

REFINING OF FERRONICKEL

Christian Redl, Matthias Pfennig, Roland Kristl, Siegfried Fritsch, Heinz Müller

INTECO special melting technologies GmbH, Bruck/Mur, Austria
e-mail: christian.redl@inteco.at, matthias.pfennig@inteco.at, roland.kristl@inteco.at,
siegfried.fritsch@inteco.at, heinz.mueller@inteco.at

ABSTRACT

Refining of the crude metal from the electric furnace is one essential step in the production of Ferro-Nickel. The most important tasks in the refining process are the removal of carbon, silicon and phosphorus, sulfur as well as deoxidation. Additionally the melt shall be brought to the right temperature for the subsequent granulation.

Different metallurgical units in varying configurations can be used in the refinery. This paper focuses on ladle based refining and highlights differences and advantages to converter based process lines.

Several projects using ladle furnaces in combination with oxygen blowing units have been set in operation in the recent past. The used equipment as well as latest metallurgical results from these projects are presented.

INTRODUCTION

Production of ferro-nickel by pyrometallurgical process is still the most widely utilized method for the processing of nickel lateritic ores. The Ni-content of lateritic ore is normally low and in the range of 0.8 – 3 %.

The most important production route is the RKEF (rotary kiln - electric furnace) process [1, 2, 3]. For this route lateritic ore is screened, crushed and blended to produce a consistent process plant feed with defined ratios of iron and nickel as well as SiO₂ and MgO. This feed is charged into a rotary kiln where it is calcined and prereduced by coal or powdered coke. Afterwards the calcine and residual coke is charged into the electric furnace (also named submerged arc furnace (SAF)). Here it is melted by electric energy and reduced yielding crude FeNi with Ni contents usually between 13 and 25 %. Unreduced components (mainly FeO, SiO₂, MgO) are removed as slag whereas crude FeNi metal is tapped semi-continuously into ladles.

This crude metal contains undesirable tramp elements such as sulfur, phosphorous, carbon and silicon. Especially sulfur and phosphorous are very unwanted in the steel production where most of the FeNi is used as alloying element. Therefore the tramp elements have to be removed before the FeNi is casted into bars or granulated. Low carbon contents are necessary to minimize the carbon input during steel production, which would lead to longer treatment times in the stainless steel refining process.

Due to differences in the lateritic deposits regarding nickel oxide and iron oxide content, the content of impurities, sulfur content in the reductant coke etc. the chemical composition of the crude FeNi varies widely (e.g. carbon content can be up to 2 %, sulfur content up to 1 %). Nevertheless the requirements on the refined FeNi are almost equal. Typical values are given in table 1.

As it can be seen from the above the ranges of the impurities C, Si, P and S might be rather high in the crude metal, while the aims for these elements after refining are very low.

To reach the above aims in a reasonable treatment time requires a flexible plant for the following processes:

- Removal of carbon, silicon, phosphorus and sulfur
- Deoxidation and desulfurization
- Heating

Depending on the composition of the crude ferro-nickel tapped from the electric reduction furnaces different plant configurations can be used in the refinery. The most common routes are described.

Table 1: Maximum element contents in refined ferro-nickel

Element	Limit value in refined FeNi
Carbon	< 0.040 %
Silicon	< 0.30 %
Phosphorous	< 0.030 %
Sulfur	< 0.050 %

DIFFERENT PRODUCTION ROUTES IN THE REFINERY

Ladle furnace route

In the "ladle furnace route" [4] the entire metallurgical treatment is done in only one vessel, namely the ladle. It is used e.g. in the ferro-nickel plants of Loma de Niquel (Venezuela), Barro Alto (Brazil), Onca Puma (Brazil) and contains the following main process steps.

Table 2: Process steps in ladle furnace route

	Process step	Aim
1	Tapping from electric furnace into the ladle	
2	Oxygen blowing during tapping using blowing station	Chemical heating Removal of carbon, silicon, phosphorus
3	Deslagging	Removal of Fe ₂ O ₃ , SiO ₂ and P ₂ O ₅ rich slag
4	Ladle furnace treatment	Deoxidation and desulfurisation Electrical heating
5	Optional oxygen blowing	Final decarburisation
6	Granulation	

The main advantage in this production route is that only the treatment ladle is used during the entire process from tapping to granulation. This means less refractory lined equipment will be in operation resulting in lower total refractory consumption as well as low temperature losses.

Converter route

During this production route different process vessels are used (ladles, converter, electric arc or ladle furnace). This route is used e.g. at FeNi Industries (Macedonia), Larco (Greece). Again the main process steps are described below:

Table 3: Process steps of converter route

	Process step	Aim
1	Tapping from electric furnace into the transport ladle	
2	Oxygen blowing in the converter	Enrichment of nickel Removal of carbon, silicon, phosphorus
3	Deslagging	Removal of Fe ₂ O ₃ , SiO ₂ and P ₂ O ₅ rich slag
4	Electric arc or ladle furnace treatment	Deoxidation and desulfurisation Electrical heating
5	Granulation	

The main difference to the ladle furnace route is that the different process steps are done in different metallurgical vessels (transportation ladle, converter vessel, treatment ladle or electric arc furnace).

The usage of converters in the refinery process is advantageous compared to the ladle furnace route if there is a very high starting carbon ($C > 0.60\%$) or silicon ($Si > 1.00\%$) content. In some special cases it might be required to considerably increase the Ni content in the refined FeNi (e.g. from 13 % at tapping to more than 20 % after refining). This enrichment of Ni requires substantial oxidation of iron resulting in enormous amounts of slag, which can be better handled by a converter than a ladle.

Other refining routes

Beside the two main refining routes described above there exist a number of possible variations. E.g. melt agitation for improved desulfurisation can be done by a shaking ladle system or a refractory stirrer (for example used at PT Antam, Indonesia). For desulfurisation also treatment stations with injection (CaSi, CaC₂) or wire feeding (mainly CaSi) units can be used independently of the prevailing refinery equipment.

LADLE FURNACE ROUTE

In what follows the focus is on the ladle furnace route and the results are based on the refinery plants installed by INTECO during the last two decades (Minera Loma de Niquel (Venezuela), Barro Alto (Brazil, commissioned 2011), Minera Onca Puma (Brazil, commissioned 2011)).

Treatment schedule for the ladle furnace route

Figure 1 shows a typical treatment schedule of a refinery process using the following production route:

Oxygen blowing during tapping - deslagging - ladle furnace treatment - granulation

During tapping the melt will be gas (nitrogen) stirred and oxygen is blown for removal of silicon, carbon and phosphorus. Fluxes as well as optional aluminium or FeSi for chemical heating will be added during tapping.

The ladle will then be placed by the overhead crane into the ladle transfer car. The first step at the ladle furnace is the complete removal of the oxidic slag from the ladle. For this purpose the ladle transfer car is usually equipped with a tilting device. The usage of a hydraulic deslagging machine allows effective slag skimming.

After deslagging the ladle furnace treatment starts. According to the measured oxygen content a first addition of deoxidants and lime will be done and the target temperature (approx. 1 600 - 1 620 °C) is reached by electrical heating. During and after the heating period fluxes and reduction elements are added for desulfurization. During the heating period addition of FeNi scrap is also possible. If the sulfur content is too high for a one slag treatment, an additional deslagging step might be necessary. Due to a very compact arrangement of ladle furnace and deslagging stand this can be accomplished within a very short period of time.

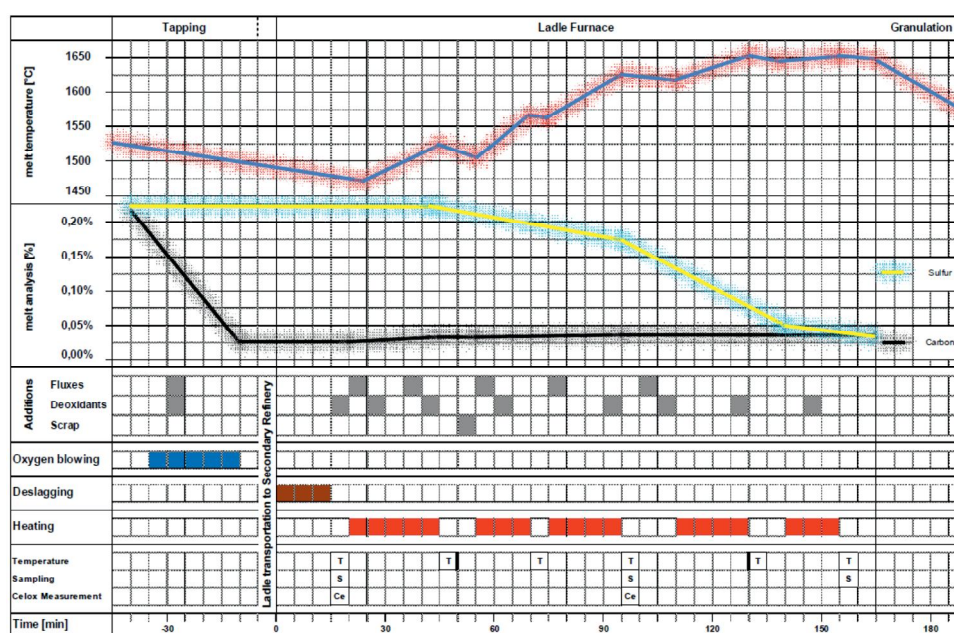


Figure 1: Standard treatment cycle in the refinery

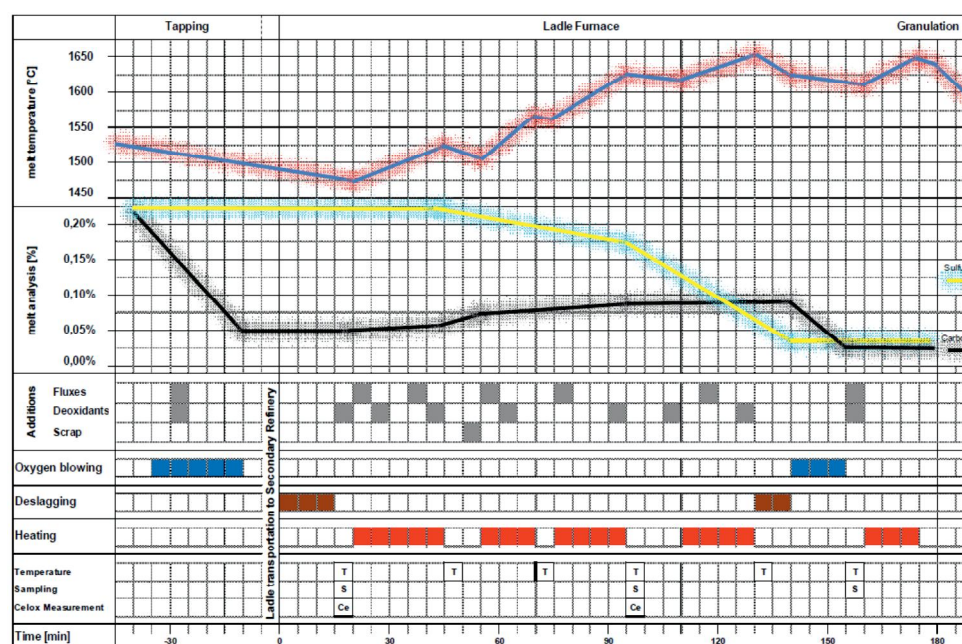


Figure 2: Treatment cycle with additional oxygen blow for final decarburisation

For the final desulfurization to a sulfur content below 0.050 % Al and CaSi wire can be injected into the melt and new slag will be added. If required the heat is transferred to the oxygen blowing station for final adjustment of carbon and silicon content (figure 2). The final temperature for granulation will be adjusted by electrical heating afterwards.

The total ladle furnace process including deslagging and electrical heating varies depending on the composition of the crude FeNi and heat size and is typically between 90 and 180 minutes.

The granulation time depends on the capacity of the granulation stand. Ideally the granulation time should not exceed 50 % of the ladle furnace treatment time as in this case enough time will be available to prepare the ladle for the next heat.

Required plant set up for the ladle furnace route

For the production of FeNi without any enrichment of the Ni- content in the secondary metallurgy the following equipment is necessary:

- Oxygen blowing station with ladle stirring device at tapping position
- Ladle furnace (approx. 0.15 - 0.20 MVA/t) with the additionally equipment:
 - Ladle transfer car with tilting device (for deslagging)
 - Deslagging machine
 - Slag pot transfer car with slag pot
 - Temperature and sampling manipulator
 - Wire feeding machine
 - Gas stirring system (for porous plug and top lance)
 - Injection system for fine material (desulfurisation agents)
 - Material handling and feeding system
- Secondary oxygen blowing station (optional)
- Fast analyser for carbon and sulfur

Typical refinery equipment is depicted in figure 3.



Figure 3: Refinery equipment (left: oxygen blowing station; centre: deslagging stand; right: ladle furnace)

Metallurgical results for the ladle furnace route

In the figures below metallurgical results from two different FeNi production plants are shown. "Plant A" (shown in blue) has the possibility for oxygen blowing during the refinery cycle by a special blowing station installed near the ladle furnace. In "Plant B" oxygen blowing is only possible during tapping from the electric furnace.

The results show the average values during hot commissioning (approx. 70 heats).

Figure 4 shows that the carbon content of 0.03 % can be reached independent of the tapping carbon content. Main decarburisation takes place during tapping. The average oxygen yield depends on the final carbon content and is in the range of 30 to 60 %.

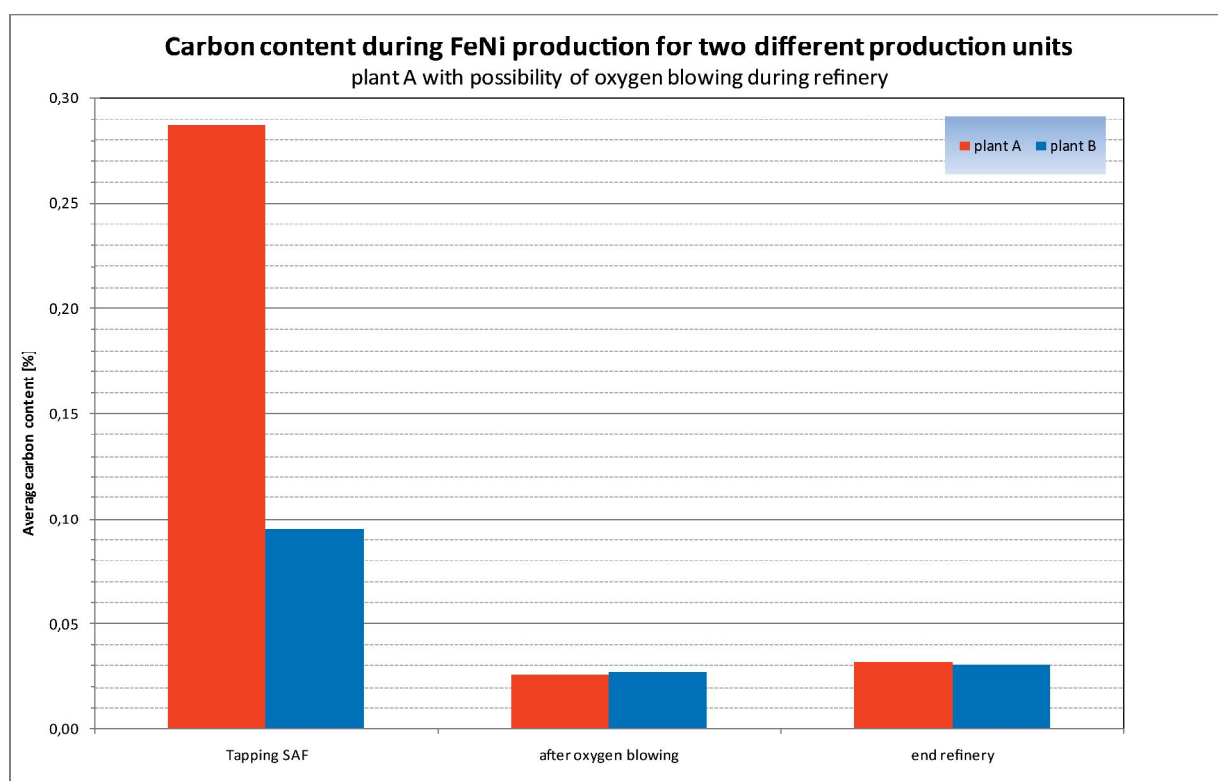


Figure 4: Carbon content during FeNi production

Carbon pick up might occur during electrical heating or may result from scrap addition. The carbon pick up depends on the electrical heating time and is shown in figure 5 for the hot commissioning phase. The achieved average carbon pick up value was 1.3 ppm/min power on time.

Initial sulfur content depends mainly on the sulfur content of the reduction coke used in the rotary kiln and the SAF. Lowest final sulfur contents can be achieved during refinery independent of the initial sulfur content (figure 6). The final sulfur content depends on treatment time, available treatment units (injection and/or wire feeding system) and desulfurisation practice.

Dephosphorisation takes place during oxygen blowing at the tapping stand. Therefore flux and lime additions should be possible during tapping. In all cases the target phosphorous content of below 0.030 % was achieved during the first oxygen blowing period at the tapping stand (figure 7). A precondition for these results is a complete deslagging before the start of refinery treatment.

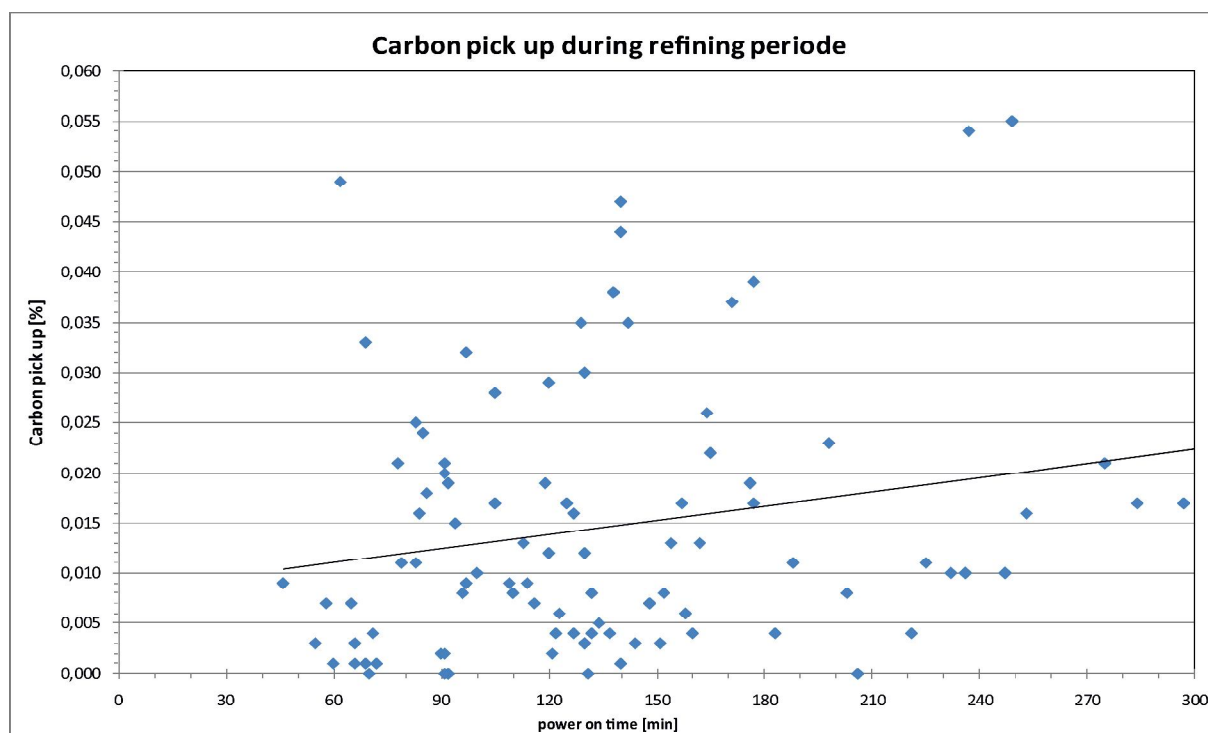


Figure 5: Carbon pick up during refining period (measured in the hot commissioning phase)

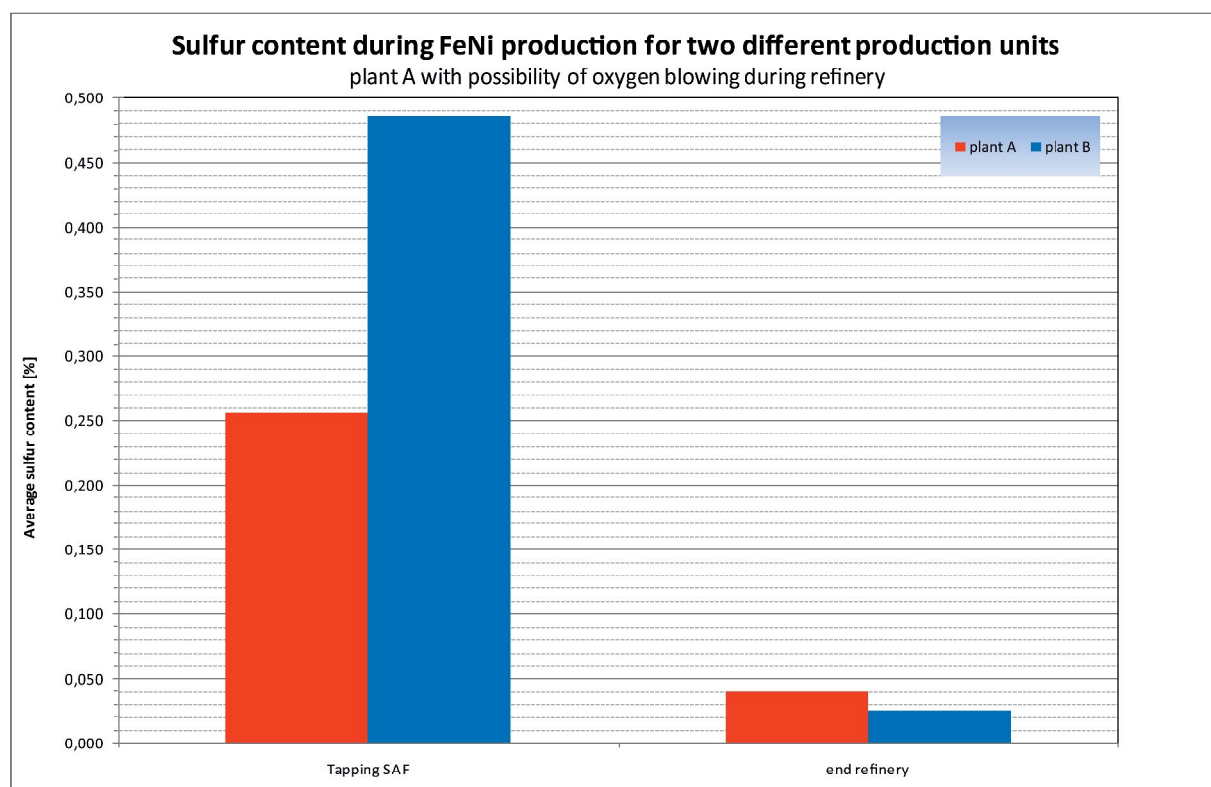


Figure 6: Sulfur content during FeNi production

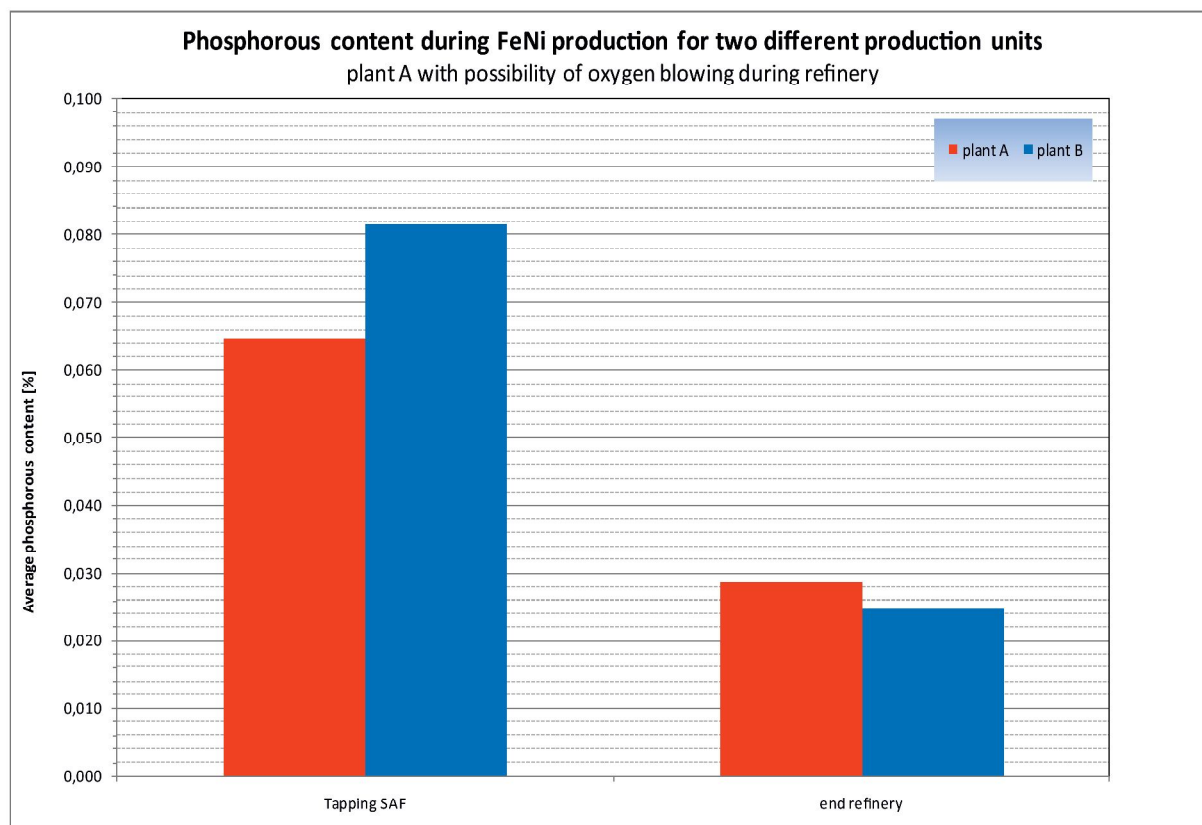


Figure 7: Phosphorous content during FeNi production

CONCLUSION

Ladle based refinery plants have been successfully installed for the refining of crude FeNi produced by the RKEF route. Refining operation using oxygen blowing during tapping and a ladle furnace treatment afterwards are flexible to cope with varying compositions of the crude metal.

It has been proven that all requirements regarding carbon, silicon, phosphorous and sulfur content of the refined FeNi can be met easily.

REFERENCES

- [1] Durrer, R., Volkert, G., Metallurgie der Ferrolegierungen, Springer Verlag (1972).
- [2] Dalvi, A.D., Bacon, W.G., Osborne, R.C., The Past and the Future of Nickel Laterites, PDAC 2004 International Convention, Ontario, Canada (2004).
- [3] C. Walker, S. Kashani-Nejad, A.D. Dalvi, N. Voermann, I. Candy and B. Wasmund, Future of Rotary Kiln - Electric Furnace (RKEF) Processing of Nickel Laterites, Proceedings of the European Metallurgical Conference, EMC 2009, Innsbruck, Austria, (2009).
- [4] Fernando Hernandez, P. et al, Heating of FeNi Alloy in Ladle Furnace by Electrical Energy and Chemical Energy, Proceedings XXXI Seminario de Fusao, Refino e Solidificacao dos Metais, Associacao Brasileira de Metalurgia e Materiais (2000).