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RHENIUM

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Rhenium

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U.S. estimated rhenium production decreased by about 29%, while apparent consumption of rhenium decreased by about 25% from that of 2008 (table 1). World production of rhenium in 2009 was estimated to be about 46,200 kilograms (kg), a 16% decrease from that of 2008 (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 domestic recovery from ores and from 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 other land-based turbine applications. Rhenium is used in the turbine blades closest to the combustion zone in gas turbine engines. This 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. Other applications of rhenium, primarily as tungsten-rhenium and molybdenum-rhenium alloys, are more diverse; these included electrical contact points, flashbulbs, heating elements, metallic coatings, temperature controls, thermocouples, vacuum tubes, and x-ray tubes and targets. Industry continued to research the potential for increased recycling of rhenium-bearing turbine blades and the development of new alloys and catalysts.

World consumption of rhenium in 2009 was estimated to be about 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). Other end uses for rhenium alloys were in crucibles, electrical contacts, electromagnets, electron tubes and targets, heating elements, ionization gauges, mass spectrographs, metallic coatings, semiconductors, temperature controls, thermocouples, and vacuum tubes.

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 Company (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, the 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 with 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 extreme 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 also continued to recycle used, high-pressure turbine blades (HPTBs) made of a rhenium-bearing nickel superalloy that was 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 their rhenium came from recycling, and they expected the percentage to increase in 2010 (Metal-Pages, 2009b).

Construction of Kennecott Utah Copper's molybdenum autoclave process (MAP) facility, approved during the second quarter of 2008, continued to be delayed owing to decreased molybdenum prices. The MAP was expected to enable lower grade concentrate to be processed more efficiently than in conventional roasters, allow improved molybdenum recovery, and 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 metric tons per year (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. The facility was expected to be completed in the fourth quarter of 2011 and was expected to reach full capacity in 2012 (Metal-Pages, 2009a.)

Prices

Rhenium metal powder and APR average annual prices were estimated to be about $6,700 per kilogram and $7,800 per kilogram of rhenium content, respectively. The powder price was about $9,000 per kilogram in January, before it began its decline to $6,500 per kilogram in May. The powder price remained steady at nearly $6,500 per kilogram until August when it reached its yearly low of $4,800 per kilogram. The powder price increased slightly to close the year at about $5,200 per kilogram in December. The APR price was about $10,000 per kilogram in January and February before it began its decline in March to $9,600 per kilogram. The APR price continued a gradual decrease to $6,800 per kilogram in June and stayed at approximately $6,300 per kilogram for the remainder of the year.

Foreign Trade

Compared with those of 2008, imports of rhenium metal decreased by about 40% (table 2) owing to weaker U.S. demand, while imports of APR increased by about 28% (table 3). Chile and Germany were the leading suppliers of rhenium metal to the United States; Chile, Mongolia, Poland, 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 46,200 kg in 2009 (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 lesser 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 further test drilling, near its Merlin site in northwestern Queensland, revealed an additional high-grade source of molybdenum and rhenium. The new site was expected to be named the Little Wizard project. According to the company, the Merlin project was the highest grade source of molybdenum and rhenium identified anywhere in the world. An initial mineral resource estimate revealed potential for approximately 91,000 t of contained molybdenum and 152,000 kg of rhenium. In 2010, the company expected to begin a prefeasibility study to develop the Merlin deposit. Environmental permitting would be undertaken in parallel with the prefeasibility study and was expected to be completed by November 2010 (Ivanhoe Australia Ltd., 2009, 2010.)

Canada.—In December, MetalCORP Ltd. (Toronto, Ontario) announced the results of the first mineral resource estimate for its Playter molybdenum-rhenium deposit in eastern Ontario, prepared by AMEC Americas Ltd. Inferred resources were estimated to be 874,410 t grading 0.25% molybdenum and 1.67 grams per metric ton of rhenium. AMEC was unable to make an estimate for some of the mineralization owing to lack of verified data and recommended further drilling. According to MetalCORP, the resource estimate showed higher-than-expected metal grade but a lower-than-expected tonnage, and the company was uncertain if further exploration was advisable (MetalCORP Ltd., 2009).

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 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 currently equipped for rhenium recovery. In December 2008, Molymet stopped fundraising to finance a new $120 million molybdenum smelter near Mejillones in Chile.

In December, Codelco announced that it had requested approval from the regional environment commission to refurbish and restart operations of the rhenium recovery plant at its Chuquicamata site at a cost of $4.5 million. The plant was expected to produce 2.1 t of rhenium metal briquettes in 2010, increasing to 2.8 t/yr in 2011. 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 also expected to undergo refurbishment in 2010, which was expected to further decrease rhenium production (Kazakhmys plc, 2010).

Poland.—KGHM Ecoren S.A. (Lubin) announced that the construction of the technological line for rhenium metal recovery from APR at the Legnica Technological Park LETIA was expected to be completed by early 2010. According to the company, the Glogów copper mill in southwestern Poland has Europe's only facility for recovering rhenium from industrial waste. The project was launched in September 2007 on the basis of a rhenium recovery method developed by KGHM and the Institute of Non-Ferrous Metals in Gilwice, Poland. The innovative rhenium recovery technology used is based on recycling acid effluents, with the recovery of the APR from acid solutions containing the metal. In 2009, production of APR decreased to 3.5 t from 4.9 t in 2008 (KGHM Ecoren S.A., 2009). Poland's rhenium production is mostly committed on long-term contracts to British customers Rolls-Royce Group plc and Johnson Matthey plc (Metal-Pages, 2009b).

Outlook

The global economic downturn, particularly in North America and Europe, severely affected the major markets for rhenium and world rhenium demand dropped by 16% in 2009. In 2010, rhenium demand is expected to recover. The United States is the world's largest producer of aerospace superalloys and is, therefore, the largest consumer of rhenium (Roskill Information Services Ltd., 2010, p. 34). With the top three consumers alone—GE, Pratt & Whitney, and Cannon Muskegon Corp.—consuming an estimated 45 t/yr of rhenium, more developments like Poland's new rhenium facility are needed.

As the life cycle of turbine blades in jet engines is approximately 10 years, significant quantities of second-generation blades (3% Re) are 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 recycling is currently performed 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)

	2005	2006	2007	2008	2009
Production[2]	7,900	8,100	7,100 r	7,900 r	5,600
Apparent consumption[e, 3]	30,200 r	40,200 r	38,800 r	40,600 r	30,500
Imports:					
Metal	21,800	22,000	30,500	35,900	21,500
Ammonium perrhenate	10,300	24,300	15,100	11,200 r	14,300

[e]Estimated. [r]Revised.

[1]Data are rounded to no more than three significant digits.

[2]Rhenium contained in molybdenite concentrates, based on calculations by the U.S. Geological Survey. Data rounded to two significant digits.

[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]

	2008		2009	
Country	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)
Belgium	157	$192	--	--
Canada	--	--	39	$73
Chile	28,500	55,800	20,100	47,200
China	12	60	--	--
France	419	673	--	--
Germany	1,640	7,090	1,030	3,820
Guadeloupe	1	4	--	--
Japan	13	38	--	--
Netherlands	5,060	8,450	219	1,940
United Kingdom	130	462	119	61
Total	35,900	72,800	21,500	53,100

-- 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 3

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

	2008		2009	
Country	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)
Belgium	162	$4	--	--
Chile	246	776 r	4,800	$361
China	1,350	6,080 r	--	--
Germany	214	1,220	--	--
Kazakhstan	8,890	15,100	--	--
Korea, Republic of	4	13 r	--	--
Mongolia	238	753 r	2,390	180
Netherlands	--	--	1	4
Poland	--	--	1,870	698
Russia	100	314	--	--
United Kingdom	2	6	5,260	12,400
Total	11,200 r	24,200	14,300	13,700

[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	2005	2006	2007	2008	2009
Armenia	1,200	1,200	400 r	400 r	400
Canada	1,300	1,200	1,200	1,600	1,800
Chile[3]	21,500 r	19,800	22,900	27,600	25,000
Kazakhstan	8,000	8,000	5,500 r	5,500 r	3,000
Peru	5,000	5,000	5,000	5,000	5,000
Poland[4]	--	1,040 [5]	2,420 [5]	3,390 [5]	2,420 [5]
Russia	1,400	1,400	1,500	1,500	1,500
United States[4, 6]	7,900	8,100	7,100	7,900	5,600
Uzbekistan	NA	NA	NA	NA	NA
Other	1,000	1,000 r	1,500 r	2,000 r	1,500
Total	47,300 r	46,700 r	47,500 r	54,900 r	46,200

[r]Revised. NA Not available. -- Zero.

[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, 2010.

[3]Data revised based on new information from Comisión Chilena del Cobre; also includes rhenium content from Mexico processed at Molymet in Chile.

[4]Reported figure.

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

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