

### ***Relevance***

The solution to the problems of quality and competitiveness of industrial enterprises is based on rationalization and the use of the latest information modeling technologies in order to modernize existing and create new facilities taking into account the latest requirements.

The current project solves a topical scientific problem – creation, development of information models (IM). An algorithm for creating information models from a conceptual mathematical model to special configurations of a computer model has been built. Verification of information models with real technologies Vanyukov, ISASMELT™, Ausmelt, ElTeniente, Salvador, Mitsubishi, QSL, Outokumpu, KIVCET has been carried out. For each technological scheme of copper, lead, zinc, tin production, an information model has been developed taking into account the indicators of the content and extraction of the target component at each level of its hierarchical structure. Topics related to the verification and certification of software used to develop information models have also been touched upon.

### ***Project goal***

Development of an information model for managing production processes based on the fundamental law of conservation of the sum of information and entropy; verification of an information model for managing production, covering all technological stages of mining-enrichment-smelting-converting-rough refining-electrolytic refining in non-ferrous metallurgy; creation of a reference model of production in the context of generating scientific, technical and socio-economic reserves at the micro, meso, and macro levels.

### ***Expected and achieved results***

The current project solves a relevant scientific problem – creation, development of information models (IM) based on the principles of mathematical modeling, information theory, computer modeling, theory of metallurgical processes. An algorithm for creating information models from a conceptual mathematical model to special configurations of a computer model has been built. The proposed approach is based on a hierarchical scheme of modeled production processes with an end-to-end technology: mining – enrichment – smelting – converting – rough refining – electrolytic refining. The project is interdisciplinary. To solve the problems set in the project, a connection of 7 different disciplines was carried out, each of which has its own subject, object, research methodology: mathematical modeling; computer modeling; programming; statistical data processing and analysis; physicochemical methods of analysis; theory of metallurgical processes; metallurgy of ferrous, non-ferrous and rare metals. The project employs DataScientists – mathematicians and physicists, programmers and metallurgists. The project's executors are specialists in mathematical modeling, physical modeling, programming, machine learning, optimization methods and complex data analysis methods, they consult on production technologies and help to correctly interpret data. Our product - information models integrated into the production process and allowing to work more efficiently - can be created only thanks to the collective participation of all the listed departments.

The scientific novelty of the research conducted consists in the creation of new mathematical models and software modules for the development of information models covering all technological stages in the production of non-ferrous metals: mining-enrichment-smelting-converting-rough refining-electrolytic refining.

Scientific developments, hypotheses, and project ideas are new.

The adequacy and correctness of the mathematical model has been proven. The developed information model is intended to solve current problems of socio-economic and scientific-technical development of the Republic of Kazakhstan, balanced risk management of mining and metallurgical enterprises.

In 2024, a mathematical model was developed for upgrading existing and creating new process flow charts in the production of non-ferrous metals; an IM was developed for process stages of copper production for the content and extraction of the target component at each level of the Vanyukov, Outokumpu, Salvador, ElTeniente schemes. The scientific novelty of the research consists in the creation of new mathematical models and software modules for the development of information models covering all process stages in the production of non-ferrous metals from mining to electrolytic refining in order to obtain an industrial product of the required quality. Wolfram Mathematica was used to construct and visualize diagrams, graphs of functions of one or more variables, networks, graphs, geographic information, interactivity and movement in any of the classic formats.

In 2025, an information model (IM) of technological stages of lead production was developed based on the content and recovery of the target component at each level of the ISASMELT™, KIVCET, and Mitsubishi process flows. The hierarchical structure of lead production companies was studied, and a mathematical model of the

technological processes of lead production for ISASMELT™, KIVCET, and Mitsubishi was created.

A physico-mathematical model of the hierarchical structure of lead production companies was developed.

An algorithm was designed and implemented to verify the ideal hierarchical scheme against the structure of actual production processes using the example of lead production stages: mining–beneficiation–smelting–converting–crude refining–electrolytic refining.

A hierarchical scheme of lead production companies with real technological processes and flowsheets was developed and verified.

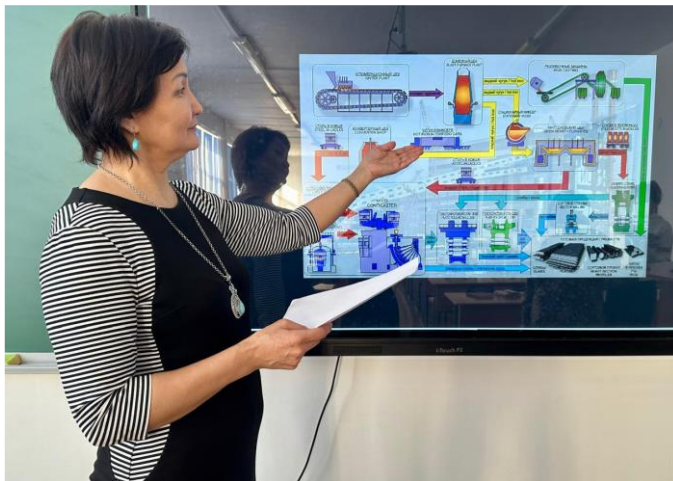


Figure 1. At the seminar "Information Technologies in metallurgy"



Figure 2. Discussion of research results

### **Research group**

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### **List of publications**

For the period from 2024 to July 2025, the following scientific articles were prepared and published in accordance with the calendar plan: 2 articles in a peer-reviewed domestic publication recommended by

the KOKNVO:

1) Кажикенова С., Беломостной Д., Шайхова Г., Шалтаков С., Салхаева Д. Труды Университета, 1 (98), 2025, 64 -72 - "Влияние на структуру и свойства расплавленных систем ультразвуковой обработки"

2) Kazhikenova S., Shaikhova G., Shaltakov S. Eurasian physical technical journal, 2025, 22, 1(51), 93-102 – «Investigation of some physical and structural properties of melts by ultrasounds».

2 articles in peer-reviewed scientific journals included in the Web of Science and Scopus:

3) Kazhikenova S., Shaikhova G., Shaltakov S. Arch. Metall. Mater., 70 (2025), 1, 499-507 – «Influence of temperature on ultrasound absorption and structural properties of melts»

4) Kazhikenova S. Journal of Information Systems Engineering and Management, 10, 43s (2025), 932-938 - «Complex entropy-informational criteria in ferrous metallurgy»

report in the proceedings of the International Conference

5) Kazhikenova S. «Proceedings of International Conference 2025», 14-16, Adana, Turkey, 14th - 15th April, 2025.

Certificates of entry of information into the state register of copyrighted objects have been obtained:

1.Шайхова Гульназира Сериковна, Кажикенова Сауле Шаратовна "Использование аналитической геометрии при решении прикладных задач в математическом моделировании по горно-металлургической специальности" (работа финансируется Комитетом науки Министерства образования и науки Республики Казахстан (ИРН AR23486482)) No 50531 от "17" октября 2024 г.

2.Шайхова Гульназира Сериковна, Кажикенова Сауле Шаратовна, Шалтаков Сагындык Нагашибаевич «Использование элементов линейной и векторной алгебры при решении производственных задач по математическому моделированию по горно-металлургической специальности (работа финансируется Комитетом науки Министерства образования и науки Республики Казахстан (ИРН AR23486482) с «01» ноября 2024 года

### ***Information for potential users:***

The developed information model is designed to solve urgent problems of socio-economic and scientific-technical development of the Republic of Kazakhstan, balanced management of mining and metallurgical enterprises. The target audience is enterprises of the mining and metallurgical industry. Information models integrated into the production process make it possible to implement new production solutions cheaper and easier, develop new products with lower economic costs; will reduce the labor intensity of engineering by up to 40% when developing the second and subsequent projects, obtain an expert assessment of metallurgical production in terms of generating scientific, technical and socio-economic reserves at the micro, meso and macro levels.

### ***Application area:***

The target audience is enterprises of the mining and metallurgical industry.

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