science for a changing world

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RHENIUM

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Rhenium

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In the past decade, the two most important uses of rhenium have been in high-temperature superalloys and platinum-rhenium catalysts. High-temperature superalloys are used in single-crystal turbine blades in aircraft engines and other land-based turbine applications. 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 research on rhenium recovery from recycling turbine blades and the development of new alloys and catalysts.

In the United States, rhenium is a byproduct of molybdenite concentrates recovered as a byproduct of porphyry copper ore mined in the copper-molybdenum mines in the Western States. 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 but also from domestic recovery and stocks. U.S. apparent consumption of rhenium increased by about 38% from that of 2004 (table 1). Metal powder and ammonium perrhenate (APR) values were estimated to be about $1,475 and $1,225 per kilogram (kg), respectively.

Consumption

Metallurgical uses, such as in superalloys and powder metallurgy, were estimated to represent about 70% of rhenium consumption; rhenium improves the strength properties of nickel alloys at high temperatures (1,000° C). An additional 20% was used in production of reforming catalysts (Roskill Information Services Ltd., 2004, p. 46). Other uses for rhenium alloys, which collectively represented only about 10% of total consumption, were in crucibles, electrical contacts, electromagnets, electron tubes and targets, heating elements, ionization gauges, mass spectrographs, metallic coatings, temperature controls, thermocouples, semiconductors, and vacuum tubes.

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. This 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.

Foreign Trade

Imports of metal increased sharply, about 85% (table 2), owing to strong U.S. demand, while imports of APR decreased by about 15% (table 3). Imports for consumption of rhenium metal are listed in tables 1 and 2, and those of APR are listed in tables 1 and 3.

World Review

World production of rhenium was estimated to be about 45.9 metric tons (t) (table 4). That represents the quantity of rhenium recovered from concentrates that were processed to recover rhenium values. Rhenium was recovered as a byproduct from porphyry copper-molybdenum or porphyry copper concentrates mined primarily in Armenia, Canada, Chile, Kazakhstan, Peru, Russia, the United States, and Uzbekistan. The major producers of rhenium metal and compounds were Chile, Germany, 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 mines 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 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). Identified U.S. resources are estimated to be about 4,500 t, and identified rest-of-the-world resources are estimated to be about 5,500 t.

Armenia.—In 2005, Yerevan Pure Iron OJSC (Yerevan) saw sales increase to $140 million from $55 million based on increased production and rising global prices. Production volume increased about 58% compared with that of 2004, as the plant produced 3,000 t of ferromolybdenum, 300 t of metallic molybdenum, and 150 kg of rhenium. The Yerevan plant received molybdenum concentrates from CJSC Zangezur Copper & Molybdenum Plant (Zangezur) in which Yerevan holds a 15% interest (Metal-Pages, 2006§[1]). The Yerevan plant's entire production was exported to Europe by Germany's Khronomet. Khronomet owns 51% of the shares in the Yerevan plant and 60% of the shares in the Zangezur plant.

Chile.—It is generally assumed that about 50% of world rhenium production comes from Chile, and that the world consumption is about 40 to 45 metric tons per year (t/yr) (Taylor,

[1]References that include a section mark (§) are found in the Internet References Cited section.

2002§). The leading producer of molybdenum concentrates in Chile is Corporacion Nacional del Cobre (Codelco); most of their concentrates are roasted and processed for rhenium recovery by Molibdenos y Metales S.A. (Molymet). According to industry sources, Molymet also received concentrates from two other mines in Chile and at least one in Peru. Since 2000, Molymet received rhenium-bearing residues recovered from the stacks of the roasters at its subsidiary plant, Molymex, S.A. de C.V. (Molymex), in Mexico. Molymex receives molybdenite concentrates from Grupo Mexico's La Caridad Mine and from producers in Canada, Chile, Peru, and the United States. Since 2003, Molymet also received rhenium-bearing residues from its subsidiary plant, Sadaci N.V. in Belgium, which toll roasts molybdenum concentrates from a variety of sources. The combined rhenium recovery by Molymet was estimated to be about 20.5 t in 2005.

Molymet planned to boost molybdenum concentrate processing capacity at the San Bernardo, Chile, plant by 18,000 t/yr [40 million pounds per year (Mlb/yr)] and at its Sadaci subsidiary plant in Ghent, Belgium, by 4,500 t/yr (10 Mlb/yr). The expansion in Chile was expected to be completed in mid-2007, while that in Belgium was expected to be completed in 2009. Molymet roasted molybdenum concentrates at plants in Belgium, Chile, and Mexico, and all roaster residues were sent to the San Bernardo facility for rhenium recovery (Ryan's Notes, 2004).

Kazakhstan.—Rhenium production capacity at Zhezkazganredmet (Redmet), the Kazakhstan rhenium producer, was thought to be about 1,000 kg of APR per month. Historically, Redmet received rhenium-bearing residues from the copper mine and smelter complex at Dzhezkazgan and both companies were under government control. However, after Kazakhmys Corp. bought controlling interest in Dzhezkazgan Copper Works, ownership of Redmet was in dispute. Subsequently, exports of APR from Kazakhstan were halted in the third quarter of 2005 while the dispute over control of Redmet was resolved. This action removed about 25% of world rhenium production from the market at a time when demand for superalloys in aerospace applications was increasing; as a result, the price of APR rose in the fourth quarter of 2005 (Metal-Pages, 2005§).

Current Research and Technology

Record energy prices have accelerated research and development of natural gas-to-liquid (GTL) technology. The GTL process consists of the following four stages, all which require catalysts: 1) gas cleaning, 2) reforming into syngas, 3) Fischer-Tropsch synthesis, and 4) hydrocracking (Brumby, 2005§). There are only 8 GTL plants worldwide today but as many as 30 additional plants are being considered, some starting in 2007. Many of these plants are considering a rhenium-promoted, cobalt/aluminum oxide catalyst with up to 1% rhenium content because of its increased carbon monoxide hydrogenation rate. It has been estimated that there are about 9,000 trillion cubic feet of stranded natural gas, which equates to about 900 billion barrels of synthetic liquid fuels, enough to supply about 25 years of world demand at current levels of consumption (Metal Bulletin Monthly, 2004).

Outlook

Current world demand for rhenium is likely to increase during the coming years. Demand for rhenium in nickel-base, single-crystal superalloys is estimated to account for about 60% of current world rhenium consumption. The F-35 Joint Strike Force Fighter project is projected to include production of about 3,000 aircraft and 6,000 engines using high-rhenium content superalloys. The F-22 Raptor is expected to add another 700 aircraft. These 3,700 aircraft will use 6% rhenium superalloys, while the previous generation F-16 fighter (about 4,600 aircraft) used 3% rhenium superalloys (Journal of Metals, 2004). Rhenium consumption is also expected to increase in the commercial aircraft industry as both the Boeing Company and Airbus S.A.S. are reporting record sales.

In addition to continued growth in rhenium consumption in single-crystal superalloys for use in gas engine turbine blades, increased rhenium consumption in catalysts is expected. A GTL industry with a 1-million-barrel-per-day capacity would utilize an estimated 25,000 t of catalysts (Brumby, 2005§). If only one-half of the planned GTL plants noted under Current Research and Technology are built within the next decade using rhenium-promoted catalysts, rhenium demand will probably increase by12.5 t/yr. With 125 t of rhenium in catalysts, recycling these catalysts on a 5-year interval, assuming 10% loss, could create another 2.5 t/yr of rhenium demand. This is compared with an estimated 1 t/yr of rhenium consumed by recycling catalysts in the existing petroleum reforming industry. An additional 15 t/yr of rhenium demand in a 45-t worldwide industry would severely impact the current supply-demand balance.

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, a significant portion of the molybdenum concentrate production of Codelco, the leading producer of molybdenum concentrates in Chile, is exported unroasted or roasted without rhenium recovery. It has been estimated that capturing lost rhenium will probably increase world rhenium production capacity by about 12 t/yr (Roskill Information Services Ltd., 2004, p. 84).

References Cited

Journal of Metals, 2004, World rhenium production must rise to meet demand: Journal of Metals, v. 56, no. 4, April, p. 77.

Metal Bulletin Monthly, 2004, Major trade in minor metals: Metal Bulletin Monthly, issue 402, June, p. 40.

Roskill Information Services Ltd., 2004, The economics of rhenium (6th ed.): London, United Kingdom, Roskill Information Services Ltd., 85 p., plus appendixes.

Ryan's Notes, 2004, No vacation for moly market: Ryan's Notes, v. 10, no. 52, December 27, p. 1.

Internet References Cited

Brumby, Andreas, 2005 (November 14), Recycling GTL catalysts—A new challenge, accessed December 5, 2006, via URL http://cat.inist.fr/?aModele=afficheN&cpsidt=17186659.

Metal-Pages, 2005 (November 25), Supply problems could be on the horizon for rhenium, accessed December 5, 2006, via URL http://www.metalpages.com/subscr/story.php?id=21405.

Metal-Pages, 2006 (January 6), Armenian moly output up, accessed December 5, 2006, via URL http://www.metal-pages.com/subscr/story.php?id=22102.
Taylor, Karen, 2002 (May 30), Rhenium—Waiting for take off, accessed June 7, 2002, via URL http://www.metal-pages.com/news_story.asp?newsid=6435.

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)

	2001	2002	2003	2004	2005
Supply[2]	5,500	4,000	3,900	5,900	7,100
Apparent consumption[e, 3]	28,900 [r]	20,900 [r]	18,400 [r]	26,100 [r]	36,000
Imports:					
Metal	20,200	14,300	13,200	11,800	21,800
Ammonium perrhenate	4,560	3,780	1,990	12,100	10,300

[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.
[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]

	2004		2005	
Country	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)
Austria	2	$3	--	--
Belgium	8	9	--	--
Belize	--	--	34	$30
Chile	10,700	11,700	19,600	20,600
France	4	4	3	3
Germany	1,060	1,130	1,340	1,590
Netherlands	14	14	173	226
Russia	5	7	--	--
United Kingdom	4	9	544	720
Uzbekistan	--	--	50	63
Total	11,800	12,900	21,800	23,300

-- 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]

	2004		2005	
Country	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)
Belgium	--	--	72	$50
Chile	--	--	288	265
China	666	$618	714	437
Estonia	1,500	17	60	22
France	253	321	--	--
Germany	1,660	672	1,440	1,340
Kazakhstan	4,950	4,020	4,530	2,920
Korea, Republic of	--	--	2	3
Netherlands	2,630	1,690	1,650	1,140
Poland	--	--	432	297
United Kingdom	400	226	1,110	572
Total	12,100	7,560	10,300	7,040

-- 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	2001	2002	2003	2004	2005
Armenia	750	800	1,000	1,000	1,200
Canada	1,700	1,700	1,700	1,700	1,700
Chile[3]	16,000 r	15,700 r	20,100 r	21,300 r	20,500
Kazakhstan	2,500	2,600	2,600	5,000 r	8,000
Peru	5,000	5,000	5,000	5,000	5,000
Russia	1,200	1,400	1,400	1,400	1,400
United States[4]	5,000 r	3,400 r	3,400 r	5,900	7,100
Uzbekistan	NA	NA	NA	NA	NA
Other	590	1,000	1,000	1,000	1,000
Total	32,700 r	31,600	36,200 r	42,300 r	45,900

[r]Revised. NA Not available.
[1]Estimated data are rounded to no more than three significant digits; may not add to totals shown.
[2]Table includes data available through June 13, 2006.
[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 molybsenite concentrates.