Alternative Exploitation Technology of Mineral Deposits

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ABSTRACT: In the present research work, we offer a technology and instrument for mining of mineral deposits. The technology is based on the preliminary mineral concentration. The instrument is represented with the use of non-contact measurement of the geophysical properties of the ore products. The technology is analyzed in the application of the wolfram, molybdenum and fluorite containing deposits.

KEYWORDS: Quarry, rock, sorting, lump separation

INTRODUCTION

Reserve depletion of the mineral raw materials makes mining factories with the purpose to keep metal tapping increase the volume of the processed mined rock, which on application of the existing technologies can occur to be inefficient. For saving profitability new mineral deposits, acquisition technologies are necessary, which are based on the preliminary concentration of the mined rock with the usage of the ecologically sound prills radiometric separation and small-portion grading.

As an example of a new technology creating two variants of the exploitation of the wolfram deposit are analyzed: the first one is according to the accepted technology, and the second one is with the usage of the preliminary upgrading of the mined rock with the radiometric technology. When using the accepted deposits acquisition technology (Fig. 1) according to the data of the geological testing the block (operation block) in the process of the mining operations divides into conditioned ore and dredge, which is mined selectively. Conditioned ores are dispatched to the dressing plant, and off-grade mined rock is brought into barrow. Commercial and conditioned ores are those ores with the WO_3 mass fraction more than 0.1%. In the tails of the flotation upgrading WO_3 mass fraction constitutes 0.04%.

As we can see in the scheme of Figure 1 proportion of the conditioned ores is only 13.5% of the mined rock, 34.6% metal and 86.5% of the mined rock (stripping ratio 2.36 m^3/t) goes to the barrow of the off-grade mined rock taking away 65.4% of metal, which was in the operation block. Therefore, even the first phase of mining results in the great loss of the commercial component, and those losses are not in the interior of but in the barrows. At the concentrating plant ore undergoes ragging, reduction and floatation. In the tails of the floatation other 11.4% of the commercial component go. As a result, of all the commercial component mass, initially contained in the operation block, in the concentrate remains only 23.2% of metal, and 76.8% are lost in the process of mining and ore processing in the barrows of the off-grade ores and in the tails of the concentration plants. Can this technological scheme be considered as effective or at least profitable? No wonder, that initially profit-making mining ventures rather fast turn out to be unprofitable. This example is not a unique or specific case. The similar scheme of ore-processing is typical for most of the ore-mining and smelting plants.

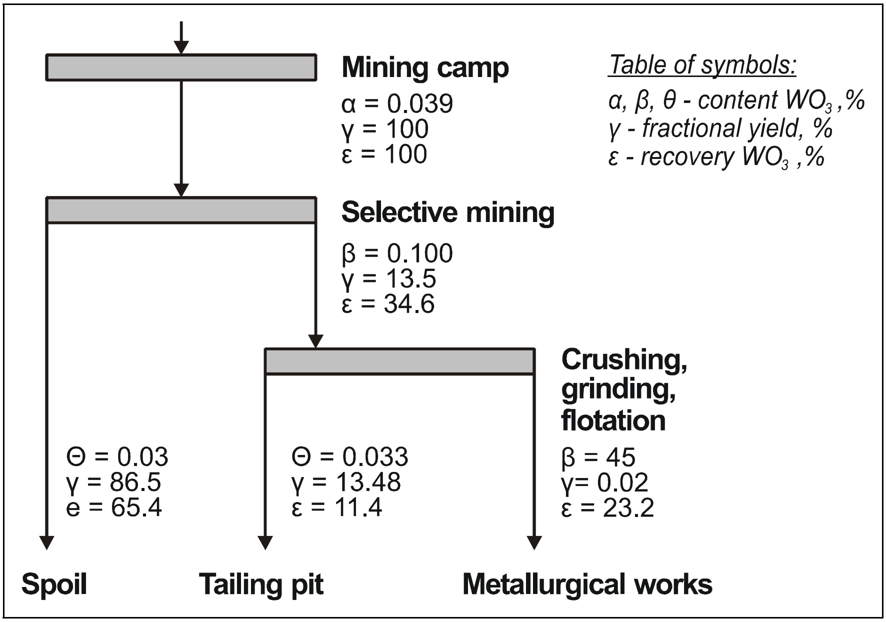

Figure 1. Wolfram Deposit Mining Technology

For the technological schemes efficiency upgrading and for the reducing of the commercial components losses in the process of mining and processing of the mineral raw materials set of operations was held (Новиков 1992), which includes testing of the technological sample of the off-grade ore, taken in the barrows of this deposit. Parts of the 25–50 mm size with the average mass fraction of the tungsten trioxide in the sample 0.057% (Tab. 1) were tested. The results of testing show, that metal distribution in the prills and ore portions is not uniform: in general off-grade mined rock mass of the sample turns out to be half represented as a quite conditioned ore, in which there are 92.8% of the whole metal, which average mass fraction is 0.106%, that is more than set industrial minimum (group portions I and II together). Still further conditioned part of the sample, where 11.4% of metal is, is also half off-grade ore with the average mass fraction WO_3 (group portion II), that is less than in the tails of floatation. Consequently, in this case the barrow of the off-grade ores is 25% represented by the quite conditioned ores, in which 81.4% of the commercial component is contained with the average mass fraction of metal 0.185%. Such a barrow cannot be considered as waste. It shall be taken as industrial quite suitable for operation, but with much less expenses, than primary deposit, as the mined rock in it is already mined and stored. It is more effectively to mine the conditioned part of the off-grade ore, than to send that to the barrow and store almost dead rock, which can give road metal, building stone or material for the laying of mine working.

Therefore, to reduce the losses of the commercial components in the process of mining and mineral raw material processing it is necessary to use technologies of the preliminary concentration of mined rock, which includes overburden, off-grade and conditioned ores.

For realizing research work about the possibility of separation there were taken samples of 8 different districts of the wolfram deposit, which formed a mixed sample with the prills size -50+25 mm. It consists of natural subtypes of the vein-disseminated wolfram molybdenum ores in the metasomatically altered skarns for fissile limestone, pyroxene plagioclase and biotitic hornfels and amphibolized diabases. During separation of the sample tailings outcropping constitutes 64.8% with the metal losses in it only 1,0% (Новиков 1997).

Table 1. Distribution of WO_3 in the Portions of the Off-Grade Ore

Group of Portions	Separate Portions	Mass Fraction WO_3 [%]		Recovery WO_3 [%]	
		In the Separate Portion	Gathered	In the Separate Portion	Gathered
I	1	0.543	0.543	47.5	47.5
	2	0.165	0.342	15.7	63.2
	3	0.101	0.271	7.5	70.7
	4	0.068	0.217	5.7	76.4
	5	0.054	0.185	5.0	81.4
II	6	0.036	0.160	3.3	84.7
	7	0.030	0.142	2.6	87.3
	8	0.026	0.128	2.2	89.5
	9	0.021	0.115	1.9	91.4
	10	0.017	0.106	1.4	92.8
III	11	0.015	0.098	1.3	94.1
	12–20	0.002	0.057	4.6	100.0

Estimation of the technological data during ore separation was made according to the particular samples. The results of the possibility of the preliminary concentration of the scheelite containing ores with the use of X-ray luminescent method is represented in the Table 2.

Table 2. Technological parameters of the X-ray luminescent separation of the scheelite containing ore samples

№	Separation Products	Pinnacle [%]	Content [%]		Recovery [%]	
			WO_3	Mo	WO_3	Mo
1	2	3	4	5	6	7
1	Concentrate	53.0	0.272	0.047	94.9	89.5
	Tailings	46.0	0.017	0.006	5.1	10.5
	Initial	100.0	0.152	0.026	100.0	100.0
2	Concentrate	29.0	0.184	0.027	74.0	55.8
	Tailings	70.1	0.026	0.009	26.0	44.2
	Initial	100.0	0.072	0.014	100.0	100.0
3	Concentrate	66.9	0.214	0.025	88.0	75.1
	Tailings	33.1	0.059	0.017	12.0	24.9
	Initial	100.0	0.163	0.022	100.0	100.0
4	Concentrate	70.0	0.232	–	96.6	–
	Tailings	30.0	0.019	–	3.4	–
	Initial	100.0	0.168	–	100.0	–

In the Table 3 we can see, that more than 50% of dump tailings product (by the content of tungsten trioxide) can be separated from the ore. During the testing besides the distribution of WO_3 distribution of molybdenum (Mo) in the separation products was supervised. Its recovering into the concentration was up to 89.5%. Therefore, X-ray luminescent separation of the scheelite lets to recover not only wolfram containing prills, but also other valuable associate minerals. Separation product testing showed, that appliance of separation allows to reduce the carbonate modulus 2.6–3.5 times, which improves the process of floatation and increases WO_3 recovery into the concentrate.

A project of new technological scheme of this deposit is performed in the Figure 2. It was based on the studying of technological samples and on the bases of the experimental-production tests of the upgrading processes and pre-concentration of the wolfram deposit ores.

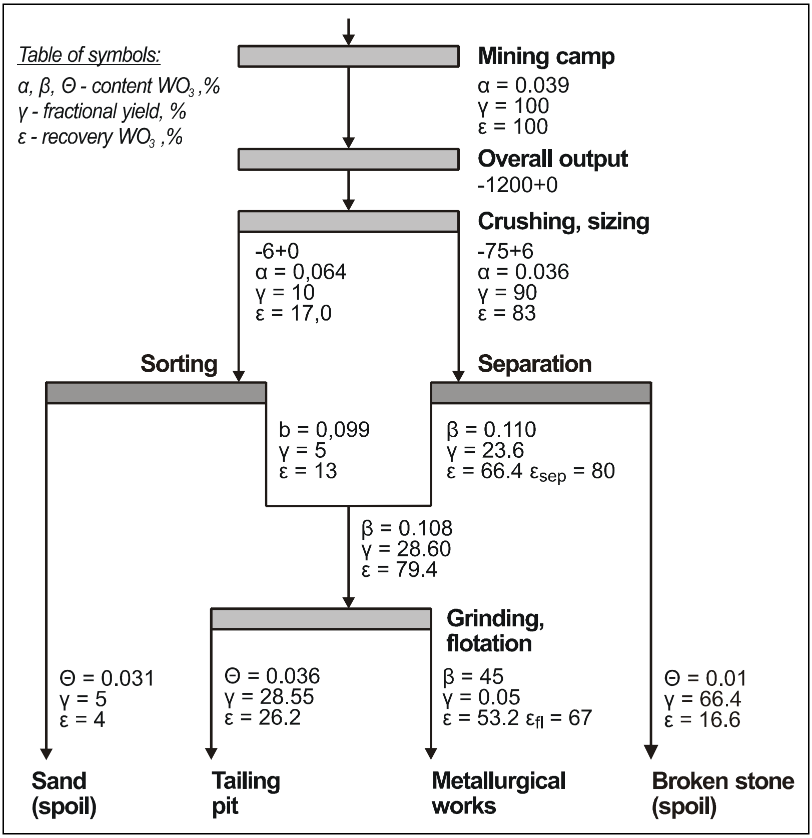

Figure 2. New technology of wolfram deposit mining

New Technology provides bulk mining of the mined rock, which undergoes coarse and medium ragging, is classified according to the size. Prills with the conditioned content of the commercial component is recovered of it with the appliance of the radiometric separation. In the process of the radiometric separation there is homogenizing and upgrading of the initial raw material, which is brought to the concentration plant. That happens owing to removing of the dead rock and harmful impurities, which reduce the effectiveness of the floatation process. In this case, those impurities are calci-spar, limestone and crystalline limestone. Even partial removing reduces carbonate modulus 10 and more times, which sufficiently improves the process of floatation and increases the recovery of the tungsten trioxide into the concentrate.

Noted tendencies are typical not only for rare metal ores, which are characterized by non-uniform distribution of the metalizing process and poor content of the commercial components. They remain and concerning deposits, where commercial components from the geological mineralogical point of view are distributed in the ore relatively uniform, and its content gains to some dozens percent. For example, in the Table 3 there are results of the processing of two technological samples of the fluorite ore of one of the mining-and-processing integrated works. One of the samples performs amenable ore, which comes to the concentration plant, where the fluorite floatation takes place. Another sample is taken from the barrow of the off-grade ores. Fluorite mass fraction in the tradable amenable iron is to be not less than 30%, in the floatation tailings 14–16%. Table 3 shows, that dose of off-grade fraction in the tradable ore of the current production is 30%, when in the barrow of off-grade ore there is up to 30% of off-grade ores, suitable for processing.

Table 3. Fluorite distribution in the portions of conditioned ore of the current production and of the off-grade ore of the barrows of the current production

Type of Raw Material	Group of Portions	Separate Portions	Fluorite mass fraction [%]		Fluorite recovering [%]	
			In the Separate Portion	Gathered	In the Separate Portion	Gathered
Amenable iron of the current production	I	1	72.5	72.5	31.4	31.4
		2–13	46.4	50.2	57.3	88.7
		14	28.4	48.9	3.3	92.0
	II	15	18.9	46.7	2.8	94.8
		16	13.9	44.6	2.0	96.8
		17–20	5.5	36.9	3.2	100.0
Barrow of off-grade ores of the past production	I	1–6	47.15	47.15	70.6	70.6
	II	7	20.6	43.14	5.4	76.0
		8	15.1	39.31	4.2	80.2
		9–20	6.73	19.9	19.8	100.0

In Table 4 technical and economic data of work of mining plant, which produces fluorite using traditional and new ore processing technologies are compared. Traditional technology lies in selective mining of conditioned ore and its processing at the concentration plant by means of floatation into the fluorite concentrate. New technology provides reconstruction of the technological scheme by implementing preliminary concentration on the basis X-ray luminescent prills separation with subsequent finishing of the obtainable concentrate to the necessary condition by means of floatation at the concentration plant. At the same time additional involving of barrows of the off-grade ores of the past productions into the processing is perceived to be. These measures will increase annual production output of the plant (fluorite concentrate) 1.39 times. Besides as additional production the plant will get more than one million tons of road metal, and the volume of ore mining and processing will remain the same; there will be reduction of already existing barrows through their partial processing; the amount of tailings, sent to the tailing dump will be reduced, that means that there will be a definite work done about the improving of the ecological situation in the circuit of action of the mining plant. Implementing of the preliminary prills concentration into the technological scheme of ore processing improves (averages and stabilizes) the quality of the supplied to the concentration plant furnace charge by removing of calcite which in the process of floatation is harmful impurity and it reduces the recovery index. As a result, the volume of processing at reduction and floatation is considerable reduced, throughout recovery gets its 8% increase, relative net cost of processing 1 ton of ore reduces 1.5 times, when the annual volume and cost of the fluorite concentrate output increases 1.4 times.

Table 4. Technical and economic data of fluorite ores mining and processing with the use of traditional and suggested technologies

Data	Unit Measure	Processing Technology	
		Traditional	New
Ore mining and processing volume, including:	Thousand tons/year	1140	2000
– conditioned ore (underground resources)	Thousand tons/year	1140	1140
– off-grade (from barrows)	Thousand tons/year	–	860
Production output:			
– concentrate (92% CaF_2)	Thousand tons/year	259.7	360.7
– road metal	Thousand tons/year	–	1006.3
Fluorite mass fraction:			
– in conditioned ore	%	31.4	31.4
– in barrows	%	–	15.7
Calcite mass fraction:			
– in conditioned ore	%	14.0	14.0
– in barrows	%	–	52.7
Processing volume in reduction and floatation	Thousand tons/year	1140	994
Fluorite throughout recovering:			
– from conditioned ore	%	66.75	74.69
– from barrows	%	–	47.75
Tails volume in tailing dump	Thousand tons/year	881	633
Relative processing cost of 1 ton of ore	%	100.0	66.1
Additional investment into the implementation of new technology. Payback period	A year	–	1.0

Technology of the preliminary upgrading with the use of the radiometric separators is widely implemented in diamond and uranic industries. In Yakutia plants of Stock Company ALROSA for more than 20 years have been using hundreds of luminescent separators processing dozens million tons of raw material with size 1 and more per year. For realization of the technology of preliminary upgrading of different ores LLC EGONT worked out multi-channel separators for prills separation of class −50+10 mm and installation for small-portion grading of class -10+0 mm with the dose dividing from 1 kg and more.

In the Figure 3 there is a scheme of separator for separating prills products of 10 to 50 mm size. Ore is set into the bunker. The first vibrating feeder (VF) with the flat shoe uniformly sends ore to the second VF, which shoes are divided into 4 channels. Due to the motion speed of prills in the second shoe, they all are distributed in ranges and fall down by free-fall ellipse through the X-ray area in the tailing launder. In the X-ray area detectors measure each prill about definite features. If parameters correspond to the preselected ones then electro-pneumatic valve (EPV) blows out the commercial prill, which falls by the usual course into the concentration launder. Each EPV can operate up to 50 times per second. Separators are fully automated, safe for the operating crew and do not have any ecologically harmful subsequences. Technological data of the separator for ores and scrap material separating are performed in Table 5. Detailed information about separators, produced by LLC EGONT, can be found on www.egont.ru.

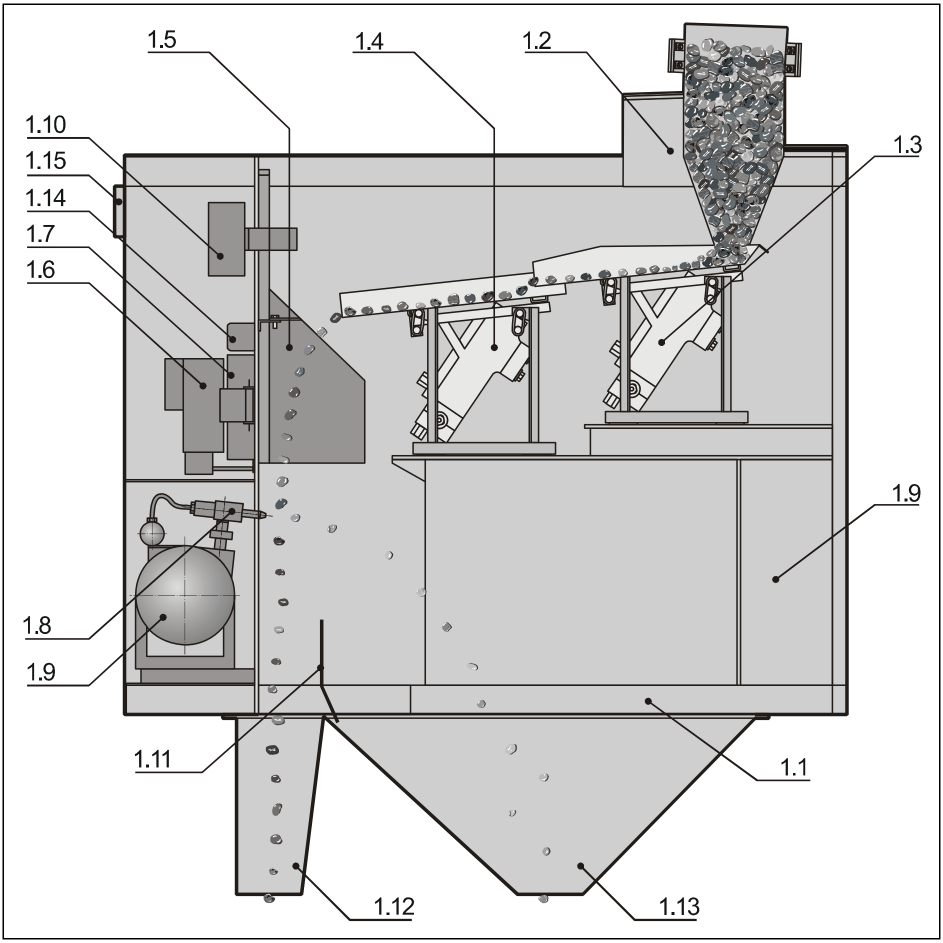

Figure 3. Construction of the separator for separating products of 10 to 50 mm size (LLC EGONT).
1.1. Frame, 1.2. Loading bunker, 1.3. Driving up vibrating feeder, 1.4. Spreading vibrating feeder, 1.5. Separatory curtains, 1.6. X-ray block, 1.7. Registration block, 1.8. Electro-pneumatic valve, 1.9. Air preparation system, 1.10. Electro-pneumatic valve control box, 1.11. Separatory curtain, 1.12. Collecting launder for not upgrading products, 1.13. Collecting launder for the selected by the separator product, 1.14. Indication block, 1.15. Connecting box

Table 5. Technical characteristic of the X-ray spectrum separator РСЭ-50

№	Parameters Title	Unit Measure	Values of Data by Size [mm]	
			From 50 to 20	From 20 to 10
1.	Productivity by separation: – scrap – ores	 t/h t/h	 10 30	 3 8
2.	Content of the separable metals in prills, min – chromium, manganese – sum of iron, copper, zinc	 % %	 5 2	 6 3
3.	Number of separation channels	units	8	
4.	Recovery of commercial prills for 1 approach, min	%	95	
5.	Channel control	–	automated	
6.	Running continuously	h/day	up to 22	
7.	Consumption: – electric energy consumption – compressed air consumption for 1 t concentrate	 kW/h cubic meter	 1.2 25	
8.	Dimensions: – separator – control cabinet	 m m	 1.97×1.22×1.55 0.6×0.6×1.9	
9.	Weight: – separator – control cabinet	 t t	 1.3 0.25	

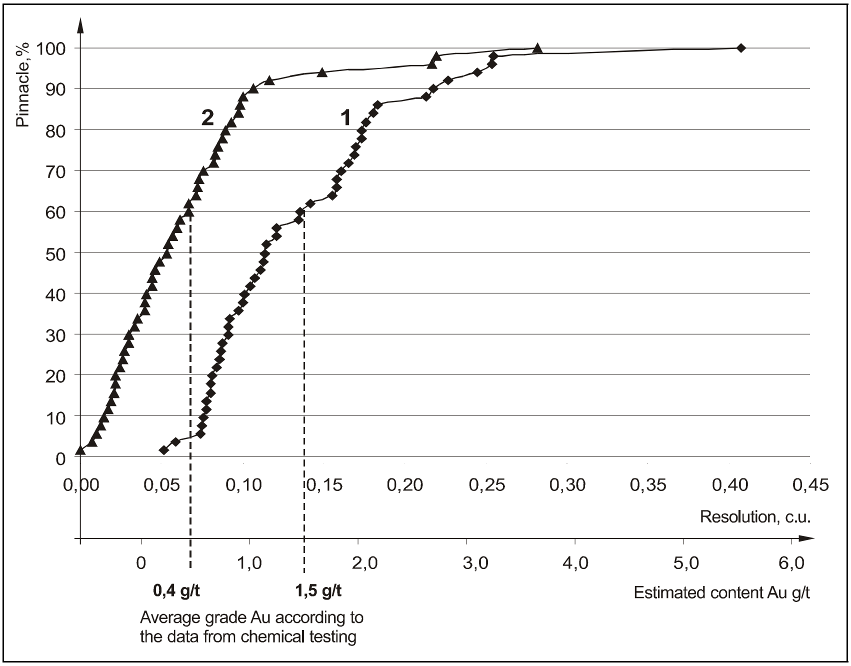

Figure 4. Structuring of conditioned ore (Au = 1.5 g/t) and non-conditioned ore (Au = 0.4 g/t) gold-containing deposit by X-ray characteristics (according to the data from 100 samples)

X-ray spectrum small-portion separation –10+0 mm can be used together with X-ray spectrum separation of prills in size –50+10 mm (Новиков 2008).

Research of small-portion separation opportunities is analyzed on the example with ore of gold-containing deposit, which is characterized by correlation between arsenic and gold. We tested conditioned ore (Au = 1.5 g/t) and non-conditioned ore (Au = 0.4 g/t) –10+5 mm. You can see data on Figure 4.

The samples for research was three folded averaged by coning and quartering method, but as we see on Figure 4, signal level of more precipitate samples differs from the one which contains less gold. We can conclude that by ragging and screen sizing, which must be produced by ore preparation for separation, averaging level will be minor and all mining wastes impurities in the structure of conditioned ore (dikes, proplasts and so on) and non-conditioned ore –10+0 mm will be removed and don't get into payable ore. Therefore conditioned and non-conditioned ore with the usage of prilled separation and small-dosed separation can be processed by the one technological line without their separation into the levels of mining technological works.

In such a way it is possible to control the whole ore stream for small-portion separation and not to exclude implicated empty portions (without commercial component) into further processing. Such technology can be used not only for gold-containing ore but for ferrous and non-ferrous ore as well.

CONCLUSION

Economically rational and fuller exploitation of deposits including its off-grade blocks becomes possible with the advent of radiometric preliminary upgrading based on prills separation and small-portion grading. Thereby rational use of natural resources together with minerals component stock-increasing provide the extension of mining company lifecycle.

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