100 tests, adding up to 1000 hours of operation.

Decision: With the risk dully abated in the pilot plant, it was decided for the implementation of the first industrial plant to use the Tecnored ironmaking for the production of pig iron.

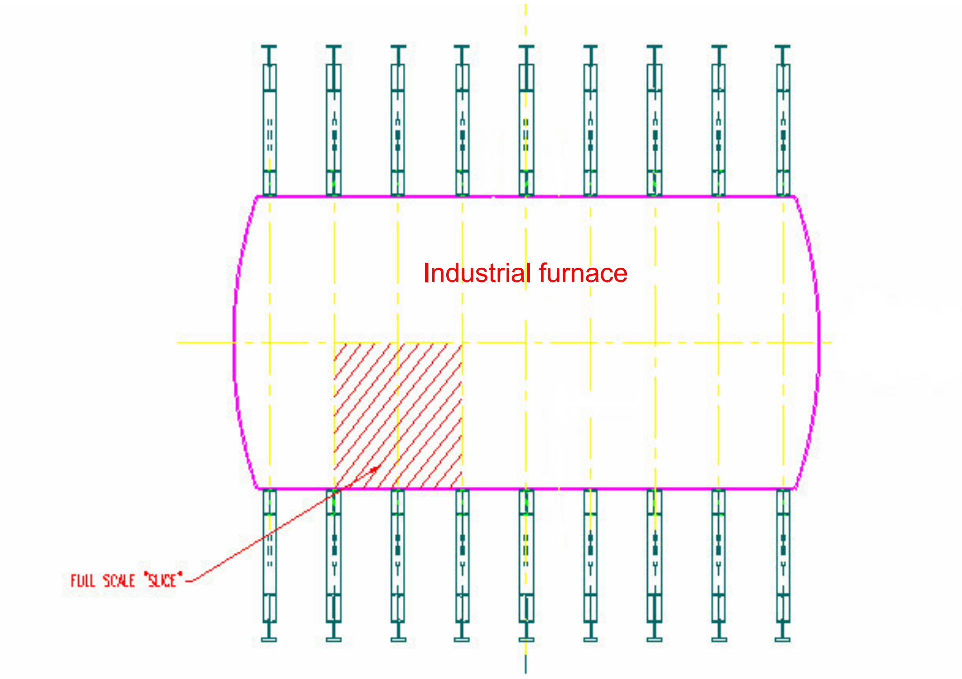

Figure 5. Full size modular slice of the industrial furnace

Further details of the risk abatement phase of the technology development are discussed ahead.

2.2 Risk Abatement Procedure

A Tecnored plant consists of three major facilities and operating areas: material preparation; ironmaking; utilities and support facilities. But for the Tecnored furnace, all other equipment and systems in the plant are of classical design and extensively used in conventional iron and steel production, therefore, proven and free of any technological risks.

In light of that, Tecnored decided for a risk abatement procedure based on troubleshooting, shut-downs and start-ups simulation as well as continuous operation of a full size slice of the industrial furnace of 2 t/h capacity.

This audacious approach confirmed the robustness and flexibility of the process, besides to provide a wealth of information required for a reliable engineering of the industrial furnace, since the reactor and the peripherals replicated the industrial operation on the more than 100 tests, adding up to 1000 hours of operation [4].

The minimization of the scale-up risk, resulting from the methodology adopted by Tecnored takes two forms. First, the modular furnace linear scale up capability does not require significant changes to operational parameters as the production rates and capacities are increased. Pressures, characteristic dimensions, temperatures, unit transport requirements, mass and energy balances are equivalent to or easily derivable from smaller, unit cell module information.

The second risk mitigation area is that of raw materials. In many melting/smelting processes the size of the equipment and throughput requirements dictate the physical and chemical characteristics of the raw materials. Thanks to the modular concept, Tecnored has been developed using the very same raw materials to be used during industrial operation.

Furthermore, the operation of the modular slice resulted in the correlation of pilot plant data and theoretical/mathematical models for process design, flame engineering, raceway phenomena, heat and mass balance studies, finite element thermal and mechanical stress analysis and structural design development of large industrial furnaces, hearth design and design of the furnace cooling and charging system, detailed plant lay-outs and development of state of the art hot blast, cold blast and gas cleaning systems.

This phase of the technological development may be summarized as follows:

Motivation:

- Sound risk abatement of the technology;
- Technology transfer from circular to rectangular furnaces;
- Evaluation/understanding of the inter-correlations between flame geometry, raceway, melting zone formation and resulting shape, hot and cold blast tuyeres design and furnace geometry;
- Operation with fuels and charges made up of either pellets or briquettes and incorporating a variety of reductants and iron bearing materials.

Methodology applied:

- Critical analysis of the results by comparing with the planning and mathematical modeling predictions;
- Simulation of different start-up and shut-downs conditions;
- Simulation of different troubleshooting techniques;
- Operation of the furnace with different internal geometry;

- Application of physical and mathematical modeling of the process;
- Cold tests to determine the behavior of fuels and agglomerates during charging (repose angle, sliding friction, yield strength, internal friction angle, etc);
- Inner probing during operation for mapping of the thermal and gaseous profile inside the furnace;
- Mathematical modeling of the cold blast flame;
- Inner probing for raceway mapping;
- Furnace quenching for late dissection;
- Online monitoring of the stockline using top cameras;
- Variation of number, geometry and position of the tuyeres;
- Close assistance from laboratory analysis;
- Supervisory control, monitoring and recording of the main process parameters.

Main results:

- Risk abatement of the new technology (Tecnored furnace);
- Steady state operation of the furnace using different raw materials and under different operational conditions;
- Definition of the furnace internal dimensions, top to bottom, including hot and cold blast devices;
- Definition of the optimum operational pattern (permeability; thermal and gaseous profiles; coal bed formation, shape and positioning; tapping procedures; etc);
- Melting zone formation, shape, positioning and stability;
- Hot and cold blast flows operational ranges;
- Charging system requirements;
- Instruments location throughout the furnace;
- Actions to avoid and/or fix operational hiccups;
- Start-up and shut-downs procedures.

For all the tests using the full size modular slice, a number of resources are available in case of an information concerning a specific test has to be retrieved. These resources are:

- Test report (planning, follow-up and posterior analysis);
- Mass and heat balances of the tests (forecast x actual);
- Video tapes of the stockline monitoring, including coal bed formation;
- Files database of all data recorded during operation (temperatures, pressures and flows).

3 CONCLUSIONS

Before the Tecnored development, in the basic iron and steel industry very large capital investments were always required for new technology introduction because of the large scale of the equipment used. Additionally, there were significant risks of major failures related with scale-up problems of the new technology.

Tecnored devised a very beneficial way to develop this metallurgical process and the fundamental equipment design though the design, engineering, and operation of a full-scale modular slice of the industrial furnace, mitigating the technological risk and keeping the investment as a fraction of similar attempts.

This approach has proven to be a novel and extraordinary tool for completion of the test-assisted design and as a time and cost effective risk abatement procedure for the industrial-scale furnace.

The technology development has been assisted by a strong cooperation with universities and research centers responsible for bench scale testing, fundamentals application, mathematical modeling, know-how transfer, personnel formation, etc.

Last but not least, rather than to adapt the self-reduction to an existing equipment such as blast-furnace or cupolas, the status of the technological evolution of the Tecnored process corroborated the early findings that a new furnace should be devised to fit into the process, in order to get the best possible benefits from the technology

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EVOLUÇÃO TECNOLÓGICA DO PROCESSO TECNORED

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Resumo

O processo brasileiro Tecnored é uma tecnologia emergente de produção de ferro primário, desenvolvida numa abordagem única que combinou a aplicação de fundamentos teóricos e empíricos à testes realizados na planta piloto, com suporte de universidades e centros de pesquisa. As campanhas na planta piloto objetivaram o entendimento, simulação e operação do forno Tecnored em diferentes fases, utilizando diferentes tamanhos de reatores, incluíndo uma fatia modular do forno industrial. Assim, as principais variáveis da tecnologia tais como as dimensões internas do reator, engenharia de chama, padrão de "raceway", perfil térmico e gasoso, formação, aspecto e manutenção da zona coesiva, etc., foram desenvolvidas em condições reais de operação. Essa estratégia de utilizar uma fatia do forno industrial provou ser uma eficiente ferramente para minimizar riscos tecnológicos e ajudar no projeto do forno industrial, atualmente em construção. Este trabalho descreve as diferentes fases do desenvolvimento tecnológico e os seus respectivos objetivos e realizações.

Palavras-chave: Processos alternativos; Auto-redução; Carvão; Tecnored.