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2018 Minerals Yearbook

RHENIUM [ADVANCE RELEASE]

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Rhenium

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In 2018, U.S. rhenium mine production on a contained-weight basis increased slightly to 8,220 kilograms (kg), whereas estimated apparent consumption of rhenium increased by 11% from that of 2017 to 47,600 kg (table 1). Domestic demand for rhenium metal and other rhenium products was met by imports, by production as a byproduct during the processing of domestic ores and stocks, and by secondary recovery of spent catalysts and superalloy scrap. Secondary rhenium production continued; however, lower rhenium prices and higher scrap prices have caused some rhenium recyclers to decrease secondary rhenium recovery. In addition to being a major source of primary rhenium, the United States had some of the leading refiners, fabricators, and distributors of rhenium products. World primary production of rhenium on a contained-weight basis in 2018 was about 48,600 kg, a 4% decrease from the revised value for 2017 (table 4). Data in this report are rounded to no more than three significant digits, and percentages are calculated from unrounded data.

Production

In the United States, primary rhenium is produced as a byproduct from molybdenite concentrates that are recovered as a byproduct of porphyry copper-molybdenum ore mined in Arizona, Montana, New Mexico, and Utah. During roasting of the molybdenite concentrates to produce molybdenum oxide, rhenium is oxidized to rhenium heptoxide (Re_2O_7) and passes up the flue stack with the sulfur gases. When the flue dusts and gases are scrubbed, rhenium is dissolved in the resulting sulfuric acid and is eventually precipitated out as ammonium perrhenate (NH_4ReO_4; APR).

For 2018, domestic mine production data for rhenium (table 1) were calculated by the U.S. Geological Survey from reported molybdenum concentrate production at copper-molybdenum mines at four operations. Additionally, estimated rhenium production data from Kennecott Utah Copper LLC [Rio Tinto plc (London, United Kingdom)] and Centerra Gold Inc. were included in the total U.S. rhenium mine production total.

At the Rio Tinto Kennecott smelter in Garfield, UT, the copper concentrate that is produced contains trace amounts of rhenium. In 2014, the smelter underwent a large maintenance shutdown, which included commissioning of a new plant to recover rhenium. When the copper concentrate is smelted, the rhenium volatilizes in the flash smelting process and is recovered as a rhenium-rich acidic liquid. Using continuous ion-exchange technology, approximately 1,000 kilograms per year (kg/yr) of rhenium can be recovered (Outotec Oyj., 2015; Rio Tinto plc, 2015, p. 15).

Centerra Gold Inc. owned a molybdenum roasting and processing plant in Langeloth, PA. The processing plant had previously been fed by the company's Thompson Creek Mine in Idaho. However, the Thompson Creek Mine was placed on care-and-maintenance status in 2014 and did not produce any molybdenum in 2018. The Langeloth processing plant continued to produce and sell APR and rhenium metal pellets, all recovered as byproducts of processing molybdenum disulfide on a toll basis from various third-party operations (Centerra Gold Inc., 2018, p. 113).

Secondary rhenium is recovered from spent oil refinery catalysts, from foundry revert (pre-consumer and mill scrap), and by recycling scrapped end-of-life gas turbine parts (nickel-base superalloy scrap), specifically blades and vanes. Of these sources, only the recycling of scrap produces additional new rhenium units available to the open market as rhenium metal or APR. In superalloy scrap recycling, rhenium is completely separated from the other alloys, whereas in the processing of superalloy revert, the rhenium remains part of the alloy throughout the cleaning and remelting process. Therefore, processing scrapped engine parts to generate engine revert is a much cheaper and quicker process.

The quantity and availability of end-of-life engine parts containing rhenium has increased rapidly since 2004 (Roskill Information Services Ltd., 2015, p. 38). However, in 2018, several recyclers continued to reduce their output owing to lower rhenium metal and APR prices, but industry sources reported that if prices increased significantly again, recycling activity was expected to increase.

Some of the major companies with the capability to recycle rhenium from spent catalysts and superalloy scrap in the United States were AAA Molybdenum Products Inc. (Broomfield, CO), Colonial Metals Inc. (Elkton, MD), Gemini Industries Inc. (Santa Ana, CA), Heraeus Precious Metals North America Inc. (Santa Fe Springs, CA), Sabin Metals Corp. (Scottsville, NY), Titan International Inc. (Pottstown, PA), and Umicore Cobalt & Specialty Materials (Wickliffe, OH).

Canada, Germany, and the United States continued to be the leading secondary rhenium producers. Secondary rhenium production also took place in Estonia, France, Japan, Poland, and Russia. According to industry sources, approximately 20 to 30 metric tons (t) of rhenium was recycled worldwide in 2017. However, this could decrease by approximately 3 to 4 t in 2018, owing to the continued decrease in rhenium prices (Metal Bulletin, 2018).

Consumption

The common product for almost all rhenium producers has been a basic-grade APR, usually sold as a white crystalline powder. This basic-grade APR can be sold as is, or further purified into a catalyst grade APR for use by catalyst manufacturers, or purified and transformed into metal or metal powder for use by superalloy manufacturers (Roskill Information Services Ltd., 2015, p. 20).

During the past 30 years, the two most important uses of rhenium have been in high-temperature superalloys and platinum-rhenium catalysts for producing gasoline. Rhenium is used in single-crystal, high-temperature, superalloy turbine blades for aircraft engines and land-based turbine applications. Rhenium also is used in the turbine blades closest to the combustion zone in gas turbine engines. The use of rhenium-containing blades allows the engine to be designed with closer tolerances and allows operation at higher temperatures, which prolongs engine life and increases engine performance and operating efficiency. Platinum-rhenium catalysts are used to produce high-octane, lead-free gasoline. Industry continued to research the potential for increased recycling of rhenium-bearing turbine blades in 2018, as well as the development of new alloys and catalysts. Other applications of rhenium, primarily as tungsten-rhenium and molybdenum-rhenium alloys, are more diverse and include crucibles, electrical contact points, electromagnets, electron tubes and targets, flashbulbs, heating elements, ionization gauges, mass spectrographs, metallic coatings, semiconductors, temperature controls, thermocouples, vacuum tubes, and X-ray tubes.

According to QYResearch, estimated global rhenium consumption in 2018 was 56,600 kg, an increase of 4% compared with 54,600 kg in 2017. In North America, superalloy consumption was estimated at 72%; catalyst consumption, 19%; and other, 9% (QYResearch, 2019, p. 32–34).

The United States was the world's leading producer of aerospace superalloys and therefore was the leading consumer of rhenium. The three leading U.S. consumers of rhenium were Cannon Muskegon Corp. (Muskegon, MI), General Electric Aviation (Evendale, OH) (a subsidiary of General Electric Co., Fairfield, CT), and Pratt & Whitney (a division of United Technologies Corp., Hartford, CT).

Pratt & Whitney continued to receive rhenium for all its engine platforms from Molibdenos y Metales S.A. (Molymet) (Chile) after signing a $690 million agreement in 2014. This high-profile commitment from a large aerospace engine manufacturer highlighted the importance that rhenium holds in the aerospace industry. However, rhenium also represented the third most expensive total material cost per engine, behind titanium and nickel alloys, even though it represented only a fraction of the total weight in the actual engine (Haflich, 2016).

Rhenium was used in petroleum-reforming catalysts to produce high-octane hydrocarbons, which were used in the formulation of lead-free gasoline. Bimetallic platinum-rhenium catalysts have replaced many of the monometallic catalysts. Bimetallic platinum-rhenium catalysts tolerate greater amounts of carbon formation when making gasoline and allow the production process to operate at lower pressures and higher temperatures, which leads to improved yields (production per unit of catalyst used) and higher-octane ratings. Platinum-rhenium catalysts also were used in the production of benzene, toluene, and xylenes, although this use was minor compared with their use in gasoline production.

Prices

Rhenium has a limited market of consumers. A large percentage of rhenium sales, especially for rhenium metal, are made under long-term contracts. The details of the long-term contracts are typically not made public. The open-trade market for both APR and rhenium metal is relatively small.

In 2018, the annual average price of APR catalytic-grade rhenium, as reported by Argus Media group—Argus Metals International, was $1,410 per kilogram of contained rhenium, an 8% decrease compared with $1,530 per kilogram in 2017. The annual average price of rhenium metal pellets (minimum 99.9% rhenium) was $1,470 per kilogram of contained rhenium in 2018, a 5% decrease from $1,550 per kilogram in 2017.

Foreign Trade

Imports of rhenium metal in 2018 were 32,000 kg, a 20% increase compared with 26,700 kg in 2017 (tables 1, 2). Chile continued to be the leading supplier of rhenium metal to the United States. In 2018, imports of APR decreased to 7,370 kg of contained rhenium, a 6% decrease compared with 7,820 kg imported in 2017 (table 1).

World Review

World production of rhenium on a contained-weight basis was 48,600 kg in 2018 (table 4). This total was based on the quantity of rhenium recovered from copper and (or) molybdenum concentrates that were processed to recover rhenium. This total does not include rhenium from secondary recovery processes.

Rhenium was recovered as a byproduct from porphyry copper-molybdenum ores mined primarily in Chile, Mexico, Peru, and the United States. In Mexico and Peru, substantial amounts of rhenium were contained in unroasted molybdenum concentrates that were exported to Chile and the United States for processing. Armenia, China, Kazakhstan, Poland, and Uzbekistan also produced rhenium. The Republic of Korea and Russia may have produced rhenium, but available information was inadequate to make reliable estimates (table 4). Rhenium was associated with copper minerals in sedimentary ore deposits in Kazakhstan and Poland, countries where ore was processed for copper recovery, and the rhenium-bearing residues were recovered at copper smelters. Rhenium-bearing residues from both sources were processed for recovery either as APR for use in catalysts or as a metal powder for use in superalloys. The major producers of rhenium metal and compounds in 2018 continued to be Chile, Poland, and the United States.

World reserves of rhenium are contained primarily in molybdenite in porphyry copper deposits. U.S. reserves of rhenium are concentrated in Arizona, Montana, Nevada, New Mexico, and Utah. Chile's reserves are found primarily at four large porphyry copper deposits and in smaller deposits in the northern half of the country. In Peru, reserves are concentrated primarily in the Toquepala open pit porphyry copper mine and in about 12 other deposits. Other world reserves are contained in porphyry copper deposits and sedimentary copper deposits in Armenia, Australia, Canada, China, Iran, Kazakhstan, Mongolia, Poland, Russia, and Uzbekistan. U.S. reserves were estimated to be about 400,000 kg; rest-of-the-world reserves were estimated to be about 2,000,000 kg.

Canada.—Maritime House Ltd. operated a rhenium recycling plant in Napanee, Ontario. The company produced catalyst-grade APR and rhenium-metal pellets from a wide range of rhenium-bearing scrap. The plant's capacity was 5,000 to 6,000 kg/yr of rhenium (Maritime House Ltd., undated a, b).

Chile.—Molymet operated the largest rhenium recovery plant in the world, based in Nos, with an estimated capacity of 40,000 kg/yr of rhenium metal and APR. The Nos plant had three roasters with a total molybdenum concentrate treatment capacity of 43,000,000 kg/yr. In addition to its Chilean operations, Molymet had molybdenum concentrate roasting facilities in Mexico (Molymex S.A. de C.V.), roasting plants in Belgium (Sadaci N.V.), a powder metallurgy plant in Germany (Chemiemetall GmbH), and a metal facility in China (Luoyang High-tech Molybdenum & Tungsten Material Co. Ltd.) (Roskill Information Services Ltd., 2015, p. 55). Molymet had supply agreements with Cannon Muskegon, Pratt & Whitney, General Electric, Plansee USA LLC (Franklin, MA), and MiRus LLC (Marietta, GA) (Molibdenos y Metales S.A., 2019, p. 26).

In 2018, Molymet reported sales volumes of 26,050 kg of rhenium, a 27% increase from 2017 (Molibdenos y Metales S.A., 2019, p. 16). Molymet toll roasted byproduct molybdenum concentrates for Corporación Nacional del Cobre de Chile (Codelco) sourced from Canada, Mexico, Peru, and the United States. Codelco and Glencore plc also roasted byproduct molybdenum concentrates in Chile, but those roasters were not equipped for rhenium recovery (Molibdenos y Metales S.A., 2018, p. 175, 213).

Codelco continued to operate its molybdenum processing plant, Molyb, which had the ability to recover rhenium (Corporación Nacional del Cobre de Chile, undated, p. 103). The plant began molybdenum production in 2016, but information about rhenium recovery rates was unavailable.

China.—In China, as in many countries, there were numerous traders that claimed to be able to supply rhenium or APR. However, it is difficult to separate those traders from manufacturing companies (Roskill Information Services Ltd., 2015, p. 65). Rhenium production and processing was concentrated in Jiangxi and Shaanxi Provinces. Estimates for China were based on data from China's National Statistical Bureau.

Estonia.—Toma Group (Tallinn) continued to recycle metal alloys containing rhenium at its facility in Tallinn. The company recycled molybdenum-rhenium alloys, tungsten-rhenium alloys, nickel-base superalloys, and other rhenium-containing scrap metals sourced from companies in Europe and the United States. Toma continued to research ways of recycling new materials more efficiently (Toma Group, 2014).

Germany.—Buss & Buss Spezialmetalle GmbH (Sagard), in a joint venture with Molycorp, continued to recycle rhenium-containing alloys and rhenium scrap into catalyst-grade APR (99.9% rhenium) and rhenium pellets (99.9% rhenium) at its facility in Sagard (Buss & Buss Spezialmetalle GmbH, undated).

H.C. Starck GmbH & Co. KG (Goslar) continued to recycle rhenium from catalysts and superalloy scrap (H.C. Starck GmbH & Co. KG, undated).

Heraeus Precious Metals GmbH & Co. KG (a division of W.C. Heraeus GmbH) was one of the leading recyclers of rhenium from catalysts. Heraeus also produced APR, rhenium pellets, and rhenium powder. Heraeus operated recycling facilities in Hanau and in Sante Fe Springs, CA (Heraeus Precious Metals GmbH & Co. KG, undated, p. 11–12).

Kazakhstan.—Zhezkazganredmet (Redmet), Kazakhstan's state-owned rhenium producer, received rhenium-bearing residues from the Zhezkazgan Copper Works mine and smelter complex. The smelter was owned by Kazakhmys plc until October 2014 when the company transferred ownership to Cuprum Holding Group. Kazakhmys then changed its name to KAZ Minerals plc. When the Zhezkazgan smelter was controlled by Kazakhmys, it received 50% of Redmet's production as payment for the rhenium residues. However, it was unclear whether this arrangement continued with Cuprum in 2017. Operations at the Zhezkazgan smelter and refinery were closed in mid-2013 in order to construct a second smelting to process copper and molybdenum ore from the Bozshakol mining and concentrating complex in Kazakhstan (Roskill Information Services Ltd., 2015, p. 72–74). In December 2018, it was announced that the Zhezkazgan smelter had reopened with the second smelting furnace working at full operation (Azernews, 2018).

Poland.—KGHM Ecoren S.A. (Lubin), a division of copper producer KGHM Polska Miedź S.A., continued to operate its metallic rhenium refinery near the Legnica copper smelter. Ecoren reported that United Kingdom-based customers Johnson Matthey plc and Rolls-Royce Group plc were the major purchasers of its rhenium products. The facility had an annual capacity to convert APR into 3,500 kg of metallic rhenium. It was also able to supply rhenium metal in powder form according to customer requirements. Ecoren received waste sulfuric acid from the KGHM plant and then, through hydrometallurgical processes, captured the rhenium to produce the APR and rhenium metal (KGHM Ecoren S.A., undated a, b).

Outlook

Superalloy producers and processors are constantly seeking to improve the performance and properties of their high-pressure turbine blades and vanes. Advances in heat-resistant ceramic coatings and air cooling are particularly important to allow blades to operate in environments where temperatures exceed their melting points. Research continued to explore the addition of ruthenium, a more affordable alternative to rhenium, to improve corrosion resistance. Although the benefit of adding rhenium to superalloys is well established, economics cannot be ignored, and the high price of rhenium has always been an important consideration (Roskill Information Services Ltd., 2015, p. 113).

No primary rhenium projects in 2018 are expected to significantly contribute to rhenium availability in the near future. Continued low prices of rhenium caused many rhenium recyclers to stop recycling rhenium to focus on a more profitable market. A substantial increase in rhenium prices is necessary for a turnaround in the rhenium recycling industry (Metal Bulletin, 2018). Compared with the high cost of rhenium recycling, processing engine revert represents a simpler, quicker, and more cost-effective way to capture and reuse rhenium. The supply of engine revert is expected to continue to have an impact on the stabilization of the rhenium market.

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TABLE 1
SALIENT U.S. RHENIUM STATISTICS[1]

(Kilograms)

	2014	2015	2016	2017	2018
Production, mine, rhenium content[2]	8,510	7,900	8,440	8,200	8,220
Apparent consumption:[e, 3]					
Gross weight	43,600	49,100	50,300	52,500	57,400
Rhenium content	33,500	39,700	40,300	42,700	47,600
Imports:					
Ammonium perrhenate, gross weight	10,700	9,130	8,570	11,300	10,600
Ammonium perrhenate, rhenium content	7,400	6,340	5,950	7,820	7,370
Rhenium metal, rhenium content	17,600	25,400	25,900	26,700	32,000
Total, rhenium content	25,000	31,800	31,900	34,500	39,400
World production, rhenium content	45,100	47,900	49,000	50,400 [r]	48,600

[e]Estimated. [r]Revised.
[1]Table includes data available through February 20, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Estimated mine production of rhenium is calculated by the U.S. Geological Survey based on the production of molybdenum concentrates. Secondary rhenium production not included.
[3]Calculated as production plus imports minus exports.

TABLE 2
U.S. IMPORTS FOR CONSUMPTION OF RHENIUM METAL, BY COUNTRY OR LOCALITY[1]

	2017		2018	
Country or locality	Rhenium content (kilograms)	Value (thousands)	Rhenium content (kilograms)	Value (thousands)
Austria	45	$42	--	--
Belgium	--	--	13	$43
Canada	375	487	2,230	3,270
Chile	21,600	57,200	26,100	55,700
China	350	1,850	360	1,730
Germany	2,240	3,130	2,700	3,260
Korea, Republic of	54	180	--	--
Poland	1,990	7,940	620	2,390
Russia	--	--	1	5
Singapore	65	215	--	--
United Kingdom	18	58	--	--
Total	26,700	71,100	32,000	66,400

-- Zero.
[1]Table includes data available through February 20, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 3
U.S. IMPORTS FOR CONSUMPTION OF AMMONIUM PERRHENATE, BY COUNTRY OR LOCALITY[1]

	2017		2018	
Country or locality	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)
Canada	3,790	$1,410	1,700	$1,170
Chile	--	--	971	661
China	750	768	50	35
Estonia	--	--	10	7
Germany	1,860	1,180	1,520	1,400
Japan	278	254	--	--
Kazakhstan	1,850	3,150	2,000	1,760
Korea, Republic of	100	85	900	546
Netherlands	144	99	--	--
Poland	920	749	2,710	2,030
Russia	101	49	48	25
Spain	--	--	110	82
Thailand	600	437	600	432
United Kingdom	874	1,880	--	--
Total	11,300	10,100	10,600	8,150

-- Zero.

[1]Table includes data available through February 20, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 4
RHENIUM: WORLD PRODUCTION, BY COUNTRY OR LOCALITY[1, 2]

(Kilograms, rhenium content)

Country or locality[3]	2014	2015	2016	2017	2018
Armenia	351	350 e	281	260 r	281
Chile[e, 4]	25,000	26,000	27,000	27,000	27,000
China[e]	2,350	2,500	2,500	2,500	2,500
Kazakhstan[e]	300	1,000	1,000	1,000	1,000
Poland[5]	7,710	9,170	9,310	10,930 r	9,090
United States	8,510	7,900	8,440	8,200	8,220
Uzbekistan	900 e	1,000 e	466	460 e	460 e
Total	45,100	47,900	49,000	50,400 r	48,600

[e]Estimated. [r]Revised.

[1]Table includes data available through July 29, 2019. All data are reported unless otherwise noted. Totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Estimated mine production of rhenium based on the production of molybdenum concentrates. Secondary rhenium production not included.

[3]In addition to the countries and (or) localities listed, the Republic of Korea and Russia may have produced rhenium, but available information was inadequate to make reliable estimates of output.

[4]Includes rhenium contained in molybdenum concentrates from Canada, Mexico, Peru, and the United States, processed at Molibdenos y Metales S.A. in Chile.

[5]Based on information from KGHM Ecoren S.A. Calculation based on 69.2% rhenium content of ammonium perrhenate.