THE MAIN REASONS FOR INCREASED COPPER LOSSES WITH SLAGS FROM VANYUKOV FURNACE

INTRODUCTION

Over the past decades, in copper pyrometallurgy have found wide application autogenous processes, such as flash smelting or processes: Outokumpu, Mitsubishi, Noranda, El-Teniente, Aizasmelt, Ausmelt and smelting in the Vanyukov furnace. The last of the above processes is used at BCP and distinguished by high specific productivity, the ability to process relatively poor in copper sulfide concentrates of any granulometric composition, using blast with high oxygen content. However, along with the above advantages, the process has a number of disadvantages, one of which is high copper losses with slag.

Slags play an important role in pyrometallurgical processes. If earlier slag was regarded as waste, now it is a secondary resource, since the favorable physical and mechanical characteristics of copper slag make it possible to use it for the production of products such as cement, aggregate, ballast, abrasive, roofing granules, glass, tiles, etc. Therefore, the integrated use of recycled materials is becoming increasingly popular [1-3].

Today, the deterioration of the composition of the raw material base, the entry into production of concentrates with an increased zinc content (Table 1) caused a change in the physicochemical properties of the slag, which led to an increase in copper losses during the smelting of the charge.

It is generally accepted that the loss of metals in slags has 2 reasons: chemical dissolution of metals and...
cate flux containing 70 % SiO₂, showed that with a de-
additional coal (0.5 – 0.9 t/h) and pyrite concentrate
the rate of dissolution of SiO₂ increases, and with
the charge is insufficient to maintain the heat balance of the
the isothermal zone of the furnace. After excavation, the
crucible of much larger size in a thin layer. After that,
taken from the calculation of the complete slagging of
CO, CO₂ and H₂O.

The negative effect of aluminum oxide on the dissolu-
tion of quartz in various oxide-sulfide melts was con-
stituted in [16 - 17]. When studying the phase formation in the
FeO – silicate ore system, the process of slagging was studied using various fluxes, used mainly at BCP and
containing approximately the same amount of SiO₂, but
differing in the content of Al₂O₃ and CaO (Table 2).

Based on the results of X-ray phase and petrograph-
ical analysis, it was revealed that the basis of all three ores is α-quartz.

Besides α-quartz, ore No. 1 contains: andalusite Al₃SiO₉, anorthoclase (K, Na) AlSiO₃, pyrophyllite Al₃SiO₁₀(OH)₂, muscovite, kaolinite, and single grains of hematite and iron hydroxides.

Ore No. 2, in addition to α-quartz, contains: andesine CaAl₂SiO₇, muscovite KAl₃[Si₃AlO₁₀](OH)₂, calcite CaCO₃, pyrite, kaolinite Al₂SiO₁₀(OH)₂, hyper-
thene (Mg, Fe) OsSiO₃.

In ore No. 3, in addition to α-quartz, calcite, musco-
vite, iron hydroxides, and single grains of pyrite are also
determined.

Thus, in the studied ores, one of the main slag-forming
substances - silica partially bound with alumina, in
ore No. 2 there is also a compound of magnesium with silica - hypersthene. Therefore, it should be expected that the lower the content of “free” silica in the FeO-SiO₂ system, the more difficult slag formation will be, since the amount of ore for slagging the resulting iron (II) oxide was calculated based on the chemical composition of the flux in terms of SiO₂, taking its activity equal to 1. The more difficult the formation of fayalite is, the easier and
more complete the oxidation of iron (II) oxide will be.

The source of FeO was oxalic iron (analytical grade),
which, when heated to 850 °C, decomposes into FeO,
CO₂ and H₂O.

A weighed portion of FeC₂O₄·2H₂O and ore was taken from the calculation of the complete slagging of obtained FeO with silica available in the ore, then it was
thoroughly mixed, ground and placed in a pre-calced crucible of much larger size in a thin layer. After that,
the crucible was lowered into a preheated furnace. The
sampling interval is 1 min, that is, after 1, 2 ... 14 min
after lowering the crucible with a weighed portion into the isothermal zone of the furnace. After excavation, the crucible was tempered on a massive iron plate.

Experiments were carried out at a temperature of 1
210 – 1 220 °C to slow down the rate of slag formation.
The time of the beginning and end of phase formation with these fluxes in the temperature range 1 210 – 1 220
°C is the same, but slagging and oxidation of iron (II)
oxide proceeds in them in different ways.
By X-ray phase analysis, it was possible to determine that during the slagging of FeO and ore No. 1, with the least amount of “free” silica, along with the appearance of fayalite (the base of the sample), magnetite, α-quartz and the maximum, in comparison with the other two fluxes, content of hematite are recorded.

Petrographic analysis also revealed pyroxene of the augite type (Ca, Na) (Mg, Fe, Al) [(Si, Al) 2O₆] in this sample. When the melt is held for 10 minutes in a given temperature range, augite becomes the basis of the sample instead of fayalite. The rest of the components are also present in the sample.

During slag formation in the system ore No. 2 – FeO, in addition to hematite, magnetite, fayalite and α-quartz (as in X-ray structural analysis), petrographic analysis determines - FeO wustite, iron hydroxides and small sulfide inclusions. After 10 minutes of exposure at 1 210 – 1 220 °C, there appears pyroxene, presumably augite and quartz glass. Iron hydroxides and wustite disappear.

When alloying ore No. 3 with iron oxide (II) in the temperature range 1 210 – 1 220 °C at the beginning of slag formation with a 5 - minute exposure, petrographic analysis determines: magnetite, α-quartz, albite NaAl-SiO₃ [2U (-), N ~ 1,530], wustite, fayalite. Then, upon complete melting of the sample and holding it in a given temperature range, the following phases were found in the sample: magnetite, delafossite (the original colored ore No. 3 contains copper), fayalite, augite, α-quartz, hematite, and quartz glass.

Thus, in the interaction of silica fluxes with a high alumina content, along with fayalite, a compound of the augite type (Ca, Na) (Mg, Fe, Al) [(Si, Al) 2O₆] appears in the slag phase. Moreover, when iron (II) oxide is slagged with ore No. 1, with a maximum Al₂O₃ content, augite appears immediately, at the beginning of the slag phase formation process and, when it is completely formed, becomes the basis of the sample instead of fayalite. With a lower content of Al₂O₃, during slagging of FeO with ores No. 2 and 3, augite is formed later and does not prevail over fayalite in terms of content. Augite is an aluminous pyroxene that melts with difficulty at a temperature of 1 500 °C [18].

It was found that the lower the Al₂O₃ content and the higher the CaO content in the ore with the same silica content, the greater the fraction of the fayalite phase in the slag and the slower the oxidation process of the wustite dissolved in it, which is consistent with the data from [14]. The presence of CaCO₃, calcite in ores 2 and 3, which completely dissociates in the temperature range 900 – 1 000 °C with a maximum development at 940 °C, will increase the contact area of slag-forming oxides with FeO and thus accelerate the formation of the slag phase.

It was noted that at the initial stage, in the first 5 - 6 minutes, in the presence of «free» quartz in the ore-iron (II) oxide system, the rate of slag formation is quite high. Then, with a decrease in the content of «free» quartz in the system, the rate of slag formation slows down.

A decrease in the phase of a-quartz will accordingly decrease the rate and completeness of slagging of iron oxide (II). It should be noted that all compounds with silica are stable in the temperature range of 1 210 – 1 220 °C and will negatively affect the kinetics of slagging.

Currently, at BCP, when melting the charge, silicate gold-bearing ore of the reflective class is used. X-ray fluorescence analysis showed that it contains, mas. % : 67,65 SiO₂; 14,56 Al₂O₃; 0,51 MgO; 2,47 CaO; 3,13 K₂O; 2,70 Fe₂O₃. Then its fluxing ability will be:

$$\text{FA} = \frac{C_{\text{SiO}_2} + C_{\text{CaO}} - 1,73*C'_{\text{Al}_2\text{O}_3} - 0,39*C''_{\text{Al}_2\text{O}_3}}{0,75*C_{\text{MgO}}}$$

or

$$\text{FA} = 67,65 + 2,47 - 1,73 * 10,07 - 0,39 * 4,49 - 0,75 * 0,51 = 50,65$$

that is, about half of the supplied flux is not flux, moreover will require additional heat for heating and melting.

X-ray phase analysis revealed in the ore sample: quartz; albite - NaAlSi₃O₈; calcite - CaCO₃; grossular - Ca₃Al₂Si₃O₁₂; anorthoclase - (Na, K)(Si, Al)O₄ and muscovite - 2M1 - KAl₂(Si, Al)₂O₄(OH)₂.

Considering the given phase composition of the flux ore and its transformation upon heating, it can be argued that a rather viscous slag melt (albite, anorthoclase, mullite) will form in the furnace [18] with impregnations of unmelted individual aluminosilicates and quartz. The interaction of quartz with the oxidizing iron of the concentrates will be slowed down, and part of the iron will begin to oxidize to magnetite or hematite, which will contribute to an increase in copper losses both in dissolved and suspended state, due to the strong heterogenization of the slag and its high oxidation potential.

To study the distribution of elements in the slag dump slag was taken from the PV-1 mixer, it’s composi-
tion, mas. %: 22.93 SiO$_2$; 5.10 Al$_2$O$_3$; 0.86 MgO; 1.61 CaO; 39.7 Fe; 1.07 Cu; 2.45 Zn; 0.46 Pb; 0.90 K$_2$O; 0.65 Na$_2$O. The distribution of some elements in slag is shown in Figure 1.

It can be seen from the presented micrograph that the area rich in silicon is interconnected with the area with the lowest iron content, but the maximum one for aluminum and calcium. The areas rich in iron contain much less silica than the most enriched in aluminum and calcium, which is evident from their color on the micrograph.

That is, the flux used at BCP when melting the charge poorly slags out the oxidizing iron. The bonds between silica and oxides of aluminum and calcium in the ore are not broken, so there is no good interaction between the oxidizing components of the charge and the silica of the flux.

**CONCLUSION**

The conducted studies had shown the main reasons for increased copper losses with dump slags at BCP:

- low melting temperature, as a result of a decrease in the quality of processed copper concentrates and flux materials;
- insufficient fluxing ability of silicate ore used in charge smelting, which is associated with the preferred use of gold-bearing ores, rich in aluminum oxide, and, for rapid slag formation, requires feeding into the furnace a large excess of it, against the calculated one, to obtain a relatively homogeneous melt. However, an increase in the loading of flux materials, in turn, leads to an even greater deficit of heat and the production of heterogeneous slag melts with a high copper content in them, both in dissolved form and in the form of mechanical suspension. And the output of furnace slag itself will increase, which will further increase the total loss of copper.

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**REFERENCES**


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