MANGANESE ORE AND ALLOYS PILOTING TOOLS AT ERAMET RESEARCH

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ABSTRACT

Before ERAMET entered the Manganese business, in 1996 by taking over Comilog then in 1999 by taking over Elkem Mn alloys facilities, the R&D Center in Trappes already had a long experience in piloting electric arc furnace operations, but none on Mn. The purpose of this presentation is to give an overview of the last 10 years history of piloting in ERAMET RESEARCH on both the ore sintering pilot, built in 2001 for the sintering plant commissioning in Gabon, and the Mn alloys smelting pilot. On the latter, since September 2000, 7 campaigns have been run at ERAMET RESEARCH, with objectives focused on both SiMn and HCFeMn processes. The duration of the campaigns has increased from 5 days to 3 weeks in 2006, whereas the power load was limited to 150–250 kW. The present new development of the Mn business in ERAMET, especially with the integration of Tinfos facilities and some smelting investments projects to come, have led ERAMET to decide to invest in 2009 in a larger pilot scale equipment, a 1 MW furnace, more appropriate to answer to the future needs of the ERAMET Mn Division.

1 INTRODUCTION

The Research Center in Trappes was built in 1972 as the common research facility for both Société Le Nickel (SLN) and Penarroya. As shareholders changed, its name also changed : it was called Minemet Recherche in 1975, Metaleurop Recherche in 1988, CRT in 2000 and Eramet Research in 2008.

From its birth, the Research Center in Trappes has contributed to develop new processes and improve the performances of the mineralogical, hydrometallurgical and pyrometallurgical plants of its customers. It therefore already had a ferroalloy and non ferrous metal smelting pilot facility and a long experience in continuous piloting when Eramet overtook Comilog in 1996.

Comilog produced most of the Mn alloys in blast furnaces in Boulogne and China. This proportion was considerably reduced when the Norwegian plants of Sauda and Porsgrunn as well as the US Marietta plant were bought by Eramet in 1999 and later when Boulogne blast furnace was closed. In 2001, Comilog started its sintering plant in Gabon, Complexe Industriel de Moanda, to supply the Mn plants of the group as well as external cutomers.

In this paper, we will present how the Research Center has developed competences and built equipment to support Eramet in this development. The pilot sintering facility currently used to improve the quality of the sinter and optimize the process management will be described. The methodology and the objectives of the 7 pilot campaigns run since 2000 in Eramet Research will also be presented. Limitations in the current piloting equipment as well as new scientific objectives has led us to design and build a new pyrometallurgy facility, which will be described in the last chapter of this paper.

2 THE SINTERING PILOT FACILITY

After the sintering plant was built in 2001 in Gabon to valorize the ore fines produced at the Comilog mine, a sintering pilot was designed at ER to contribute to improve the sinter quality as well as the strand productivity. It enables to simulate the preparation of the sinter mix before firing, its sintering, as well as the complete sinter characterization. At the pilot scale, parameters influencing productivity and quality results are carefully fixed and allow to draw clear and relevant conclusions.

2.1 Preparation of the sinter mix

The moisture of the sinter mix dramatically influences its permeability that directly affects the productivity of the sinter strand. Therefore, moisture must be carefully controlled. To meet this objective, all the different components are dried and then mixed in 15 kg batches. Moistening and cold agglomeration of the mix are performed in a pelletizing disc in which the water sprayer flow rate is carefully controlled. Since bias can be introduced by the operators when loading, the green agglomerate is directly fed in the sintering pot.

2.2 Sintering

Eramet Research is equipped with a sintering pot, conical to make easier the removal of the sinter cake. The pressure drop between top and bottom of the sintering pot is fixed by a dedicated regulation of the suction fan. Many thermocouples, embedded above, under and in the sinter mix enable to control the firing and gas temperatures, as well as the sintering front location evolution (Fig. 1). These measurements enable to assess the productivity of the trial.

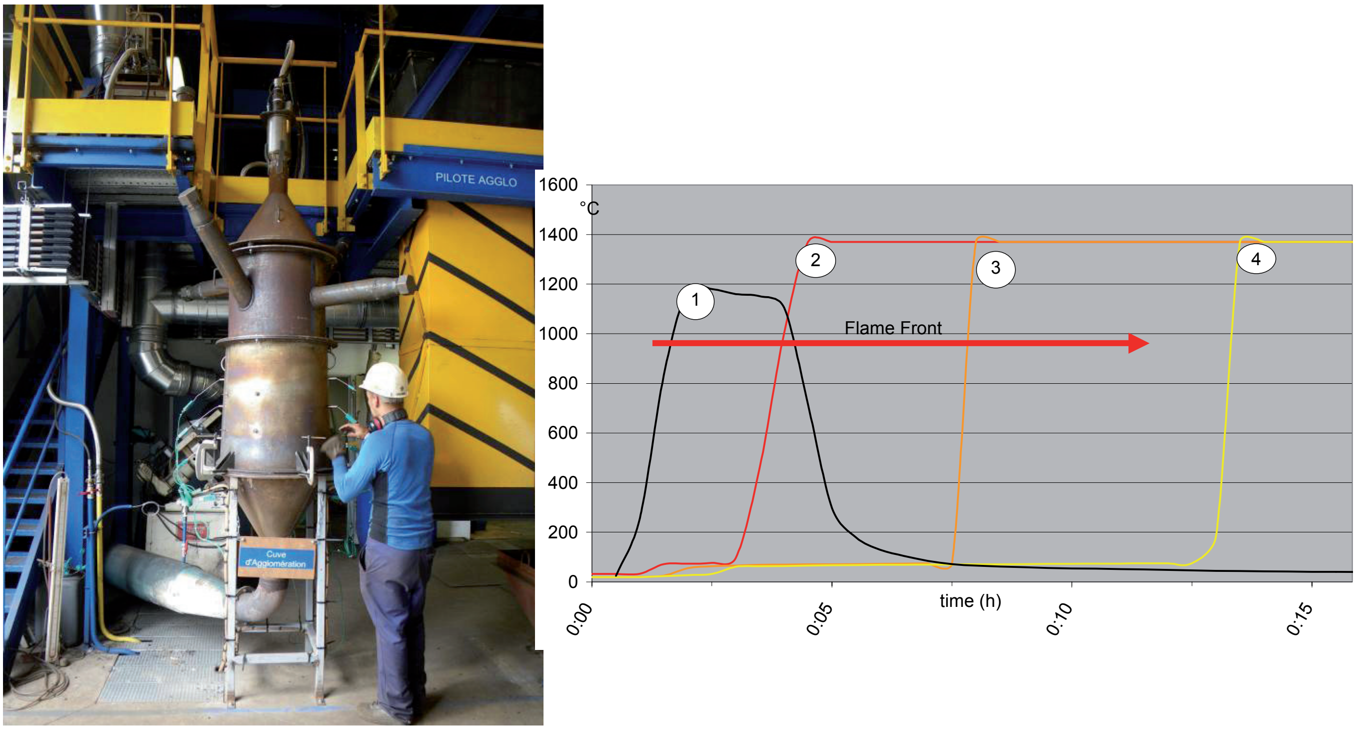

Figure 1: Sintering pilot facility at Eramet Research and evolution of the temperature within the load during a test (numbers represent the position of the thermocouples, from top to bottom of the charge).

2.3 Characterization

To evaluate the sinter quality, the sinter cake is then sieved to determine the sinter chemical analysis and mechanical strength according to the ISO 3271 standard. Samples can also be observed through a microprobe analyser (fig. 2) to understand more deeply the sintering and dissolution mechanisms and to correlate the microstructure of the product to its mechanical strength.

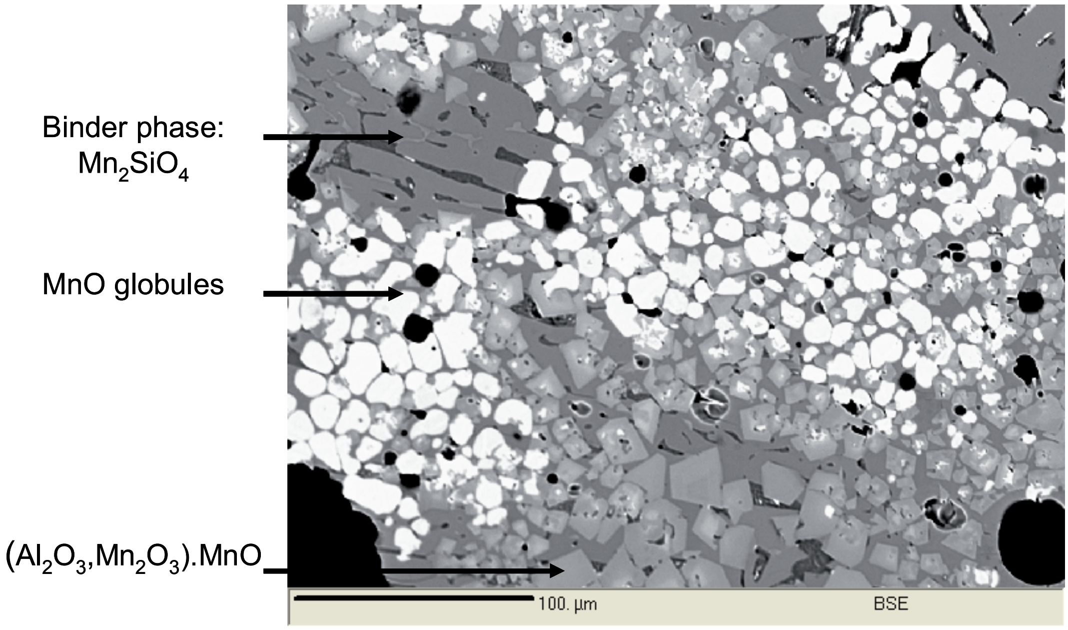

Figure 2: Microstructure of a piece of sinter. One can clearly identify the various phases of the material : MnO globules, Mn3O4 spinelle particles and the binding phase.

2.4 Performances

Pilot results have been successfully used to define and improve the sinter mix recipe (coke and flux proportion…) of the industrial products, in order to increase their mechanical strength, i.e. reduce the generation of fines during transportation.

Until 2007, the 0-1 mm fines from the mine were dumped. Only the richer 1-8 mm fraction was used to produce sinter. In 2007, Eramet Comilog decided to study the possibility to recover part of the 0-1 mm fraction and use it in the sinter plant.

Before testing industrially the impact of such a fraction on the sintering process, trials were preformed at Eramet Research in order to assess their effect on the product characteristics and on the plant productivity. At pilot scale, trial results showed a sharp decrease in productivity as the proportion of Mn “sand” was increased, due to a lower permeability of the sinter mix (figure 3). Such results were confirmed at the industrial scale and allowed to find the most adapted proportion of 0-1 mm fraction in order to minimize productivity losses and to maximize the use of such a fraction.

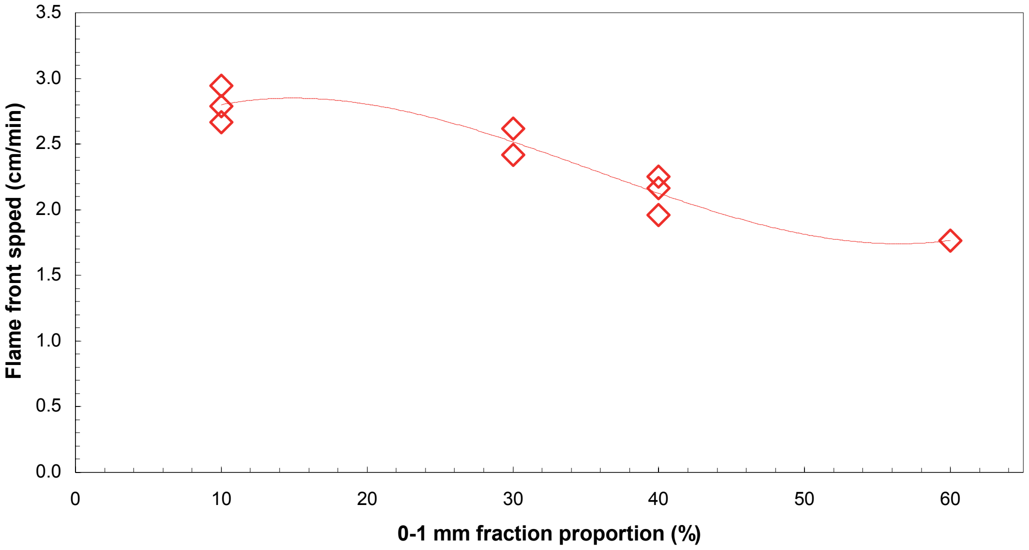

Figure 3: Evolution of the strand productivity as a function of the proportion of 0-1 mm fraction introduced in the mix.

3 ERAMET RESEARCH Mn ALLOYS SMELTING PILOTS

3.1 Background

Since September 2000, 7 pilot campaigns have been performed at Eramet Research. Both Std SiMn and HC-FeMn processes were investigated focusing on different technical and safety issues :

- two campaigns aimed at understanding the conditions leading to eruptive phenomena at the top of the submerged arc furnaces (i.e. 2000 Std SiMn campaign, 2003 HC-FeMn campaign),
- whereas thermal issue in HC-FeMn process, impact of the reducing agent quality in SiMn production, slag/metal separation or resistance increase in HC-FeMn furnaces were also studied.

The decision to work on the above subjects came from internal discussions between the plants, the Industrial Management and Eramet Research Centre.

Because of the growing challenges within Eramet Mn division and thanks to the experience developed at Eramet Research, the duration of the pilot campaigns has increased from 5 days (e.g. 2000 first campaign) up to 3 weeks (e.g. 2004-2005-2006 campaigns) for the last 10 years.

3.2 Pilot campaign approach

The first pilot operations carried out at Trappes Research Center in the 70’s aimed at studying non-ferrous and then FeNi production. Pilot scale campaigns enable to go further than laboratory scale studies and to perform tests that are much more difficult to handle on industrial furnaces and could even be dangerous. Because pilot furnaces can also be much more fully instrumented than industrial furnaces, we can safely explore operating points that are out of the normal industrial operating points. That’s why the past experience has been used since 2000 to tackle some important issues in the scope of Mn alloys production.

Except for the first pilot campaign (i.e. 2 interdependent electrodes), the semi-closed pilot furnace used to performed the different trials was a 1-phase cylindrical furnace with a bottom electrode. The dimensions of the different pilot furnaces were always defined to get the same surfacic load as Eramet industrial furnaces. The power limitation came from the main transformer current limitation (i.e. 6000 A) : because of the very low resistance of Mn alloys smelting processes, the power load in the furnace was limited to 150-250 kW, thus limiting the size of the furnaces to about 1 m in diameter.

Figure 4: Picture of the 2006 pilot set up in Trappes.

The design of the furnace itself (i.e. geometry, lining) and some of its facilities (i.e. taphole area, furnace cover…) were changed to match each time with the different objectives :

- For example, the goal of 2001 campaign being to determine the appropriate lining in the scope of HC-FeMn production, the design of the furnace was completely changed compared to 2000, using a water cooled conductive lining on one half of the furnace and an insulating lining on the other part.
- Following the same philosophy, the tapping area of the pilot hall was changed in 2006 to enable to investigate different tapping arrangements (i.e. “in line cascade”, “90° cascade”).

All the pilot furnaces have been operated under resistance control as most of Eramet furnaces are. The same kind of tools as the ones developed in the plants for the daily follow-up are also used during pilot campaigns : i.e. thorough mass balance, slag and metal analyses for each tap, electrical parameters analysis…

However, some specific pilot scale follow-up tools have been developed to better understand the phenomena occurring during a given campaign :

- To follow the burden height, the liquids level and the coke bed size, soundings are performed 1 or 2 times in-between taps.
- Impedance profile impedance profiles are performed to measure the electrical resistivity in the furnace as a function of the position of the electrode.
- Heat-flows : in different sections of the furnace and at different levels, thermocouples are placed into the sidewalls and hearth lining to be able to accurately monitor the heat flows.

The safety has also always been a concern for all the pilot campaign performed at Eramet Research. As the configuration of the pilot hall always changes from one trial to the other, a risk analysis is performed before each pilot campaign, all the people involved in the project get a safety information and some specific training are organised (e.g. crane driving). After the campaign, a safety debriefing is organised and fault tree analyses are performed if some incidents occurred during the trials. By this way, Eramet Research has improved the safety during pilot campaigns for the last ten years.

3.3 Transfer of the pilot results to the plants

For each campaign, 3 shifts made of 4 people ran the furnace under the control of a research engineer and of the head of the pyrometallurgy department. Each junior engineer will be in charge of the organization of a pilot campaign while working in Trappes, as we consider this mission as his/her first industrial experience, and therefore an essential part of his/her education for his/her future position in a plant. Many results will be transferred this way eventually.

As many people coming from the different plants of Eramet Mn division (i.e. Norway, U.S., France) as possible have been integrated into the pilot teams to take advantage of their experience of the process (i.e. furnace behaviour, tapping etc…). They will also be the main vectors to transfer good practices from Trappes to the plants.

In the following sections, 3 examples of pilot campaigns that led to changes in Eramet plants or that were at least followed by industrial tests are presented.

In 2001, Eramet Research pilot campaign focused on the optimum lining in the scope of HC-FeMn production. Both slag and ore smelting situations were studied and the monitoring of the lining temperature all around the furnace stressed that the high heat flows experienced at the slag level were due to convective heat transfer between the liquid slag and the inner sidewall whereas the heat transfer was mainly convective at the metal level leading to lower heat flows. To cope with such a situation, it appeared that a conductive lining combined with shell water cooling was much more efficient than an air cooled insulating lining. Eramet Norway Sauda was the first plant within the group to use the “freeze lining” concept to reline one of its HC-FeMn furnaces in 2002.

A second example of relevant result from a pilot campaign consists in burden optimisation. Actually, the HC-FeMn 2003 pilot campaign aimed to study the parameters responsible for eruptive phenomena in submerged arc furnaces. Different burden compositions were tested and it appeared that the moisture content of the charge was a first order parameter leading to mix bridging and then possible eruptive phenomena when collapsing. A maximum moisture content was thus determined to limit the risk of blowing conditions, which is today applied in Eramet safety standard.

The third example of results from pilot campaign deals with power increase through resistance increase in the scope of HC-FeMn production. As industrial furnaces are operated at a rather low resistance, most of them are limited by the current that the electrical system can sustain. Therefore, increasing the resistance operating point is the most efficient way to increase the power. Different parameters were tested at a pilot scale and it appeared that the size of the coke bed and the grain size of the reducing agent used were first order parameters to manage to increase the resistance. Operating with a small coke bed and using small coke enabled to increase the power at a pilot scale. Industrial tests were then performed by Eramet Norway using small coke to produce HC-FeMn, which confirmed the above results. These results are in agreement with those of P.A. Eidem *et al.* [1].

4 THE NEW PYROMETALLURGY PILOTING FACILITY

4.1 Constraints and stakes for the new facility

Because of the growth of the Mn branch of group, in particular with the acquisition of Tinfos in 2008 and projects announced in Gabon and China, stakes to improve the performances of the Mn alloys furnaces are becoming larger. Within the Eramet group, demand for piloting is therefore growing. The new pilot facility should enable Eramet Research to carry out 2 continuous smelting campaigns per year, each campaign during 4 to 6 weeks.

It has been clearly identified [1] that the use of highly oxidized ore such as that of Comilog from Gabon will result in lower specific energy and coke consumptions, provided the pre-reduction reactions can completely develop in the burden. As described above, it has proved difficult to build up burdens in small furnaces, which made the current piloting facility inadequate to study pre-reduction reactions. A larger scale was necessary.

Axis-symmetric geometry allows for simpler instrumentation and makes interpretation of the results and modelling easier. When studying the chemical reactions taking place in the furnace, single phase furnaces are better suited. Of course, industrial Mn alloys smelting furnaces are usually 3-phase furnaces. Our facility will therefore allow for both settings.

Preparation of the raw materials is well known to have a great influence on the performances of the EAF's as well as to be the cause of a wide dispersion of the results. A rotary kiln was therefore included in the charge preparation chain, to control the humidity and temperature of the materials entering the furnace.

Of course, all these equipments will meet the latest health and safety requirements. Special care was brought to the design of the gas and dust collecting system.

Finally, we are designing a research tool that will be used in the next 10 to 20 years : high flexibility in the operating ranges of all the equipments as well as in the types and numbers of instruments that can be connected to all the equipments is therefore required. The piloting platform is designed to accept various geometries of furnaces and to reduce delays for adaptation to these changes.

4.2 Definition of the power supply characteristics

The new power supply was designed for low impedance processes, since Mn smelting is the EAF process to smelt ferroalloys which requires the lowest resistance [4]. The target power load dissipated in the furnace is 1 MW, which generates the material flow that we considered as sufficient to study pre-reduction reactions.

Calculations were made following classical designing rules presented in [3]. We only considered that the resistance of a 1 MW single-phase furnace would be that of a 3 MW 3-phase furnace, which is to say that, for design purposes, a 3-phase furnace is considered as 3 single-phase furnaces in parallel. The resistance of the load should therefore be comparable to that of the furnace described by S. Yoneka *et al*. in [5], i.e. of the order of a few milliohms. This implies that the bus bars and electrode be designed to minimize their resistance.

Furthermore, because of the geometry of the electrical circuit, we expect that the reactance of a single-phase furnace be much larger than that of a 3-phase furnace. Current offset factor as low as 0.4 was used for the design.

4.3 Design of the new power supply

The 15 kV power supplied to Eramet Research will be reduced to 1100 V in a 3-phase variable transformer. This voltage will be further reduced in 3 single-phase transformers. The maximum secondary current in each transformer will be 10 000 A.

Only the connections from the variable transformer to the single phase transformers will change when switching from the single-phase to the 3-phase configuration :

- In the former case, the 3 transformers will be connected in parallel to 2 of the phases of the variable transformer ;
- In the latter, a Y or Δ circuit will be formed to supply the EAF.

4.4 Design of the furnace

4.4.1 Furnace diameter

3-phase furnace : Once the current at full power has been evaluated, the minimal distance between electrodes can be calculated. The electrode circle is then defined. For a 1 MW Mn furnace, we estimated that the minimal crucible diameter can be 2.6 m. The outside diameter will depend on the thickness of the lining, therefore on the scientific objectives of the tests.

Single phase furnace : there is no such limitation for a single phase furnace. It is therefore possible to aim for power load/unit surface area closer to industrial values, typically 350 kW/m^2. This ratio will define the CO gas velocity at the bottom of the burden, therefore, for a given permeability, the gas velocity in the burden.

4.4.2 Furnace height

The altitude of the furnace platform will be adjustable, since the furnace height may vary from one test to the other. Indeed, to increase gas-solid reaction times, deep furnace will be preferred.

4.4.3 Side wall furnace lining

The type of lining will of course depend on the scientific objectives of each piloting campaign, including which process is studied. To match this high flexibility goal, 2 types of equipments were included in the design of the test platform.

As mentioned above, previous pilot campaigns in Trappes have led to the conclusion that freeze lining was well adapted for FeMn alloys smelting. Therefore, instrumented water supplies have been installed to allow for the water cooling of the external steel shell and the monitoring of the heat flows through the walls.

Temperatures and heat flows through the side walls will also be monitored directly in the lining of the furnaces, for safety reasons first, especially close to the tapping holes, and secondly for scientific purposes. Whereas the water cooling system will deliver a global view of the heat flows, thermocouples will allow the study of the local heat flows, giving more subtle hints about the phenomena occurring in the furnace. The steel casing and the data recording system have been designed to make it possible to set numerous thermocouples in the lining, at different altitudes and depths.

4.4.4 Hearth lining and bottom electrode

For a single phase furnace, the design of the hearth and bottom electrode has to be thoroughly done in order to minimize risks of burn through. For the next pilot, MgO ramming paste will be used for the lining. A multiple steel pin electrode, embedded in the hearth, will constitute the bottom electrode.

To evacuate the large heat flows through the hearth, generated by the presence of the steel pins and plate, water cooling of the side walls was extended well below the tap holes, and a large air flow will be directed towards the bottom of the steel casing.

5 CONCLUSION

We have described in this paper the piloting tools available in Trappes to simulate 2 essential processes for Eramet : the sintering strand and the electric arc furnace.

We have presented our methodology to prepare each pilot campaign on the electric arc furnace, and, for both pieces of equipments, insisted on the transfer of the results to the plants. 4 examples have been developed :

- The recycling of the 0-1 mm fraction of “Mn sands” in the production of Mn sinter in Gabon ;
- The implementation of conductive lining with shell water cooling on the HCFeMn industrial furnaces ;
- The update of Eramet safety standards to take into account the water content in the charge of the EAF’s ;
- The impact of coke grain size on the electrical resistance of the furnace, to increase its operating power load.

The limitations of the existing tools have also been presented. Because these limitations prevented the research teams from addressing such strategic issues as gas-solid reaction kinetics in the burden of the furnace, it was decided to invest in a highly flexible tool that can be used to study all types of low impedance EAF processes and meet various scientific goals. This has put demanding constraints on the design of the various pieces of equipments, most particularly the power supply and instrumentation. 3-phase and single phase pilot furnaces will be built in the next years on this new pilot platform.

This new equipment will be used for the first time in the first semester of 2010, in a 4-week campaign of production of high carbon ferromanganese.

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