

## Independent particle and lot selection of increment samples in the theory of sampling

Vladimir Z. Kozin<sup>1\*</sup>, Aleksei S. Komlev<sup>1</sup>

<sup>1</sup> Ural State Mining University, Ekaterinburg, Russia

\*e-mail: [gmf.dek@ursmu.ru](mailto:gmf.dek@ursmu.ru)

### *Abstract*

**Introduction.** *The theory of sampling developed by Pierre Gy does not prove the compatibility and consistency of discrete and continuous selection models. Discrete (independent particle) and continuous (lot) selection models are determined by incompatible properties of increment samples, which prevented from creating the consistent theory of sampling.*

**Research methodology.** *The inconsistencies are removed at assuming the idea that there are differences in both separate ore lumps or mineral-dressing products and any locally selected parts of the rock mass under test called increment samples simultaneously available in any rock mass under test. The said differences are described by independent particle dispersion and increment samples dispersion. Composite sample permissible error formed in both discrete and continuous selection is attained by selection of the number of particles collected into the increment sample or their parts and the number of increment samples. Particle dispersion, increment sample dispersion, the number of particles in an increment sample and the number of increment samples combined in one formula make up the complete formula of the fundamental sampling error.*

**The development of the theory of sampling.** *Based on the complete formula, the possibility of obtaining minimum masses of various sizes has been shown. Thus, for one and the same preset permissible error and from one and the same massif under test, it is possible to collect minimum mass of 17.55 kg (individual particle selection), minimum mass of 170.3 kg (collecting with the bucket sampler), and minimum mass of 10 g under the individual particle selection of particle parts (which is fulfilled under X-ray fluorescent on-stream analysis of material). Discrete selection of increment samples without particles destruction is an especial case of continuous selection method when it is possible to accept the condition that increment samples dispersion is equal to zero. It is possible under ideal mixing of the massif under test.*

**Discussion.** *Minimum mass of a sample is not a constant. It is a function of increment sample mass. Minimum mass in individual particle selection can be accepted as a reference value of the minimum mass. In lot selection it can be significantly higher than the reference one, while in case of reducing particle size it can be significantly lower than the reference one.*

**Key words:** *fundamental sampling error; minimum sample mass.*

**Introduction.** A basic theory of sampling (TOS) [1] providing a basis for the international standards [2, 3] is subject to strong criticism. It is particularly stated that “the theory of Gy fails to provide theoretical and/or experimental proof that two of its major theoretical parts, namely the discrete selection model and the continuous selection model, are compatible and inconflicting” [4].

Both selection models are based on different theoretical prerequisites. Discrete sampling is considered as selection of ideally mixed massif, which makes it possible to deduce a formula of the “fundamental” sampling error (FSE) based on the classical formula of mean dispersion. Transition to continuous selection requires the introduction

of a new parameter of the massif under test characterizing its heterogeneity (the state of being not mixed) which is not considered as a fundamental characteristic. Despite numerous “updates” in the theory, the link between these two selection models has not been revealed and remains unclear [5, 6].

D. S. Dihalu and B. Geelhoed [4] criticized the theory of sampling in especially dramatic fashion. They claim that the existing theory is weak and contains numerous correction factors being not practical enough which impedes or totally eliminates its practical application.

Indeed, after the fullest presentation of Pierre Gy’s theory had been printed in the English language in 1979 and 1982 [1], more than 250 research works [5–8] were published amplifying and refining the theory. Considering the cumbersomeness and complexity of the theory together with undefined or declared coefficients, it should be concluded that the theory is not practical and prevents engineers from making strong calculations and conclusions on sampling.

Alternative and practical theory of sampling was developed independently of Pierre Gy’s works based on fundamental distributions of mass fraction in individual particle selection of increment samples and typical particle particles as well as with the use of engineeringly validated reductions and experimental validation of the coefficients used. It has been shown that the theory of sampling must not only ensure random errors calculation but also the accuracy of sampling results, i. e. the absence of the systematic error; it must also consider the asymmetrical distribution of mass fractions in increment samples. New errors have been injected: probable systematic and procedural errors not considered in the sampling standards [9]. Duplicate sampling [10] and the methods of determining and using the coefficients of variation [11] were criticized; alternative solutions were proposed.

As it was justly noted in work [4], “utopically, a complete and flawless theory of sampling would be a correct synthesis of the insights of the major scientists that have made their contributions throughout the years. We propose to use the term “Theory of Sampling”, or “TOS”, for such a perfect and complete to-be developed theory”.

This article will provide a complete formula of the fundamental sampling error which is absent in Pierre Gy’s theory and shows the compatibility and consistency of discrete and continuous selection models together with the theory’s development which reveals the dependence between the composite samples minimum masses and increment samples masses.

**Research methodology.** The theory of sampling is based on random errors calculation and the determination of sample masses which ensure the permissible error. The existing theory considers the fundamental error of discrete selection and the error of continuous selection to be independent and totally unrelated. This is a critical weakness of the theory. Sampling is always related to two fundamental parameters of the massif under test, as soon as we can observe:

– difference between individual particles which make up the massif under test; this difference is called individual particles dispersion  $S_p^2$ ;

– difference between individual increment samples which contain  $n_{incr}$  of particles collected from the massif; this difference is described by increment samples dispersion  $S_{incr}^2$ .

The two indicated characteristics are congruent in individual particle selection of increment samples, i. e. under  $n_{incr} = 1$ . In this case  $S_{incr}^2 = S_p^2$  and the sampling error is determined by the number of increment samples  $N_{incr}$ :

$$S_\alpha^2 = \frac{S_p^2}{N_{incr}} = \frac{S_{incr}^2}{N_{incr}}.$$

In case the massif under test is ideally mixed, then  $S_{\text{incr}} = 0$ , the fundamental error will be predetermined only by the difference in particles, and  $N_{\text{incr}}$  may be accepted as equal to one, then:

$$S_{\alpha}^2 = \frac{S_p^2}{n_{\text{incr}}}.$$

This instance is congruent with Pierre Gy's Fundamental Sampling Error (FSE).

As soon as the number of particles selected into the increment sample  $n_{\text{incr}}$  is predetermined by the sampling conditions (by samplers), and  $S_{\text{incr}}$  cannot be equal to zero, as a result the fundamental error is predetermined by the difference both in the particle  $S_p^2$  and increment samples  $S_{\text{incr}}^2$ :

$$S_{\alpha}^2 = \frac{1}{N_{\text{incr}}} \left( \frac{S_p^2 - S_{\text{incr}}^2}{n_{\text{incr}}} + S_{\text{incr}}^2 \right) \quad (1)$$

and will be determined by both  $S_p^2$ , так и  $S_{\text{incr}}^2$ .

This expression is the demonstration of discrete and continuous selection models compatibility and consistency being a complete formula of the fundamental sampling error.

In the theory of sampling it is artificially separated assuming that there is instance  $S_{\text{incr}}^2 = 0$  and instance  $S_p^2 / n_{\text{incr}} = 0$ .

But it is not so, individual particle dispersion  $S_p^2$  is high, and despite  $n_{\text{incr}}$  being usually high as well, both items in formula (1) can be comparable.

**Example:**  $\alpha = 2$  g/t;  $\rho_m = 18\,000$  kg/m<sup>3</sup>;  $\rho_r = 3000$  kg/m<sup>3</sup>;  $\beta_m = 10^6$  g/t;  $d_{\text{max}} = 0.5$  mm. Where:  $\alpha$  – mass fraction of gold in ore;  $\rho_r$  и  $\rho_m$  – rock and mineral (gold) density;  $d_{\text{max}}$  – the size of the material under test;  $\beta_m$  – mass fraction of gold in pure metal.

Individual particle dispersion of the exposed material under test is

$$S_{\text{pt}}^2 = \frac{\rho_m}{\rho_r} \alpha \beta_m = \frac{18000}{3000} \cdot 2 \cdot 10^6 = 12 \cdot 10^6 \text{ (g/t)}^2.$$

The coefficient of variation is usually  $V_{\text{incr}} = 50\%$ , then increment samples dispersion is

$$S_{\text{incr}} = \frac{V_{\text{incr}} \alpha}{100 \%} = \frac{50 \% \cdot 2}{100 \%} = 1 \text{ g/t}.$$

$N_{\text{incr}} = 100$  of increment samples with the mass of 0.5 kg has been collected.

The number of particles in the increment sample is

$$n_{\text{incr}} = \frac{q}{f \rho d^3} = \frac{0.5}{0.2 \cdot 3000 \cdot (0.5 \cdot 10^{-3})^3} = 6.7 \cdot 10^6.$$

$$\text{Then } S_{\alpha}^2 = \frac{1}{100} \left( \frac{12 \cdot 10^6 - 1}{6.7 \cdot 10^6} + 1 \right) = \frac{1}{100} (1.8 + 1) = 0.028 \text{ (g/t)}^2.$$

So, discrete and continuous selection models are synthesized in one formula (1), discrete selection model being an especial case of continuous selection model, when  $S_{\text{incr}}^2 = 0$  is accepted.

**The development of the theory of sampling.** Based on the fundamental error, the sample mass is given by

$$q = q_{\text{incr}} \cdot N_{\text{incr}} = q_{\text{incr}} \frac{(S_p^2 - S_{\text{incr}}^2 / n_{\text{incr}}) + S_{\text{incr}}^2}{S_{\text{aperm}}^2} = \frac{S_p^2}{S_{\text{aperm}}^2} q_p + \frac{S_{\text{incr}}^2}{S_{\text{aperm}}^2} (q_{\text{incr}} - q_p) = q_0 + \Delta q.$$

Minimum sample mass in the discrete selection model is  $q_0$  ( $q_{\text{incr}} = q_p$ ) is predetermined by individual particle dispersion, permissible error and the number of particles selected into the sample.

Minimum sample mass in the continuous selection model increases by the value of  $\Delta q$  which depends on the dispersion of increment samples and increment sample mass.

But into the increment sample [12–14] a part of a particle  $\Delta q_p$  can be selected, and in this case

$$q = \frac{S_p^2}{S_{\text{aperm}}^2} \Delta q_p = N_{\text{incr}} \cdot \Delta q_p = \Delta q_0.$$

Consequently, minimum sample mass can be less than  $q_0$ , and under  $\Delta q_p \ll q_p$  it can be low enough, in particular it can be equal to the sample weights for the analysis.

Note that the number of increment samples in  $N_{\text{incr}}$  in this case is predetermined by the individual particle dispersion  $S_p^2$  and will be very high.

In order to estimate the ratios of  $q_0$ ,  $\Delta q$  and  $\Delta q_0$  let us consider the following example.

**Example:** copper ore which enters the mill;  $d_{\text{max}} = 15$  mm;  $d_g = 1.2$  mm;  $b = 1.5$ ;  $\alpha = 0.8\%$ ;  $\beta_m = 34.6\%$ ;  $\rho_m = 4100$  kg/m<sup>3</sup>;  $\rho_r = 3000$  kg/m<sup>3</sup>;  $f = 0.4$ ;  $P_{\text{perm}} = 3.5\%$ . Here  $d_{\text{max}}$  is the size of the sampled rock;  $d_g$  is the size of copper mineral grains;  $b$  – impregnation index (heterogeneous impregnation);  $\alpha$  – mass fraction of copper in ore;  $\beta_m$  – mass fraction of copper in the copper mineral (chalcopyrite);  $\rho_m$  – the density of the copper mineral;  $\rho_r$  – rock density;  $f$  – form factor;  $P_{\text{perm}}$  – permissible relative sampling error.

Minimum mass under the individual particle selection is  $q_0$ .

Lump dispersion of clusters is

$$S_p^2 = S_{\text{pt}}^2 \left( \frac{d_g}{d} \right)^{3-b} = \frac{\rho_m}{\rho_r} \alpha \beta_m \left( \frac{d_g}{d} \right)^{3-b} = \frac{4100}{3000} \cdot 0.8 \cdot 34.6 \left( \frac{1.2}{15} \right)^{3-1.5} = 0.86\%^2.$$

Permissible RMS error is

$$S_{\text{aperm}} = \frac{P_{\text{perm}} \alpha}{2 \cdot 100} = \frac{3.5 \cdot 0.8}{2 \cdot 100} = 0.014\%.$$

Lump mass is

$$q_p = f \rho_r d_{\text{max}}^3 = 0.4 \cdot 3000 (15 \cdot 10^{-3})^3 = 0.004 \text{ kg.}$$

Minimum mass under ideal mixing is

$$q_0 = \frac{S_p^2}{S_{\text{aperm}}^2} q_p = \frac{0.86}{0.014^2} \cdot 0.004 = 17.55 \text{ kg.}$$

The number of increment samples  $N_{\text{incr}}$  in the individual particle selection method equal to the number of particles in the composite sample is 4388.

**Minimum sample mass in continuous selection model.** If a bucket sampler was applied to collect increment samples, then the increment sample mass is predetermined by its structure and is calculated according to the formula:

$$q_{\text{incr}} = \frac{Qb}{\vartheta} = \frac{130 \text{ t/h} \cdot 50 \text{ mm}}{0.6 \text{ m/s}} = 3 \text{ kg,}$$

where  $Q$  is the productivity, 130 t/h;  $b$  is the width of the samplers' slit, 50 mm;  $\vartheta$  is the speed of the bucket crossing the ore flow,  $\vartheta = 0.6$  m/s.

The dispersion of 3 kg increment samples is determined by experiment and makes up  $S_{\text{incr}}^2 = 0.01\%^2$ . The number of the increment samples

$$N_{\text{incr}} = \frac{S_{\text{incr}}^2}{S_{\text{perm}}^2} = \frac{0.01\%^2}{0.014^2} = 51.$$

Minimum mass is

$$q = q_0 + \Delta q = q_0 + N_{\text{incr}}(q_{\text{incr}} - q_p) = 17,55 + 51(3 - 0.004) = 170.3 \text{ kg.}$$

The use of the sampler only has led to the minimum sample mass of 170.3 kg for one and the same massif, which significantly exceeds the minimum mass of 17.55 kg under the individual particle selection of increment samples.

**Minimum sample mass under under increment samples collection with particle destruction.** If for increment samples a part of a partilce with the mass of  $\Delta q_p = 0.000001$  kg will be collected, then minimum mass of the composite sample will be by an order less.

Particles of such size (dust motes) will be exposed, and for them individual particle dispersion is

$$S_{\text{pt}}^2 = \frac{\rho_m}{\rho_r} \alpha \beta_m = \frac{4100}{3000} \cdot 0.8 \cdot 34.6 = 37.8\%^2.$$

The number of increment samples of dust motes will be equal to

$$N_{\text{incr}} = \frac{S_{\text{pt}}^2}{S_{\text{perm}}^2} = \frac{37.8}{0.014^2} = 193 \text{ 000.}$$

Minimum mass in this case is

$$\Delta q_0 = \frac{S_{\text{pt}}^2}{S_{\text{aperm}}^2} \cdot \Delta q_p = \frac{37.8\%^2}{0.014^2\%^2} \cdot 0.000001 \text{ kg} = 0.01 \text{ kg.}$$

As we can see, everything depends on the choice of the particles number (or particle fraction), collected into the increment sample, i. e. on its mass. There can be any increment sample mass, and as a rule, it depends on the chosen instrument for sampling.

**Discussion.** Discrete (individual particle) selection method makes it possible to obtain the minimum mass  $q_0$ , which depends only on the mass the particles  $q_p$  and their properties characterized by the individual particles dispersion  $S_p^2$ .

Continuous (lot) selection model results in the increase in the composite sample minimum mass by the value of  $\Delta q$ , which depends on the increment sample mass  $q_{incr}$  and increment samples dispersion  $S_{incr}^2$  under significant reduction of increment samples number  $N_{incr}$ .

Discrete selection of particle parts  $\Delta q_p$  results in the reduction of the sample mass up to value  $\Delta q_0$  which depends on the mass of the particle  $\Delta q_p$  which is collected into the increment sample and increment samples dispersion  $S_{pt}^2$  under significant increase in the number of increment samples  $N_{incr}$ .

There can be any minimum mass of the composite sample of one and the same mass if under test, from tiny (10 g) to large (170.3 kg). Everything depends on the chosen mass of the increment sample.

It should be noted that the indicated samples: 10 g, 17.55 kg and 170.3 kg were collected with the same permissible random error of 3.5%, but in the first instance 193000 increment samples were collected, in the second instance – 4388, and 51 in the third.

**Summary.** The theory of sampling, based on the idea about the primary nature of increment sample mass which may be randomly picked, it can be a part of a lump or the whole lump or a set of lumps, is consistent. The composite sample selection error for any increment sample mass is described by one formula (1) which includes the number of particles in the increment sample  $n_{incr}$  and the number of increment samples  $N_{incr}$  together with the individual particles dispersion and increment samples dispersion.

Increment sample mass depends only on the sampler chosen for samples collection. As soon as increment sample mass can be changed within wide range, minimum mass can also change in wide range.

Discrete (individual particle) selection model is an especial instance of continuous (lot) selection model when the composite sample can be collected as the increment sample due to ideal mixing. Ideal mixing is not an obligatory condition as soon as the same sample may be collected with individual increment samples.

#### REFERENCES

1. Gy. P. *Sampling of particulate material: theory and practice*. Elsevier: Amsterdam; 1979 and 1982. 431 p.
2. Holmes R. J. Challenges of developing ISO sampling standards. *Fifth World Conference on Sampling and Blending. Conference Proceedings*. Gecamin Ltda, 2011. P. 57–63.
3. Esbensen K. H., Minkinen P. Illustrating Sampling standards – how to guarantee complete understanding and TOS – compliance? *Fifth World Conference on Sampling and Blending. Conference Proceedings*. Gecamin Ltda, 2011. P. 383–392.
4. Dihal D. S., Geelhoed B. A. *Critique of Gy's Sampling Theory*. Available from: <http://vixra.org/abs/1203.0081>
5. Richard Minnitt, Kim H. Esbensen. *Pierre Gy's development of the Theory of Sampling: a retrospective summary with a didactic tutorial on quantitative Sampling of one – dimensional lots*. Available from: <https://www.researchgate.net/publication/314234218>
6. Geelhoed B. *Approaches in Material Sampling*. Delft University Press; 2010. 152 p.
7. Geelhoed B. Is Gy's Formula for the fundamental sampling error accurate? Experimental evidence. *Minerals Engineering*. 2011; 24(2): 169–173.
8. Dihal D. S., Geelhoed B. A new multi-axial particle shape factor – application to particle sampling. *Analist*. 2011; 136(18): 3783–3788.
9. Kozin V. Z. *Sampling of mineral raw material*. Ekaterinburg: UrSMU Publishing; 2011. (In Russ.)
10. Kozin V. Z., Komlev A. S., Stupakova E. V. On the use of duplicate testing to estimate random errors. *Obogashchenie Rud = Mineral Processing*. 2019; 6: 35–40. (In Russ.)

11. Kozin V. Z., Komlev A. S. Determination of variation coefficients of a mass part of components in concentration products. *Obogashchenie Rud = Mineral Processing*. 2019; 1: 28–33. (In Russ.)

12. Liapin A. G. Engineering analytical control over mineral production and processing process. *Gornyi zhurnal = Mining Journal*. 2009; 4: 14–16. (In Russ.)

13. Morozov V. V., Stoliarov V. F., Konovalov A. M. Improving the effectiveness of flotation control with the use of on-stream analyzers of pulp composition. *Obogashchenie Rud = Mineral Processing*. 2003; 4: 33–36. (In Russ.)

14. Zaitsev V. A., Makarova T. A., Barkov A. V., Bakhtiarov A. V., Moskvina L. N. Non-destructive control of the composition of polymetallic ore and concentrates. *Tsvetnye metally = Non-ferrous Metals*. 2006; 8: 60–67. (In Russ.)

Received 10 March 2020

#### Information about authors:

**Vladimir Z. Kozin** – DSc (Engineering), Professor, Dean of the Mining Engineering Faculty, Ural State Mining University. E-mail: gmf.dek@ursmu.ru

**Aleksei S. Komlev** – PhD (Engineering), senior researcher of the Department of Mineral Processing, Ural State Mining University. E-mail: tails2002@inbox.ru

УДК 622.7.09:620.113

DOI: 10.21440/0536-1028-2020-4-54-61

### Покусковой и многокусковой отбор точечных проб в теории опробования

Козин В. З.<sup>1</sup>, Комлев А. С.<sup>1</sup>

<sup>1</sup> Уральский государственный горный университет, Екатеринбург, Россия.

#### Реферат

**Введение.** В теории опробования, разработанной Пьером Жи, нет доказательств совместимости и непротиворечивости дискретного и непрерывного отбора проб. Дискретный (покусковой) и непрерывный (многокусковой) отбор проб определяются несовместимыми свойствами точечных проб, что не позволяло создать непротиворечивую теорию отбора проб.

**Методология исследования.** Противоречия снимаются при принятии положения об одновременном наличии в любом опробуемом массиве различий как отдельных кусков руды или продуктов обогащения, так и любых локально выделяемых частей опробуемого массива, называемых точечными пробами. Эти различия описываются покусковой дисперсией и дисперсией точечных проб. Достижение допустимой погрешности объединенной пробы, формируемой как при дискретном, так и при непрерывном отборе, обеспечивается выбором отбираемого в точечную пробу числа кусков или их частей и числа точечных проб. Обобщение в одной формуле покусковой дисперсии, дисперсии точечных проб, числа кусков в точечной пробе и числа точечных проб и составляет полную формулу фундаментальной погрешности опробования.

**Развитие теории опробования.** На основе полной формулы показана возможность получения минимальных масс разной величины. Так, для одной и той же заданной допустимой погрешности от одного и того же опробуемого массива можно отобрать минимальную массу 17,55 кг (покусковой отбор), минимальную массу 170,3 кг (отбор с помощью ковшового пробоотбирателя) и минимальную массу 10 г при покусковом отборе частей кусков (что выполняется при рентгенофлюоресцентном анализе материала в потоке). Покусковой отбор точечных проб без разрушения кусков является частным случаем непрерывного отбора, когда можно принять условие, что дисперсия точечных проб равна нулю. Это возможно при идеальном перемешивании опробуемого массива.

**Обсуждение результатов.** Минимальная масса пробы не является постоянной величиной. Она является функцией массы точечной пробы. Опорной величиной минимальной массы может быть принята минимальная масса при покусковом отборе. При многокусковом отборе она может быть значительно больше опорной, а при снижении крупности кусков может быть значительно меньше опорной.

**Ключевые слова:** фундаментальная погрешность опробования; минимальная масса пробы.

#### БИБЛИОГРАФИЧЕСКИЙ СПИСОК

1. Gy. P. Sampling of particulate material: theory and practice. Elsevier: Amsterdam, 1979 and 1982, 431 p.
2. Holmes R. J. Challenges of developing ISO sampling standards. Fifth World Conference on Sampling & Blending, Conference Proceedings, Gecamin Ltda, 2011. P. 57–63.
3. Esbensen K. H., Minkinen P. Illustrating Sampling standards – how to guarantee complete understanding and TOS – compliance? Fifth World Conference on Sampling & Blending, Conference Proceedings, Gecamin Ltda, 2011. P. 383–392.
4. Dihalal D. S., Geelhoed B. A. Critique of Gy's Sampling Theory. URL: <http://vixra.org/abs/1203.0081>

5. Richard Minnitt, Kim H. Esbensen. Pierre Gy's development of the Theory of Sampling: a retrospective summary with a didactic tutorial on quantitative Sampling of one – dimensional lots. URL: <https://www.researchgate.net/publication/314234218>
6. Geelhoed B. Approaches in Material Sampling, Delft University Press, 2010. 152 p.
7. Geelhoed B. Is Gy's Formula for the fundamental sampling error accurate? Experimental evidence // Minerals Engineering. 2011. No. 24(2). P. 169–173.
8. Dihalu D. S., Geelhoed B. A new multi-axial particle shape factor – application to particle sampling // Analyst. 2011. No. 136(18). P. 3783–3788.
9. Козин В. З. Опробование минерального сырья. Екатеринбург: УГГУ, 2011. 315 с.
10. Козин В. З., Комлев А. С., Ступакова Е. В. Об использовании дубликатного опробования для оценки случайных погрешностей // Обогащение руд. 2019. № 6. С. 35–40.
11. Козин В. З., Комлев А. С. Определение коэффициентов вариации массовой доли компонентов в продуктах обогащения // Обогащение руд. 2019. № 1. С. 28–33.
12. Ляпин А. Г. Инженерно-аналитический контроль технологий добычи и переработки минерального сырья // Горный журнал. 2009. № 4. С. 14–16.
13. Морозов В. В., Столяров В. Ф., Коновалов А. М. Повышение эффективности управления флотацией с использованием поточных анализаторов состава пульпы // Обогащение руд. 2003. № 4. С. 33–36.
14. Зайцев В. А., Макарова Т. А., Барков А. В., Бахтияров А. В., Москвин Л. Н. Неразрушающий контроль состава полиметаллических руд и продуктов обогатительного цикла // Цветные металлы. 2006. № 8. С. 60–67.

Поступила в редакцию 10 марта 2020 года

#### Сведения об авторах:

**Козин Владимир Зиновьевич** – доктор технических наук, профессор, декан горно-механического факультета Уральского государственного горного университета. E-mail: [gmf.dek@ursmu.ru](mailto:gmf.dek@ursmu.ru)  
**Комлев Алексей Сергеевич** – кандидат технических наук, старший научный сотрудник кафедры обогащения полезных ископаемых Уральского государственного горного университета. E-mail: [tails2002@inbox.ru](mailto:tails2002@inbox.ru)

**Для цитирования:** Козин В. З., Комлев А. С. Покусковой и многокусковой отбор точечных проб в теории опробования // Известия вузов. Горный журнал. 2020. № 4. С. 54–61 (In Eng.). DOI: 10.21440/0536-1028-2020-4-54-61

**For citation:** Kozin V. Z., Komlev A. S. Independent particle and lot selection of increment samples in the theory of sampling. *Izvestiya vysshikh uchebnykh zavedenii. Gornyi zhurnal = News of the Higher Institutions. Mining Journal.* 2020; 4: 54–61. DOI: 10.21440/0536-1028-2020-4-54-61