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RHENIUM [ADVANCE RELEASE]

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Rhenium

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U.S. estimated rhenium production increased by about 11%, while apparent consumption of rhenium increased by about 7% from that of 2007 (table 1). World production of rhenium in 2008 was estimated to be about 56,500 kilograms (kg), a 12% increase from that of 2007.

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 and 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 principally by imports and also from domestic recovery from ores and from stocks.

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 recycling the rhenium-bearing alloy from turbine blades and the development of new alloys and catalysts.

Metallurgical uses, such as in nickel-based superalloys and powder metallurgy, were estimated to represent about 77% of rhenium consumption; rhenium improves the strength properties of nickel alloys at high temperatures (1,000° C). An additional 15% was used in the production of reforming catalysts for the petroleum industry (Roskill Information Services Ltd., 2007, p. 88). Other uses for rhenium alloys, which collectively represented only about 8% of total consumption, 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 in March that it planned to introduce new nickel-based superalloys into its aircraft engines before yearend 2008, potentially reducing its reliance on rhenium. GE was in the advanced stage of engine testing of a rhenium-free alloy which was to be used in stationary parts such as engine nozzles and shrouds. Another alloy that uses one-half the amount of rhenium compared with currently used alloys was being tested for use in rotating parts, specifically turbine blades. According to the company, it would like to reduce its dependence on rhenium by one-half, and that includes its intensive recycling program. The recycling program involves used, high-pressure turbine blades (HPT) made of a rhenium-bearing nickel superalloy that are cleaned and melted for reuse in manufacturing new HPT blades. Although the lifespan of engine parts varies, a turbine blade will usually last approximately 10 years. According to the company, in 2007, GE reduced its need for new rhenium by 1% as a result of its recycling program (Metal-Pages Ltd., 2008c).

Rio Tinto plc (London, United Kingdom) expected to recover rhenium from its molybdenum concentrates using the Molybdenum Autoclave Process (MAP). The construction of the MAP facility was approved during the second quarter of 2008 but was delayed owing to falling molybdenum prices (Rio Tinto plc, 2008, p. 42). 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 (Metals Place, 2008). The new facility would have the capacity to recover approximately 4 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 product would be ammonium perrhenate (APR) (Metal-Pages Ltd., 2008f).

Prices

Metal powder and APR average annual prices were estimated to be about $10,500 per kg and $10,200 per kg of rhenium content, respectively. Powder prices were about $9,600 per kg in January, rose steadily to about $10,900 per kg in July, and slowly decreased to close the year at about $9,800 in December. APR price was about $8,900 per kg in January, rose steadily to about $10,500 per kg in April where it remained until it decreased in December to about $10,000 per kg.

Foreign Trade

Imports of metal increased by about 18% (table 2) owing to increased production in Chile and the Netherlands and strong U.S. demand, while imports of APR decreased by about 27% (table 3), owing to reduced imports from Chile, Germany, and Kazakhstan. 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 56.5 metric tons (t) in 2008 (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, 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, Netherlands, 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 one-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 recent drilling at the Mount Dore project, in northwestern Queensland, has discovered and confirmed a significant zone of high-grade molybdenum and rhenium mineralization. Drilling of this new discovery, which was expected to be named the Merlin project, has significantly extended the mineralized zone and also has returned high-grade rhenium assays. Work at the site including a cost benefit assessment, an initial mineral resource estimate, and metallurgical testing was expected to be completed in early 2009 (Ivanhoe Australia Ltd., 2008, p. 1).

Canada.—In October, MetalCORP Ltd. (Toronto, Ontario) announced assay results of several high-grade molybdenum-rhenium occurrences from its recently completed prospecting exploration program on its Fearless property east of the Playter molybdenum-rhenium deposit in eastern Ontario (MetalCORP Ltd., 2008). In the fourth quarter of 2007, MetalCORP discovered very high-grade molybdenum and rhenium values at the Playter deposit on its Big Lake property. In June 2008, MetalCORP announced that it discovered a second zone of molybdenum and rhenium in porphyry rock at the Playter deposit, potentially making it the largest molybdenum-rhenium deposit in Canada (Metal-Pages Ltd., 2008e).

Chile.—The Chilean company 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 roast byproduct molybdenum concentrates in Chile, but those roasters are not currently equipped for rhenium recovery.

In November, Codelco announced that it would decide by the first quarter of 2009 on whether or not it would produce rhenium. The plan would require Codelco to invest $50 million to install a rhenium recovery plant at its Chuquicamata site, with the aim of recovering approximately 2 t/yr of rhenium. Codelco's former rhenium processing plant at Chuquicamata was previously closed owing to a lack of commercial interest in the product (Metal-Pages, Ltd., 2008b).

Kazakhstan.—Zhezkazganredmet (Redmet), Kazakhstan's state-owned rhenium producer, receives rhenium-bearing residues from the Dzhezkazgan Copper Works mine and smelter complex in Kazakhstan. Dzhezkazgan is controlled by Kazakh Copper, and its parent Samsung Corp., which receives 50% of Redmet's production as payment for the rhenium residues. Redmet's production capacity was estimated to be about 8,000 kg per year of contained rhenium as APR.

Poland.—In September, KGHM Ecoren S.A. announced that it signed a 5-year, $100 million contract for the delivery of the APR produced at the Glogów copper mill to Rolls-Royce Motor Cars Ltd. (United Kingdom). KGHM has the advantage of being an integrated rhenium producer, owning the mine, smelter, and the new rhenium recovery plant. According to the company, the Glogów copper mill in southwestern Poland has Europe's only facility for recovering rhenium from industrial waste. The recovery 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. Work was underway to launch a line to produce metallic rhenium pellets. KGHM produced more than 3.5 t of rhenium in 2007 and was expected to produce almost 5 t of rhenium in 2008. In 2009, the company expected to produce 6 t of rhenium (Warsaw Voice, The, 2008).

KGHM signed a 5-year rhenium cooperation contract with precious metals refiner Johnson Matthey plc (United Kingdom). The value of the contract was estimated to be about $50 million. Johnson Matthey has a petroleum catalyst division and is also a supplier of platinum group metals to large catalyst manufacturers (Metal-Pages, Ltd., 2008d).

Outlook

World demand for rhenium is likely to remain stable during the near term. Boeing Co. (Chicago, IL) was expected to supply approximately 480 commercial planes in 2008, an increase of approximately 40 planes from that of 2007. Airbus S.A.S. (Toulouse, France) was expected to deliver approximately 470 commercial airplanes in 2008, an increase of 17 planes from that of 2007. The U.S. military has targeted production of 3,000 F-35 aircraft, 6,000 engines, and 700 F-22 Raptors, all of which would use third-generation nickel-based superalloys containing 6% rhenium (Metal-Pages Ltd., 2008a). Without the 6% rhenium content in the blades, these engines would not be capable of developing the necessary thrust needed to fly such a large plane. In 2009, owing to the downturn in the financial markets, the global aerospace industry was expected to decrease commercial and cargo aircraft deliveries, potentially causing a decrease in rhenium demand. However, an increased use of rhenium in catalytic converters in petroleum refining, and the use of rhenium in technology currently being developed to convert natural gas to liquid could stabilize the demand for rhenium in 2009.

As the life cycle of turbine blades in jet engines is approximately 10 years, significant quantities of second-generation blades (3% rhenium) are accumulating. If technology was developed to allow recycled, second-generation blades to be used in the manufacture of new third-generation blades, requirements for virgin rhenium could potentially be reduced by about 50%. Both H.C. Starck GmbH and Haraeus Holding GmbH in Germany are currently investigating rhenium recycling.

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 instance, Rio Tinto's new MAP facility would allow Rio Tinto to recover approximately 4 t/yr of rhenium, potentially increasing U.S. rhenium production by more than 50%.

References Cited

Ivanhoe Australia Ltd., 2008, High-grade molybdenum and rhenium discovery confirmed at northern end of Ivanhoe Australia's Mount Dore project: Melbourne, Australia, Ivanhoe Australia Ltd., December 8, 14 p. (Accessed October 21, 2009, at http://www.ivanhoeaustralia.com/i/pdf/IVA0005MR-Merlin_Project.pdf.)

Metal-Pages Ltd., 2008a, Boeing sees stable Q2 revenues despite 787 delays: Metal-Pages Ltd., July 23. (Accessed November 18, 2009, via http://www.metal-pages.com.)

Metal-Pages Ltd., 2008b, Codelco–Jury out on rhenium production: Metal-Pages Ltd., November 26. (Accessed October 20, 2009, via http://www.metal-pages.com.)

Metal-Pages Ltd., 2008c, GE looks to reduce rhenium use in superalloys: Metal-Pages Ltd., March 5. (Accessed October 20, 2009, via http://www.metal-pages.com.)

Metal-Pages Ltd., 2008d, KGHM Ecoren and Johnson Matthey sign 5-year rhenium contract: Metal-Pages Ltd., October 28. (Accessed October 21, 2009, via http://www.metal-pages.com.)

Metal-Pages Ltd., 2008e, MetalCORP moly discovery may be among world's largest: Metal-Pages Ltd., June 24. (Accessed November 18, 2009, via http://www.metal-pages.com.)

Metal-Pages Ltd., 2008f, Rio Tinto to invest $270 million in moly, rhenium: Metal-Pages Ltd., June 11. (Accessed October 20, 2009, via http://www.metal-pages.com.)

MetalCORP Ltd., 2008, MetalCORP discovers several high grade molybdenum-rhenium occurrences over an extensive area on the Fearless property: Thunder Bay, Ontario, Canada, MetalCORP Ltd. (Accessed November 18, 2009, at http://www.metalcorp.ca/s/NewsReleases.asp?ReportID=322338.)

Metals Place, 2008, Kennecott to invest $270 million in molybdenum processing facility: Metals Place, July 21. (Accessed August 10, 2009, via http://metalsplace.com/news/articles.)

Rio Tinto plc, 2008, Rio Tinto plc 2008 annual report and financial statements: London, United Kingdom, Rio Tinto plc, 184 p.

Roskill Information Services Ltd., 2007, The economics of rhenium (7th ed.): London, United Kingdom, Roskill Information Services Ltd., 116 p.

Warsaw Voice, The, 2008, Recycling rhenium: The Warsaw Voice, September 18. (Accessed October 20, 2009, via http://www.warsawvoice.pl/.)

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Rhenium. Ch. in Mineral Commodity Summaries, annual.

Rhenium. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Other

Engineering and Mining Journal.

Metal Bulletin.

Metal Bulletin, monthly.

Rhenium. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

TABLE 1

SALIENT U.S. RHENIUM STATISTICS[1]

(Kilograms, gross weight)

	2004	2005	2006	2007	2008
Production[2]	6,500	7,900	8,100	7,090	7,910
Apparent consumption[e, 3]	25,700	36,900	46,900	48,100	51,500
Imports:					
Metal	11,800	21,800	22,000	30,500	35,900
Ammonium perrhenate	10,600	10,300	24,300	15,100	11,000

[e]Estimated.

[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.

[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]

	2007		2008	
Country	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)
Belgium	10	$16	157	$192
Chile	22,700	35,400	28,500	55,800
China	822	1,010	12	60
France	--	--	419	673
Germany	2,650	4,110	1,640	7,090
Guadaloupe	--	--	1	4
Japan	--	--	13	38
Netherlands	3,480	6,070	5,060	8,450
United Kingdom	871	3,070	130	462
Total	30,500	49,600	35,900	72,800

-- Zero.

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

Source: U.S. Census Bureau, with adjustments by the U.S. Geological Survey.

TABLE 3

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

	2007		2008	
Country	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)
Chile	2,340	$4,990	246	$775
China	1,580	4,890	1,350	6,070
Estonia	32	92	--	--
Germany	1,160	3,270	214	1,220
Kazakhstan	9,930	27,900	8,890	15,100
Korea, Republic of	--	--	4	12
Mongolia	--	--	238	752
Russia	46	129	100	314
United Kingdom	48	135	2	6
Total	15,100	41,400	11,000	24,200

-- Zero.

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

Source: U.S. Census Bureau, with adjustments by the U.S. Geological Survey.

TABLE 4

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

(Kilograms)

Country	2004	2005	2006	2007	2008
Armenia	1,000	1,200	1,200	1,200	1,200
Canada	1,700	1,300 r	1,200 r	1,200 r	1,600
Chile[3]	21,300 r	20,500 r	19,800	22,900	27,600
Kazakhstan	5,000	8,000	8,000	7,700	7,700
Peru	5,000	5,000	5,000	5,000	5,000
Russia	1,400	1,400	1,400	1,500	1,500
United States[4]	6,500 [5]	7,900 [5]	8,100 [5]	7,100 [5]	7,900
Uzbekistan	NA	NA	NA	NA	NA
Other	1,000	1,000	2,000	4,000	4,000
Total	42,900 r	46,300 r	46,700 r	50,600 r	56,500

[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]Table includes data available through June 28, 2009.

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

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

[5]Reported figure.