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2010 Minerals Yearbook

RHENIUM [ADVANCE RELEASE]

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Rhenium

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U.S. estimated rhenium production increased by about 9%, while apparent consumption of rhenium increased by about 27% from that of 2009 (table 1). World production of rhenium in 2010 was estimated to be about 47,200 kilograms (kg), a 4% increase from that of 2009 (table 4).

Production

In the United States, rhenium is a byproduct of molybdenite concentrates that are recovered as a byproduct of porphyry copper-molybdenum ore mined in the Western States. Rhenium recovery requires roasting in a facility equipped to capture the rhenium compounds in the stack gases. In the United States, only one molybdenum concentrate roasting facility is currently so equipped—the Freeport McMoRan Copper & Gold Inc. Sierrita facility in Arizona. Domestic mine production data for rhenium (table 1) were derived by the U.S. Geological Survey (USGS) from reported molybdenum production at the copper-molybdenum mines. 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 both spent catalysts and superalloy scrap.

Consumption

In the past decade, the two most important uses of rhenium have been in high-temperature superalloys and platinum-rhenium catalysts. 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 and the development of new alloys and catalysts.

Other applications of rhenium, primarily as tungsten-rhenium and molybdenum-rhenium alloys, are more diverse; these 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.

World consumption of rhenium in 2009 was estimated to be 53,500 kg, of which 78% was consumed in superalloys, 14% in catalysts, and 8% in other end uses (Roskill Information Services Ltd., 2010, p. 27).

Rhenium was 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 were used in the production of benzene, toluene, and xylenes, although this use was small compared with that used in gasoline production.

General Electric Aviation (GE), a subsidiary of General Electric Co. (Fairfield, CT), announced that it had developed two new alloys as part of the company's overall strategy to conserve and recycle rhenium. The first new alloy, N500, a rhenium-free alloy, was expected to be used in stationary parts such as engine nozzles and shrouds. The second new alloy, René N515, used less rhenium (1.5%) while providing the properties of other second-generation alloys that used significantly more rhenium (3%). According to the company, René N515 has been tested extensively and has been introduced into the CFM56 turbine blades in jet engines. Computer modeling enabled the development and introduction of the alloy in 2 years, compared to the traditional developmental time of 4 years (Fink and others, 2010). However, it was important to note that René N515 has been described as having an oxidation resistance capability at 1,175 °C. This temperature was not expected to be an operating temperature that could power many of the larger jet engines that run at higher temperatures. The only alloys capable of running at these higher temperatures were the current second-generation (3% Re) and third-generation (6% Re) alloys, making GE's new alloys inadequate for larger jet engines (Lipmann Walton & Co. Ltd., 2010).

GE has also been working to lessen its dependence on rhenium by researching a variety of innovative component designs and by using advanced manufacturing processes. Recycling materials from unserviceable engine parts continued to be performed through GE's Reclamation Program that was launched in 2006 in response to the volatile market and rising prices. GE recycles used, high-pressure turbine blades (HPTBs) made of a rhenium-bearing nickel superalloy that are cleaned and melted for reuse in manufacturing new HPTBs. Although the lifespan of engine parts was variable, a turbine blade was expected to last approximately 10 years. According to the company, more than 10% of its rhenium came from recycling, and it expected the percentage to increase in 2010 (General Electric Aviation, 2011).

According to the company, GE's Reclamation Program also has numerous benefits for its customers, who receive significant value for the scrap metal they return. The U.S. Navy was one of the first participants in the program. Approximately 23 metric tons (t) of material has been picked up from the U.S. Navy's Fleet Readiness Center (Jacksonville, FL) and recycled. That includes out-of-use F414, F404, and T700 engines, which are also some of the models that have the highest rhenium content (General Electric Aviation, 2011).

Rio Tinto plc announced that Kennecott Utah Copper's molybdenum autoclave-process (MAP) facility, first approved in June 2008 and then later put on hold, was given approval to restart construction in April 2010. First production from phase I of the project was anticipated in the fourth quarter of 2012, and production at full capacity of 13,600 metric tons per year (t/yr) of molybdenum was scheduled for the fourth quarter of 2013. The phase 2 expansion to 27,200 t/yr of molybdenum was anticipated to be completed in the first quarter of 2015 (Rio Tinto plc, 2011, p. 78). The MAP was expected to enable lower grade concentrate to be processed more efficiently than in conventional roasters, to allow improved molybdenum recovery, and to enable production of chemical-grade molybdenum products (Rio Tinto plc, 2010, p. 40). The new facility would have the capacity to recover approximately 3 to 5 t/yr of rhenium. Unlike the roasting process, the autoclave system would extract rhenium at the crystallization stage and recover it, as in the old roasting process, via ion exchange. The final products would be high-purity ammonium perrhenate (APR) suitable for catalysts and rhenium metal for the aerospace industry.

Northern Dynasty Minerals Ltd. (Vancouver, British Columbia, Canada) announced the results of a preliminary assessment technical report from its Pebble copper-gold-molybdenum-rhenium project in Alaska. Based on a 45-year open pit mine life, the report estimated that the project could produce close to 14 million metric tons of copper, 635,000 t of molybdenum, and 1,200 t of rhenium, in addition to gold, palladium, and silver. Mine construction would take 4 years, employing a maximum labor force of 2,080. The project, also known as the Pebble Partnership, is a 50-50 joint venture between Northern Dynasty and Anglo American plc (London, United Kingdom). According to the companies, a range of options are currently being examined including conventional open pit mining, underground mining, or a combination of both (Northern Dynasty Minerals Ltd., 2011, p. 10–13).

Prices

In 2010, the annual average price of APR catalytic-grade rhenium as reported in Metal Bulletin was $4,630 per kilogram, a 39%* decrease compared with the $7,580 per kilogram annual average price of 2009. The annual average price of rhenium metal pellets (minimum 99.9%) was $4,720* per kilogram in 2010, a 37% decrease from the $7,500* per kilogram annual average price of 2009. The rhenium metal pellet price was $4,740* per kilogram until July, when it trended downward for the remainder of the year.

Foreign Trade

Imports of rhenium metal in 2010 increased to 23,100 kg, a 7% increase compared with 21,500 kg rhenium metal in 2009 (table 2). Imports of APR increased to 25,500 kg, a 78% increased compared with 14,300 kg APR in 2009, owing to stronger U.S. demand (table 3). Chile and the United Kingdom were the leading suppliers of rhenium metal to the United States; Kazakhstan, Poland, Russia, and the United Kingdom were the leading suppliers of APR. Imports for consumption of rhenium metal are shown in tables 1 and 2, and those of APR are shown in tables 1 and 3.

World Review

World production of rhenium was estimated to have been about 47,200 kg in 2010 (table 4). This estimate was based on the quantity of rhenium recovered from concentrates that were processed to recover rhenium values.

Rhenium was recovered as a byproduct from porphyry copper-molybdenum ores mined primarily in Canada, Chile, Mexico, Peru, Poland, and the United States. Rhenium is also associated with copper minerals in sedimentary deposits in Armenia, Kazakhstan, Russia, and Uzbekistan, where ore is processed for copper recovery, and the rhenium-bearing residues are recovered at the copper smelter. 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 were Chile, Germany, the Netherlands, the United Kingdom, 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. Chilean 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, Russia, and Uzbekistan, and in sedimentary copper-cobalt deposits in Congo (Kinshasa). U.S. reserves were estimated to be about 390 t, and rest-of-the-world reserves were estimated to be about 2,100 t.

Australia.—Ivanhoe Australia Ltd. (Melbourne) announced that it completed a prefeasibility study on its Merlin molybdenum-rhenium project in northwestern Queensland. The prefeasibility study projected average output of approximately 5,300 t/yr of molybdenum as molybdenum trioxide and 7.2 t/yr of rhenium as APR during at least a 10-year mine life. Concentrate production was targeted for the third quarter of 2013, with commercial production to start in the first quarter of 2014 (Metal-Pages, 2011).

Chile.—Molibdenos y Metales S.A. (Molymet) (Santiago) maintained roasting facilities equipped for rhenium recovery in Belgium, Chile, and Mexico. Molymet primarily toll roasted byproduct molybdenum concentrates for Corporación Nacional

*Correction posted on May 15, 2012.

del Cobre de Chile (Codelco), but 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.

In January, Codelco resubmitted approval plans to Chile's National Environmental Comission (CONEMA) for its $4.5 million plan to refurbish and restart operation of a rhenium recovery plant at its Chuquicamata Mine. In November 2009, the company had submitted a request but later withdrew it in order to carry out some technical adjustments. The plant was expected to have the capability to produce 1,800 kilograms per year of metallic rhenium and was expected to run for 20 years (Business News Americas, 2010). The rhenium recovery plant was built in 1990 and began production in 1991, but operations were halted in 1996 after rhenium market conditions deteriorated (Platts Metals Week, 2009).

Kazakhstan.—Zhezkazganredmet (Redmet), Kazakhstan's state-owned rhenium producer, received rhenium-bearing residues from the Dzhezkazgan Copper Works mine and smelter complex in Kazakhstan. Dzhezkazgan was controlled by Kazakh Copper, and its parent Samsung Corp., which received 50% of Redmet's production as payment for the rhenium residues. A disagreement, beginning in 2007, between Kazak Copper and Redmet resulted in rhenium production slipping from 8 t in 2006 to an estimated 3 t in 2009. The Dzhezkazgan plant was scheduled to undergo refurbishment in 2010, which further decreased rhenium production to an estimated 2 t in 2010 (Kazakhmys plc, 2010).

Poland.—KGHM Ecoren S.A. (Lubin), a division of Polish copper producer KGHM Polish Copper S.A., opened a metallic rhenium refinery near the Legnica Copper Smelter. The facility, completed in October 2009, took only 5-1/2 months to build. Ecoren reported that British customers, Rolls-Royce Group plc and Johnson Matthey plc, were the major purchasers of its rhenium products. The facility has an annual capacity to convert APR into 3.5 t of metallic rhenium. It is also able to supply rhenium metal in powder form according to customer's requirements. Ecoren also increased its crystalline APR production capacity, which was expected to be 6 to 7 t/yr of APR. Ecoren receives the waste sulfuric acid from the KGHM Polish copper plant and then, through hydrometallurgical processes, captures the rhenium to produce the APR and rhenium metal (KGHM Ecoren S.A., 2011).

Outlook

The global economic downturn, particularly in North America and Europe, severely affected the major markets for rhenium, and world rhenium demand decreased by 16% in 2009. In 2010, rhenium demand began to recover. The United States is the world's leading producer of aerospace superalloys and is, therefore, the largest consumer of rhenium (Roskill Information Services Ltd., 2010, p. 34). With the leading three consumers—GE, Pratt & Whitney, and Cannon Muskegon Corp.—consuming an estimated 45 t/yr of rhenium, more production from new plants, such as Poland's new rhenium facility, are needed. Rhenium consumption was estimated to increase by an average of 5% per year between 2009 and 2015 to reach 71,500 kg in 2015 (Roskill Information Services Ltd., 2010, p. 27).

As the life cycle of turbine blades in jet engines is approximately 10 years, significant quantities of second-generation blades (3% Re) were accumulating. Technology is beginning 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.

Potential molybdenum producers continued to look at ways to increase the value of future production since the collapse in the molybdenum price. For some, producing byproduct rhenium is a strong possibility. Perhaps the greatest potential for increased rhenium production lies in the molybdenum concentrates that are presently being roasted in facilities that are not equipped to recover the rhenium values. For example, Rio Tinto's new MAP facility would allow Rio Tinto to recover approximately 3 to 5 t/yr of rhenium, potentially increasing U.S. rhenium production by more than 50%.

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TABLE 1

SALIENT U.S. RHENIUM STATISTICS[1]

(Kilograms, gross weight)

	2006	2007	2008	2009	2010
Production[2, 3]	8,100	7,100	7,900	5,600	6,100
Apparent consumption[e, 4]	46,900 [r]	48,100 [r]	51,600 [r]	37,100 [r]	46,900
Imports:					
Metal	22,000	30,500	35,900	21,500	23,100
Ammonium perrhenate	24,300	15,100	11,200	14,300	25,500

[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]Data are rounded to two significant digits.

[4]Calculated as production plus imports minus exports and industry stock changes.

TABLE 2

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

	2009		2010	
Country	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)
Canada	39	$73	10	$21
Chile	20,100	47,200	21,900	50,200
Germany	1,030	3,820	314	520
Italy	--	--	89	584
Netherlands	219	1,940	--	--
Poland	--	--	7	24
United Kingdom	119	61	771	1,430
Total	21,500	53,100	23,100	52,800

-- Zero.

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

Source: U.S. Census Bureau, as adjusted by the U.S. Geological Survey.

TABLE 3

U.S. IMPORTS FOR CONSUMPTION OF AMMONIUM PERRHENATE, BY COUNTRY[1]

Country	2009		2010	
	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)
Canada	--	--	96	$275
Chile	4,800	$361	--	--
Germany	--	--	2,890	813
Kazakhstan	--	--	4,590	3,530
Mongolia	2,390	180	--	--
Netherlands	1	4	2,850	1,250
Poland	1,870	698	4,100	8,270
Russia	--	--	3,770	1,060
United Kingdom	5,260	12,400	6,070	2,410
Uzbekistan	--	--	1,090	308
Total	14,300	13,700	25,500	17,900

-- Zero.

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

Source: U.S. Census Bureau, as adjusted by the U.S. Geological Survey.

TABLE 4

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

(Kilograms)

Country	2006	2007	2008	2009	2010
Armenia	1,200	400	400	400	400
Canada	1,200	1,200	1,600	1,000 r	1,000 p
Chile[3]	19,800	22,900	27,600	25,000	25,000
Kazakhstan	8,000	5,500	5,500	3,000	2,000
Peru[4]	5,000	5,000	5,000	5,000	5,000
Poland[5]	1,000 r	2,400 r	3,400 r	2,400 r	4,700
Russia	1,400	1,500	1,500	1,500	1,500
United States[6, 7]	8,100	7,100	7,900	5,600	6,100
Uzbekistan	NA	NA	NA	NA	NA
Other	1,000	1,500	2,000	1,500	1,500
Total	46,700	47,500	54,900	45,400 r	47,200

pPreliminary. rRevised. 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]Table includes data available through June 27, 2011.

[3]Data also includes rhenium content from Belgium, Mexico, and the United States, processed at Molymet in Chile.

[4]No rhenium is recovered in Peru, but unroasted molybdenum concentrates containing rhenium are exported to Molymet in Chile for processing.

[5]Data based on new information from KGHM Ecoren S.A. Calculated based on 69.2% rhenium content of ammonium perrhenate.

[6]Reported figure.

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