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OPTIMIZATION OF THE PROCESS FLOW PRODUCING STEEL CONTINUOUS CAST SEMI–FINISHED PARTS

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Abstract: At present, steel is elaborated in oxygen and electric arc furnaces. The paper presents the results of the research done on the structure of charge loads, the main chemical elements, equivalent carbon, the reduction of nitrogen content in the steel produced in an electric steel plant, using a 100 t EBT–type electric arc furnace, LF–type ladle furnace installations, VD vacuum degassing and a 5–strand continuous casting machine. The data related to steel vacuum treatment have been processed in EXCEL in view of establishing correlations among the dependant parameters, respectively the amount of nitrogen and the yield of its removal, and the independent ones: the total duration of vacuum treatment. The resulting correlations are given both in analytical and graphical form, as well as through their technological analysis. The research resulted in a series of conclusions applicable in research and in current practice.
Keywords: steel, carbon, vacuum processing, nitrogen, removal

1. INTRODUCTION

The specific steel consumption (kg/inhabitant) is, in any economically high developed country, directly correlated with the national income. Starting the latter half of the 20th century and up to the present day, steel industry underwent a series of highly important technological restructuring processes.

At present, steel is world–wide elaborated [1–4]:

- in oxygen furnaces (integrated process flow: raw materials–coke plant–agglomeration–blast furnaces–steel plant (with continuous casting machines); the charge consists of 80% liquid cast iron and 20% scrap (ferrous waste);
- in electric steel plants (equipped with EBT–type electric arc furnaces, with bottom tapping); the load consists of 100% scrap, which can be partially replaced by iron sponge, metal pellets.

Hunedoara used to have two process flows, one consisting of Siemens Martin Steel Plant 1 – 800 Rolling mill and another one, made of Siemens Martin Steel Plant 2, 1000 Blooming and 1300 Rolling Mill and the rolling mills of Pestiș.

At present, as a result of steel industry restructuring, the Integrated Steel Plant of Hunedoara completely closed down the Siemens Martin Steel Plant 1 (5 furnaces of 100t/furnace, about 1000 t of quality carbon and low–alloy steel/day), the Siemens Martin Steel Plant 2 (lance oxygen bubbling, 8 furnaces, 460 t/furnace, 11 000 t of steel/day) as well as the Electric Steel Plant 1 (alloy steels, 2x20t and 2x50t, an average of 700t of alloy steel/day; vacuum processing facilities VAD–VOD for the 50t furnaces, and VOD for the 20t stainless steel furnaces). The Electric Steel Plant II has been modernized, the 2 UHT–type 100t electric arc furnaces (1200t of steel/day) being replaced by an EBT–type 100t furnace (an average of 16 charges/day, respectively 1600t of liquid steel/day). It also has a Ladle Furnace (LF) installation and a VD–type vacuum installation, without heat addition, which reduces the vacuum processing to 32 minutes at most. Steel processing in VD–type installations has the advantage of steel degassing and thermal and chemical metal bath homogenizing [5–8].

Figure 1. LF–type installation

2. THE EXPERIMENTAL FRAMEWORK

In elaborating the paper herein, we surveyed the process flow of 13 steel charges, meant for 20 Mn 10 grade pipe steel. As to the structure of the charge, one can say it was of high quality and well prepared.

The industrial experiments were carried out at an electric steel plant, using a 100t EBT–type electric arc furnace, with LF–type ladle furnace installation, a 100t VD, and a 5–strand Continuous Casting Machine for blooms, billets and rods.

From the quality point of view, the research focused on the structure of the charge, the chemical elements of the steel, its nitrogen content, the yield of its removal and its absorption in the ladle after the vacuum process, all of which were considered dependant parameters [9–11]. The independent parameters considered were: the total duration of the vacuum process, the duration of the process under advanced vacuum, the time span steel is kept in the ladle from the end of the vacuum process until it is poured into the tundish.

3. DATA PROCESSING AND RESULTS

The data have been processed in EXCEL and the correlations obtained were between a dependent and an independent parameter, the paper only presenting the polynomial correlations of degree 1 to 4, namely:

- degree 1: $z = a_1x + a_2$;
- degree 2 $z = a_1x^2 + a_2x + a_3$;
- degree 3; $z = a_1x^3 + a_2x^2 + a_3x + a_4$;
- degree 4; $z = a_1x^4 + a_2x^3 + a_3x^2 + a_4x + a_5$;

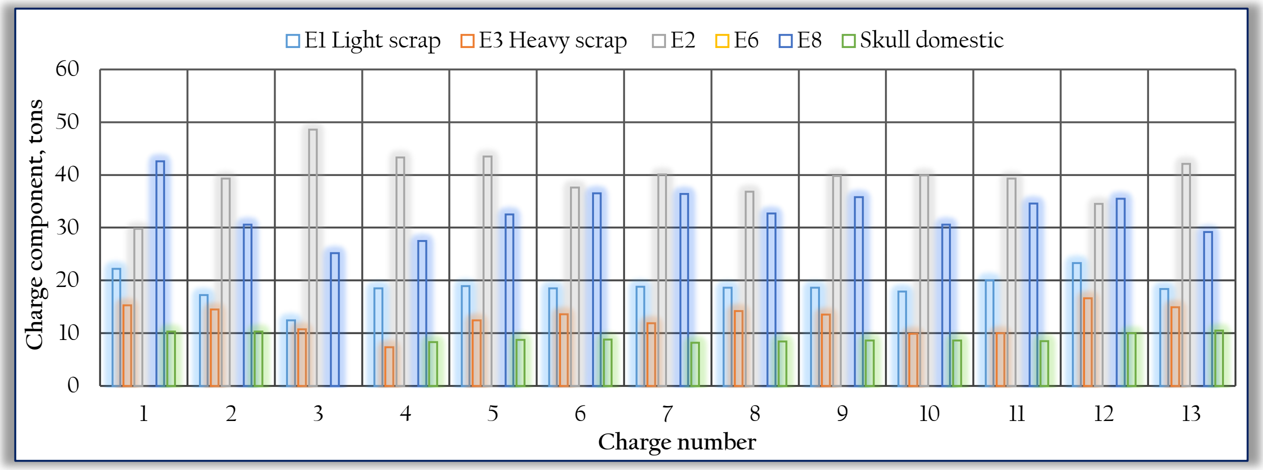

Figure 2. The structure of the EBT–type electric arc furnace charge

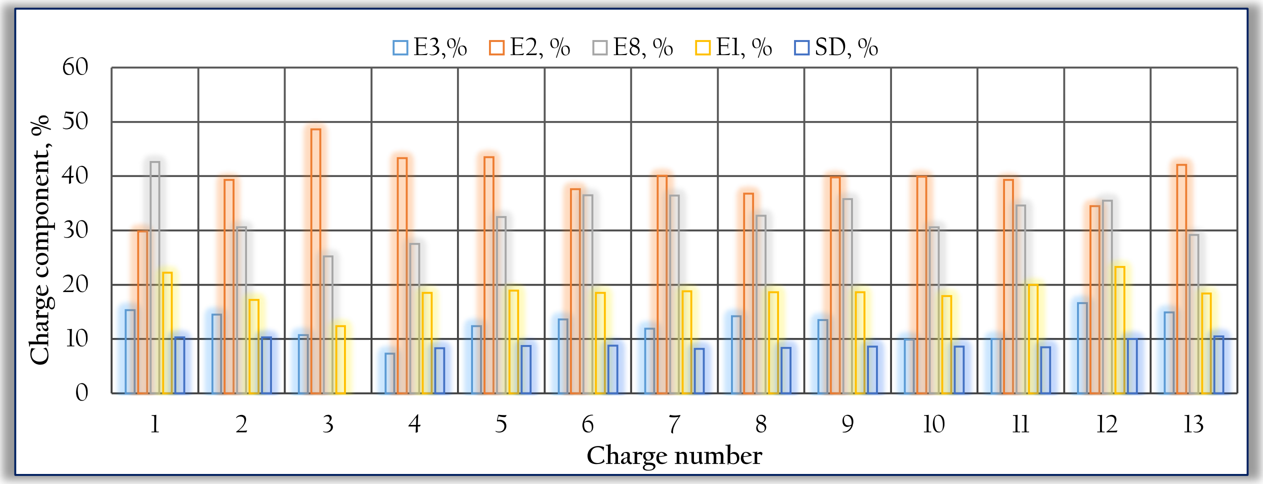

Figure 3. The structure of the electric arc furnace charge, %

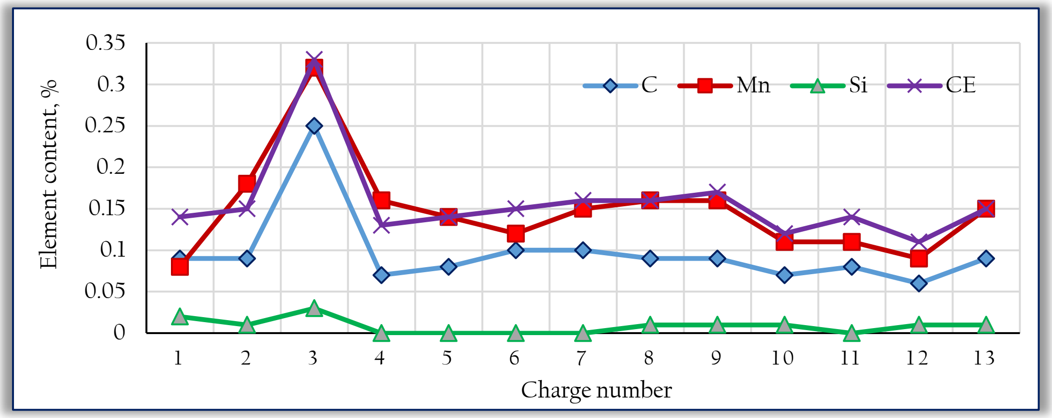

Figure 4. Contents in C, Mn, Si and CE (sample)

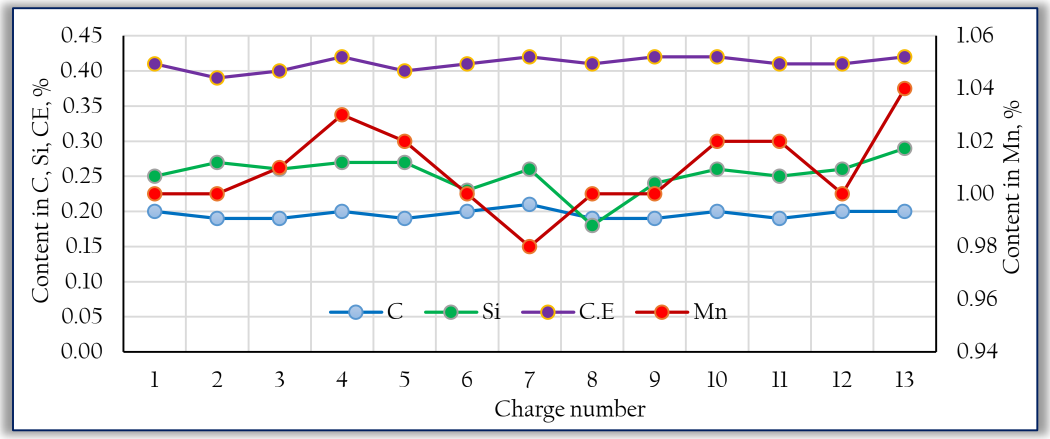

Figure 5. Content in C, Si, Mn and CE (final)

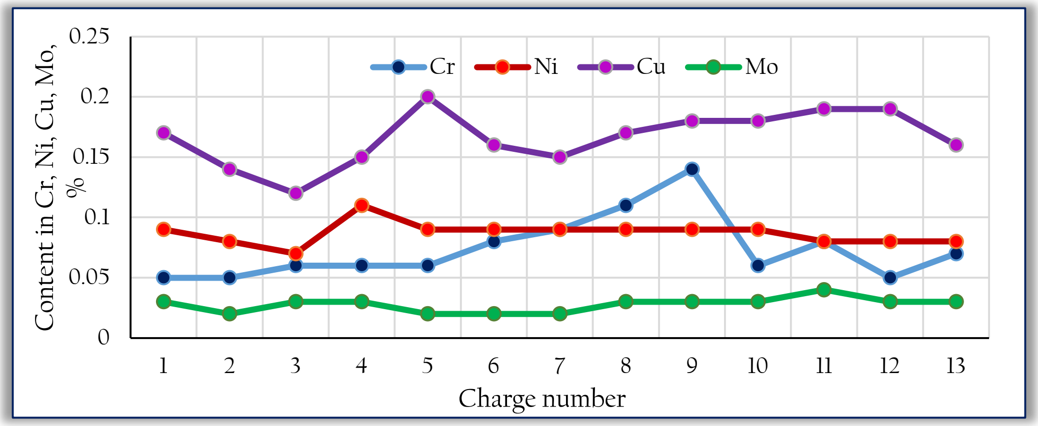

Figure 6. Content in Cr, Ni, Cu and Mo (sample)

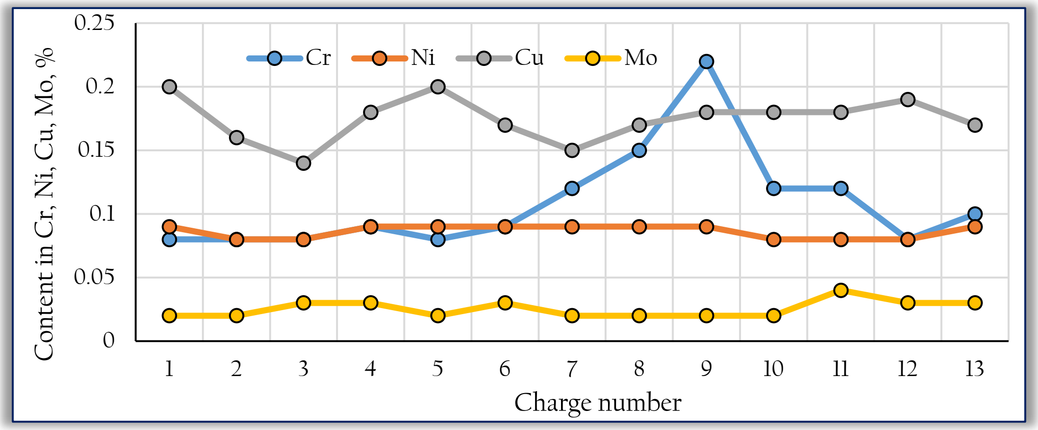

Figure 7. Content in Cr, Ni, Cu and Mo (final)

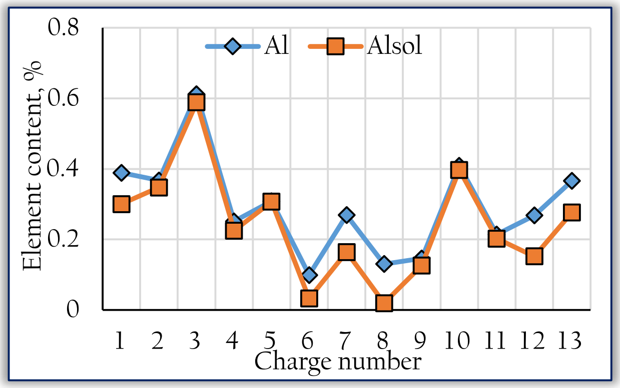

Figure 8. Content in Al and Al sol (sample)

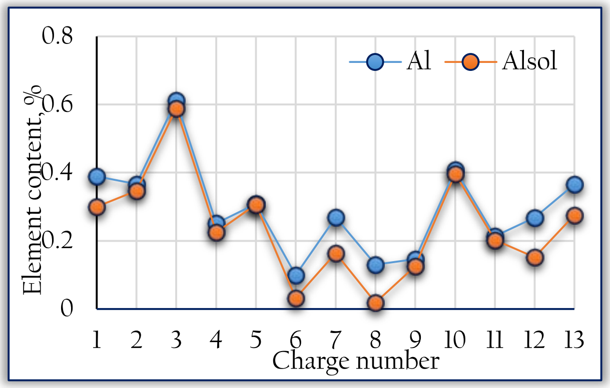

Figure 9. Content in Al and Al sol (final)

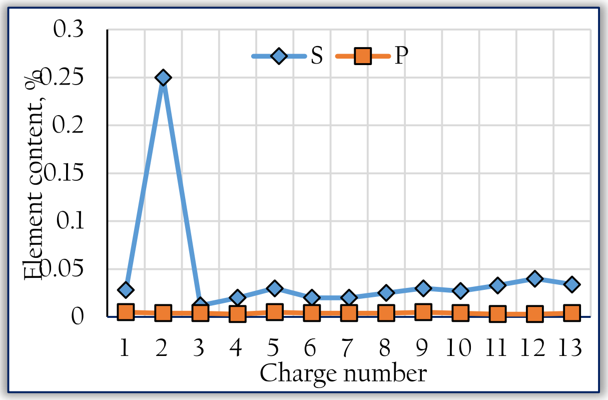

Figure 10. Content in S and P (sample)

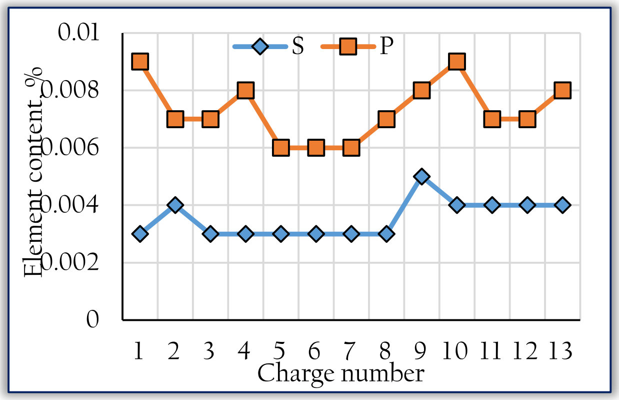

Figure 11. Content in S and P (final)

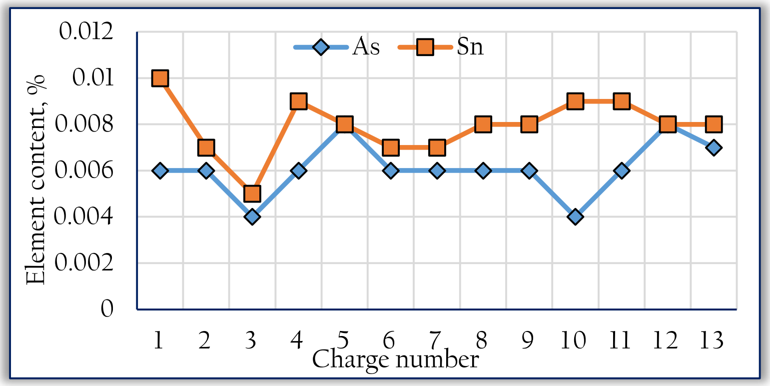

Figure 12. Contents in As, Sn (final)

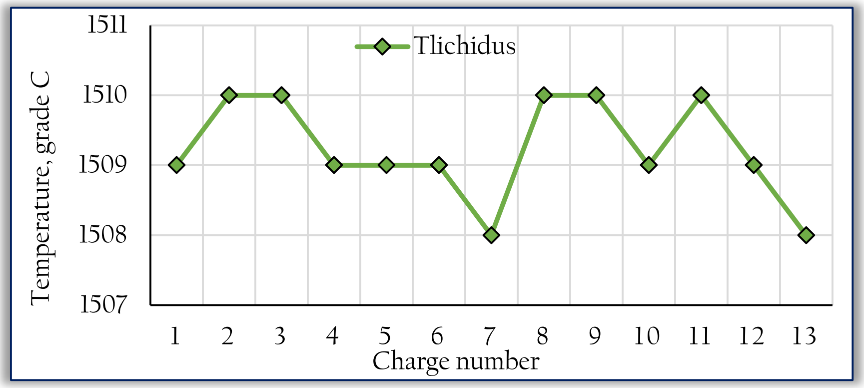

Figure 13. Liquidus temperature (final)

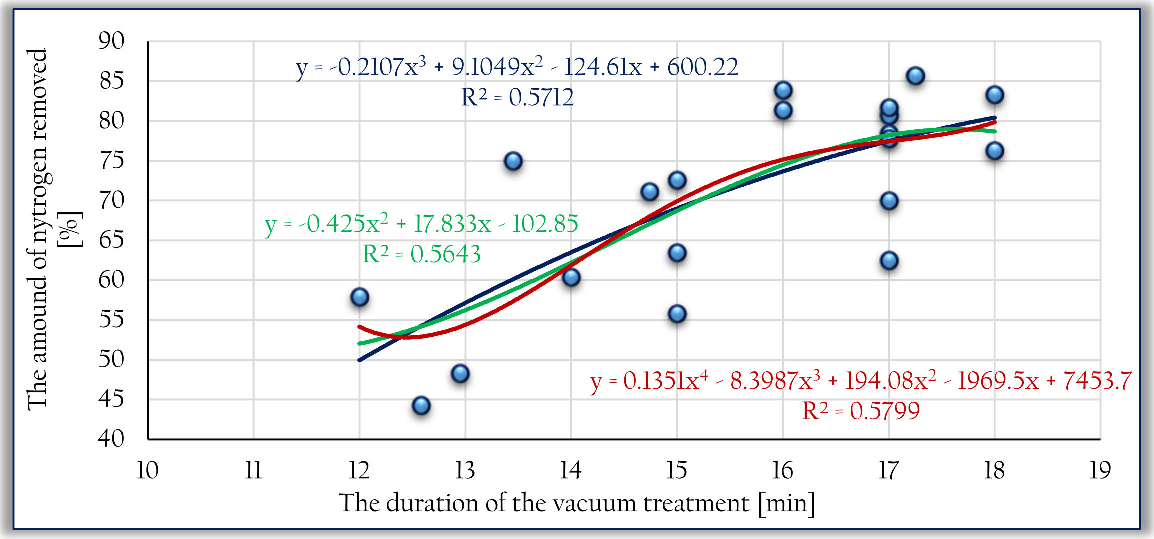

Figure 14. The amount of nitrogen removed=f(D_{vid})

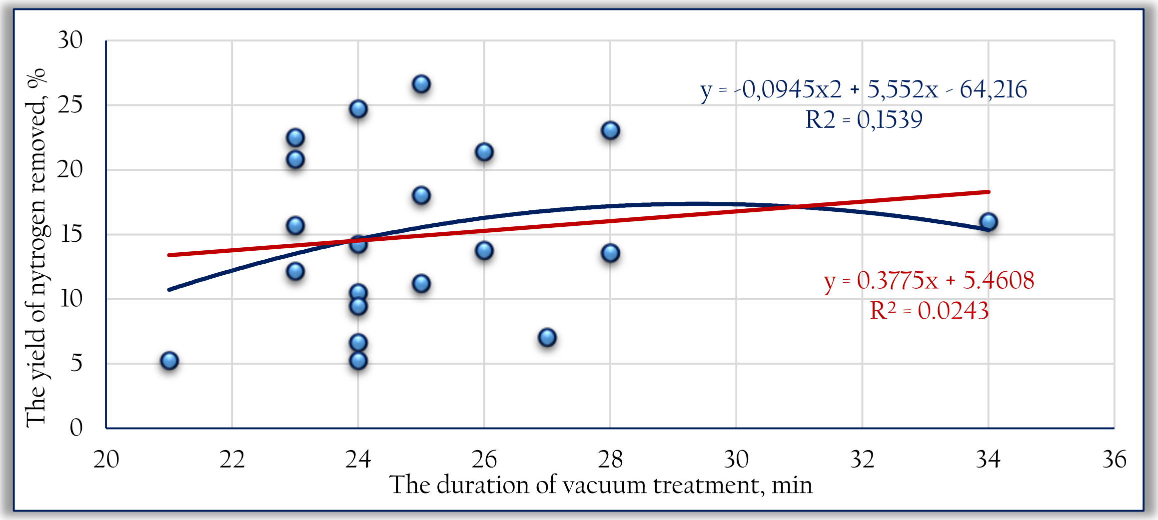

Figure 15. The yield of N removed=f(D_{vid})

4. THE TECHNOLOGICAL ANALYSIS OF THE RESULTS

As to the structure of the charge, Figures 2 and 3 entitle us to consider that it was good quality, well prepared for charging and there were no significant variations in terms of component participation.

In figures 4 and 5 the formula of equivalent carbon was used:

$$CE = C + \frac{Mn+Si}{6} + \frac{Cr+Mo+V}{5} + \frac{Cu+Ni}{15} \quad (1)$$

One can notice that variations are quite narrow, with the exception of charge 3 where there was probably an electrode break (Figure 4). The analysis of the diagram in figure 5 shows an extremely slight variation of the three elements, C, Mn and Si, which grants very similar physical and chemical characteristics for the different charges, i.e., almost identical processing conditions in the tundish. The CE content 0.36 – 0.40% grants very good welding conditions and the more constant the chemical structure, the better the welding process. Figures 6 and 7 show that elements Cr, Ni, Cu, Mo are below the accepted limits for a charge, which is a positive fact, since they are expensive alloy elements. Form this point of view, the charge can be considered as well prepared.

The recommended contents of total and soluble Al are not exceeded, higher values with charges 2, 4, 13 being explained by the higher addition of aluminium in the bath, as for the rest, the variations being within normal limits. Aluminium influences grain size in the sense that it finishes it (Figure 8, Figure 9).

The very low contents in S and P are influenced by the quality of the charge and the processing technology. Very good contents (Figure 10, Figure 11).

Figure 12 shows that the values of Sn and As are below the limits, but it is good to monitor Sn, for it is not removed by oxidizing. Figure 13 shows the variation of the temperature of the liquid with the final samples, i.e. 2^0C, which means a very good technology granted by the highly skilled personnel. Figures 14 and 15 show that the total vacuum processing time of 26 – 28 minutes grants a good efficiency of the nitrogen removal process from the metal bath.

5. CONCLUSIONS

The results obtained by data processing in EXCEL can lead to the following conclusions:

- a good and homogenous charge, as well as a highly skilled personnel can lead to the elaboration of high quality steel charges;
- ensuring a total vacuum processing time of 28–32 min. leads to a good yield of the nitrogen removal process from the metal bath;
- steel treatment in the LF and VD installations leads not only to the reduction of charge time, but also to similar time spans for the elaboration stages and to small variations of the final chemical structure, which is of particular importance for the beneficiaries (the pipe users).

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