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RHENIUM [ADVANCE RELEASE]

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Rhenium

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In 2013, U.S. estimated primary rhenium production decreased by about 10%, while apparent consumption of rhenium decreased by about 12% from that of 2012 (table 1). Domestic demand for rhenium metal and other rhenium products was met by imports, from recovery from domestic ores and stocks, and from the recycling of spent catalysts and superalloy scrap. Secondary rhenium production has increased more quickly than primary production in recent years, mainly owing to the increasing availability of superalloy scrap. In addition to being a major source of primary rhenium, the United States also has some of the leading refiners, fabricators, and distributors of rhenium products. World primary production of rhenium in 2013 was estimated to be about 48,900 kilograms (kg), an 8% decrease from that of 2012 (table 4).

Production

In the United States, 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 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). In the United States in 2013, only one molybdenum concentrate roasting facility was so equipped—the Freeport-McMoRan Copper & Gold Inc. Sierrita facility in Arizona. Domestic primary mine production data for rhenium (table 1) were derived by the U.S. Geological Survey (USGS) from reported molybdenum production at copper-molybdenum mines at four operations. All responded to the survey representing 100% of production.

Consumption

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 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 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.

Of the approximately 55,000 kg of rhenium consumed annually, 80% was used as a 3% or 6% addition to complex nickel-base alloys for the manufacture of single-crystal turbine blades for either aircraft engines or industrial gas turbine engines. Turbine engine producers, such as General Electric Aviation (GE) (a subsidiary of General Electric Co., Fairfield, CT), Pratt & Whitney (a division of United Technologies Corp., Hartford, CT), and Rolls Royce plc, were estimated to consume 45,000 kilograms per year (kg/yr) of rhenium (Minor Metals Trade Association, 2012).

Pratt & Whitney announced that it entered into a long-term agreement with Molibdenos y Metales S.A. (Molymet) (Chile) to buy $690 million worth of rhenium. Under the agreement, Molymet would continue to supply rhenium to be used in all of Pratt & Whitney's engine programs, including the next generation PurePower® engine family and the F135 military engine that will power the F–35 Lightning II (Pratt & Whitney, 2014).

Rhenium is used in petroleum-reforming catalysts for the production of high-octane hydrocarbons, which are used in the formulation of lead-free gasoline. Bimetallic platinum-rhenium catalysts have replaced many of the monometallic catalysts. Rhenium catalysts tolerate greater amounts of carbon formation when making gasoline, and make it possible to operate the production process 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 are used in the production of benzene, toluene, and xylenes, although this use is minor compared with their use in gasoline production.

Prices

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

In 2013, the annual average price of APR catalytic-grade rhenium as reported in Metal Bulletin was $3,400 per kilogram, a 15% decrease compared with the $3,990 per kilogram annual average price of 2012. The annual average price of rhenium metal pellets (minimum 99.9%) was $3,160 per kilogram in 2013, a 22% decrease from the $4,040 per kilogram annual average price of 2012. The rhenium metal pellet price averaged $3,440 per kilogram until May, and then continually trended downward until reaching $3,000 per kilogram by yearend.

Foreign Trade

Imports of rhenium metal in 2013 were 22,700 kg, a 17% decrease compared with 27,400 kg of rhenium metal in 2012 (table 2). Chile and Poland were the leading suppliers of rhenium metal to the United States. Imports of APR decreased to 18,000 kg, a 6% decrease compared with 19,200 kg in 2012 (table 3).

World Review

World primary production of rhenium was estimated to have been about 48,900 kg in 2013 (table 4). This estimate was based on the quantity of rhenium recovered from concentrates that were processed to recover rhenium values. Secondary world production of rhenium was expected to continue to increase.

Rhenium was recovered as a byproduct from porphyry copper-molybdenum ores mined primarily in Chile, Mexico, the Republic of Korea, Peru, and the United States. In addition to the countries listed, China and Russia were thought to produce rhenium, but output was not reported quantitatively. Rhenium is also associated with copper minerals in sedimentary ore deposits in Armenia, Kazakhstan, Poland, Russia, and Uzbekistan, countries where ore is processed for copper recovery, and the rhenium-bearing residues are recovered at copper smelters. Rhenium-bearing residues from both sources are processed for recovery either as APR for catalyst uses or as a metal powder for superalloys. The major producers of rhenium metal and compounds in 2013 were 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 several porphyry copper deposits and sedimentary copper deposits in Armenia, northwestern China, Iran, Kazakhstan, Poland, Russia, and Uzbekistan, and in sedimentary copper-cobalt deposits in Congo (Kinshasa). U.S. reserves were estimated to be about 390,000 kg, and rest-of-the-world reserves were estimated to be about 2,100,000 kg.

Canada.—Molycorp, Inc. reported that its hydrometallurgical rhenium recovery plant in Napanee, Ontario, was focusing on the recycling of rhenium-bearing superalloys. The facility, according to the company, was the first of its kind in North America to be used primarily for toll refining of rhenium-bearing scrap to produce rhenium as a service to its clients (Molycorp, Inc., undated).

Chile.—According to Molymet, it 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 has three concentrate roasters with a total molybdenum treatment capacity of 43,000,000 kg/yr. In addition to its Chilean operations, Molymet has molybdenum concentrate roasting facilities in Mexico (Molymex S.A. de C.V.), roasting and ferromolybdenum 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., 2013, p. 34). Molymet toll roasted byproduct molybdenum concentrates for Corporación Nacional del Cobre de Chile (Codelco) and also sourced concentrates from Canada, Mexico, Peru, and the United States. Codelco and Xstrata plc also roasted byproduct molybdenum concentrates in Chile, but those roasters were not equipped for rhenium recovery.

Codelco announced the construction of its new molybdenum roaster in the port city of Mejillones. The roasting plant, equipped with a rhenium circuit, was expected to produce its first rhenium in early 2016 (Metal-Pages, 2014a).

Estonia.—Toma Group (Tallinn) continued to recycle metal alloys containing rhenium at its facility in Tallinn. The facility had a capacity to recycle 130 kg of 69.4% rhenium in APR, from approximately 3,000 kg per month of various alloys. 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, undated).

Germany.—Buss & Buss Spezialmetalle GmbH (Sagard), in a joint venture with Molycorp, continued to recycle rhenium-containing alloys, rhenium scrap into catalyst-grade APR (99.9% rhenium), and rhenium pellets (99.9% rhenium) at its facility in Sagard. Annual capacity for secondary rhenium production was estimated to be approximately 2,000 kg (Buss & Buss Spezialmetalle GmbH, 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 operated recycling facilities in Hanau and in Sante Fe, CA (Heraeus Precious Metals GmbH & Co. KG, undated).

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

Japan.—Kohsei Co. Ltd., a Tokyo-based manufacturer of nonferrous metals, announced that its Kitakyushu plant had begun to extract rhenium from the turbine blades of scrapped jet engines. The company was expecting to extract approximately 2,000 kg of rhenium from 100,000 kg of scrapped components in the initial year of operation (Kohsei Co., Ltd., 2014).

Kazakhstan.—Zhezkazganredmet (Redmet), Kazakhstan's State-owned rhenium producer, received rhenium-bearing residues from the Zhezkazgan Copper Works mine and smelter complex. Zhezkazgan was controlled by KAZ Minerals plc, formerly Kazakhmys plc, and its parent Samsung Corp., which received 50% of Redmet's production as payment for the rhenium residues. KAZ Minerals temporarily suspended its operations in mid-2013 at its Zhezkazgan smelter and refinery. The company expected to upgrade the facility to process copper-molybdenum ore from the newly developed Bozshakol mining and concentrating complex in Kazakhstan (Metal-Pages, 2014b).

Korea, Republic of.—LS-Nikko Copper Inc. was dependent on rhenium recovered from copper concentrates coming from South America to its Onsan smelter (Lipmann, 2014). LS-Nikko is a 50–50 joint venture between the Republic of Korea and Japan established in 1999.

Poland.—KGHM Ecoren S.A. (Lubin), a division of Polish copper producer KGHM Polska Miedź S.A., continued to operate its metallic rhenium refinery near the Legnica copper smelter. Ecoren reported that British customers Johnson Matthey plc and Rolls-Royce Group plc were the major purchasers of its rhenium products. The facility has an annual capacity to convert APR into 3,500 kg of metallic rhenium. It is also able to supply rhenium metal in powder form according to customer requirements (KGHM Ecoren S.A., 2013). KGHM commissioned a new rhenium recovery circuit at its third copper plant in Legnica, giving it an additional capacity of 500 to 600 kg/yr of rhenium. Ecoren received waste sulfuric acid from the KGHM Polish copper plant and then, through hydrometallurgical processes, captured the rhenium to produce the APR and rhenium metal (KGHM Ecoren S.A., 2013).

Outlook

The United States is the world's leading producer of aerospace superalloys and is, therefore, the leading consumer of rhenium (Roskill Information Services Ltd., 2010, p. 34). With the leading three consumers—Cannon Muskegon Corp., GE, and Pratt & Whitney—consuming an estimated 45,000 kg/yr of rhenium, more production from new plants, such as KGHM Ecoren's rhenium facility in Poland, are needed. Rhenium consumption is expected to increase by an average of 3% per year between 2013 and 2018 and is expected to reach 70,400 kg in 2018 (Roskill Information Services Ltd., 2013, p. 101).

Because the life cycle of turbine blades in jet engines is approximately 10 years, significant quantities of second-generation blades (3% rhenium) continue to accumulate. Technology is continuing to be developed to allow recycling of second-generation blades for recovery of rhenium that can be used in the manufacture of new third-generation blades, potentially reducing requirements for virgin rhenium by about 50%. The majority of rhenium is recycled in Germany and the United States, but significant amounts are also being recovered in Estonia and Russia. Rhenium recycling rates continue to increase worldwide.

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

(Kilograms, gross weight)

	2009	2010	2011	2012	2013
Production[2]	5,580	6,100	8,610	7,910	7,110
Apparent consumption[e, 3]	37,100	39,700	42,100	48,100	42,400
Imports:					
Metal	21,500	23,100	23,800	27,400	22,700
Ammonium perrhenate	14,300	15,100	13,800	19,200 r	18,000

[e]Estimated. [r]Revised.
[1]Data are rounded to no more than three significant digits unless otherwise specified.
[2]Rhenium contained in molybdenite concentrates, based on calculations by the U.S. Geological Survey.
[3]Calculated as production plus imports minus exports and industry stock changes.

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

	2012		2013	
Country	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)
Belgium	7	$55	--	--
Canada	39	74	859	$1,370
Chile	23,900	55,200	18,800	47,000
China	--	--	11	7
Germany	397	862	364	942
Poland	2,980	10,200	2,500	8,890
United Kingdom	140	1,210	210	1,250
Total	27,400	67,500	22,700	59,500

-- Zero.
[1]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[1]

	2012		2013	
Country	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)
Canada	850	$1,450	--	--
Chile	--	--	61	$320
Germany	2,300	3,910	76	261
Kazakhstan	9,470	16,100	3,990	8,200
Korea, Republic of	6,000 r	10,200 r	13,900	22,000
Netherlands	182	346	--	--
United Kingdom	413	858	--	--
Total	19,200 r	32,900 r	18,000	30,800

[r]Revised. -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau; data adjusted by the U.S. Geological Survey.

TABLE 4

RHENIUM: ESTIMATED WORLD PRODUCTION, BY COUNTRY[1, 2]

(Kilograms)

Country[3]	2009	2010	2011	2012	2013
Armenia	400	400	400	350 r	300
Chile[4]	25,000	25,000	24,000	27,000	25,000
China	NA	NA	NA	NA	NA
Kazakhstan	3,000	3,000	3,000	3,000	2,500
Poland[5, 6]	2,422	4,656	6,000	8,075 r	7,530
Russia	NA r	NA r	NA r	NA r	NA
United States[6, 7]	5,580	6,100	8,610	7,910	7,110
Uzbekistan	4,800	4,800	5,400	5,400	5,500
Other	1,500	1,500	1,500	1,200	1,000
Total	42,700 r	45,500 r	48,900 r	52,900 r	48,900

[r]Revised. NA Not available.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes data available through June 15, 2014.

[3]In addition to the countries listed, China and Russia also produce rhenium but output is not officially reported, and available general information is inadequate for the formulation of reliable estimates of output levels.

[4]Includes rhenium contained in molybdenum concentrates from Belgium, Mexico, Peru, and the United States, processed at Molymet in Chile

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

[6]Reported figure.

[7]Calculated rhenium contained in molybdenite concentrates. Data are rounded to two significant digits.