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Table: Metal content of the concentration products in the operations, %

No.	Feed	1st roughing		2nd roughing		Control		1st reclean		2nd reclean		3rd reclean	
		c	t	c	t	c	t	c	t	c	t	c	t
	X_f	X_1	X_7	X_9	X_8	X_{10}	y_t	X_2	X_6	X_3	X_4	y_c	X_5
1	3.0	36.10	0.52	2.62	0.052	0.63	0.025	51.94	13.43	53.90	9.07	56.60	11.48
2	3.3	38.22	0.58	12.55	0.27	3.63	0.08	45.97	11.77	52.45	11.21	54.73	15.89

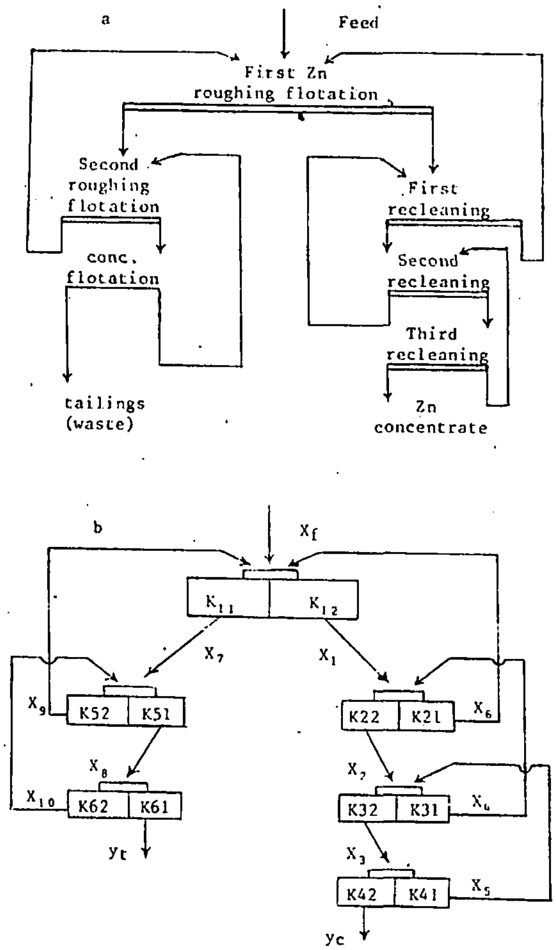

Fig.2 Qualitative (a) and structural (b) schemes of the zinc flotation process.

only to obtain the respective transfer coefficients. By the use of the static model it is possible to modify the methods for calculation of the qualitative and quantitative and water-slime schemes of flotation traditional for concentration plants and to simplify them to a considerable degree without reducing their accuracy. This is extremely important for operational-control of the process. However, nost important in our view is the possibility of improving the characteristics of the flotation process by optimisation of its static model. Optimisation of the zinc flotation process by its mathematical model was realised by the simplex planning method[1]) on an MN-18 analogue computer.

The initial matrix, corresponding to twice the number of technological flotation operations, comprised 12 transfer coefficients, the values of which were varied in 13 trials in order to attain a higher quality in the zinc concentrate and to reduce the losses of metal in the tailings. Values of the coefficients taken as optimum were obtained as a result of 22 trials. The table gives comparative data corresponding to the obtained regime (1) and to the best result (2) obtained during the testing of zinc flotation.

Here it must be emphasised that the optimum values of the transfer coefficients (K_i) and the zinc content (X_i) obtained in the concentration products from the corresponding operations lie within the limits of the variation intervals of these parameters established from the results of a test of the process. Comparison of the results obtained showed that an improvement in the quality characteristics of the process can be obtained as a result of purposeful redistribution of the loads between the individual operations of the process. Thus, for example, the yield of the concentrate of the second roughing flotation is increased considerably under the optimum conditions, as a result of which the zinc content of the tailings in this operation and of the tailings of the control flotation, which are waste products, is greatly reduced. At the same time the yield of the froth product in the second recleaning operation is reduced, and its zinc content increases. The improved quality of the froth product of the first recleaning operation makes it possible to obtain a concentrate of higher quality in the second and third recleaning operations.

It is interesting to note that only under the optimum conditions was it possible to obtain recycled products ($X_9 X_{10}$) close in content to the feed of the operations ($X_7 X_f$), to which they are accordingly directed. In this case it is in our opinion possible to eliminate the control flotation without actually altering the values of the transfer coefficients ($K_{62} K_{61}$), since the extraction into the froth products amounts to less than 1%. Trends similar to those described for the optimum conditions are also traced in some of the operations of the best trial. The approach described above may be of use to investigators in the solution of problems associated with the analysis and perfection of technological concentration schemes.

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Mathematical model of the leaching of the cobalt matte in ferric chloride solutions

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At the present time statistical methods are widely used to obtain a mathematical description of processes in the optimum region, including experimental design methods, since the control of technical processes is possible if there is a mathematical relationship between the parameters[1-3]).

In the present work investigations were carried out into the optimum conditions for the leaching of cobalt matte in solutions of ferric chloride. This is one of the most effective solvents for complex sulphide-containing raw material [4,5]).

The cobalt in the matte is mainly combined with the metallic phase (an alloy of iron with nickel) which contains up to 90% of the total amount in the matte. A cobalt matte containing 1.08 wt.% Co, 1.4 wt.% Ni, 49.1 wt.% Fe, and 25 wt.% S was treated with ferric chloride solution at a temperature close to its boiling point (~105°C). The cobalt content of the solutions and precipitates was determined by a photocolorimetric method[6]. The optimum particle sizes of the cobalt matte and the amounts of hydrochloric acid added to the solution for acidification purposes were first determined.

On this basis investigations were carried out in order to obtain a mathematical relationship between the degree of transfer of cobalt into solution, the leaching time, and the concentration of the solvent, and the results were treated by the experimental design method[2,3]. The factors and variation levels are given in the table.

Table

Factors	Zero level X=0	Variation interval	Upper level X = +1	Lower level X = -1
Fe^{3+} concentration g/l X_1	175	25	200	150
Leaching time h X_2	3	1	4	5

The statistical treatment of the data was realised on a Minsk-32 computer by the programme for the matrices of a multi-factorial experiment. For the degree of transfer of cobalt into solution we obtained the following equation, which adequately describes the experimental data with a 5% significance level:

$$y = 100.975 - 1.0917X_1 - 0.675X_2 + 1.625X_1X_2 - 1.9063X_1^2 - 0.9438X_2^2$$

The variance of the trial was $S^2\{y\} = 0.97583$; the variance of the reproducibility was $S^2(y) = 9.11$. $F_{calc.} = 3.42$; F_{tab} (0.05; 3; 3) = 9.28. The variance of the coefficients was: $S\{b\} = 0.1068$; $S\{b_i\} = 0.34926$, $S\{b_{ic}\} = 0.42249$, $S\{b_{ii}\} = 0.3858$.

On further treatment of the mathematical model on a computer in order to obtain a relationship for the extraction of cobalt it was found that the transfer of cobalt into solution from the cobalt matte amounts to ~100% with a ferric chloride concentration of 150g/l and with a leaching time of 1 hour. The extraction of cobalt into solution obtained experimentally was 99.5%. These conditions must be considered optimum.

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REVIEW OF BOOK BY A N Zelikman, G M Vol'dman and L V Belyaevskaya entitled "The theory of hydrometallurgical processes" (a text book for Universities), Metallurgiya, Moscow 1975

A A Zhukhovitskii

At the present time hydrometallurgy is developing very fast. It has always been characterised by a variety of processes. Their correct application and the optimum choice of parameters require the use of physicochemical theory. This determines the need for a text book devoted to the theory of hydrometallurgical processes. It should perhaps be mentioned that there are no such books in the world literature. The interest with which the book under review was received can thus be understood.

Serious difficulties are encountered in the writing of such a book both in respect of the choice of material and in the attainment of a sufficient degree of rigour and comprehensibility. The book under review covers all the main processes of hydrometallurgy (leaching, ion exchange, extraction, precipitation, crystallisation, autoclave reduction, cementation, settling, filtration and washing). Thus, in spite of the comparatively small size of the book (25 quires), it contains a very large amount of material. In the exposition of all these topics essential data are given on the thermodynamics, kinetics and mass transfer; examples of calculations are presented, and specific problems of practical importance are discussed. The scientific level of exposition satisfies the essential needs. The presentation is clear and intelligible. The wide teaching experience of the authors, who have worked on this course for many years, makes itself felt.

It is only possible to mention isolated faults in the book. Perhaps insufficient attention has been paid to the problems of the dynamics, macrokinetics, and modelling of the processes. In the meantime these aspects are important for calculation of the equipment and for discussing the problems of productivity. There is some non-uniformity of exposition, which is difficult to avoid in the collective writing of a book. Thus, the last chapters of the book differ somewhat from the remainder in the level and character of exposition. The detailed presentation of the material in them did not make it possible to pay sufficient attention to the principles and mechanisms of the processes. There are of course isolated unfortunate formulations and points. This applies, for example, to the definition of an ideal solution, in which, in the opinion of the authors "there is no interaction between the components and also between the molecules (atoms, ions) of one and the same component" (page 25). As a whole the book will undoubtedly be of great use both to teachers and students and to workers in industry and scientific institutes. In conclusion it is possible to express the desire that, on the basis of this book (intended as a text book for university students), the authors will write a text book for the corresponding special courses in the physicochemical departments of metallurgical institutes.