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2019 Minerals Yearbook

RHENIUM [ADVANCE RELEASE]

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Rhenium

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In 2019, U.S. estimated primary rhenium production on a rhenium content basis increased slightly to 8,360 kilograms (kg) and estimated apparent consumption of rhenium on a rhenium content basis increased by 11% compared with that in 2018 (table 1). Domestic demand for rhenium metal and other rhenium products was met by imports, by production as a byproduct during the recovery of domestic ores and stocks, and by the recycling of spent catalysts and superalloy scrap. Although secondary rhenium production continued, lower rhenium prices and higher scrap prices caused some recyclers to decrease or completely eliminate rhenium recycling. In addition to being a major producer of primary rhenium, the United States also had some of the leading refiners, fabricators, and distributors of rhenium products in terms of production and sales. World primary rhenium production on a rhenium content basis in 2019 was 53,200 kg, a 4% increase from 51,300 kg (revised) in 2018 (table 4). Data in this report were rounded to no more than three significant digits, and all percentages were calculated from unrounded data.

Legislation and Government Programs

National Defense Stockpile.—The Defense Logistics Agency Strategic Materials (DLA Strategic Materials) listed the possible acquisition of 5,000 kg (gross weight) of tungsten-rhenium metal in fiscal year 2019 (October 1, 2018 through September 30, 2019), unchanged from that in fiscal year 2018. The quantity of tungsten-rhenium metal that could be acquired in fiscal year 2019 remained at 5,000 kg. In October 2019, the DLA Strategic Materials announced the possible acquisition of 5,000 kg, gross weight, of tungsten-rhenium metal in fiscal year 2020 (Defense Logistics Agency Strategic Materials, 2017, 2018, 2019).

Production

In the United States, rhenium was produced as a byproduct from molybdenite concentrates that were recovered as a byproduct of the processing 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 2019, domestic primary mine production data for rhenium (table 1) were partially derived by the U.S. Geological Survey from reported molybdenum 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 United States rhenium mine production total.

At the Rio Tinto Kennecott smelter in Garfield, UT (Rio Tinto plc), the copper concentrate that was processed contained trace amounts of rhenium. In 2014, the smelter underwent a large maintenance shutdown which included commissioning a new plant to recover rhenium. When the copper concentrate was smelted, the rhenium volatilized in the flash smelting process and was recovered as a rhenium-rich acidic liquid. Using continuous ion-exchange technology, approximately 1,000 kilograms per year (kg/yr) of rhenium could be recovered (Outotec Oyj, 2015; Rio Tinto plc, 2015, p. 15). In December, Rio Tinto announced a $1.5 billion investment to continue copper and molybdenum production at its Bingham Canyon Mine until 2032. However, rhenium recovery was discontinued in early 2019 and, according to the company, there were no immediate plans to restart rhenium production in the near future (Rio Tinto plc, 2019).

Centerra Gold Inc. owned a molybdenum roasting and processing plant in Langeloth, PA. The processing plant previously had received feedstock from 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 2019. The Langeloth processing plant continued to produce and sell APR and rhenium metal pellets recovered as byproducts of processing molybdenum disulfide on a toll basis from various third-party operations (Centerra Gold Inc., 2018, p. 113). The facility had the capacity to produce 5 metric tons per year (t/yr) of rhenium (Roskill Information Services Ltd., 2019).

Northern Dynasty Minerals Ltd. announced that it had advanced its Pebble copper-gold-molybdenum project to the permitting and development stage and would publish a final environmental impact study in 2020. The Pebble deposit is located 320 kilometers (km) southwest of Anchorage, AK. The company announced that rhenium was contained in the deposit (Roskill Information Services Ltd., 2019; Northern Dynasty Minerals Ltd., undated).

Secondary rhenium was recovered from spent oil refinery catalysts, foundry revert (pre-consumer and mill scrap), and recycling of scrapped end-of-life gas turbine parts (nickel-base superalloy scrap), specifically blades and vanes. The nickel-base superalloy scrap usually contained between 2% and 8% rhenium. A rhenium content of less than 1% was considered uneconomical to recover. Superalloys can contain more than 20 alloying elements, making it a difficult and costly process. Both catalysts and alloys were typically recycled using hydrometallurgical processes; however, pyrometallurgical processes also were used. Of these sources, only the recycling of scrap produced additional new rhenium units available to the open market as rhenium metal or APR.

Major companies with the capability to recycle rhenium from spent catalysts and superalloy scrap in the United States included AAA Molybdenum Products Inc. (Broomfield, CO), Colonial Metals Inc. (Elkton, MD), Gemini Industries Inc. (Santa Ana, CA), Meridian Metals Management LLC (Charleston, SC), Sabin Metals Corp. (Scottsville, NY), Titan International Inc. (Pottstown, PA), and Umicore Cobalt & Specialty Materials (Wickliffe, OH).

In superalloy scrap recycling, rhenium was completely separated from the other alloys, whereas in the processing of superalloy revert, the rhenium remained part of the alloy throughout the cleaning and remelting process. Processing scrapped engine parts to generate engine revert was a much cheaper and quicker process. The quantity and availability of end-of-life engine parts containing rhenium increased rapidly in the past 15 years (Roskill Information Services Ltd., 2015, p. 38). Between 2014 and 2019, the availability of engine revert more than doubled from 5 metric tons (t) to 13 t (Roskill Information Services Ltd., 2019).

There were numerous independent engine-revert processors in the United States. Some of these processors included CAI Custom Alloys Inc. (Belvidere, IL), Caledonian Alloys Inc. (Charlotte, NC), ICD Alloys & Metals LLC (Winston-Salem, NC), and United Alloys and Metals Inc. (Columbus, OH).

Canada, Germany, Japan, and the United States continued to be the leading secondary rhenium producers. Secondary rhenium production also took place in Estonia, France, Poland, and Russia. Roskill Information Services Ltd. estimated worldwide secondary rhenium production to be 18 t in 2019. This total included both recycled metallic scrap and end-of-life engine revert. Spent catalysts were not included in this estimate owing to the fact that almost all spent catalysts consumed in the oil refining industry were regenerated and did not enter the rhenium market (Roskill Information Services Ltd., 2019).

Consumption

During the past 30 years, the two most important uses of rhenium were in high-temperature superalloys and as platinum-rhenium catalysts for producing gasoline. Other applications of rhenium, primarily as tungsten-rhenium and molybdenum-rhenium alloys, included 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.

Rhenium was used in single-crystal, high-temperature superalloy turbine blades for aircraft engines and land-based turbine applications. Rhenium was used in the turbine blades closest to the combustion zone in gas turbine engines. The use of rhenium-containing blades allowed the engine to be designed with closer tolerances and allowed operation at higher temperatures, which prolonged engine life and increased engine performance and operating efficiency. In 2019, various industries continued to research the potential for increased recycling of rhenium-bearing turbine blades and the development of new alloys and catalysts.

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 allowed the production process to operate at lower pressures and higher temperatures, which led to improved yields (production per unit of catalyst used) and higher octane ratings. Platinum-rhenium catalysts were also used in the production of benzene, toluene, and xylenes, although this use was minor compared with their use in gasoline production. Rhenium recovered from spent catalysts was typically consumed in the production of new catalysts and little secondary material entered the open market.

According to Roskill, estimated global consumption of rhenium in both APR and rhenium metal was estimated to be 75,000 kg of contained rhenium. Superalloys accounted for approximately 79% of total consumption in 2019 (Roskill Information Services Ltd., 2019).

The United States was the world's leading producer of aerospace superalloys and was, therefore, 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).

Europe was the second-leading rhenium market. Rolls Royce Holdings plc continued to be a leading consumer in the aeroengine sector, and Arconic Corp.'s facilities in Europe and Doncasters Group Ltd. were leading consumers in the superalloy market (Roskill Information Services Ltd., 2019). Rhenium also was consumed in China, Japan, and Russia.

Lower volumes of rhenium were consumed in medical and pharmaceutical applications. In August, MiRus LLC announced that the U.S. Food and Drug Administration had approved its MiRus pedicle screw system made from a proprietary molybdenum-rhenium alloy. According to the company, the use of the molybdenum-rhenium alloy allowed for a smaller, stronger, and more durable medical implant in spinal surgery (MiRus LLC, 2019).

Prices

Rhenium had a small number of consumers. A large percentage of rhenium sales, especially for rhenium metal, was made under long-term contracts. The details of the long-term contracts were typically not made public. The prices discussed in this section reflect APR and rhenium metal sales in the open-trade market, which was relatively small compared with the volume sold under long-term contracts.

In 2019, the annual average price of APR catalytic-grade rhenium, as reported by Argus Metals International, was $1,280 per kilogram of rhenium content, a 9% decrease compared with the $1,410 per kilogram annual average price in 2018. The annual average price of rhenium metal pellets (minimum 99.9% rhenium) was $1,300 per kilogram of rhenium content in 2019, a 12% decrease from the $1,470 per kilogram annual average price in 2018.

Foreign Trade

Imports of rhenium metal in 2019 equaled 31,500 kg, slightly less than the 32,000 kg of rhenium metal imports in 2018 (tables 1, 2). Chile (84%) continued to be the leading source of rhenium metal to the United States. In 2019, imports of APR increased to 18,400 kg (gross weight), a 73% increase compared with the 10,600 kg imported in 2019 (tables 1, 3). The leading sources of APR in 2019 were Kazakhstan (22%), Germany (20%), and Chile and Poland (17% each).

World Review

World primary production of rhenium on a rhenium content basis was estimated to be 53,200 kg in 2019 (table 4). This estimate was based on the quantity of rhenium-containing concentrates that were processed to recover rhenium.

Rhenium was recovered as a byproduct from porphyry copper-molybdenum ores mined primarily in Chile, Mexico, Peru, and the United States. Substantial amounts of rhenium contained in unroasted molybdenum concentrates in Mexico and Peru were exported to Chile, the Netherlands, and the United States for processing. Armenia, China, Kazakhstan, Poland, and Uzbekistan also produced rhenium. Germany and Russia may have produced rhenium from copper concentrates, but available information was inadequate to make reliable estimates of output (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 2019 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 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, and reserves in the rest of the world were estimated to be about 2,000,000 kg. Reserve estimates for China, Poland, and Uzbekistan were not available and were not included in the world reserve estimate.

Canada.—Maritime House Ltd. operated a rhenium recycling plant in Napanee, Ontario. According to the company, it had upgraded its plant and had a patented process to recycle rhenium from a wide range of rhenium-bearing scrap. The plant produced catalyst-grade APR and rhenium metal pellets and had a capacity of 5 to 6 t/yr of rhenium (Maritime House Ltd., undated a, b).

Chile.—According to Molibdenos y Metales S.A. (Molymet), the company operated the largest rhenium recovery plant in the world, with an estimated capacity of 40,000 kg/yr of rhenium. Molymet produced APR, rhenium metal powder, rhenium briquettes, and perrhenic acid as byproducts of roasting molybdenum concentrates at the Molymet Nos and Molynor plants. The Nos plant had three roasters with a total molybdenum concentrate treatment capacity of 43,000,000 kg/yr. The Molynor plant is located in the Mejillones Port complex, approximately 65 km from Antofagasta. In addition to its Chilean operations, Molymet had molybdenum concentrate roasting facilities in Mexico (Molymex S.A. de C.V.), roasting and ferromolybdenum plants in Belgium (Sadaci N.V.), and a powder metallurgy plant in Germany (Chemiemetall GmbH) (Roskill Information Services Ltd., 2015, p. 55; 2019). Molymet's main clients were Cannon Muskegon, Pratt & Whitney, General Electric, Plansee USA LLC (Franklin, MA), and MiRus LLC (Atlanta, GA) (Molibdenos y Metales S.A., 2019, p. 29).

Codelco continued to operate its molybdenum processing plant, Molyb, located at the Mejillones Industrial Park, 64 km north of Antofagasta. The facility began molybdenum production in 2016 and had the capacity to produce 16,000 t/yr of molybdenum trioxide and 8 t/yr of rhenium (Roskill Information Services Ltd., 2019; Molyb, undated).

China.—Primary rhenium production and processing was concentrated in Hubei, Hunan, and Shaanxi Provinces. Hengyang Zhiyuan New Material Co. Ltd. in Hunan Province was expected to have the largest rhenium capacity in China. Estimates for China were based on data from China's National Statistical Bureau.

Germany.—Buss & Buss Spezialmetalle GmbH (Sagard), a subsidiary of Neo Performance Materials Inc., continued to recycle rhenium-containing alloys and rhenium scrap into catalyst-grade APR 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 both catalysts and high-grade rhenium-bearing alloys. Heraeus produced APR, perrhenic acid, potassium perrhenate, rhenium pellets, and rhenium powder. Heraeus operated recycling facilities in Hanau and in Sante Fe Springs, CA. According to the company, the total rhenium refining capacity was approximately 5 to 10 t/yr of rhenium (Heraeus Precious Metals GmbH & Co. KG, undated).

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 (now KAZ Minerals plc) until October 2014, when the company transferred ownership to Cuprum Holding Group. When the Zhezkazgan smelter was controlled by Kazakhmys, it received 50% of Redmet's sales as payment for the rhenium residues. Operations at the Zhezkazgan smelter and refinery were closed in mid-2013 to upgrade the facility to process copper-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 and the second ore smelting furnace was working at full operation (Azernews, 2018).

Poland.—KGHM Metraco S.A. (Lubin), a division of Poland-based copper producer KGHM Polska Miedź S.A., continued to recover rhenium from three rhenium recovery circuits that were in operation at all three of KGHM's copper smelters, Głogów I, Głogów II, and Legnica. Catalyst-grade APR (69.4% rhenium) was produced at the hydrometallurgical plant at the Głogów II copper smelter, and 99.9% rhenium metal pellets were produced at the rhenium facility at the Legnica copper smelter (KGHM Metraco S.A., undated; KGHM Polska Miedź S.A., undated).

Russia.—There has been no primary rhenium production in Russia since 2015. However, there were a number of secondary APR producers that processed spent catalyst or scrap alloys.

Outlook

Superalloy producers and processors are constantly seeking to improve the performance and properties of their high-pressure turbine blades and vanes. Advancements in heat-resistant ceramic coatings are particularly important to allow blades to operate in environments where temperatures exceed their melting points. Ruthenium-bearing superalloys have been developed containing 5.8% to 7% rhenium, but they have not been adopted on a commercial scale owing to their lower environmental resistance and higher production cost compared with nickel-base superalloys (Roskill Information Services Ltd., 2019).

There were no primary rhenium projects in 2019 that were expected to significantly contribute to rhenium availability in the near future. Continued low prices of rhenium caused many rhenium recyclers and primary rhenium producing facilities to stop recycling or producing rhenium to focus on a more profitable market. Compared with the high cost and difficulty of recycling rhenium, processing engine revert represents a simpler, quicker, and more-cost-effective way to capture and reuse rhenium. The supply of engine revert was expected to continue to have an impact on the stabilization of the rhenium market.

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TABLE 1
SALIENT RHENIUM STATISTICS[1]

(Kilograms)

	2015	2016	2017	2018	2019
Production, mine, rhenium content[2]	7,900	8,440	8,200	8,220	8,360
Apparent consumption:[e, 3]					
Gross weight	49,100	50,300	52,500	57,400	62,600
Rhenium content	39,700	40,300	42,700	47,600	52,600
Imports:					
Ammonium perrhenate, gross weight	9,130	8,570	11,300	10,600	18,400
Ammonium perrhenate, rhenium content	6,340	5,950	7,820	7,370	12,800
Rhenium metal, rhenium content	25,400	25,900	26,700	32,000	31,500
Total, rhenium content	31,800	31,900	34,500	39,400	44,300
World production, rhenium content[e]	50,400 [r]	51,600 [r]	53,000 [r]	51,300 [r]	53,200

[e]Estimated. [r]Revised.
[1]Table includes data available through September 21, 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]

	2018		2019	
Country or locality	Rhenium content (kilograms)	Value (thousands)	Rhenium content (kilograms)	Value (thousands)
Belgium	13	$43	--	--
Canada	2,230	3,270	2,870	$2,120
Chile	26,100	55,700	26,500	50,900
China	360	1,730	41	66
Czechia	--	--	1	5
France	--	--	6	6
Germany	2,700	3,260	1,800	2,360
Poland	620	2,390	197	240
Russia	1	5	--	--
Switzerland	--	--	50	175
United Kingdom	--	--	30	30
Total	32,000	66,400	31,500	55,900

-- Zero.
[1]Table includes data available through August 7, 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]

	2018		2019	
Country or locality	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)
Armenia	--	--	150	$148
Canada	1,700	$1,170	1,150	375
Chile	971	661	3,100	1,450
China	50	35	--	--
Estonia	10	7	577	348
France	--	--	84	64
Germany	1,520	1,400	3,760	4,250
Kazakhstan	2,000	1,760	4,060	2,820
Korea, Republic of	900	546	1,370	797
Poland	2,710	2,030	3,150	2,060
Russia	48	25	347	167
Spain	110	82	--	--
Thailand	600	432	--	--
United Kingdom	--	--	62	86
Uzbekistan	--	--	578	414
Total	10,600	8,150	18,400	13,000

-- Zero.

[1]Table includes data available through August 7, 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]	2015	2016	2017	2018	2019
Armenia	350 e	281	260	281	280 e
Chile[e, 4]	26,000	27,000	27,000	27,000	30,000
China[e]	2,500	2,500	2,500	2,500	2,500
Kazakhstan[e]	1,000	1,000	1,000	1,000	500
Korea, Republic of	2,500	2,600	2,600	2,700	2,800
Poland[5]	9,170	9,310	10,930	9,090	8,340
United States	7,900	8,440	8,200	8,220	8,360
Uzbekistan	1,000 e	466	460 e	460 e	460 e
Total[e]	50,400 r	51,600 r	53,000 r	51,300 r	53,200

[e]Estimated. [r]Revised.

[1]Table includes data available through August 20, 2020. All data are reported unless otherwise noted. Totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

[2]Calculated rhenium contained in molybdenum concentrates. Secondary rhenium production not included.

[3]In addition to the countries and (or) localities listed, Germany 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.