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## A ANALYSIS AND CLASSIFICATION OF RESOURCE SAVING TECHNOLOGIES FOR REPRODUCTION OF MINERAL RESOURCES OF TITANIUM INDUSTRY

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At present self-sufficiency in mineral feedstock of the Russian economy has dropped significantly, with some types of mineral feedstock becoming extremely scarce after the collapse of the USSR.

Analysis of mineral resource base of the companies of titanium-magnesium, chemical, paint and varnish and other sectors of industry, producing titanium products, has shown that these sectors have almost no titanium feedstock of their own production, even with account of titanium low consumption.

The use of resource saving technologies instigates creation of new forward-looking methods for reproducing mineral resource base of the titanium industry by bringing new, unconventional types of extractable resources into the economic turnover and is one of main ways to increase the natural resource potential of the industry. A rational combination of modern highly productive machinery and resource saving technologies is the only possible way for the development of a number of valuable extractable resources, including titanium dioxide.

The paper gives an overview of key aspects of the modern resource saving technologies for expansion of reproduction in the basic industries. An idea is put forward to recreate the titanium industry resource base in the Russian Federation based on the modern resource saving technologies. A classification of the modern resource saving technologies is proposed.

**Key words:** resource saving, titanium dioxide, industrial strategy, complex use.

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**Introduction.** Basic sectors of titanium industry today are characterized by technological multistructurality. Along with productions having state-of-the-art machinery and using relatively new technologies, there are still productions with morally and physically obsolete equipment and technology of material intensive and resource consuming nature. Such technologies are no longer driving the economic growth. Increase in the number of such productions leads to the lower efficiency of the industry. Some companies and plants with modern equipment and technology which can potentially become drivers of future economic growth are mostly oriented for manufacturing of products for military-industrial complex of the country. Such productions are to some extent loaded with state orders. But with a trend towards curtailment of production in the sectors of military-industrial complex, the share of state orders is relatively small. Due to poor current adaptation of such companies to the conditions of market economy, their production and economic potential weakens and they lose a potential possibility to act as economic growth drivers [7].

In creation and application of modern resource saving technologies in mining and processing industries, including for complex use of titanium-containing feedstock, the decisive factor is implementation of a resource saving strategy in the economy and transition to economic growth of a higher quality.

Implementation of a resource saving strategy in the mining industries helps to requalify certain types of extractable feedstock from inefficient or low efficient to highly efficient, expand and strengthen the natural resource potential of the industry by introducing new types of mineral feedstock to the industrial production and secure acceleration of the process of mineral resource base reproduction. The use of modern resource saving technologies shall lead to a leap-ahead break-through effect, giving the country economy, certain industrial sector or enterprise a new quality of economic growth driven by predominantly intensive development factors [11].

Besides the direct economic effect implementation of resource saving technologies produces a secondary economic effect in adjacent and related industries and selected areas of the economy. In addition



conditions are created for getting intangible effect on a nationwide scale (securing the country's economic independence due to refusal from import products, improving its defense capacity, etc.) Thus, the effect of applying resource saving technologies is wave-shaped.

Though currently there are no specific technical solutions tested in field conditions for resource saving technologies, this should not be a reason for not making strategic decisions on the development and implementation of resource and energy saving technologies. [19] With the current state of science and technology both in the Russian Federation and abroad almost any technical issues related to the equipment and technology compatibility can be addressed. Backlog of Russia in this respect in some of the areas is mainly a consequence of a number of objective factors of economic development in the context of administrative economic system, when the scientific and technological advances were rejected by this system and a problem of their 'implementation' emerged, which in conditions of the departmental disunity and economic independence could not have brought any positive results [1, 2].

**Classification of resource saving technologies.** The management of scientific and technical progress and the use of its achievements in the present conditions of market relations formation is mainly based on economic interest. An issue of expanding the scope of resource saving technologies application can be addressed both on nationwide scale and at cross-industry and sectoral levels.

It shall be mentioned here that the production capacity of resource saving technology has certain limits. Limitation of production capacities is a consequence of limited economic resources. Each resource unit has a certain output capacity, determining the efficiency of its use. The output capacity has certain limits. For example, even when the most perfect resource saving technology is used, it is impossible to get more titanium dioxide from one ton of titanium-bearing ore than is actually contained in this ton. The maximum possible product output with a given volume and structure of available resources, intended for production of this certain product is the limit of production capacities. The limit of production capacities can be described with a production capacities curve. Production capacities curve may shift, expanding or narrowing the capacities. This happens when the total available economic resources, including natural resources, increase or decrease, or specific resource consumption per unit of end product is increased or decreased. This is almost identical to decrease or increase of resource capacities of the industry [3, 4].

Thus when more advanced resource saving technologies are applied, the costs per unit of end product with the same total resource volume are less, that ultimately leads to an increase in natural resources and expansion of production capacities.

Therefore, the use of obsolete 'resource-wasting' technologies decreases the production capacities of certain industries and leads to a loss of valuable resources.

The mentioned above and other features of the resource saving technologies can be grouped by certain classification criteria:

1. By length of implementation period: long-term; mid-term; short-term.
2. By economic effect of implementation: with direct effect; with direct and secondary effect; with wave-shaped effect.
3. By purpose: strategic tactical.
4. By capital intensity: capital-intensive, science-intensive.
5. By impact on the market: creating new markets, helping to enter the global market; increasing capacity of the new market.
6. By implementation medium: cross-sectoral; sectoral; corporate; company-specific.
7. By implementation efficiency: national economic; budgetary; commercial.
8. By degree of novelty: developed based on inventions; developed based on R&D; developed based on existing technologies.
9. By degree of validation: validated in industrial conditions; passed pilot production tests; short-term; developed in laboratory conditions.
10. By basic elements: based on new sources of energy use new types of feedstock, materials.

Classification is built based on ten groups of classification criteria, with each group further divided into subgroups. Classification of resource saving technologies can serve as a starting point for



improving material and production potential of the industry and determining a sequence of resource saving technologies selection for developing an industrial strategy for reproduction of the mineral resource base.

The modern paradigm and the fundamental principle of complex use of extractable resources, including titanium-containing ores, is elimination of the resource-wasting technologies and lower consumption of economic resources per unit of product throughout the entire process chain from ore mining and beneficiation, including stages of chemical and metallurgical processing, to getting the end product. The complex use of feedstock is first of all based on economic interests – an intention to produce the maximum volume of product of higher consumer value at lower cost of material, financial and non-material resources [10, 12].

The dependence of the costs and benefits on the natural conditions and economic (social) factors of production in nature-exploiting industries is especially distinct, can be quantified and commensurable, and should be reflected in the method for determining the total economic potential of the national economy.

Reproduction of natural resources, including the mineral resources, is not only and not so much a technical process, as an economic one. Moreover natural resources become reproducible when turned into such in economic sense. Meanwhile there are some external factors impacting the process of mineral resource base reproduction, including: restricted volume of investment; capacity of the domestic and global markets with regard to the products manufactured from this type of products manufactured from this raw material; size of acceptable equilibrium estimates for these kinds of products, competitiveness, production capacity and consumption of similar and interchangeable products, etc. Expanded reproduction of the mineral resource base of the country will require higher investments in the short term already materialized in the renovated fixed assets and application of resource saving technology for the manufacturing of each unit of product.

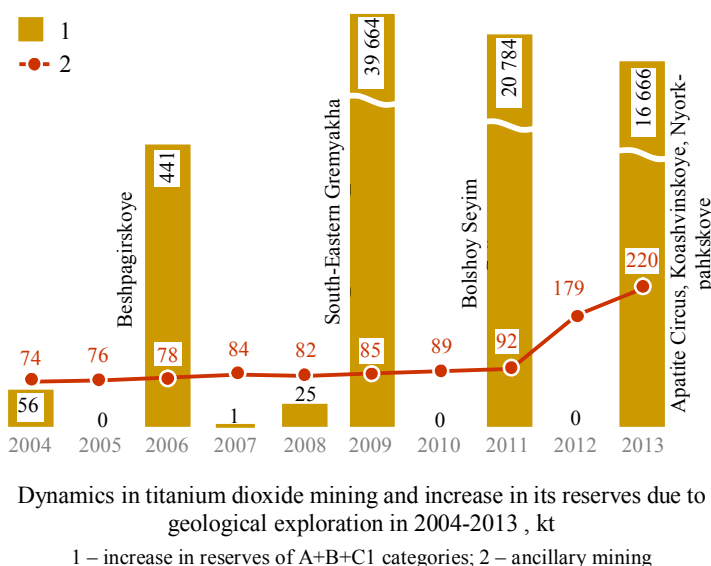
Therewith reduction of impact of favorable natural factors or diminishing natural ‘fertility’ of the extractables shall be offset by a higher impact of additional investments. This will lead to a reduction of total direct and materialized labor costs per unit of end product and creation of favorable ‘supernatural’ factors playing the role of additional drivers of economic growth. Consequently resource saving technologies shall meet specific requirements that emerge under the concurrent influence of natural, economic and other external factors.

**Application of resource saving technologies for reproduction of mineral resources of titanium sector of industry.** Such resource saving technologies shall be created that would rocket sky-high the labor productivity, not only neutralizing the adverse effects of natural factors on economic development, but also creating a favorable context and conditions for the industry transition to economic growth of a new quality.

In these conditions a need appears in economic assessment of new types of extractable resources, including titanium-containing feedstock, processed using resource saving technologies, i.e.

the quantification of consumer value, public utility of end products and national economic effect produced thereby.

Thus, the government for the first time accounted for 16.666 mln t of reserves of titanium dioxide of A+B+C1 categories and 5.728666 mln t of reserves of C2 category concentrated in the apatite-nepheline deposits Apatite Circus, Koashvinskoye and Nyork-pahkskoye in the Murmansk region in the state balance included in the State Report on Subsoil Resources. Due to this the explored reserves of titanium dioxide increased by 7 % in 2013 (is shown on Figure) versus 2012; and the inferred reserves increased by almost 2 % [2].





Analysis of discovered, explored and operated deposits of titanium-bearing feedstock and prospects of their complex utilization for production of pigment titanium dioxide revealed [5, 6], that reserves of traditional titanium-bearing feedstock in the Russian Federation are rather scarce. Besides their quantity is not complying with the standards, complicating their processing and making it impossible to produce high quality titanium dioxide of required grades [1].

The process flow for complex use of titanium-magnetite ores based on the resource-saving principle includes the following steps: ore beneficiation by dry and wet magnetic separation with extraction of a single collective iron-titanium-vanadium concentrate [9, 12]; this concentrate pelletizing with preliminary roasting for reduction of iron oxides; electric smelting of metallized pellets in ore-smelting furnaces to produce vanadium-containing cast iron and titanium slag; vanadium iron purging in converters for its devanation [8] resulting in steel and vanadium slag product; steel product treatment by duplex process 'converter-electric furnace' for the production of high-quality steel naturally alloyed with vanadium and titanium; processing of titanium slag using sulfuric acid technology with release of the pigment titanium dioxide; processing of vanadium slag to produce ferrovanadium [5].

**Conclusion.** Specific features of the resource saving technologies can be grouped by certain classification criteria. Classification of resource saving technologies can serve as a starting point for addressing an issue of improving material and production potential of the industry and first of all of its basic sectors.

Based on presented technology for complex use of titanium-magnetite ores new previously not used types of titanium-containing feedstock are introduced in the economic turnover. Industrial experiment works and research carried out in the recent years demonstrated that the use of non-conventional sources of titanium feedstock for production of pigment titanium dioxide has a number of significant advantages. The end product manufactured under this technology has higher quality compared to similar product manufactured under conventional technology from conventional types of titanium feedstock. This technology allows to widen a range of extracted useful components and a range of products manufactured from one unit of source feedstock. All this helps to accelerate the process of extensive reproduction of mineral resources of titanium-consuming industries and increase the material and production potential of titanium sector of non-ferrous metallurgy. Justification of a rational sectoral structure of establishment and development of cross-sectoral industrial complex is one of the most critical and complex challenges of the regional economy.

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