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The Experience of the Implementation of Modern Blast Furnace Equipped with Bell-Less Top Charging Device under Conditions of Changing Quality of Charge Materials

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Abstract

The main results of the implementation of rational modes of charging of the modern blast furnace No. 3 of PJSC «Yenakiievo Iron and Steel Works», equipped with modern bell-less top, in the conditions of changing quality of the charge materials are given.

Key words: *blast furnace, burden materials, charging, bell-less top charging device, burden distribution*

In October 2011, after the reconstruction a modern blast furnace (BF) No.3 with capacity of 1790 m^3 equipped by Paul Wurth bell-less feeding system was commissioned at PJSC "Yenakiievo Iron and Steel Works" (YISW). The pre-launch studies performed by the members of IFM together with representatives of PJSC "YISW" helped to identify and implement after the blowing of furnace the modes of BLT operation necessary for the effective application of used programs of BF charging [1].

The main feature of charging conditions in 2012 was a transition in the second half of the year to high-basic hot sinter at almost simultaneous deterioration of coke quality. The first half the year the BF No.3 operated with the agglomerate with the basicity by CaO/SiO_2 = 1,16–1,21 units and with 24 % of pellets in the iron ore part of the charge. In the second half of the year, it was decided to use sinter of own production with the basicity of 1.81-2.22 units and a temperature of 300 °C, the content of pellets in the iron ore part of the charge in this case was 54%.

In 2012, the coke of various quality was used at the BF No.3, it was evaluated by the parameters of coke strength reactivity (CSR) and coke reactivity indicator (CRI). Thus, in the first half of the year the coke of two types of differing values of CSR and CRI indicators was used; and in the second half of the year the three types of coke were used (Table 1). In the second half of the year coke quality has deteriorated significantly: the weighted average of CSR index decreased compared with the first half of the year from 51 to 43%, and the weighted average value of the CRI index increased from 31 to 39% (Table 1).

Table 1 The quality of coke used at BF No.3 in 2012

January-June 2012		July-December 2012	
Coke composition, %	CSR CRI	Coke composition, %	CSR CRI
58	55 28	10	52 33
42	46 35	74	43 39
		16	38 42

In 2012, in the conditions of changing quality of the charge materials six major charging programs aimed at increasing the use of gas reducing ability were implemented at the BF No.3. The estimated distribution of ore loads (OL) by the radius of the furnace top for used programs of charging are given in Figure 1.

In the first quarter of 2012 two charging programs were used at the BF No. 3 according to the recommendation of IFM. The first version of the set charging program aimed at "opening" of the peripheral zone was implemented on the BF January 21, 2012. The "opening" of the peripheral zone was due to the instable operation of the blast machine in the start-up and adjustment period, i.e. due to its periodic stops, accompanied by slag lining creeping. After the installation of the charging program the temperature of peripheral gases has increased from 300 to 400 °C, while at the same time, the operation of the furnace was accompanied by more even burden yield.

Because of the absence of automated gas sampling by the furnace radius at BF No. 3 the qualitative indicator of distribution of charge materials is the blast furnace gas temperature indicated by thermobeam. The analysis of thermobeam indications during the usage of charging program installed January 21, 2012 on the furnace showed that the operation of the furnace in the period under review had been characterized by the developed axial gas distribution with a slight increase of blast furnace gas temperature in the wall zone. The distribution of the temperatures of blast furnace gas indicated by two stationary thermobeams is shown in Figure 2.

The need of further adjustment of charging program, which involved increasing of the weight of iron-containing materials discharged from the 10th angular position of the chute (into the peripheral zone of the furnace), was caused by increased temperature of peripheral gases, which reached 446 ° C in average in the period from Jan.21 to March 01, 2012. The degree of usage of reducing ability of the gas (η_{CO}) in this case was 45.4%, after changing the program on March 15, 2012 the temperature of the periphery decreased to 356 °C (ηSO = 45.9%).

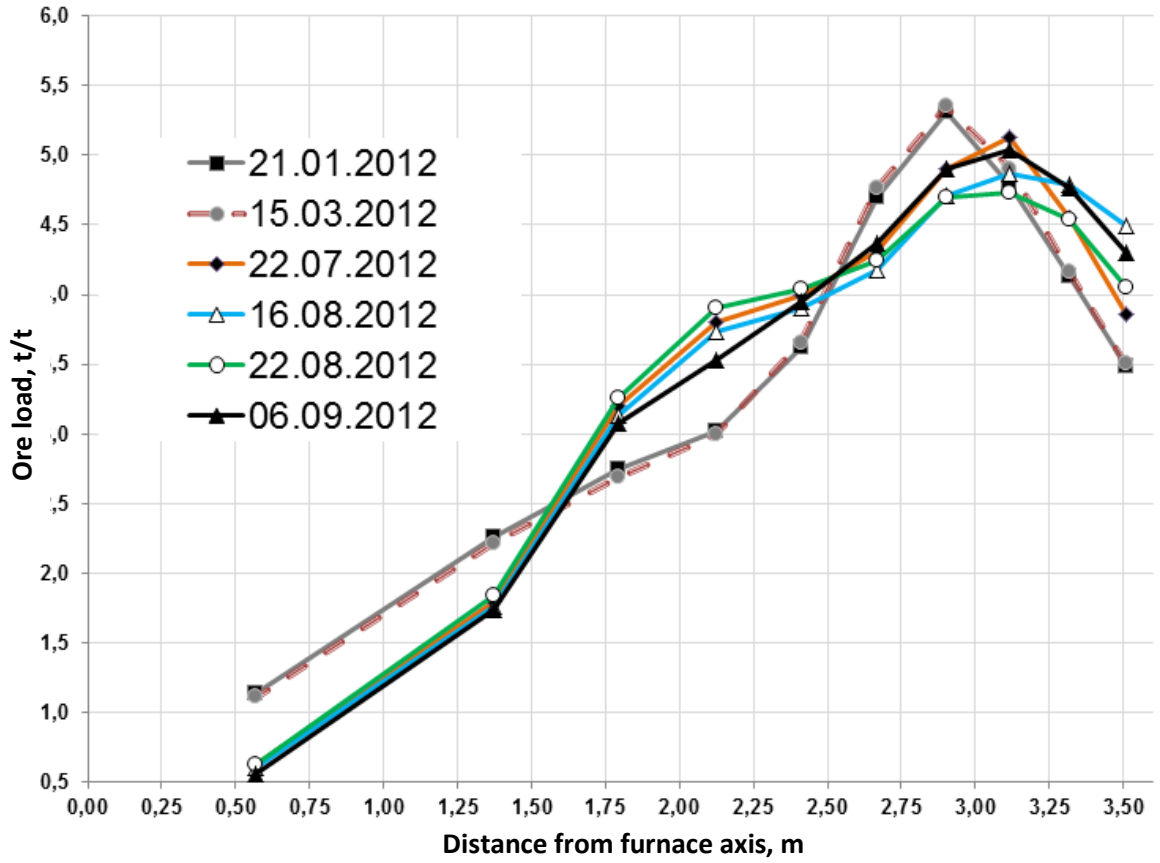
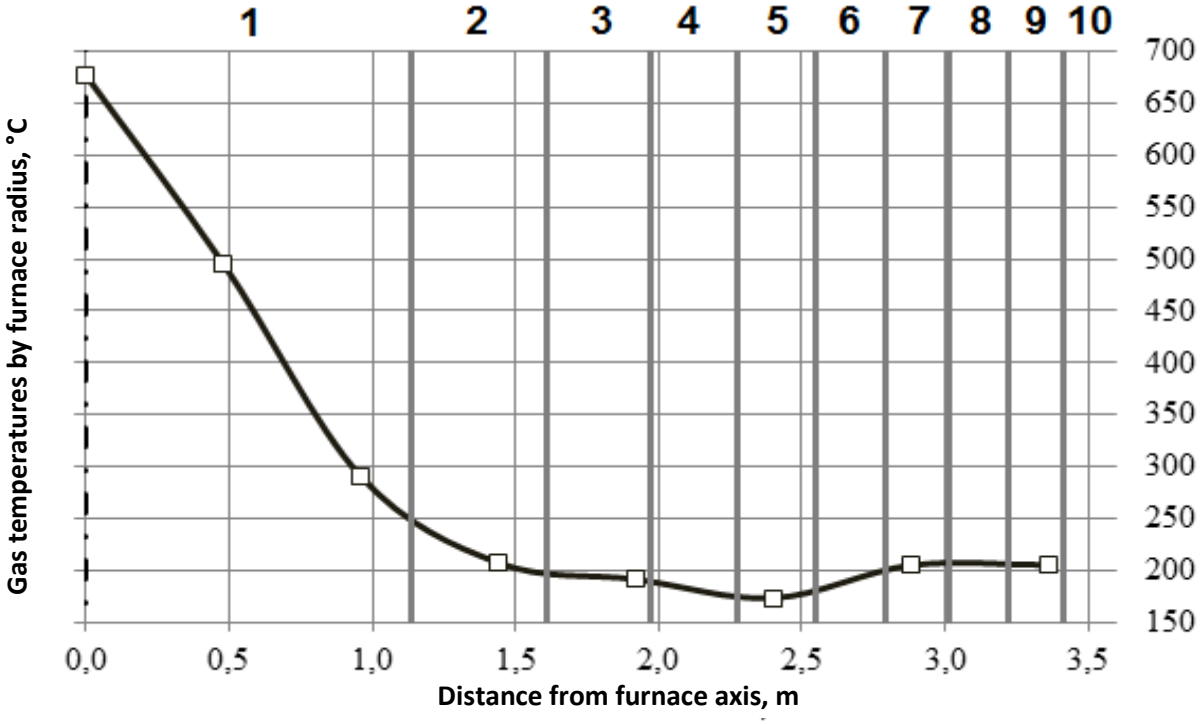


Figure 1 The estimated distribution of ore loads by the furnace top radius fro six options of furnace charging used at BF No.3 in 2012.

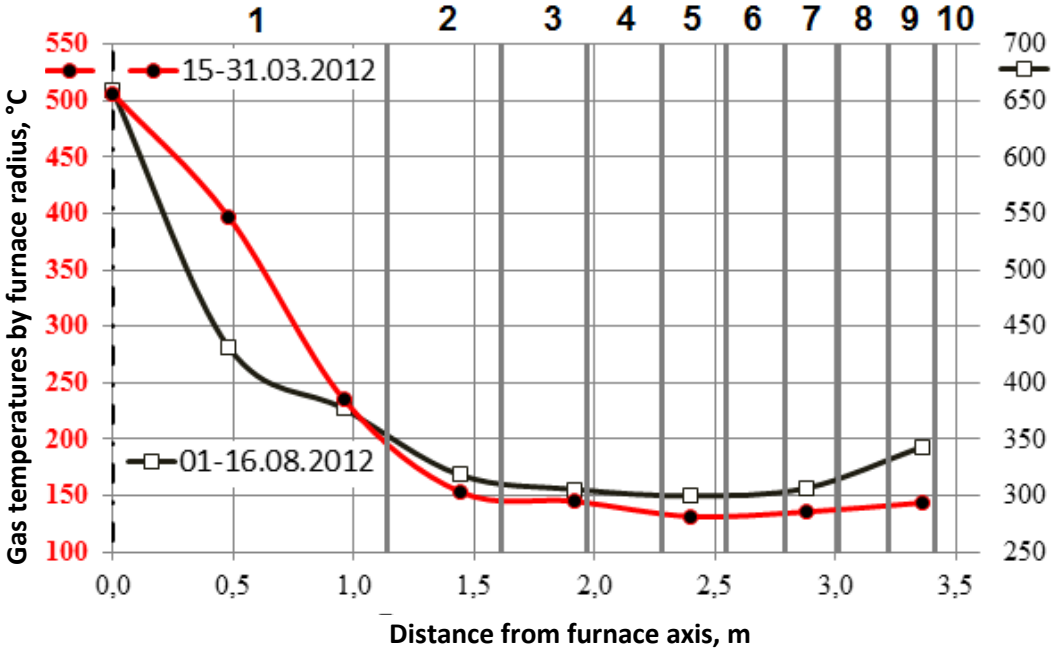


1...10 – equal areas of the furnace top

Figure 2 The top gas temperature distribution along the radius of the furnace top

To achieve high level of usage of the reducing ability of gases the distribution of OL along the radius of furnace top must be characterized by their nearest values in the intermediate zone of the furnace top (No.3 – No.6 are furnace top zones equal by the area) and exceed the average OL by 5-10% higher in the charge cycle [2, 3]. In the conditions of BF operation with the unstable quality of iron ore materials, deterioration of coke quality and low intensity of melting at a rate of blast less than that of the design, without oxygen concentration, with such radial distribution of OL along the furnace top it is not always possible to achieve a high degree of usage of the reducing ability of gases.

The necessity to adjust the charge program at the end of July 2012 was due to the complete replacement since July 01, 2012 of imported agglomerate with hot high-basic agglomerate of local production and increased content of pellets in the charge, resulting in a temperature increase of peripheral gas from 490 to 600 ° C and a decrease in the degree of use of reducing ability of gases from 45 to 42%. The charge program, implemented on July 22, 2012, was aimed at increasing of OL in the peripheral zone to reduce the temperature of peripheral gas by reducing the weight of the coke discharged from the 9th angle position in portions number 3, 7 and 11 as well as at the increase of gas permeability of axial zone by an additional charge of coke in it (portions number 5 and number 9). This charge option allowed to increase the thickness of the layers of coke at its constant weight in the feeding due to the exclusion of the extra 13th portions of axial coke from the charging program. The charging program installed since July 22, 2012 is aimed at providing a more narrow axial zone than that used since March 15, 2012 , the axial zone (Fig. 1). This is shown by the temperature distribution of the BF gas after installation of charge program at the BF No. 3 since March 15, 2012 and after the installation of charge program since July 22, 2012, shown in Figure 3.



1...10 – equal areas of the furnace top

Figure 3 The top gas temperature distribution along the radius of the furnace top

Due to the deterioration of coke quality since Aug. 01, 2012, characterized by the decrease of the CSR index for all suppliers, the increase of the temperature of the peripheral gases continued and reached a value of 635 °C. This caused a further adjustment of charge program on Aug.16, 2012 with increasing of OL in the peripheral zone of the furnace top (in the 10th and 9th circular zones) from 4.63 to 5.07 t/t, in average, by increasing the amount of iron-

containing materials, discharged from the 10-th angle position in each iron loading ore portion of charge cycle. The implemented changes in the program have reduced the temperature of peripheral gases to 488 °C.

The poor quality of coke and a significant content of "-5 mm" in skip agglomerate (in some periods up to 22%) led to frequent "upper suspending", which were accompanied by an increase of the upper pressure drop, which led to the forced furnace upsetting. In addition, the poor performance of the bottom of the furnace due to blockage of the furnace in the absence of drilling materials led to the "lower suspending", accompanied by an increase of the lower pressure drop. These features have caused "unloading" of the peripheral zone of the furnace on Aug. 22, 2012 by reducing of iron materials discharged from the 10th angle position by 7% - from 19 to 12%, which led to a decrease in the OL of the peripheral zone from 5.07 to 4.69 t/t in the 10th and 9th annular zones furnace top in average.

In the beginning of September 2012 the sinter quality has improved slightly: the standard deviation of the basicity, compared to the previous two months, decreased from σ (CaO/SiO_2) = 0.32 units. to σ (CaO/SiO_2) = 0.22 units. Thus, the average basicity was 2.20 units compared to 1.96 units in July-August, resulting in the improvement of strength characteristics of the agglomerate, and consequently, in the reduction of quantity of fraction "-5 mm" to 12% in the skip agglomerate. The improvement of the quality of sinter contributed to the stabilization of the operation of upper zone of the furnace: the absence of the "upper suspending", which allowed to make changes to the charge program aimed at further reduction of the temperature of the peripheral gases. On September, 2012 the following changes of charging program have been implemented: the amount of iron-containing materials discharged from the 10th angular position was increase in two portions of the charge cycle (№ 4 and № 10) by 2%, from 17 to 19%, and also the amount of coke discharged from the 1st and 2nd angular positions was increased from 50 to 62% in total. Moreover, in the portions of coke discharged from the angular positions of the chute 9-4 the amount of coke discharged from the 9th angular position is reduced by 2%.

As the studies have shown [1], the operation of the furnace with the contents of the pellets of iron ore part of the charge, exceeding 50%, facilitates their systematic hitting in the peripheral zone of furnace top section at the discharge from BLT chute, despite the formation of materials in skips, providing no pellets in the first (left) skip. It is caused by the features of material flow from the BLT hopper which consist in unloading of central part of the melting stock column from the hopper and greater flowability of pellets compared to agglomerate. The increased concentration of pellets in the peripheral zone of the furnace top can lead to the development of furnace peripheral operation [4, 5] and to the upper "suspending", especially in the conditions of degraded coke quality, and therefore, to the overrun of coke.

To reduce the concentration of pellets in the peripheral zone of the furnace, it was recommended once or twice in a cycle of charging to split the iron-containing portion of the load discharged from the angular positions of the tray 10-4 into two parts, with unloading of each skip into the furnace separately – the first (left) containing agglomerate or sinter with additives, and a second (right), containing mainly pellets. Table 2 shows the distribution of materials by the angular positions of the BLT chute of the portion number 4 in the base and "separated" (skip) options. The calculated structure of the melting stock column in the furnace top for “separated” (skip) option of charging program is shown in Fig. 4. The "separated" option of the charging program was implemented at the BF No. 3 on November 15,

2012 in 11:30 a.m. Table 3 shows the change in temperature of the peripheral gases after the implementation of the "separated" option of the charging program. As the table shows, the temperature of the peripheral gases 8 hours after the charging program implementation decreased by 54 °C. The said approach should be used further to reduce the temperature of the periphery; at the same time attention should be paid to the lack of this approach, comprising the increase of charge cycle time by 8 minutes in average. It is possible to avoid increasing the charging cycle time by charging the second skip in "no measure" mode (without reaching the pre-set level of the charge).

Table 2 The distribution of materials by the angular positions of BLT chute for two options of the charging program

BASE OPTION Left+right skip		"SEPARATED" OPTION			
		Left skip		Right skip	
No. of angle position of the chute	% of materials	No. of angle position of the chute	% of materials	No. of angle position of the chute	% of materials
10	19	10	36		
9	20	9	38		
8	14	8	26		
7	14			7	30
6	12			6	26
5	11			5	23
4	10			4	21

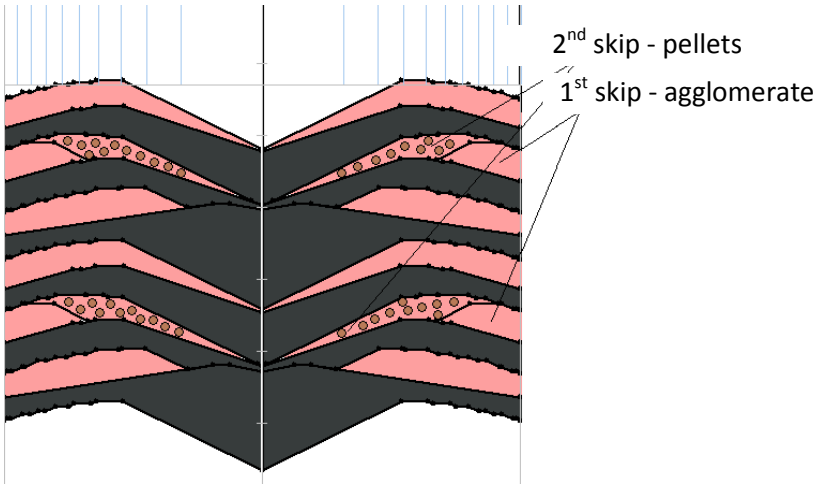


Figure 4 The calculated structure of the melting stock column on the blast furnace top after discharging of charging program, in which

Table 3 The dynamics of changes in peripheral gases temperature (T_{pf}) after the implementing of the "separated" option of the charging program

Date and time	T_{pf}, °C
15.11.2012 $15^{\underline{15}}$	709
15.11.2012 $17^{\underline{00}}$	714
15.11.2012 $19^{\underline{00}}$	684
15.11.2012 $21^{\underline{00}}$	669

portions number 4 and number 10 are discharged skip by skip

15.11.2012 $23^{\underline{00}}$	655

It is known that one of the main control actions aimed at the adjustment of charge distribution by the radius of the furnace equipped with bell-type feeder is the change of the stock line level. At the blast furnaces with modern ACS, equipped with BLT, it is irrelevant, since at the change of the stock line level the change of the slope angles of BLT feeder is made in the automatic mode in compliance with the conditions of hitting of the charge flow centre to the centre of centre of the annular zone furnace top corresponding to the angular position of the chute [3]. The control of the distribution of charge gas flow by the radius of the blast furnace quipped with BLT feeder should be performed only by the change of charging program. The results of the measurements carried out before the start of BF No.3 of parameters of movement of coke flow and iron-containing materials helped to specify the calculated trajectories of the movement of charge materials in the work area of the furnace and to determine the angles of chute sloping, giving the required range of adjustment of distribution of charge materials on the furnace top [1]. Calculated values of the angles of chute slope, determined on the basis of experimental data for different stock line levels at a pitch of 0.1 m, were entered in the appropriate matrixes of management system of BLT feeder of BF No.3 and are currently used in the automatic mode [1].

However, one should pay attention to the negative features, peculiar to the distribution of the BLT feeder charge by the furnace radius at the change of stock line level, which are as follows:

– the increase of the width of charge materials flow at lowering of stock line level breaks the directed discharge into pre-set annular zones of the blast furnace top; thus, for the conditions of BF No.3 according to the results of pre-launch investigations it was determined that at the lowering of stock line level by 0.5 m the width of the flow increased, in average, by 7.4%;

– distortion of the radial distribution of charge materials at stock line levels below the cylindrical part of furnace top, due to the peculiarities of redistribution of materials by the radius in the blast furnace shaft;

– the distortion of the charge flow at its contact with thermobeams, which is particularly important for conditions of BF No.3, where the thermobeams have a rectangular cross-section with a width of contact side of 200 mm.

Currently, the basic means for controlling the level of the stock line in the BF No. 3 is one electromechanical gauge. After reaching a predetermined level of stock line by the gauge, the signal is received at the BLT feeder, allowing the discharge of the charge materials; thus, for selecting predetermined angles of BLT feeder chute slope it is accepted that level of stock line, which is measured by electro-mechanical gauge before its elevation. During the pre-launch studies at the BF No. 3 it was found that during the operation at low levels of stock line (2.5 m or below) the distortion of the flow of charge materials by thermobeams leads to circumferential unevenness characterized the by the areas of the surface with the cavities up to 0.5 m [1]. The experience of the development of blast furnaces equipped with BLT feeder helped the investigators of IFM to determine that the unevenness of annular charge distribution of 0.5 m or more distorted the radial distribution of materials and the results of its evaluation, which makes it difficult to organize the rational interaction between charge and gases [2]. The furnace sector of the studied furnace, in which the control of the level of the stock line is performed by electromechanical probe, is located in the zone of influence of stationary thermobeams on the flow of charge materials and, therefore, at the use of information about the

level of the stock line the pre-set radial distribution of the charge is distorted. Consequently, the actual events in the future are to maintain the operating level of the stock line in the range of 1.5-2.0 m and to use radar level gauges determining the level of the stock line in the peripheral zone of the furnace for full control over the charging process.

In the current process and charging conditions of blast furnace mill of PJSC Yenakiieve Iron and Steel Works in 2012 the use of BLT feeder on the BF No.3 when testing the rational charging programs together with the implemented recommendations of the IMF on forming the portions, distribution of charge components along the furnace radius, ensuring the resistibility of the lining, contributed to the saving of coke and improving of the stability of the furnace operation. It is evidenced by change graphs of coke consumption on the BF No.3 compared to the BF No. 5, equipped with bell-type feeder, which are shown in Fig. 5. As the graphs show, the actual consumption of coke on the BF No. 3 for the 2012 amounted to an average 470.4 kg/t of pig iron, which is 13.0 kg/t of pig iron less than on BF No. 5. At the same time, it should be noted that before the deterioration of the charge materials quality (January-June 2012), the difference in the actual consumption of coke between BF No.3 and BF No.5 was 17.5 kg/t of pig iron, however, BF No. 3 was operating in the better condition during the described period. To equalize the condition on the furnaces No. 3 and No. 5 the calculation of influence of technological factors on the specific coke consumption was performed [6]; it showed that coke consumption on the BF No.3 in the first half of 2012 amounted 14.7 kg/t of pig iron less than on the BF No.5. During the operation of blast furnace plant with the charge materials of deteriorated quality (July-November 2012) the studied furnaces operated in almost identical conditions, but the actual consumption of coke in the second half of 2012 at the BF No. 3 was 7.5 kg/t of pig iron less than at the BF No.5. The presented results of comparative characteristics of technical and economic parameters of these furnaces demonstrated the effectiveness of usage of BLT feeder on the BF No.3.

The experience of assimilation of BLT feeder at BF No.3 showed that there should be the following operations for the reasonable selection of the charging programs, especially in the conditions of usage of low-quality coke:

- equipping of BF No.3 with the modern system of gas samples collection along the furnace radius;
- controlling of furnace charging basing on the data of radar level gauges, which should be installed according to IFM technical specification;
- maintaining the operational level of stock line in the range of 1.5-2.0 m and changing it only in cases of absolute necessity;
- operating with coke mass quantity in the feed not less 9.0 t, which will provide the thickness of layers of charge materials of 0.4-0.5 m and, subsequently, will promote the sustainable gas distribution in the furnace.

Conclusions

The implementation of charging programs on the BF No.3 in 2012 in the conditions of changing quality of charge materials allowed to provide acceptable technical and economic indicators of smelting, despite the difficulties caused by the lack of complete and accurate information of control means mounted on the furnace. To make the reasonable choice and efficiency of valid charging programs implemented on the BF No.3 in the conditions of expected low quality of coke, it is necessary to implement a set of measures represented in the present article.

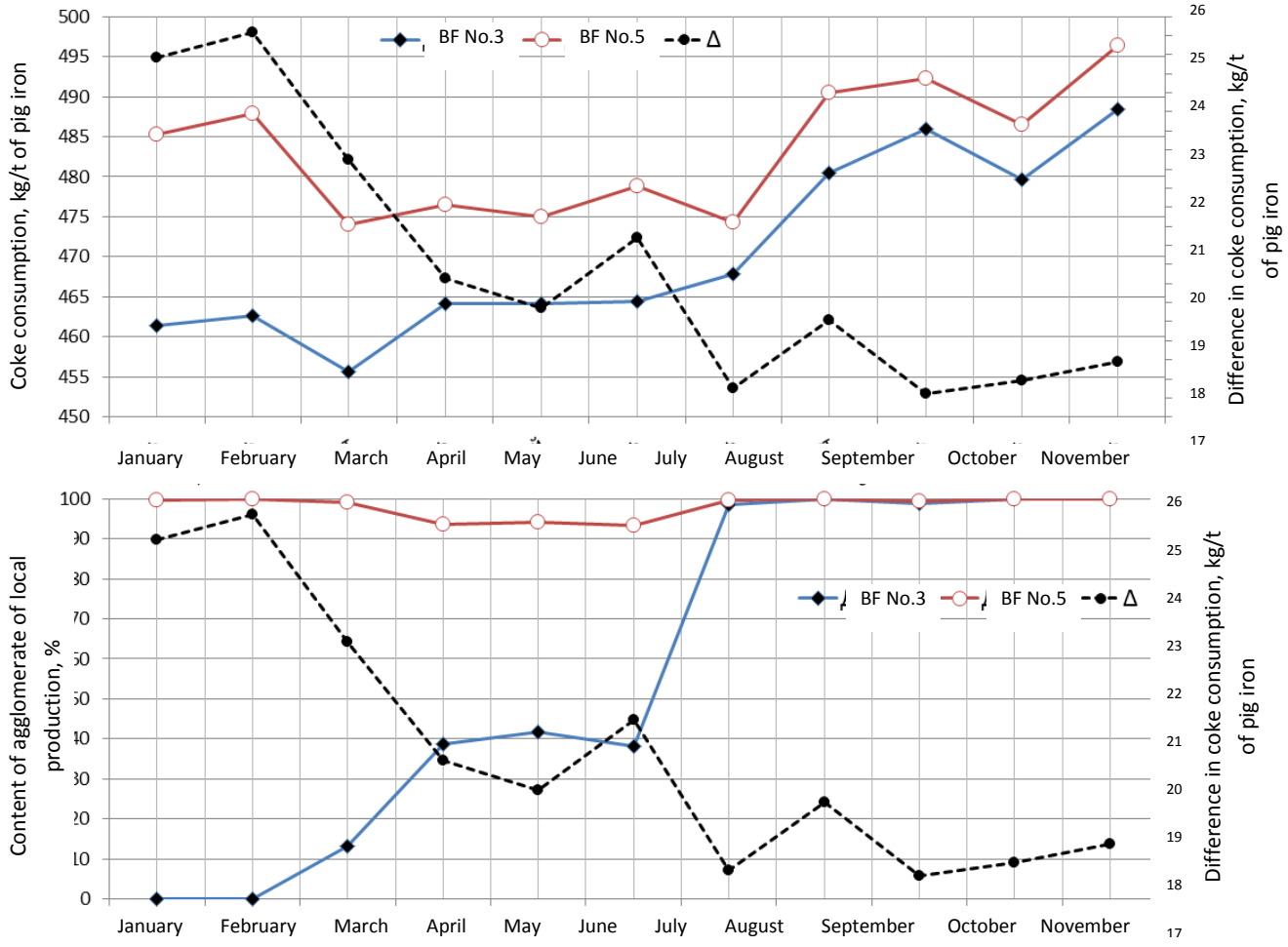


Figure 5 The actual consumption of coke and content of local production sinter in the BFs No.3 and No.5 of PJSC Yenakiieve Iron and Steel Works for 2012

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