



DOI: 10.31643/2024/6445.19

Metallurgy



## Analysis of the thermal regime of converting of copper-lead matte with high-sulfur copper concentrate

Zoldasbay E.E., \* Argyn A.A., Dosmukhamedov N.K.

Satbayev University, Almaty, Kazakhstan

\* Corresponding author email: [aidarargyn@gmail.com](mailto:aidarargyn@gmail.com)

Received: April 17, 2023  
Peer-reviewed: May 28, 2023  
Accepted: August 24, 2023

### ABSTRACT

According to the earlier conclusions about the possibility of direct processing of high-sulfur copper concentrates with copper-lead matte, analysis of the thermal regime of converting was carried out. It is shown that the traditional calculation methods used to calculate autogenous smelting are not entirely correct and require taking into account the effect of excess sulfur on the temperature regime of the process. It has been established that in the process of converting copper-lead mattes, a wide range of temperature variation is observed - from 1027 °C to 1300 °C. When the concentrate is combined with the matte, the temperature regime of the process is stabilized, which ensures the optimal level of SO<sub>2</sub> concentration in the gases required for the production of sulfuric acid. Based on the calculation of the material balance of converting copper-lead mattes using the existing technology and with the addition of a concentrate, the structure of the heat balance of the converting process was established. A strong change in the structure of the heat balance is shown, which is explained by the reduction of magnetite with excess sulfur and an increase in heat due to the oxidation of an additional amount of iron sulfide introduced with the concentrate. A comparative analysis of the technological parameters of the 1st converting period of copper-lead mattes calculated by the proposed method with the practical data of a specific metallurgical unit allows assessing the degree of approximation of the processes occurring in the unit until the thermodynamic equilibrium.

**Key words:** copper-lead matte, high sulfur copper concentrate, converting, material balance, thermal regime, sulfur, sulfiding.

### Information about authors:

**Zoldasbay Erzhan Esenbailuly**

PhD, Satbayev University, 050013, Almaty, 22 Satbayev st., Kazakhstan. E-mail: [zhte@mail.ru](mailto:zhte@mail.ru)

**Argyn Aidar Abdilmalikuly**

PhD, Satbayev University, 050013, Almaty, 22 Satbayev st., Kazakhstan. E-mail: [aidarargyn@gmail.com](mailto:aidarargyn@gmail.com)

**Dosmukhamedov Nurlan Kalievich**

Candidate of Technical Sciences, Professor, Satbayev University, 050013, Almaty, 22 Satbayev st., Kazakhstan. E-mail: [nurdos@bk.ru](mailto:nurdos@bk.ru)

### Introduction

The deterioration in the quality of primary sulfide raw materials due to the increased content of impurities in them led to the complication of the composition of the products obtained during matte smelting. This problem acquires particular relevance for the conditions of converting copper-lead mattes produced by Kazzinc LLP, which are characterized by an increased content of metal impurities: up to 25% lead, up to 4% arsenic and up to 1.0% antimony. When converting such mattes, poor quality blister copper (96-98% Cu) is obtained. Recycled converter slags contain up to 35% lead, ~3% copper and up to 1.5% of arsenic and antimony. Despite the low technological performance of the process, converting remains the main process of blister copper production in the technological scheme of the lead

production of Kazzinc LLP, due to the lack of an alternative method for processing copper-lead mattes.

The results of extensive studies of foreign experience in the processing of copper concentrates in converters [[1], [2], [3]] showed wide opportunities for using the converter as a smelting unit, especially in the first period of converting copper matte. However, despite the achieved positive results, the introduction of the developed methods into production has a restriction due to the lack of effective devices for loading a fine concentrate into the converter. Known installations for loading the concentrate into the converter require specific preparation (drying, grinding, using a complex loading installation) and do not provide a minimum dust removal when loading fine material [[4], [5], [6], [7], [8], [9]].

Many foreign researchers express an opinion about the effectiveness of using a converter exclusively as a melting unit for direct smelting of sulfide copper concentrates with copper extraction in one stage. On this principle, the processes of continuous converting and obtaining blister copper in one stage using autogenous processes are built. However, as the analysis shows, this approach is not entirely effective, due to the large yield of copper-rich slags, which require additional processing to extract valuable metals from them. In addition, the obtained converter slags are characterized by an increased content of lead, arsenic and antimony, the presence of which significantly reduces the quality of the products obtained and the extraction of copper into blister copper.

In the well-known works devoted to the direct smelting of concentrates in converters, the issues of the simultaneous use of high-sulfur components of the concentrate (pyrite, chalcopyrite, etc.) as a sulfiding agent to improve the quality of converter slag and blister copper are practically not considered. The solution of this issue will improve the efficiency of direct smelting of concentrates in converters, and improve the technological performance of the converting process as a whole.

The results of systematic studies of the theoretical features of the interaction of non-stoichiometric higher sulfides with the components of the slag melt, conducted by the Scientific Center named after I.A. Onaev [[10], [11]] showed that excess sulfur formed as a result of dissociation of higher sulfides is completely spent on magnetite reduction and slag sulfiding. Perhaps, these are single studies, where the possibility of simultaneous use of high-sulphur copper concentrate as a sulfidizing agent to improve the quality of converting products has been proved. It has been established that when the concentrate is blown into the converter slag bath at the initial moment, its chemical composition practically does not change. Higher sulfides (pyrite, chalcopyrite) are mixed in the slag bath, without dissociation to their stable sulfides. With further bubbling of the melt, excess sulfur released as a result of the dissociation of higher sulfides is completely absorbed by the slag melt and provides deep reduction of magnetite and sulfidation of oxides of non-ferrous and associated (Pb, As, Zn, Sb) metals, with their deep sublimation into dust in the form of their non-toxic sulfides [[12], [13]].

Based on the results of theoretical and experimental studies, a method was developed for depleting converter slag with high-sulfur copper

concentrate, which formed the core of the technology for direct smelting of high-sulphur copper concentrates in converters together with copper matte. The developed technology has been introduced at the Balkhash, Zhezkazgan and Irtysh copper smelters. The obtained positive results of the industrial operation of the technology provide great opportunities for its use in the conditions of converting copper-lead mattes at Kazzinc LLP.

The purpose of this work is to predict the technological modes of the converting process based on the calculation of material and heat balances for converting copper-lead mattes with high-sulfur copper concentrate.

## Research methods

The main methodological principle of the developed technology of direct smelting of concentrates in converters is a thermodynamic approach to describing the bubbling process of converting mattes. This way provides a reliable determination of the qualitative and quantitative characteristics of the formed complex condensed (liquid) and vapor-gas phases for given input converting parameters: compositions and quantities of initial materials, temperature conditions, redox potentials, etc.

The thermodynamic approach is based on the idea of achieving thermodynamic equilibrium (or a state close to it) between the smelting products (matte-slag), which makes it possible to use the laws of chemical thermodynamics to establish the behavior of non-ferrous and related impurity metals during the converting of copper-lead mattes together with a concentrate.

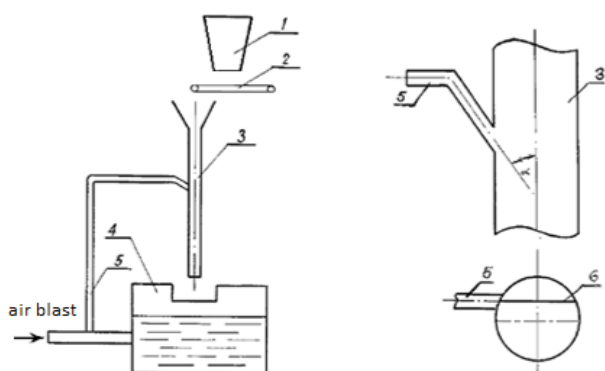
As the basic core of research, the results of works on the study of the forms of presence of metals in converting products [10], data on the behavior of compounds of non-ferrous and related metals under the conditions of converting copper-lead mattes with high-sulfur copper concentrate [13] were used.

The structuring of the obtained results with a large array of industrial data (65 points of product compositions) was carried out based on a multivariate rectilinear analysis of statistical dependencies, which provided the way to establish the optimal technological parameters and modes of the converting process. To solve such problems in metallurgical practice, mathematical models [[13], [14], [15], [16], [17], [18], [19], [20]] are widely used,

which describe with sufficient accuracy the calculation of the equilibrium yield of smelting products and the composition of chemically reacting systems. This approach leads to carry out a complex procedure for describing the converting of copper-lead mattes using a well-developed technique for constructing algorithms and programs designed to obtain reliable data.

The paper uses an iterative algorithm for modeling the converting process, which describes the existing process of converting copper-lead mattes with a sufficiently high accuracy and allows predicting the optimal parameters and thermal conditions for converting copper-lead matte together with high-sulfur copper concentrate.

To supply a finely dispersed concentrate, an ejection device can be used, which is connected to the loading pipe without any special costs and technical complications. The scheme of concentrate supply to the converter is shown in Figure 1.



**Figure 1** - Scheme of supplying fine materials to the converter

1 - bunker; 2 - conveyor; 3 - loading pipe; 4 - converter;  
5 - air duct; 6 - axis of the air flow inlet pipe,  
 $\alpha$  - nozzle inlet angle, 22-30°.

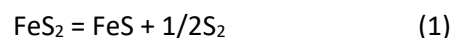
The device and method of operation of the ejection device for supplying finely dispersed materials to the converter are described in detail in [21].

## Results and discussion

Autogenous smelting of sulfide raw materials of non-ferrous metals is characterized by a complex mechanism for the formation of the final products of the process. The prediction of the technological modes of operation of furnaces, including converters, is carried out on the basis of the calculation of the material and heat balances of the

smelting. When determining the thermal effect from the interaction of the initial charge and oxidizing blast at a given amount of oxygen, the following main processes are taken into account:

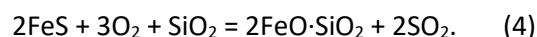
### 1. Dissociation of higher sulfides:



### 2. Oxidation of elemental sulfur released by reactions (1) and (2):



### 3. Oxidation of iron sulfide:



The amount of iron sulfide oxidized by reaction (4) is calculated from the oxygen balance. In this case, it is assumed that elemental sulfur is the first to interact with oxygen and the degree of reaction (3) is equal to unity.

The heat released during the course of reactions (3) and (4) forms the main income items of the heat balance of smelting.

Let us consider the traditional problem of simplified calculation of heat release during autogenous smelting of sulfide raw materials under conditions of equilibrium between matte, slag and gas phase. In this case, it is necessary to take into account not only  $\text{SO}_2$ , but also  $\text{S}_2$  in the composition of the gas phase, due to the equilibrium of the reaction:



The achievement of equilibrium in this case is explained by the fact that the oxidation of sulfur to  $\text{SO}_2$  proceeds until an equilibrium ratio between them is established in accordance with reaction (5). In this case, the ratio between the values of the partial pressures  $P_{\text{SO}_2}$  and  $P_{\text{S}_2}$  is determined by the activities of FeS and FeO, which depend on the composition of the matte and slag.

If we accept that the partial pressure of sulfur in the gas phase is determined by equilibrium (5), then it can be found from the expression:

$$P_{\text{S}_2} = K \cdot P_{\text{SO}_2}^{2/3} \left( \frac{a_{\text{FeS}}}{a_{\text{FeO}}} \right)^{4/3}, \quad (6)$$

$$K = \exp\left(\frac{1,906 - 9219,26}{T}\right) [14],$$

where:  $K$  – reaction equilibrium constant (5);

$a_{\text{FeS}}$ ,  $a_{\text{FeO}}$  – activity [FeS], (FeO);

$P_{\text{S}_2}$ ,  $P_{\text{SO}_2}$  – partial pressures of  $\text{S}_2$  and  $\text{SO}_2$  in the gas phase.

The calculation method is narrowed to determining the values of  $a_{\text{FeS}}$ , generating the material and heat balances of the process. Accounting for the presence of elemental sulfur in the gas phase leads to the need to reconsider the material and heat balances. Therefore, the calculations are carried out taking into account the introduction of the iteration for the partial pressure of sulfur.

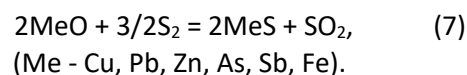
For industrial iron silicate slags, the value of  $a_{\text{FeO}}$  is in a rather narrow range (from 0.35 to 0.45), therefore, in calculations, its value is usually taken equal to  $a_{\text{FeO}}=0.4$ , which corresponds to real industrial slags. When carrying out specific calculations for multicomponent slags, experimental data [22] can be used. Taking into account the assumption of the constancy of  $a_{\text{FeO}}$ , according to the data of [23], it is possible to determine the value of  $a_{\text{FeS}}$  depending on the copper content in the matte, similarly to how it was done in [[24], [25], [26]]. After that, using expression (6), the equilibrium partial pressure of elemental sulfur in the gas phase is determined.

As initial data for the calculation, the following are usually chosen: the composition of the concentrate and quartz flux, the copper content in the matte, the Fe/SiO<sub>2</sub> ratio in the slag, the degree of enrichment of the blast with oxygen, and the operating temperature of the process.

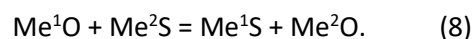
The underburning of sulfur in the gas phase and the corresponding adjustment of the oxygen consumption for smelting, due to their influence on the heat balance, are important for the correct choice of the technological regime of the autogenous process. These circumstances should strongly affect the melting of high-sulfur copper concentrate with copper-lead matte, which has an interest from the point of view of extracting copper and associated metals into targeted products. Note that the proposed calculation method is applicable for autogenous smelting of sulfide raw materials and the process of converting pure copper mattes together with high-sulfur copper concentrate.

Mentioned traditional method for calculating autogenous melts does not take into account the interaction between the components of the products formed during the smelting process - matte, slag and the gas phase, which can change the amount of heat release and the structure of the heat balance. This condition has direct relevance when performing calculations for the conditions of converting complex composition copper-lead mattes with high-sulfur copper concentrate. In this case, calculations have to consider that due to the existence of equilibrium according to reaction (5), part of the elemental sulfur formed as a result of the dissociation of higher sulfides does not burn out, but it is almost completely absorbed by the melt and is spent on slag sulfiding. Along with this, in the calculations it is also necessary to take into account the contribution to the heat balance of the 1st converting period, heat release from the oxidation reactions of PbS and ZnS, which are present in a significant amount in the matte. Thus, the complication of the mechanism of phase formation makes it necessary to consider, along with the main processes 1-3 considered above, the occurrence of additional processes 4, 5 in the slag melt:

*4. Sulfidation of oxides of non-ferrous metals, iron and associated metal impurities with elemental sulfur released by reactions (1) and (2):*



*5. Interactions between oxides and sulfides of non-ferrous metals and iron according to exchange reactions:*



The interaction of sulfur with magnetite cannot be neglected either:



as a result of which the equilibrium content of magnetite in the slag is established.

The reliability of the assumptions was verified by a comparative analysis of the results of temperature fluctuations and the composition of the converting products (matte, slag), obtained by calculation and direct measurements of the technological

parameters of converting copper-lead mattes in the industrial scale.

For technological calculations, an iterative algorithm for modeling the process of converting copper-lead mattes was used, which allows predicting the optimal parameters and thermal conditions of the converting process with a sufficiently high accuracy.

Temperature measurements of converter slags during their discharge and melts during each loading of a new portion of matte in the plant were carried out using an HD 1150A optical pyrometer. The results of measurements of the temperature and compositions of the converting products, obtained by calculation and direct measurements in the factory, showed their good consistency.

The developed modeling algorithm was used to estimate the heat balance of converting copper-lead mattes together with high-sulfur copper concentrate.

The reliability of the model was checked based on a comparative analysis of the predicted temperature and compositions of slag and matte with those measured in an industrial scale. Temperature variations observed in the conditions of converting copper-lead mattes for four charges of the converter with matte, obtained in the plant, and during the joint smelting of high-sulfur copper concentrate with copper-lead matte, are shown in Fig.2.

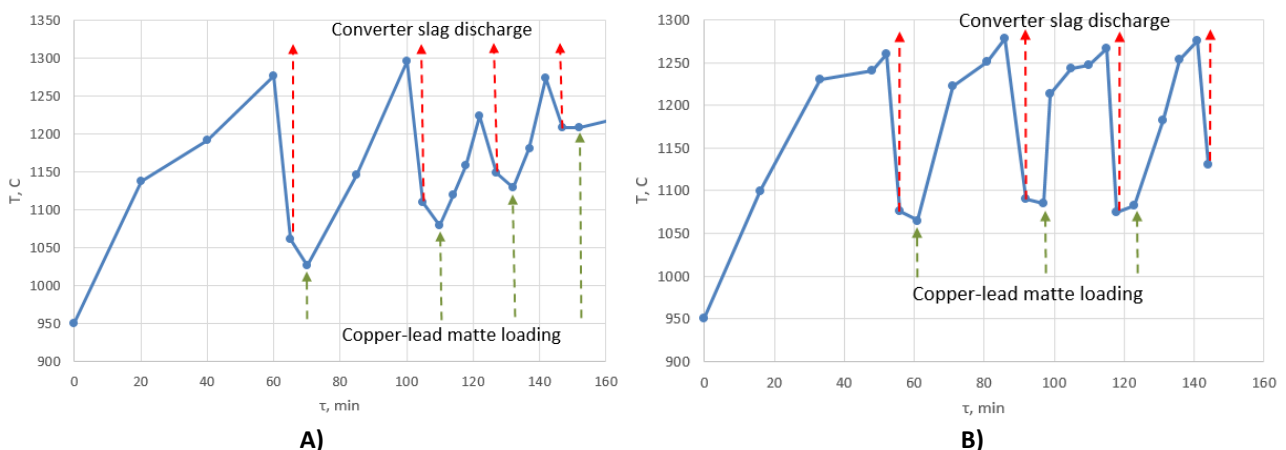
It can be seen that with the existing technology for converting copper-lead mattes, strong

temperature fluctuations are observed - from 1027 °C to 1300 °C (Fig. 2(A)). This indicates that the converter is operated in the intense thermal load mode. Fluctuations in the temperature regime reduce the stability of the converter, and, as a result, lead to a reduction in its service life.

During the joint processing of the concentrate with the matte, the temperature variation is insignificant, which is between 1120 °C and 1270 °C (Fig. 2(B)). Process temperature equalization ensures converter stability, performance and extended converter life.

Despite the small number of measured temperatures, it can be seen that the model prediction is justified for the composition of the slag. The predicted temperatures of matte and slag, according to existing technology, are usually subject to significant fluctuations, which is in good agreement with the measured temperatures. Comparative analysis of the predicted composition of the slag and the content of silica in it (Table 1), taking into account the uncertainty in the weight of added materials at the plant allows to conclude that the developed model predicts the iron content well in the slag. However, the tendency to underestimate the silica content and overestimate the iron content suggests that more material flows are being added to the converter than expected during operation.

Table 1 shows the comparative results of the measured and predicted technological indicators for the content of iron and silica in white matte and converter slags selected during the research.



**Figure 2** - Dynamics of changes in the temperature regime of the 1st period of copper-lead matte converting:

- A)** - according to the existing technology;  
**B)** - with the addition of high-sulfur copper concentrate.

**Table 1** - Comparative analysis of the compositions of the products of converting of copper-lead mattes of the 1st period

Products	Chemical composition, wt. %							
	Cu	Pb	Zn	Fe	As	Sb	S	SiO <sub>2</sub>
Copper lead matte	35.5	26.0	1.4	15.1	2.8	0.7	15.0	
Quartz flux	-	-	-	-	-	-	-	85.0
Copper concentrate	24.5	2.5	3.4	28.6	0.1	0.2	35	3.6
White matte	56.4	20.9	0.2	3.5	3.6	1.0	13.5	-
	70.6	4.0	0.2	2.9	0.6	0.6	18.2	
Converter slag	7.9	22.3	2.1	24.7	2.4	0.6	-	22.3
	1.2	0.7	0.2	47.8	0.3	0.2	-	26.8
Converter dust	1.1	55.7	0.8	2.6	5.2	0.8	5.9	1.1
	0.8	58.9	8.7	0.4	5.3	1.3	10.0	0.3

The numerator is existing technology; The denominator is new technology.

**Table 2** - Dynamics of changes in the content of SO<sub>2</sub> in waste gases

№	Discharge #	Existing technology		New technology	
		(Cu), %	SO <sub>2</sub> , %	(Cu), %	SO <sub>2</sub> , %
1	Discharge #1	4.07	5.07	1.09	8.35
2	Discharge #2	3.91	6.5	0.58	9.02
3	Discharge #3	4.34	6.08	1.47	11.26
4	Discharge #4	11.94	7.5	0.39	12.95

**Table 3** - Material balance of the 1st converting period of copper-lead matte according to the existing technology

Name	Products output		Cu		Pb		Zn		Fe		As		Sb		S		SiO <sub>2</sub>	
	%	t	%	t	%	t	%	t	%	t	%	t	%	t	%	t	%	t
Matte	57.4	100	35.5	35.5	26	26	1.4	1.42	15.2	15.2	2.8	2.8	0.7	0.7	15.1	15.1		
Blowing	36.0	62.7																
Quartz flux	6.58	11.5															85	9.7
<b>Total:</b>	<b>100</b>	<b>174.2</b>		<b>35.5</b>		<b>26.0</b>		<b>1.42</b>		<b>15.2</b>		<b>2.8</b>		<b>0.7</b>		<b>15.1</b>		<b>9.7</b>
White matte	29.8	51.8	66.5	34.5	4.5	2.34	0.1	0.07	6.02	3.1	3.8	1.9	0.3	0.1	14.6	7.6		
Converter slag	25.7	44.7	2.23	1.0	32.0	14.3	0.9	0.40	26.6	11.9	0.7	0.4	0.6	0.3			20.7	9.3
Dust	8.23	14.3	0.12	0.02	65.1	9.3	6.6	0.94	0.92	0.1	3.7	0.5	2.2	0.3	5.26	0.7	3.40	0.4
Exhaust gases	36.3	63.2													10.7	6.8		
<b>Total:</b>	<b>100</b>	<b>174.2</b>		<b>35.5</b>		<b>26.0</b>		<b>1.42</b>		<b>15.1</b>		<b>2.8</b>		<b>0.7</b>		<b>15.1</b>		<b>9.7</b>

It can be seen that after sulfiding converter slag with high-sulphur copper concentrate, its quality is significantly improved compared to converter slag obtained by the existing technology. The content of copper in the slag is reduced by more than 6 times. The lead content is significantly reduced: from 22% to 0.72%, which indicates the almost complete sublimation of lead into dust. The content of zinc and arsenic is reduced by 10 times, antimony - by 3 times. Deep sublimation of impurities into dust

removes them from the general technological chain, which as a result will significantly improve the quality of the resulting targeted products.

The results of calculations of the gas phase, obtained by the model, showed that under the conditions of converting the concentrate with the matte, the stabilization of the temperature regime in the converter allows increasing the SO<sub>2</sub> content in gases by more than 1.5 times (Table 2), and maintain

**Table 4** - Material balance of the 1st converting period of copper-lead mattes together with high-sulphur copper concentrate

Name	Products output		Cu		Pb		Zn		Fe		As		Sb		S		SiO <sub>2</sub>	
	%	t	%	t	%	t	%	t	%	t	%	t	%	t	%	t	%	t
Matte	56.9	100.0	35.5	35.5	26.0	26.0	1.4	1.42	15.2	15.2	2.8	2.8	0.7	0.7	15.1	15.1		
Blowing	31.3	54.9																
Quartz flux	5.57	9.8															85	8.3
Cu concentrate	6.20	10.9	23.6	2.6	2.5	0.3	3.4	0.37	28.6	3.1	0.1	0.01	0.2	0.02	31.9	3.5	3.6	0.4
<b>Total:</b>	<b>100</b>	<b>175.6</b>		<b>38.1</b>		<b>26.3</b>		<b>1.79</b>		<b>18.3</b>		<b>2.8</b>		<b>0.7</b>		<b>18.6</b>		<b>8.7</b>
White matte	36.3	63.8	59.5	37.9	14.2	9.1	0.1	0.08	5.47	3.5	5.2	1.9	0.4	0.1	13.6	8.8		
Converter slag	18.9	33.2	0.2	0.07	18.6	6.2			38.1	12.7	0.2		1.3	0.3			24.1	8.0
Dust	11.0	19.4	0.1	0.02	57.0	11.0	8.8	1.71	10.9	2.1	8.0	0.9	3.1	0.3	4.80	0.9	3.5	0.7
Exhaust gases	33.7	59.2													15.1	8.9		
<b>Total:</b>	<b>100</b>	<b>175.6</b>		<b>38.1</b>		<b>26.3</b>		<b>1.79</b>		<b>18.3</b>		<b>2.8</b>		<b>0.7</b>		<b>18.6</b>		<b>8.7</b>

White matte 20.0%	Slag 30.0%	Gases 44.4%	Others 5.6%	
<b>Total heat per 100 tons of matte: 239551.45 kJ</b>				
Matte 31.9%	Oxidation reactions			Others 4,9%
	FeS 49.2%	PbS 12.4%	ZnS 1.6%	

A)

White matte 20.8%	Slag 20.6%	Gases 41.7%	Sulfide decomposition 5.7%	Others 11.2%	
<b>Total heat per 100 tons of charge (matte + concentrate): 259221.56 kJ</b>					
Matte 16.2%	Oxidation reactions			Sulfidation 2.5%	Others 3.3%
	FeS 59.3%	PbS 14.9%	ZnS 3.8%		

B)

**Figure 3** - The structure of the heat balance of converting copper-lead mattes:

A) - according to the existing technology;

B) - with the addition of high-sulfur copper concentrate

the optimal level throughout 1st converting period. This ensures the stability of the sulfuric acid plant.

Tables 3 and 4 show the material balances of the 1st converting period of copper-lead mattes according to the existing technology and in their joint processing with high-sulfur concentrate, calculated according to practical plant data: ratio

(Fe)/(SiO<sub>2</sub>)=1.3, the degree of enrichment of the blast with oxygen is 23%, the operating temperature is 1523 K. Zyryanovsky high-sulfur copper concentrate was used as a sulfiding agent.

Figure 3 shows the structures of the heat balances of the 1st period of converting copper-lead matte according to the existing technology and the

joint smelting of matte with high-sulfur copper concentrate, calculated on the basis of the corresponding material balances (Tables 3, 4).

It is easy to see that the total heat per 100 kg of charge (matte + concentrate), equal to 259221.56 kJ, only slightly exceeds the value of the total heat of converting copper-lead mattes using the existing technology, which is 239551.45 kJ. At the same time, a significant change in the structure of the heat balance of converting during the joint smelting of the concentrate together with the matte looks very attractive (Fig. 3 (B)). The change in the ratio of the articles of heat input can be interpreted by the complete assimilation of elemental sulfur by the melt and sulfidation of the slag. A significant contribution to the change in the structure of the total heat balance during the joint converting of the concentrate with matte is made by an additional amount of iron sulfide introduced with the concentrate, the oxidation of which "closes" the heat balance of converting.

Thus, the calculation method proposed in this paper, which takes into account the presence and behavior of elemental sulfur and the additional amount of iron sulfide introduced with high-sulfur copper concentrate, can be used to refine the material and heat balances of converting during the joint processing of high-sulfur copper-containing concentrates and products with copper-lead mattes.

## Conclusions

1. When calculating the conversion of copper-lead mattes together with a high-sulfur concentrate, it is necessary to take into account the presence of elemental sulfur, which is almost completely consumed for the sulfiding of slag metal oxides.

2. On the example of direct processing of concentrate in converters, a comparative analysis of the heat balances of two oxidizing melts was carried

out: converting copper-lead matte according to the existing technology, and joint melting of Zyryanovsky high-sulfur copper concentrate with copper-lead matte. It is shown that in the second case there is a strong change in the structure of the heat balance towards improvement due to the process of sulfiding of the slag and oxidation of an additional amount of FeS introduced with the concentrate.

3. Comparative analysis of the technological parameters of the 1st converting period of copper-lead mattes calculated by the proposed method with the practical data of a particular metallurgical unit allows to assess the degree of approximation of the processes occurring in the unit until the thermodynamic equilibrium.

4. For a more accurate prediction of the heat balance of converting copper-lead mattes together with high-sulfur copper concentrate, it is necessary to know the activity values of magnetite, sulfides and oxides of non-ferrous metals in complex multicomponent sulfide melts.

**Conflict of interest.** On behalf of all authors, the corresponding author confirms that there is no conflict of interest.

**Financing information.** The research was carried out within the framework of grant funding from the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan for 2023-2025 in the priority area "Geology, extraction and processing of mineral and hydrocarbon raw materials, new materials, technologies, safe products and structures" of the project AP19676951 "Development of resource-saving, combined technology for the complex processing of multicomponent non-ferrous metallurgy dust with the production of marketable products".

**Cite this article as:** Zholdasbay EE, Argyn AA, Dosmukhamedov NK. Analysis of the thermal regime of converting of copper-lead matte with high-sulfur copper concentrate. *Kompleksnoe Ispolzovanie Mineralnogo Syra = Complex Use of Mineral Resources*. 2024; 329(2):82-91. <https://doi.org/10.31643/2024/6445.19>

## Мыс-қорғасын штейнін жоғары күкіртті мыс концентратымен бірге конвертерлеудің жылу режимін талдау

Жолдасбай Е.Е., Арғын А.Ә., Досмұхамедов Н.Қ.

Сәтбаев университеті, Алматы, Қазақстан



**ТҮЙІНДЕМЕ**

Жұмыста бұрын жасалған жоғары күкіртті мыс концентраттарын мыс-қорғасын штейнімен бірлесіп тікелей өңдеу мүмкіндігі туралы қорытындылар негізінде конвертерлеудің жылу режиміне талдау жүргізілді. Автогенді балқымаларды есептеу үшін қолданылатын дәстүрлі есептеу әдістері толығымен дұрыс емес және артық күкірттің процестің температуралық режиміне әсерін ескеруді қажет етеді. Мыс-қорғасын штейндерін конвертерлеу процесінде температураның өзгеруінің кең диапазоны бар екендігі анықталды – 1027 °C-тан 1300 °C-қа дейін. Концентратты штейнмен бірге конвертерлеу кезінде процестің температуралық режимі тұрақтандырылады, бұл күкірт қышқылын өндіруге қажетті газдардағы SO<sub>2</sub> концентрациясының оңтайлы деңгейін қамтамасыз етеді. Қолданыстағы технология бойынша және концентратты қосып мыс-қорғасын штейндерін конвертерлеудің материалдық балансын есептеу негізінде конвертерлеу процесінің жылу балансының құрылымы белгіленді. Жылу балансының құрылымының едәуір өзгерісі көрсетілген, бұл магнетиттің артық күкіртпен ыдырауымен және концентратпен енгізілген темір сульфидінің қосымша мөлшерінің тотығуымен жылудың жоғарылауымен түсіндіріледі. Нақты металлургиялық агрегаттың практикалық деректерімен мыс-қорғасын штейндерін конвертерлеудің 1-ші кезеңін ұсынылған әдістеме бойынша есептелген технологиялық параметрлерін салыстырмалы талдауы ондағы процестердің термодинамикалық тепе-теңдікке жақындау дәрежесін бағалауға мүмкіндік береді.

**Түйін сөздер:** мыс-қорғасын штейні, жоғары күкіртті мыс концентраты, конвертерлеу, материалдық баланс, жылу режимі, күкірт, сульфидтеу.

Мақала келді: 17 сәуір 2023  
Сараптамадан өтті: 28 мамыр 2023  
Қабылданды: 24 тамыз 2023

<b>Жолдасбай Ержан Есенбайұлы</b>	<b>Авторлар туралы ақпарат:</b> PhD, Satbayev University, 050013, Алматы, Саппаев көш. 22, Қазақстан. E-mail: zhte@mail.ru
<b>Арғын Айдар Әбділмәлікұлы</b>	PhD, Satbayev University, 050013, Алматы, Саппаев көш. 22, Қазақстан. E-mail: aidarargyn@gmail.com
<b>Досмухамедов Нурлан Калиевич</b>	Т.ғ.к., Профессор. Satbayev University, 050013, Алматы, Саппаев көш. 22, Қазақстан. E-mail: nurdos@bk.ru

## Анализ теплового режима конвертирования медно-свинцового штейна совместно с высокосернистым медным концентратом

Жолдасбай Е.Е., Арғын А.А., Досмухамедов Н.К.

Satbayev University, Алматы, Казахстан

**АННОТАЦИЯ**

В работе на основании ранее сделанных выводов о возможности прямой переработки высокосернистых медных концентратов совместно с медно-свинцовым штейном проведен анализ теплового режима конвертирования. Показано, что традиционные методы расчета, применяемые для расчета автогенных плавов не совсем корректны, и требуют учета влияния избыточной серы на температурный режим процесса. Установлено, что в процессе конвертирования медно-свинцовых штейнов наблюдается широкий диапазон варьирования температуры – от 1027 °C до 1300 °C. При совместном конвертировании концентрата со штейном температурный режим процесса стабилизируется, что обеспечивает оптимальный уровень концентрации SO<sub>2</sub> в газах, необходимый для производства серной кислоты. На основании расчета материального баланса конвертирования медно-свинцовых штейнов по существующей технологии и с добавлением концентрата установлена структура теплового баланса процесса конвертирования. Показано сильное изменение структуры теплового баланса, который объясняется восстановлением магнетита избыточной серой и увеличением тепла за счет окисления дополнительного количества сульфида железа, вводимого с концентратом. Сравнительный анализ рассчитанных по предлагаемой методике технологических параметров 1-го периода конвертирования медно-свинцовых штейнов с практическими данными конкретного металлургического агрегата позволяет оценить степень приближения протекающих в нем процессов к термодинамическому равновесию.

**Ключевые слова:** медно-свинцовый штейн, высокосернистый медный концентрат, конвертирование, материальный баланс, тепловой режим, сера, сульфидирование.

Поступила: 17 апреля 2023  
Рецензирование: 28 мая 2023  
Принята в печать: 24 августа 2023

<b>Жолдасбай Ержан Есенбайұлы</b>	<b>Информация об авторах:</b> PhD, Satbayev University, 050013, Алматы, ул. Саппаева 22, Казахстан. E-mail: zhte@mail.ru
<b>Арғын Айдар Абдилмаликулы</b>	PhD, Satbayev University, 050013, Алматы, ул. Саппаева 22, Казахстан. E-mail: aidarargyn@gmail.com
<b>Досмухамедов Нурлан Калиевич</b>	К.т.н., Профессор. Satbayev University, 050013, Алматы, ул. Саппаева 22, Казахстан. E-mail: nurdos@bk.ru

## References

- [1] Rosello A, Martinez J, Barrios P, Carrillo F. Desulfurization rate during the copper blow in a Peirce-Smith converter. *Metallurgical and Materials Transactions*. 2008; 39B:16-22.
- [2] Vieira L, Guzzo M, Bittencourt Marques M, de Souza M, Merdjani R, Kongoli F. Optimization and Control of Hoboken Converter Operations With FLOGEN CONTOP Control Expert System. *Sustainable Industrial Processing Summit SIPS. Barrios Intl. Symp. Non-ferrous Smelting & Hydro/Electrochemical Processing*. Montreal, Canada. 2017; 1:91-92.
- [3] Schlesinger ME, King MJ, Sole KC, Davenport WG. *Extractive Metallurgy of Copper*. 2011.
- [4] Bulatov KV, Skopov GV, Skopin DYu, Yakornov SA. Processing of Polymetallic Concentrates in Melting Facility "Pobeda" (LLC "Mednogorsk Copper-Sulfur Combine"). *Non-ferrous Metals*. 2014; 10:39-44.
- [5] Orlov AK, Konovalov GV, Boduen AYa. Pyrometallurgical Selection of Copper-Zinc Materials. *Journal of Mining Institute*. 2011; 192:65-68.
- [6] Wang, S, Davenport W. World copper smelter data. In *Copper 2019*, Paper no 595947. Vancouver, BC: CIM, Montreal. 2019.
- [7] Taskinen P, Akdogan G, Kojo I, Lahtinen M, Jokilaakso A. Matte converting in copper smelting. *Mineral Processing and Extractive Metallurgy*. 2019; 128(1-2):58-73. <https://doi.org/10.1080/25726641.2018.1514774>
- [8] Liu Z, Xia L. The practice of copper matte converting in China. *Mineral Processing and Extractive Metallurgy*. 2019; 128:117-124. <https://doi.org/10.1080/25726641.2018.1543147>
- [9] Zhai X, Li N, Zhang X, Fu Y, Jiang L. Recovery of cobalt from converter slag of Chambishi copper smelter using reduction smelting process. *Trans Nonferrous Met Soc. China*. 2011; 21(10):2117-2121.
- [10] Dosmukhamedov N, Egizekov M, Zholdasbay E, Kaplan V. Metals Recovery from Converter Slags Using a Sulfiding Agent. *JOM*. 2018; 70(10):2400-2406.
- [11] Dosmukhamedov NK, Fedorov AN, Zholdasbay EE, Argyn AA. Investigation of Cu, Pb, Zn, As, Sb Distribution during the lead semiproducts and copper-zinc concentrate comelting. *Non-ferrous Metals*. 2020; 1:8-14. <https://doi.org/10.17580/nfm.2020.01.02>
- [12] Dosmukhamedov NK, Argyn AA, Zholdasbay EE, Kurmanseitov MB. Behavior of Cu, Zn, Pb, As compounds during copper-zinc concentrate and matte comelting in converters. *Non-Ferrous Metals*. 2020; 2(49):11-18.
- [13] Dosmukhamedov NK, Argyn AA, Zholdasbay EE. Behavior of copper compounds and associated metal impurities in the process of converting copper-lead mattes. *Collection of scientific articles of the Interuniversity Scientific Congress "Higher School: Scientific Research"*. Moscow, Russia. 2020, 127-139.
- [14] Sohn HS, Fukunaka Y, Oishi T. *Yazawa Int. Symp.: Metallurgical and Materials Processing. Principles and Technologies (I)*, Kongoli F, Itagaki K, Yamauchi C, and Sohn HY, eds., TMS, Warrendale, PA. 2003, 131-146.
- [15] Demetrio S, Ahumada J, Durán MA, Mast E, Rojas U, Sanhueza J. Slag Cleaning: The Chilean Copper Smelter Experience. *JOM*. 2000, 20-25.
- [16] Cardona N, Mackey PJ, Coursol P, Parada R, Parra R. Optimizing Peirce-Smith Converters Using Thermodynamic Modeling and Plant Sampling. *JOM*. 2012; 64(5).
- [17] Coursol P, Tripathi N, Mackey P, Leggett T. *Can. Met. Quart.* 2010; 49(3):255-262.
- [18] Montenegro V, Sano H, Fujisawa T. Recirculation of high arsenic content copper smelting dust to smelting and converting processes. *Minerals Engineering*. 2013; 49:184-189.
- [19] Swinbourne DR, Kho TS. Computational Thermodynamics Modeling of Minor Element Distributions During Copper Flash Converting. *Metallurgical and Materials Transactions*. 2012; 43B:823-829.
- [20] Kubashevsky O, Alcock SV. *Metallurgical thermochemistry*. M.: Metallurgy. 1982.
- [21] A.S. USSR 1534081. Device for supplying fine materials to a converter with a lateral gas outlet / Dosmukhamedov NK, Egizekov MG, Spitchenko VS et al. *Opubl.* 1990, 1.
- [22] Bagrova TA, Vaskevich AD, Zaitsev VYa, Kukoev VA. Homogeneity range and activity of the components of iron-silicate melts containing CaO and Al<sub>2</sub>O<sub>3</sub>. *Nonferrous metals*. 1985; 2:7-10.
- [23] Yazawa A. *Can. Metal. Quart.* Thermodynamic considerations of Copper smelting. 1974; 13:443-453.
- [24] Vaskevich AD, Sorokin ML, Kaplan VA. General thermodynamic model of copper solubility in slags. *Nonferrous metals*. 1982; 10:22-26.
- [25] Bellemans I, De Wilde E, Moelans N, Verbeken K. Metal losses in pyrometallurgical operations - A review. *Advances in Colloid and Interface Science*. 2018; 255:47-63. <https://doi.org/10.1016/j.cis.2017.08.001>
- [26] Guntoro PI, Jokilaakso A, Hellstén N, Taskinen P. Copper matte-slag reaction sequences and separation processes in matte smelting. *Journal of Mining and Metallurgy, Section B: Metallurgy*. 2008; 54B:(3):301-11. <https://doi.org/10.2298/JMMB180214021G>