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Contributions to the Establishment of Criteria for the Optimization of the Integrate Process of Turning to Account Non-Ferrous Metal Ores

Any squanderer is an enemy of the society. Any economical man is a public benefactor.

A. Smith (1728—1790)

The directives of the Tenth Congress of the Romanian Communist Party on the development of the national economy in the 1971—1975 period envisage a substantial increase of the non-ferrous metal production in the conditions of the continuous decrease of the cost price. The objectives are to be fulfilled both through the development of the mining production and through the measures for reducing the losses of metal in exploitation, for raising productivity in the dressing installations and for improving the processing process.

The turning to account of the non-ferrous ores is usually achieved through an integrate process made up of three distinct stages: the extraction of deposit ores, the dressing of ores and the metallurgical processing. These three stages are usually unfolding in various enterprises which are functioning independently from the organizational point of view. Nevertheless, they form a unique ensemble, with the single aim at turning out the final product, the metallic ingot. Owing to this characteristic, it is logical for the establishment of the criteria of the optimization of the process of turning to account of the non-ferrous ores to analyse the unfolding of the integrate process as a single whole and not each stage taken separately as is usually done.

At the level of the national economy, the economic efficiency of a single stage of the process of turning to account of the non-ferrous ores has an importance subordinate to the efficiency of the integrate production process. It is useless to persevere on the improvement of the results in a certain stage of the integrate process unless this improvement favourably influences the final results (the extraction efficiency and the cost price of the metal).

To correctly estimate the economic efficiency of the entire extraction process it is necessary to study the relations existing among the different

technological indicators of each stage taken separately and the correlation between these indicators and the cost price of the integrate production [1.]

THE TECHNICAL-ECONOMIC INDICATORS OF THE INTEGRATE PROCESS

From the technological point of view, the optimum of the non-ferrous metal production corresponds to a most complete metal extraction, with a maximum efficiency. This means a most complete extraction of the deposit ore, with a minimum dilution, the obtaining in the dressing plants of concentrates with an increased content of metal, in the conditions of a maximum extraction and the obtaining in the metallurgical works of pure metals with minimum losses at melting.

In the plants, the estimation of the unfolding of the production process is made only from the technological point of view, on the basis of the data obtained and of the technological indicators calcullated for each process. Fig. 1 presents a scheme of the integrate process of non-ferrous metal production with notations on the data followed in various processing stages.

The main technological indicators used for the estimation and control of unfolding of the production process on various stages or in general are indicated in table 1.

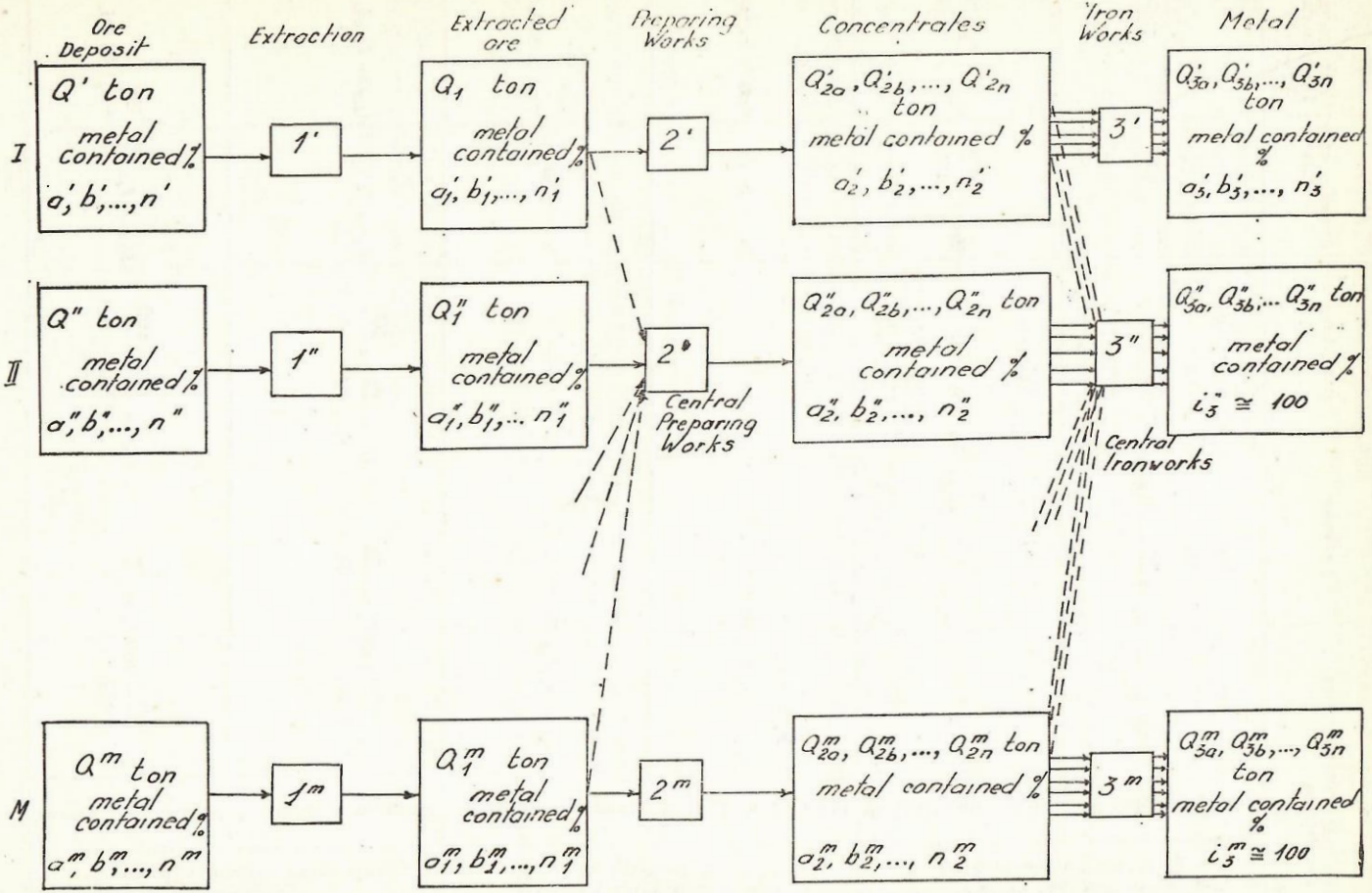
In estimating the integrate process, the fact should be taken into consideration that the technological indicators on the various stages are conditioning each other and that certain correlations can be established between them. Thus, for example, the results in dressing are generally better if the mine delivers less diluted ore and the metallurgical works obtains a higher efficiency if it receives better concentrates. In this reciprocal conditioning, the influence of some of the indicators is bigger and of other ones smaller. A special part is played by the indicators in the dressing plants because they can be chosen in such a way as to influence the integrate production as a whole. Of special importance is the quantitative extraction (ν_{2i}), obtained in the dressing plants which, as results from table 1 , gives the relation between the content of metal of the raw ore (i_1) and the concentrates (i_2).

As is known from practice, the relations among the various parameters of functioning of the installations, the characteristics of the ores and the technological indicators are very complex [2], depending especially on the characteristics of the ores. In their turn, the characteristics of the ores very frequently, often unforeseeingly and stochastically in the same mine. Due to the quite accidental character of these variations, no simple, univocal but statistical relations of the type of regressions [3] — [7] can be established between the various parameters influencing the unfolding of the integrate process the technological indicators obtained.

The studies made [3] — [5] have shown that in practice the average statistical value of the quantative extraction of concentrate (ν_2 i) most often varies lineally with the content in metal of the concentrate.

This variation can be expressed through the line of regression corresponding to a certain content of the supply :

$$\nu_{2i} = \alpha_i - \beta_i \cdot i_2 \qquad (1)$$


Ore Deposit
Extraction
Extracted ore
Preparing Works
Concentrates
Iron Works
Metal
I
II
M
Q' ton
metal contained %
a', b', ..., n'
1'
Q1 ton
metal contained %
a1', b1', ..., n1'
2'
Q'2a, Q'2b, ..., Q'2n ton
metal contained %
a2', b2', ..., n2'
3'
Q'3a, Q'3b, ..., Q'3n ton
metal contained %
a3', b3', ..., n3'
Q" ton
metal contained %
a", b", ..., n"
1"
Q1" ton
metal contained %
a1", b1", ... n1"
2"
Central Preparing Works
Q"2a, Q"2b, ..., Q"2n ton
metal contained %
a2", b2", ..., n2"
3"
Q"3a, Q"3b, ... Q"3n ton
metal contained %
i3" ≅ 100
Central Ironworks
Qm ton
metal contained %
am, bm, ..., nm
1m
Q1m ton
metal contained %
a1m, b1m, ..., n1m
2m
Q2am, Q2bm, ..., Q2nm ton
metal contained %
a2m, b2m, ..., n2m
3m
Q3am, Q3bm, ..., Q3nm ton
metal contained %
i3m ≅ 100

The Stages of the Process		Extraction	Dressing	Metallurgy	Dressing and metallurgy	Extraction Dressing and Metallurgy
Quantitative extractions of: ore, concentrate or metal %	A single component	$\nu_1 = \frac{Q_1}{Q} 100$ $\nu_{1z} = \frac{Q - Q_2}{Q}$	$\nu_2 = \frac{Q_2 a}{Q_1}$ $\nu_2 = \frac{a_1 - a_s}{a_2 - a_s} 100$ $\nu_2 = \alpha - \beta_{a_2}$	$\nu_3 = \frac{Q_{3a}}{Q_{2a}}$ $\nu_3 = Q_2 - t$ $\nu_3 = \frac{\alpha - \beta_t - \nu_2}{\beta}$	$\nu_{23} = \frac{\nu_2 \cdot \nu_3}{100}$	$\nu_{123} = \frac{\nu_1 \nu_2 \nu_3}{100^2}$
	Several components	Idem	$\nu_{2i} = \frac{Q_{2i}}{Q} 100$ $\nu_{2i} = \frac{i_1 - i_s}{i_2 - i_s} 100$ $\nu_{2i} = \alpha_1 - \beta_i i_2$	$\nu_{3i} = \frac{Q_{3i}}{Q_{2i}} 100$ $\nu_{3i} = i_2 - t_i$ $\nu_{3i} = \frac{(\alpha_i - \beta_i t_i) - \nu_{2i}}{\beta_i}$	$\nu_{23i} = \frac{\nu_{2i} \nu_{3i}}{100}$	$\nu_{123i} = \frac{\nu_1 \nu_{2i} \nu_{3i}}{100^2}$
Extraction integrated in useful component %	A single component	$\mu_i = \nu_1 I_1$ I=Enrüching	$\mu_2 = \nu_2 I_2$	$\mu_3 = \nu_3 I_3$	$\mu_{23} = \mu_2 \mu_3$	$\mu_{123} = \mu_1 \mu_2 \mu_3$
	Several components	$\mu_{1i} = \nu_{1i} I_{1i}$	$\mu_{2i} = \nu_{2i} I_{2i}$	$\mu_{3i} = \nu_{3i} I_{3i}$	$\mu_{23i} = \mu_{2i} \mu_{3i}$	$\mu_{123i} = \mu_{1i} \mu_{2i} \mu_{3i}$
Enriching (I) (or dilution for extraction)	A single component	$\rho = \frac{a - a_1}{a - a_z} 100$ (dilution)	$I_2 = \frac{a_2}{a_1}$	$I_3 = \frac{a_3}{a_2} \approx \frac{100}{a_2}$	$I_{23} = I_2 I_3$	$I_{123} = I_1 I_2 I_3$
	Several components	$\rho = \frac{i - is}{i - iz} 100$	$I_{2i} = \frac{i_2}{i_1}$	$I_{31} = \frac{i_3}{i_2} \approx \frac{100}{i_2}$	$I_{23i} = I_{2i} I_{3i}$	$I_{123i} = I_{1i} I_{2i} I_{3i}$

α_i and β_i are positive constant values which are determined by calculus or graphically from the statistical data obtained in a certain period of time in the plant.

As the quantitative extraction ν_{2i} depends both on the content in metal of the concentrate and on that of the ore supplied in dressing plant, it results that the values of α_i and β_i will be influenced by the conditions in which the mining extraction is carried out, and first and foremost by the dilution of the ore. From this reason, one can admit that the relation (1) which gives the value of ν_{2i} statistically includes also certain data about the unfolding of the extraction process.

There is a similar relation also with the metallurgical process. The quantitative extraction in the metallurgical process can be expressed through the relation:

$$\nu_{3i} = i_2 - t_i = -\frac{(\alpha_i - \beta_i t_i) - \nu_{2i}}{\beta_i} \tag{2}$$

in which t_i represents the percentage loss of metal admitted at melting. For a certain plant and a certain metal, t_i is constant. As t_i usually has values very close to those of the content of ore supplying the dressing plants ($t \approx i_1$), one can admit that $\alpha_i - \beta_i t_i = 100$, so that

$$\nu_{3i} = \frac{100 - \nu_{2i}}{\beta_i} \tag{3}$$

From the relation (2) one notes that ν_{3i} is a linear function of ν_{2i}. As ν_{2i} implicitely includes the technological indicators of the extraction and metallurgical stages, it results that this indicator can be used alone for a corresponding estimation of the unfolding of the entire integrate process.

THE COST PRICE OF THE NON-FERROUS METAL INTEGRATE PRODUCTION

For the non-ferrous metal integrate production, several general relations [1] have been established which indicate the relations existing between the integrate cost prices per ton of extracted ore (p_e), of concentrate (p_c) and of metals (p_f) and the main technological indicators.

In the case of complex ores, these relations are:

$$P_e = A + \sum_{i=a}^{i=n} B_i \frac{\nu_{2i}}{100}, \tag{4}$$

$$P_c = A \frac{100}{\sum_{i=a}^{i=n} \nu_{2i}} \frac{\psi_{2i}\,\nu_{2i}}{\sum_{i=a}^{i=n} \psi_{2i}\,\nu_{2i}} + B_i, \tag{5}$$

$$P_f = A \frac{100^2}{\sum_{i=a}^{i=n} \nu_{2i}\,\nu_{3i}} \frac{\psi_i\,\nu_{2i}\,\nu_{3i}}{\sum_{i=a}^{i=n} \psi_i\,\nu_{2i}\,\nu_{3i}} + B_i \frac{100}{\sum_{i=a}^{i=n}} \tag{6}$$

For the monometallic ores, these relations become

$$P_c = A + B\,\frac{\nu_2}{100}, \tag{7}$$

$$P_c = A\,\frac{100}{\nu_2} + B, \tag{8}$$

$$P_f = A\,\frac{100^2}{\nu_2\,\nu_3} + B\,\frac{100}{\nu_3} \tag{9}$$

In the above-mentioned relations, A represents the cost price of extraction (p_1), dressing(p_2) and the cost of transport from the mine to the plant (p_3) and B the cost price of the metallurgical processing (p_5) and cost of transport from the dressing plant to the metallurgical plant (p_4).

$$A = p_1 + p_2 + p_3$$

$$B = p_4 + p_5$$

ψ_{2i} and ψ_i represent the sale prices of the concentrates and of the metals (lei/t) and ν_{2i} and ν_{3i}, the quantitative extractions in the dressing process and metallurgy.

Knowing the values of the various parametres intervening in the above-mentioned relations, the return prices can be calcullated simply, with the aid of nomograms. [1].

METHODS FOR ESTIMATING THE UNFOLDING OF THE INTEGRATE PRODUCTION PROCESS

As the technological indicators and the cost price are conditioning each other, the improvement of some indicators in a certain stage of the process can be correctly estimated only by taking into consideration the influence on the indicators of the other stages of the integrate process and on the cost price of the finite product. The current methods in operational studies are used in establishing these relations [8].

The integrate production of non-ferrous metals can be considered as an economic system taking place in certain conditions, which constitutes the framework of restrictions determining the mathematical model with which it is assimilated. The main problem which has to be solved in establishing the criteria for a best turning to account of the non-ferrous metal ores is to work out the model, namely the mathematical relations comprising logical and quantitative descriptions of the system together with the relations existing among the elements making up the real system.

Knowing the relations among the variations of various parameters included in the mathematical relations (consequently in the model approached) and, taking into consideration the conditions existing between the real system and the model, one can establish for certain variables the values ensuring the best results in relation to a certain criterium of optimization [8.]

As is known, optimization can pursue either a technological function (the maximization of the efficiency of extraction, the co-efficient of utilization, etc.) or an economic function (the maximization of profitableness, the minimization of the price cost, etc.).

For the establishment of the economic optimum of functioning of the installations for the integrate turning to account of the non-ferrous metal ores, various authors [7], [10], [11] have suggested to consider as a criterium of optimization either the minimization of the cost price or the maximum profit.

In a recent study, [7] starting out from the relations established in [1], the minimum cost price of the metal is determined in keeping with the metal content of the concentrate obtained in dressing, in the conditions in which the expenses of exploitation, dressing and metallurgical processing are constant.

The method proposed by Taggart [10] consists in establishing the conditions in which a maximum profit is obtained in each stage of the integrate process (in fact, it is dealing with the dressing stage).

Huber -Panu [9] making a mathematical analysis of the technical and economic indicators of functioning of the dressing plants establishes that they are functioning with a highest economic efficiency if the dressing process stops when the elementary products resulted have a content in metal equal to that of the concentrates of a "null economic value".

In the present conditions when the problem is raised for all the industrial branches to work profitably, we consider that the most adequate criterium of estimating the optimum of the functioning of the installations for the integrate turning to account of the non-metalliferous ores is the obtaining of a maximum benefit simultaneously in all the stages of the integrate production process.

In a paper presented at the scientific session of the Academy of Economic Sciences in 1965, I [12] proposed a criterium of estimation of the functioning of the installations for the integrate turning to account of the non-ferrous ores on the basis of the technical-economic indicators. Starting out from the same premises, the present study aims at determinig the optimum of functioning of the installations in each stage of the integrate process so as to ensure a maximum profit for the entire process.

As a rule, the method consists in establishing a mathematical relation indicating the profit obtained in keeping with the parameters influencing the process of the turning to account of the non-ferrous ores. This relation being known, the conditions of the functioning of the installations for ensuring the best technical and economic results can be determined through a mathematical analysis and taking into consideration the correlation between the model and the system.

The profit obtained in the various stages of the integrate process of turning to account of the non-ferrous ores can be calcullated if the difference is made between the price of the turning to account of the product resulting in the respective process of production and the total cost price of this product.

The value of the mining products (concentrated, monometallic ore) is determined by the quantity of metal which can be effectively extracted out

of them (η_1, η_2, η_3), by the sale price (ψ) of the respective metals and by the penalizations or allowances on the sale prices for certain impurities contained by the mine products.

Table 2

The effective values of the products resulting in various stages of the integrate process

Stage	Effective values of the products
In the deposit	Complex ore
	$V_{zc} = \frac{D_1}{100^3} \sum_{i=0}^{n} \frac{-\psi_i \nu_{2i}^2 + 100\,\psi_i\,\nu_{2i}}{\beta_i}$ (10)
	Monometallic ore
	$V_z = \frac{\nu_1}{100^3 \beta} (-\psi \nu_2^2 + 100 \psi \nu_2)$ (11)
Exploitation	Complex ore
	$V_{ec} = \frac{1}{100^2} \sum_{i=a}^{n} \frac{-\psi_i \nu_{2i}^2 + 100\,\psi\,\nu^2}{\beta_i}$ (12)
	Monometallic ore
	$V_e = \frac{1}{100^2 \beta} (-\psi \nu_2^2 + 100\,\psi\,\nu_2)$ (13)
Dressing	All the concentrates obtained in the event of the processing of a complex ore
	$V_{cc} = \frac{1}{100} \sum_{i=a}^{n} \frac{\psi (100 - \nu_{2i})}{\beta_i}$ (14)
	A single concentrate
	$V_c = \frac{1}{100} \psi (100 - \nu_2)$ (15)
Metallurgy	All the metals recovered from the complex ore
	$V_{mc} = \sum_{i=a}^{n} \psi_i$ (16)
	A single metal
	$V_m = \psi_i$ (17)

Table 2

Stage	Type of ore	The profit obtained on each of the products obtained in various stages of the process	
Exploitation	Complex	$R_{ce} = \frac{1}{100^2} = \sum_{i=a}^{n} \frac{\nu_{2i}(100 - \nu_{2i})}{\beta_i} - A - \frac{1}{100} \sum_{i=a}^{n} B_i \nu_{2i}$	(18)
	Monometallic	$R_e = \frac{\psi\nu_2(100 - \nu_2)}{100^2\beta} - A - B\frac{\nu_2}{100}$	(19)
Dressing	Complex	$R_{cpi} = \frac{\psi_i(100-\nu_{2i})}{100\beta_i} - A\frac{100}{\sum_{i=a}^{n}\nu_{2i}\beta_i}\frac{\psi_i(100 - \nu_{2i})}{\sum_{i=a}^{n}\frac{\psi_i(100 - \nu_{2i})\nu_{2i}}{\beta_i}} - Bi$	(20)
	Monometallic	$R_P = \frac{\psi(100 - \nu_2)}{100\beta} - A\frac{100}{\nu_2} - B$	(21)
Metallurgy	Complex	$R_{fi} = \psi_i - A\frac{100}{\sum_{i=a}^{n}\frac{\nu_{2i}(100-\nu_{2i})}{\beta_i}}\frac{\psi_i\nu_{2i}(100 - \nu_{2i})}{\beta_i\sum_{i=a}^{n}\frac{\psi_i\nu_{2i}(100-\nu_{2i})}{\beta_i}} - \frac{100\,Bi\,\beta_i}{100 - \nu_{2i}}$	(22)
	Monometallic	$R_f = \psi - A\frac{100\beta}{\nu_2(100 - \nu_2)} - \frac{100\,\beta_i}{100 - \nu_2}$	(23)
In the deposit	Monometallic	$R_z = \gamma_a + \gamma_0 - A$	(24)

The effective values of the mine products (table 2) can be calcullated in keeping with the cost price of the metal ψ (lei/ton) and the main technical indicators which were indicated in table 1.

The value of the mine production can be expressed in keeping with the average content of the main component part of the deposit ore (a) by a relation of the type of:

$$V(a) = \gamma_a + \gamma_o \tag{17a}$$

or

$$V(a_1) = \gamma \frac{a_1}{(1 - P)} + \gamma_0$$

in which γ and γ_0 are constant coefficients in a considered case. In normal conditions $\gamma_0 < 0$. The relation (17 a) is established through a statistical processing, using the method of the smallest squares of the data obtained in production or experimentally in the pilot or semi-industrial phase [13].

The relations which give the values of the profitableness of each processing stage (table 3) allow to determine annalitically the conditions in which the integrate process is being achieved with a maximum profit on the whole branch.

For the establishment of the best conditions of the unfolding of the integrate process of the turning to account of the non-ferrous metal ores, the maximum values of the profit, consequently the maximum values of the functions R will have to be determined.

Generally, the profit R can be considered as a non-linear function with several variables (γ_{2a}, γ_{2b} ... γ_{2n}, A, B etc.). The direct determination of the maxim of this function is an extremely complicated problem and it can be solved only through the application of special non-linear programming methods.

The problem can be simplified by solving it in two stages. Part of the parameters entering the relations which give the profit R (for example, A, B, t, etc.) are considered constant in the first stage, the quantitative extractions in the dressing process (ν_{2a}, ν_{2b}, ... ν_{2n}), remaining variable. This supposition corresponds to the practical situation, if the fact is taken into consideration that the various phases of the process always take place in the same enterprises and by the same methods, consequently, the process of exploitation, dressing, metallurgy or the distance of transport do not vary.

This supposition being made, the maxims of the function R in the equations:

$$\frac{\partial R}{\partial \nu_{2a}} = 0; \quad \frac{\partial R}{\partial \nu_{2b}} = 0; \quad \frac{\partial R}{\partial \nu_{2i}} = 0 \tag{25}$$

are determined, taking into consideration that ν_{2a}, ν_{2i} ... etc. are positive and $\sum_{i}^{n} \nu_{2j} \leqslant 100$.

In the second stage, the maximum value of the extraction is introduced in the function R, determined as above and the maxim of the function R is determined in relation to the other parameters A, B, t, etc., taking into consideration a number of concrete conditions.

The complete solution to the problem, according to the above-mentioned system, requires laborious calculus in the case of the complex ores, an electronic computer being absolutely necessary.

For exemplifying the execution of the calculus, the case of a monometallic ore will be analysed below. If we refer to the profit obtained through the turning to account of the entire ore, the function which represents the value of the profit is:

$$R_e = \frac{-\psi\nu_2^2 + 100(\psi - \beta_B)\ \nu_2 - 100^2\ \beta A}{100^2} \geqslant 0 \tag{26}$$

The inequality $R_e \geqslant 0$ shows that from the economic point of view only the positive values of this function will have to be taken into consideration.

If, only the extraction (ν_2) is considered variable, one can easily notice that the function R will be positive only when (ν_2) will have real values comprised between the roots ν_2' and ν_2'' which annul it:

$$\nu_2',\ \nu_2'' = \frac{100(\psi - B)}{2\psi\beta} + \frac{100}{2\psi\beta}\sqrt{(\psi - B)^2 - 4\psi\beta A.} \tag{27}$$

The value for which the function R_e is maximum is determined from the condition:

$$\frac{\partial R_e}{\partial \nu_2} = \frac{-2\psi\nu_2 + 100(\psi - \beta_B)}{100^2 p} = 0, \tag{28}$$

which gives

$$\nu_{max} = \frac{100(\psi - \beta_B)}{2\psi} = 50\left(1 - \frac{\beta}{\psi}B\right), \tag{29}$$

If the max. value ν_{max} is introduced in the relation (29) the maximum value of the profit is obtained

$$R_e max = \frac{(\psi - \beta_B)^2 - 4\psi\beta_A}{4\psi\beta}, \tag{30}$$

From the relations inferred above, it results that the mining exploitation is profitable from point of view of economy if it delivers ores of a quality which should allow the obtaining, in the dressing installations, of quantitative extractions the values of which are comprised between ν_2' and ν_2''.

The maximum profit corresponds to an extraction $\nu_2 = \nu_{max}$ for which the content of the concentrate is equal to:

$$a_{max} = \frac{\alpha - \nu_{max}}{\beta} = \frac{\alpha}{\beta} - \frac{50}{\beta}\left(1 - \frac{\beta}{\psi}B\right). \tag{31}$$

According to the relation (3), a maximum metallurgical extraction will correspond to this maximum content of the concentrate

$$\nu_{3max} = \frac{100 - \nu_m}{\beta} = \frac{100}{\beta} - \frac{50}{\beta}\left(1 - \frac{\beta}{\psi}B\right) = \frac{50}{\beta} - \frac{50B}{\psi} \tag{32}$$

The quantitative extractions of the dressing and metallurgical stage once established, for which the maximum profit is obtained, one can pass on to the second stage of the calculus, namely to the establishment of the economic optimum in the conditions in which the other parameters influencing the integrate process are varying. The problem which is raised is to determine the maxim of the function:

$$R_{e\,max} = \frac{(\psi - \beta B)^2 - 4\psi\,\beta A}{4\psi\beta} = \frac{[\psi - \beta(p_4 + p_5)]^2 - 4\psi\beta(p_1 + p_2 + p_3)}{4\psi\beta} \tag{33}$$

with the supplementary conditions

$$\nu_{3\,max} + \frac{50}{\psi}(p_4 + p_5) = \frac{50}{\beta} \tag{34}$$

$$\nu_{max} + \frac{\beta}{\psi}(p_4 + p_5) = 50 \tag{35}$$

$$p_1 + p_2 + p_3 - \gamma_a 1 \frac{1}{1 - p} \leqslant \gamma_0$$

$$\beta_t = \alpha - 100$$

in which the variables are positive

$$p_i \geqslant 0\ (i = 1, 2, ..., 5)$$

$$\nu_{3\,max} \geqslant 0;\ \nu_{max} \geqslant 0; \frac{1}{1 - \rho} \geqslant 0;\ t \geqslant 0.$$

Taking into consideration the real conditions in practice $R_{e\,max}$ can be brought to a linear form. Indeed, if the function $R_{e\,max}$ in relation to B is solved, it is found out that it is positive only in the periods

$$\frac{\psi}{\beta} + \frac{2\psi}{\beta}\sqrt{\frac{\beta A}{\psi}} < B < \frac{\psi}{\beta} - \frac{2\psi}{\beta}\sqrt{\frac{\beta A}{\psi}}. \tag{36}$$

As B always has positive values lower than $\frac{\psi}{\beta}$ only the period

$$0 < B < \frac{\psi}{\beta} - \frac{2\psi}{\beta}\sqrt{\frac{\beta A}{\psi}}. \tag{37}$$

can be taken into consideration.

In this period, the function can be assimilated with a straight line. If Lagrange's relation of interpollation of the functions is applied, for B varying

in the period $10^2 - 10^3$ (which in practice is comprised in the period given by the relation (37), the equality

$$R_{e\,max}(B) = \frac{1}{4\psi\beta}\left[\frac{R_{e\,max}\,10^2(B-10^3) - R_{e\,max}(10^3)\,(B-10^2)}{(10^2-10^3)} + \right.$$

$$\left. + \frac{2\beta^2}{2!}\,(B-10^2)\right]. \tag{38}$$

is obtained.

If the calculus is made and the correction factor is given up (which has a reduced value), it results:

$$R_{e\,max} = -\left(\frac{1}{2} - \frac{10^3 + 10^2\beta}{4}\right)(p_4 + p_5) - (p_1 + p_2 + p_3) + \frac{\psi}{4\beta} -$$

$$- \frac{10^5\,\beta}{4\psi}. \tag{39}$$

The problem which is put in continuation is to determine the maxim of the function:

$$R_e = -\left(\frac{1}{2} - \frac{10^3 + 10^2\beta}{4\psi}\right)(p_4 + p_5) - (p_1 + p_2 + p_3) \tag{40}$$

so that a point $X(p_1, p_2, \ldots\ldots, p_5, \nu_{max}\ \nu_{3\,max}, \frac{1}{1-\rho}$, t and φ (the compensation factor for the inequality in the relation (35) should satisfy the vectorial equation:

$$P_0 = p_1P_1 + p_2P_2 + p_3P_3 + p_4P_4 + p_5P_5 + \nu_{max}\,P_6 + \nu_{3\,max}\,P_7 +$$

$$+ \frac{1}{1-\rho}\,P_8 + t\,P_9 + \varphi_e \tag{41}$$

in which P_1, P_2 ..... P_9, φ_e, are vectors cooresponding to the matrix:

P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	e	P_0
1	1	1	0	0	0	0	$-a_1$	0	-1	γ_0
0	0	0	$\frac{50}{\psi}$	$\frac{50}{\psi}$	0	1	0	0	0	$\frac{50}{\beta}$
0	0	0	$\frac{\beta}{\psi}$	$\frac{\beta}{\psi}$	1	0	0	0	0	50
0	0	0	0	0	0	0	0	β	0	$\alpha-100$

After the determination of the numerous best solutions of the function R_e (40), the maximum value of this function is introduced in the relation (38), determining the maximum value of the profit $R_{e\,max}$ in keeping with all the parameters intervening in the integrate production process.

The complexity of the conditions in which the integrate turning to account of the non-ferrous metal ores is achieved, and the numerous interdependences and corellations existing among the various stages make that the

above-mentioned mathematical models should be relatively complicated. They give, however, rational solutions, scientifically motivated on the basis of clear criteria, facilitating by this the taking of decisions in connection with the management of the process of the complex turning to account of the non-ferrous ores.

REFERENCES

1. LUCA M., DOBRESCU L.: *Studiul influenței variațiilor indicatorilor tehnologici asupra prețului de cost în industria extractivă.* Revista Minelor, nr. 11 și 12, 1960.
2. HUBER P.: *Elemente pentru controlul funcționării instalațiilor de preparare mecanică.* M. O. Impr. Net. 1935.
3. DUVAL R.: *Quelle est la concentration optimum à viser dans une laverie métallique.* Annales des Mines, ian., 1959.
4. DUVAL. R.: *Réactions de l'économie sur la technique en matière de préparation de minerais et état économique des affaires.* Revue de l'industrie minérale, fev. 1953.
5. SEYER R.: *Etude sur le rendement économique de la concentration mécanique des minerais RIM.* Congrès des laveries françaises, Paris, sept., 1953.
6. DOBRESCU L.: *Controlul statistic al funcționării instalațiilor de preparare.* Revista Minelor, nr. 5, 1968.
7. LUCA M., TOMOV D., ZORILESCU D.: *Modelarea procesului integrat de producție în scopul valorificării optime a zăcămintelor de substanțe minerale utile.* Conferința Națională de Tehnică Minieră, 28—30 nov., 1968.
8. CAZACU V., DIAMANDI R., DOXANESCU C, NITESCU TR.: *Cercetări operaționale și unele din aplicațiile ei în mineritul din R. S. România.* Conferința Națională de Tehnică Minieră, 28—30 nov., 1968.
9. HUBER P.: *Criterii de bază pentru stabilirea indicilor principali și controlul instalațiilor de preparare.* Revista Minelor, nr. 2 și 3, 1953.
10. TAGGORT A.: *Handbook of Mineral Dressings.* I. Wiley, New York, 1948.
11. PANDELESCU C.: *Determinarea indicilor tehnologici ce trebuie realizați de instalațiile de preparare a minereurilor pe baza factorilor tehnico-economici.* Revista Minelor,, nr. 3, 1956.
12. DOBRESCU L. ș.a.: *Folosirea indicatorilor tehnico-economici pentru aprecierea funcționării întreprinderilor din industria extractivă a metalelor neferoase.* Studiu susținut în sesiunea științifică a cadrelor didactice din A.S.E., 1965.
13. MURGU M.: *Contribuții la valorificarea optimă a zăcămintelor metalifere.* Teză de doctorat 1969.

CONTRIBUTIONS POUR ETABLIR CERTAINS CRITERES D'OPTIMISER LE PROCESSUS INTEGRE DE VALORISATION DES MINERAIS METALLIFERES NON-FERREUX

Pour établier les critères d'optimisation du processus de valorisation des minerais métallifères non-ferreux, on établit, en premier lieu, les indicateurs techniques et économiques du processus intégré et les corrélations qui existent entr'eux. L'appréciation du déroulement du processus intégré se fait à base du bénéfice maximum réalisé.

L'expression mathématique du bénéfice est une fonction non-linéaire à plusieurs variables. L'établissement de la valeur maximum du bénéfice se résout en deux étapes. Pour la première étape on considère constants tous les paramètres qui entrent dans la relation du bénéfice, à l'exception des extractions quantitatives et on établit le maximum de la fonction ainsi obtenue

en annulant les dérivées partiales, compte tenant aussi d'une série de corrélations supplémentaires. Dans la deuxième étape on introduit dans la fonction qui représente le bénéfice, les valeurs des extractions quantitatives correspondant au maximum, en obtenant une fonction linéaire dépendant des autres paramètres variables.

Le maximum de cette fonction se détermine ensuite par la méthode des programmations linéaires. On exemplifie la méthode proposée dans le cas d'un minerai bi-métallique.

ВКЛАД В ДЕЛО УСТАНОВЛЕНИЯ КРИТЕРИЕВ ОПТИМИЗАЦИИ КОМПЛЕКСНОГО ПРОЦЕССА ИСПОЛЬЗОВАНИЯ РУД ЦВЕТНЫХ МЕТАЛЛОВ

Для установления критериев оптимизации процесса использования руд цветных металлов устанавливаются, прежде всего, технико-экономические показатели комплексного процесса и существующие между ними соотношения. Оценка развертывания комплексного процесса производится на основе полученной наибольшей прибыли.

Математическое выражение прибыли является нелинейной функцией нескольких переменных. Установление наибольшей величины прибыли осуществляется в два этапа. На первом этапе считаются постоянными все параметры, входящие в соотношение прибыли, за исключением добычи в количественном выражении, и определяется максимум полученной таким образом функции путем аннулирования частных производных с учетом ряда дополнительных условий.

На втором этапе в функцию, представляющую собой прибыль, включается величина добычи в количественном выражении, соответствующая наибольшей прибыли, и получается, таким образом, линейная функция в соответствии с остальными переменными параметрами. Максимум этой функции определяется затем методом линейного программирования. Дается пример применения предлагаемого метода в случае биметаллической руды.