

Current state of production and consumption of rhenium abroad

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Abstract. The relevance of the article does not raise any doubts, especially in the context of modern consumption of rhenium. Rhenium is an industrial metal that has gained increasing recognition and is widely used not only in Russia but also in foreign countries, mainly in the form of alloys with other elements, imparting special physicochemical properties to alloys based on wolfram and molybdenum. The most popular alloys with the addition of molybdenum and tungsten are recognized. Adding of a minor amount of rhenium reduces the transition temperature of wolfram and molybdenum to the fragile state and at the same time makes it possible to maintain elasticity at high temperatures. The objective of this article is to analyze the demand for rhenium abroad and its production by analyzing the market for mineral raw materials, by studying reports, literary sources, reports of companies for the production and consumption of rhenium, which are leaders in their field of activity. The article presents the results of the analysis of rhenium global production and consumption.

1 Introduction

New rhenium alloys for various purposes and their production technology are being developed, the scope of research works is being expanded, which allow opening up new possibilities of using rhenium and its alloys, which are becoming more widely used in the field of electronics, electrical engineering, atomic and rocket technology. This greatly stimulates the development of mining and production of rhenium [1, 2]. Consumption of metal is continuously increasing, the scale of its output and production capacity of rhenium plants, as well as the number of suppliers and consumers of rhenium products have increased significantly. The range of rhenium products has become much more diverse, especially due to alloys, etc.

2 Production analysis

Among foreign countries, the extraction of rhenium from mineral raw materials is carried out in the USA, Germany, Great Britain, France, Belgium, etc. Some types of products made from metallic rhenium and its alloys are manufactured in Japan, Canada, Holland and other countries.

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By 2020, rhenium production abroad increased by 9 % compared with 2015. This happened mainly due to a significant increase in the output of rhenium in the USA, which is the largest producer and consumer of this rare metal in the world. In 2020 the United States produced approximately 72 % of all rhenium. From 2015 to 2020, the production in this country almost doubled and amounted to 23120 kg per year, and consumption reached 25140 kg per year (Fig. 1). The demand for this metal in the world is very high with limited mineral resources [3].

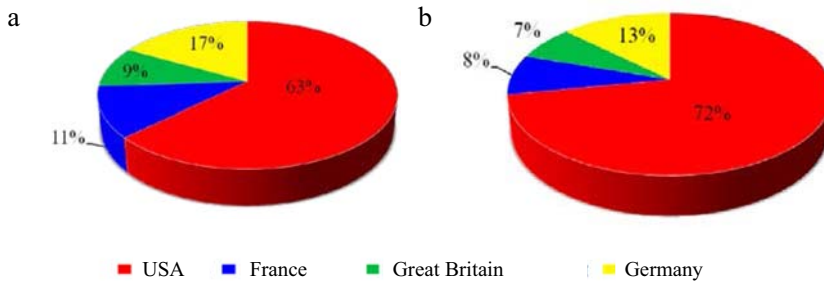


Fig. 1. The share of foreign countries in rhenium production a–2015; b–2020.

Taking into account the plans of some companies to expand their capacity, it can be assumed that if there is such demand for this metal, the production of rhenium in salts at US steel mills may increase by about 3–4 tons per year in the coming years [3].

There are six main foreign companies that produce rhenium salts from concentrate: «Engelhard Industries Limited» (Great Britain); «Degussa, W. G.»; «Haraeus G Mb. H.»; «Hermann G. Starck Berlin» (Germany), «Molybdenum Corp. of America» и «Shattuck Chemical Co» (USA). The biggest producer of rhenium products in Europe is Herman S. Starck Berlin (Germany), whose production capacity in 2015 was 3,3 tons of rhenium powder per year. Even American companies are the main suppliers of rhenium salts to the US market; their installations had a capacity of more than 2 tons of rhenium per year in 2020. The world's largest producer of rhenium metal, its alloys and products from them is the American company Chase Brass, which has a significant reserve of equipment, which will allow increasing the output of the metal to 5 tons per year [8]. Moreover, the United States purchases a large amount of rhenium throughout the world, thereby increasing the reserves of this metal (Fig. 2). [4]

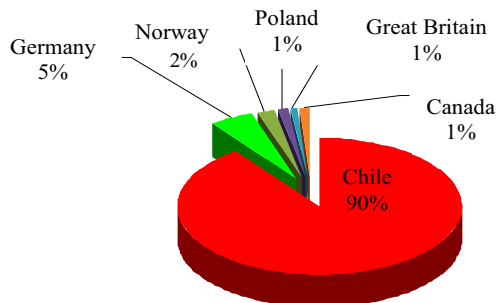


Fig. 2. The countries supplying rhenium mineral to the US market.

Along with the expansion of production at existing plants, new capacities for the production of rhenium are putting into operation. Hoboken, a Belgian company, has started the industrial production of rhenium from semifinished products from the processing of

ores in Congo (Kinshasa). The capacity of the installation the company set up is several hundred kilograms of metal per year. The world's largest rhenium workshop operates in Garfield (USA), at the plant of Kennecott Copper Co., which produces molybdenum oxide for iron and steel industry from molybdenum industrial products isolated from copper porphyry ores. The annual productivity of this workshop is 1816 kg of rhenium in salts. Molybdenum Corp. of America plans to organize the extraction of this rare metal from the molybdenite deposits of the Quest field, the average concentration of rhenium in which is 0,03% [1–4].

According to the latest data, it can be assumed that the output of rhenium in the world may increase twice or even more by 2020. At the same time, the share of the United States in the production of metal may increase significantly

3 Results (Projections of rhenium global production)

There are favorable conditions for the further production of rhenium: real raw materials, a reserve of capacity for the production of rhenium products, and metal consumers. Every year the deepening research in the field of rhenium application increases the potential of their industrial usage.

There are also problems that restrict the development of rhenium production. The main problem is the significant increase in demand for rhenium, the successful solution of which will determine the further rate of expansion of industrial output and consumption of this metal.

Heavy prices for rhenium products significantly limit the possibility of its industrial implementation. In 2015 in the United States, metal rhenium powder is 11 times the price of beryllium by, tantalum by 20 times the price of, 60 times the price of niobium, 120–130 times the price of tungsten, 165–170 times the price of molybdenum powder [3,4]. Due to the high cost, the use of rhenium abroad is limited to the manufacture of the most important parts of missiles, missile and projectile control systems, nuclear plants, electronic, electrovacuum and electrical equipment, where a small amount of metal provides high performance. Due to the current price of rhenium such industries as textile, shipbuilding, chemical, etc., cannot consume the large amount of it and still are the areas of its potential use.

Limiting the possibilities of increasing the demand for rhenium in turn inhibits the development of rhenium production. In some years, the value of consumption lags behind production, and the scale of actual production is significantly less than the production capacity of installations (in the USA – by 5–6 times, in the countries of Western Europe – about 6 times). [4-8]

The solution to the problem of increasing the demand for rhenium abroad is carried out by a wide range of activities covering all aspects of the production and industrial introduction of the metal. The efforts of scientists and companies are directed towards achieving a reduction in the cost of rhenium products and carrying out measures to expand the consumption of rhenium while maintaining high prices for it.

From 2016 to 2020 there has been a profit of the US market, as the capacity increased, the demand was insufficient and part of the raw material was sent to the stocks. From late 2014 to 2016, there was a shortage of rhenium due to increased demand from the aerospace industry. This demand has been offset from accumulated stocks. According to the forecast of the Roskill Research Institute, the consumption of rhenium in the world will only increase every year. The main reason for this is the need for production of gas turbines for aircraft jet engines.

According to the Boeing Company, air traffic will grow by an average 5 % per year over the next two decades, and freight traffic will grow by an average 5,2 % per year. In

addition to these figures for civilian aircraft, military investments in high-tech aircraft will lead to a further increase in the production of jet engines.

In its review of the aircraft market Boeing states that investors of the largest aircraft markets will provide funding for another year of record production of airliners in the world. The total value of commercial aircraft supply contracts can reach \$112 billion, while Boeing and its European competitor Airbus will occupy 95 % of this market.

Analyzing the pricing of this metal (Fig. 3), it can be noticed that there was a significant decrease in prices for rhenium salts and metal powder in the USA and European countries from 1972 to 2006 [11]. It was a period of industrial development of their production; accumulated reserves allowed to reduce prices, which greatly stimulated the increase in demand for the metal.

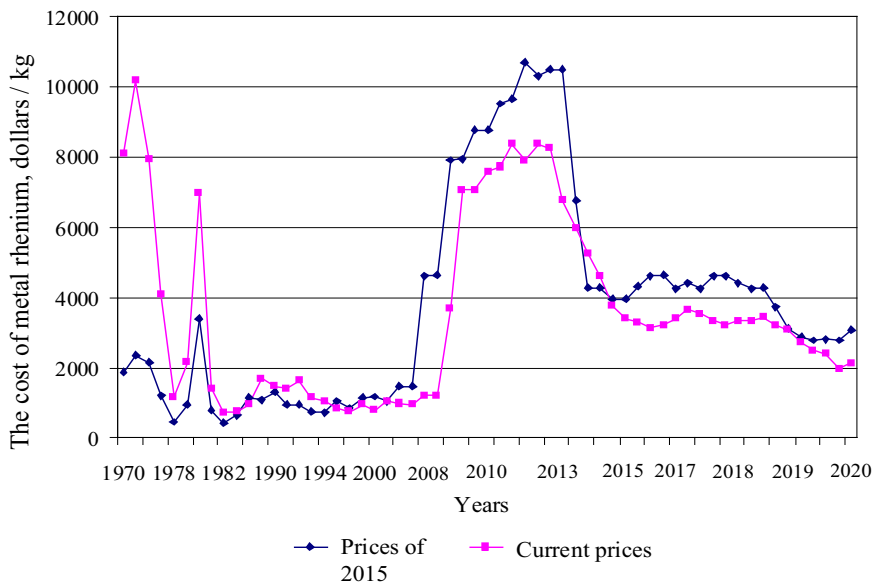


Fig. 3. Dynamics of prices for rhenium products in the USA and the EU.

In the future, prices for these types of rhenium products were at the same level. During this period, much attention was paid to the development and mastering of technologies for the production of alloys from them, as well as to improving the technology for production of rhenium powder and high-purity ingots, etc., that is, all efforts were aimed at expanding consumption of rhenium without reducing prices by implementation of cheaper rhenium alloys into production, meeting industry's demand by expanding the product range, improving quality, and organizing more effective rhenium products marketing campaigns, by more efficient use of the metal and so on.

From the end of 2010 to 2014, the price for rhenium products reaches \$12000 per kg, which is due to the consumption of this rhenium in space superalloys. Since the end of 2015 there has been a gradual decline in the price of rhenium products, less than \$ 4000 per kg (at current prices).

Alloys play a significant role in solving the problem of increasing the demand for rhenium, as their production is the largest rhenium consumer abroad. This can be clearly seen at the example of the United States (Fig. 4) [4].

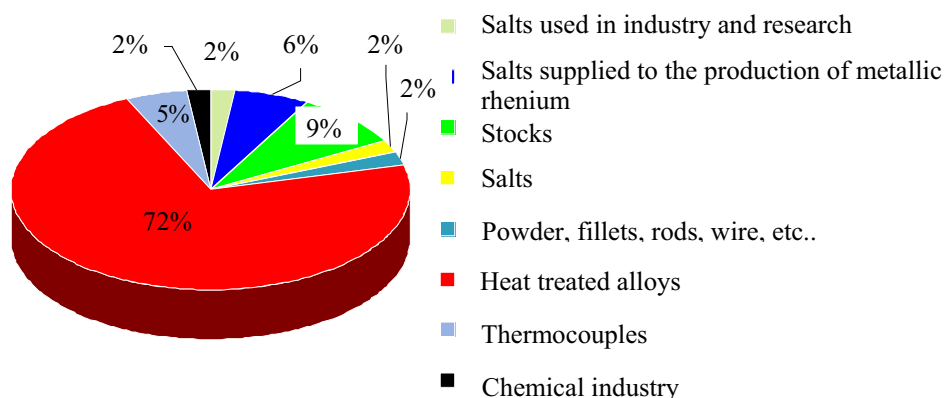


Fig. 4. Structure of consumption of rhenium products in the USA (2018).

In 2018 in the United States, 72 % of the total rhenium sold in the country was used to manufacture heat-resisting alloys, mainly with wolfram and molybdenum [12].

Alloys of rhenium with wolfram and molybdenum are now widely used in industry. Abroad, the main areas of consumption are electronics (parts of vacuum tubes, parts of thermionic energy converters, filaments, etc.), electrical engineering (thermocouples for measuring high temperatures, electrical contacts, etc.), aerospace equipment (parts of thermionic engines, nose rocket cone, parts of rocket nozzles, etc.), nuclear technology (thermocouples, radiation protection equipment, reactor structural parts, etc.). In addition, rhenium is used in welding (filler rods in welding molybdenum and wolfram), in manufacturing of coatings for various purposes, in the chemical industry (catalysts). The growing need of industry for alloys greatly stimulates the development of the production of rhenium and determines the scale of its consumption. So, in the USA in 2018 the consumption of metallic rhenium for the production of alloys was twice as much as in 2011. This was caused by the choice of other alloys by the Atomic Energy Commission of the USA: wolfram with 25 % rhenium and W alloy – 30 % Re – 30 % Mo for use as a structural material for many types of space nuclear reactors.

Great importance is attached to the development and introduction into industry of rhenium alloys with the smallest rhenium additives. As an examples the following alloys can be mentioned (%): W–1, 5Re (instead of W–3Re) for the electrovacuum industry; Ta–8W–2.5Re for the aerospace, atomic and electrical industries (thermal shields on spacecraft, rocket nozzles, material for nuclear power systems, gas turbine blades, heating elements in furnaces); Ta–8W–1Re–0.7Hf – 0.025C for aeronautical engineering; Co–25W–3Sr–2Re–1Ti–1Zr 0.4C for the manufacture of parts for power plants of spacecraft, parts of gas turbines, etc. [9-13].

Rhenium also receives industrial development in another field of application – as a catalyst in the chemical industry (production of high-octane oil products), where it can successfully replace the more expensive platinum group metals.

According to the company Chase Brass, by 2021 the need for rhenium in the United States may increase to 28 tons per year, 20 tons per year of which will be high-temperature alloys [14-23].

Much attention is paid to increasing the efficiency of production of rhenium salts from mineral raw materials by expanding their output and implementing more advanced rhenium extracting methods. All this creates prerequisites for the further reduction in the cost of salts, and, consequently, of products made from rhenium metal. Many types of rhenium-containing ores are known abroad, but only a few are of industrial interest: porphyry

copper–gold fields (USA, Chile, Peru, etc.), cupriferous sandstone fields (Congo) and uranium fields (USA). The plants processing molybdenum concentrates isolated from copper–porphyric ores, in which the content of rare metal is high from 0,02 to 0,17 %, constitutes the main share in the production of rhenium abroad (about 84 %). The main consumers of such concentrates are the USA and the countries of Western Europe (Germany, Great Britain, France).

The extraction of rhenium from molybdenum concentrates is increasing due to the expansion of the output of rhenium salts, but on average it remains low. In 2018, out of all molybdenum concentrates isolated from copper porphyry ores, approximately 16 % were transferred in marketable products in the United States, in European countries – about 18–20 %. This is mainly due to the fact that there are many concentrates rhenium cannot be extracted from. If in the United States in the coming years the output of rhenium will increase to 3 tons per year, the extraction of metal from this type of raw material will rise to approximately 28–30 %.

4 Discussions

Increasing the use of raw materials is a major reserve for rhenium output expansion. Companies put in stocks some amount of rhenium salts. Using this stock, they can quickly increase the production of metal in case of increasing demand. And due to the availability of modern production technologies these reserves of salts can be used to produce rhenium products of higher quality than it is possible with the current level of technology development.

Nowadays the manufacturing of certain types of products from metallic rhenium has been mastered to different degrees. Compared with the initial raw material – ammonium perrhenate, – the following price increase took place in the USA from 2015 to 2018: 4,5 times for rhenium metal powder, 4,9 times for rhenium bars, 4–5 times for rhenium rods, 5 times for rhenium strips; and 7,6 times for rhenium foil. Such a sharp difference in the price of salt and foil is explained not only by the complexity and imperfection of the manufacturing process, but also by the small scale of foil production.

5 Conclusions

In other countries special attention is paid to the development of new technological processes for the manufacturing of metallic rhenium and its alloys, which would make it possible to create products at the lowest cost. Thus, in the USA and Russia, the technology for processing waste from the manufacturing of rhenium metal, its alloys and products made from them has been developed and implemented. This allows reducing the loss of metal and its cost. Rhenium in waste (pieces, etc.) from its alloys with wolfram and molybdenum is estimated at \$812–961 per kg, but the market cost of such products is quite high due to the small volume of its production. It is almost equal to the cost of platinum.

Considering the currently available raw material resources of rhenium, the level of extraction of certain types of raw materials, taking into account the maximum increase in metal extraction from them, the potential annual production of rhenium abroad is estimated at 45–55 tons, which is significantly lower than the modern consumption of molybdenum and wolfram, in alloys with which rhenium can be widely used. So taking into account the unique properties of rhenium and the large potential possibilities for its use, many countries now are expanding the research and searches for large and rich sources of rhenium in order to avoid the potential raw materials deficit in case of necessity for expansion of rhenium production.

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