COBALT

By Kim B. Shedd

Domestic survey data and tables were prepared by Jo-Ann S. Sterling, statistical assistant, and the world production tables were prepared by Linder Roberts, international data coordinator.

Cobalt is a strategic and critical metal used in many diverse industrial and military applications. The leading use of cobalt is in superalloys, which are used to make parts for gas turbine engines. Cobalt is also used to make magnets; corrosion- and wear-resistant alloys; high-speed steels; cemented carbides (also called hardmetals) and diamond tools; catalysts for the petroleum and chemical industries; drying agents for paints, varnishes, and inks; ground coats for porcelain enamels; dyes and pigments; battery electrodes; steel-belted radial tires; airbags in automobiles; and magnetic recording media.

The United States did not mine or refine cobalt in 2003. However, a small number of mining operations produced negligible amounts of byproduct cobalt as intermediate products. Since 1993, sales of excess cobalt from the National Defense Stockpile (NDS) have contributed to U.S. and world supplies. In 2003, U.S. reported consumption of cobalt decreased slightly from that of 2002. World demand for cobalt increased and prices rose.

Salient U.S. and world cobalt statistics for 2003 and the previous 4 years are listed in table 1. With the exception of prices and reported production from foreign countries, all quantity and value data in this report have been rounded to no more than three significant digits. Totals and percentages were calculated from unrounded numbers.

Legislation and Government Programs

During fiscal year 2003 (October 1, 2002, through September 30, 2003), the Defense National Stockpile Center (DNSC), U.S. Department of Defense, held two long-term negotiated cobalt sales and offered cobalt under a basic ordering agreement (BOA). Under the BOA sales format, the DNSC offered cobalt on a periodic basis, depending on market needs. Each Tuesday morning, any cobalt for sale was posted on the DNSC's Web site. Prequalified prospective purchasers submitted quotes by facsimile or by online methods before a specific date and time, and the DNSC accepted or rejected the quotes within 2 business days (Defense National Stockpile Center, 2002, p. 7, 9; 2003a). The DNSC awarded cobalt under this format each month except October and November 2002 and February 2003. During the fiscal year, the DNSC sold 2,060 metric tons (t) of cobalt cathode, granules, and rondelles valued at $34.3 million (table 2). This represented 76% of the 2,720-t (6-million-pound) maximum allowed for sale under the fiscal year 2003 Annual Materials Plan (AMP). As of the end of the fiscal year, 1,020 t of cobalt had been sold but not shipped from the stockpile (U.S. Department of Defense, 2004, p. 6, 56).

The AMP for fiscal year 2004 (October 1, 2003, through September 30, 2004) maintained the maximum allowable sale of cobalt at 2,720 t (Defense National Stockpile Center, 2003b). The DNSC considered expanding its cobalt sales program to include strategic supply alliance (SSA) sales in fiscal year 2004. Under the SSA format, the list of cobalt available for sale would be posted on the DNSC's Web site, and prequalified prospective purchasers could submit bids electronically through the Web site at any time, 24 hours per day and 7 days per week. Awards would be confirmed quickly to expedite the release and shipment of materials (Holder, 2003, p. 27, 31).

During calendar year 2003, the DNSC held two long-term negotiated sales and made BOA awards each month except February. During this period, the DNSC sold 2,820 t of cobalt cathode, granules, and rondelles valued at $62.7 million. On December 31, the total uncommitted cobalt inventory held by the DNSC was 3,360 t, all of which was authorized for eventual disposal.

Production

With the exception of negligible amounts of byproduct cobalt produced from mining operations in Missouri and Montana, the United States did not mine or refine cobalt in 2003. For example, minor amounts of cobalt present in the ores mined for platinum-group metals at the Stillwater Complex of southern Montana were recovered from converter matte at Stillwater Mining Co.'s refinery and sold as a byproduct.

Formation Capital Corp. focused on raising money to renovate the precious metals refinery at its hydrometallurgical complex in Big Creek, ID, so that it could toll refine silver materials and generate cash flow for its Idaho Cobalt Project. The Cobalt Project, which was in the mine-permitting stage of development, entailed developing cobalt-copper-gold deposits in the Idaho Cobalt Belt in Lemhi County, approximately 320 kilometers (km) (200 miles) south of the refinery. Formation planned to retrofit an acid pressure leach plant in the hydrometallurgical complex to refine cobalt concentrates and produce approximately 1,500 metric tons per year (t/yr) of cobalt as cathode and/or cobalt compounds, such as carbonate, hydroxide, or oxide (Formation Capital Corp., 2002, 2003).

New management at PolyMet Mining Corp. began a program to simplify and optimize the company's NorthMet project. The NorthMet polymetallic deposit, which is in the Duluth Complex of northeastern Minnesota, was being considered for development by open pit mining and hydrometallurgical processing. In December, PolyMet and Cleveland-Cliffs Inc. signed an agreement regarding the use of selected equipment at the mothballed Cliffs Erie mill and concentrator, 8 km (5 miles) from the NorthMet Deposit (PolyMet Mining Corp., 2004, p. 1-5).

Kennecott Minerals Co. of Salt Lake City, UT, evaluated the possibility of developing a small underground nickel-copper mine northwest of Marquette, MI, on the Yellow Dog Plains. During the year, Kennecott Exploration Co. completed an exploration drilling program, began metallurgical test work, and contacted consulting firms for the environmental baseline study.

The Eagle deposit had an estimated resource of 5 million metric tons (Mt) grading 3.68% nickel, 3.06% copper, and 0.1% cobalt, with small amounts of gold, platinum, and palladium (Kennecott Exploration Co., 2003, 2004).

U.S. processors made cobalt chemicals and cobalt metal powders from refined cobalt materials and/or cobalt-bearing scrap. U.S. Geological Survey (USGS) data on chemical and metal powder production, shipments, and stocks were derived from a monthly voluntary survey of U.S. cobalt processors. Information from this survey was used to prepare the statistics on cobalt consumption and stocks in table 3. Four of the six cobalt processors on this survey provided data. Estimates were made for plants for which data were not provided. Two processors made extra-fine cobalt metal powder in the United States. Carolmet Cobalt Products (a division of n.v. Umicore s.a.) made cobalt metal powder from cobalt metal at its Laurinburg, NC, plant. Osram Sylvania Inc. produced cobalt metal powder as a byproduct of tungsten recovered from cemented carbide scrap in Towanda, PA. Production and shipments of cobalt metal powder are withheld to avoid disclosing company proprietary data.

As part of a restructuring program, OM Group, Inc. (OMG) shut down its Apex plant in St. George, UT. The plant reclaimed ammonium paratungstate and cobalt compounds from scrap (OM Group, Inc., 2002).

Met-Chem Technology, Inc., a privately owned specialty chemicals company, acquired the former Hall Chemical Company's Wickliffe, OH, manufacturing facility and its associated equipment. Met-Chem planned to restart production of cobalt and nickel chemicals in early 2004 (Met-Chem Technology, Inc., 2003).

Consumption

U.S. apparent consumption for 2003, as calculated from net imports, consumption from purchased scrap, and changes in Government and industry stocks, was slightly higher than that calculated for 2002 (table 1). Although net imports and consumption of scrap were lower in 2003, shipments from the NDS were significantly higher than those in 2002.

U.S. reported consumption for 2003 was 4% lower than that for 2002. As compared with 2002, metallurgical industries consumed 6% less cobalt, and the cobalt consumption for chemical uses was 2% higher. Reported consumption was derived by the USGS from voluntary surveys of U.S. operations. Most of the data on cobalt chemical uses were obtained from the cobalt processors survey. A second survey covered a broad range of metal-consuming companies, such as cemented carbide, magnetic alloy, and superalloy producers. For this survey, more than 70 cobalt consumers were canvassed on a monthly or annual basis. Reported consumption and stocks data in tables 1 and 3 contain estimates to account for nonrespondents.

Prices

U.S. spot prices for cathode (minimum of 99.8% cobalt), as reported by Platts Metals Week, increased from a low of $6.35 to $7.15 per pound in early January to a high of $20.50 to $21.50 per pound at yearend. The Platts annual average U.S. spot cathode price for 2003 was $10.60 per pound, an increase of 53% from that of 2002 (table 1). Prior to the increase in 2003, this annual average price had steadily declined since 1995 when it was $29.21 per pound.

Trends in the Platts prices for Zambian cobalt (minimum 99.6% cobalt) and Russian cobalt (minimum 99.3% cobalt) were similar to those for U.S. spot cathode. The annual average of weekly prices for Zambian cobalt was $9.93 per pound, 48% higher than that of 2002, and the annual average of weekly prices for Russian cobalt was $9.48 per pound, 43% higher than that of 2002.

Sales prices for 99.8% cobalt cathode reported by WMC Resources Ltd. at its Web site provided some market transparency and were considered a benchmark for cobalt prices (Metal Bulletin, 2000; Ryan's Notes, 2000). The trend in these prices was similar to those for 99.8% cobalt reported by trade journals. WMC's lowest sales price during the year was $7.15 per pound in early January, and its highest sales price was $22.50 per pound at the end of December.

Foreign Trade

Net import reliance as a percentage of apparent consumption is used to measure the adequacy of current domestic production to meet U.S. demand. Net import reliance was defined as imports minus exports plus adjustments for Government and industry stock changes. Releases from stocks, including shipments from the NDS, were counted as part of import reliance, regardless of whether they were imported or produced in the United States. In 2003, net import reliance as a percentage of apparent consumption was 79%. Because there was no measurable U.S. primary cobalt production in 2003, this indicates that 79% of U.S. cobalt supply was from imports and stock releases of primary cobalt and 21% was from scrap, which would have been generated domestically or imported.

In 2003, the United States imported 4% less cobalt than it did in 2002 (tables 4, 5). On the basis of cobalt content, 10 countries supplied more than 90% of U.S. imports of unwrought cobalt and cobalt in chemicals. Norway was the leading supplier, followed by Russia, Finland, Belgium, Zambia, Canada, Australia, China, Brazil, and the United Kingdom. Compared with those of 2002, cobalt imports from Australia, China, Norway, Russia, the United Kingdom, and Zambia increased, and imports from Belgium, Brazil, Canada, and Finland decreased.

In 2003, the United States imported 29 t, gross weight, of unwrought cobalt alloys valued at $0.7 million. Four countries supplied most of these materials—Germany (53%), the United Kingdom (31%), Japan (7%), and the Republic of Korea (3%). The United States imported 482 t, gross weight, of cobalt waste and scrap, valued at $4.0 million. Seven countries supplied 90% of this material—the United Kingdom (44%); Ireland (15%); Belgium (12%); Canada, France, and Germany (5% each); and Japan (4%). The United States also imported 167 t, gross weight, of wrought cobalt and cobalt articles valued at $10.7 million. The leading suppliers of these materials were the United Kingdom (49%), Canada (14%), Japan (11%), France (9%), Belgium (8%), and Germany (5%).

U.S. exports of unwrought cobalt and cobalt contained in chemicals increased by 30% compared with those of 2002. As

listed in table 6, 80% of the cobalt metal and chemical exports was shipped to six countries—Belgium, Canada, China, Ireland, Japan, and the United Kingdom. The remainder was shipped to 36 other countries.

Exports also included 1,010 t, gross weight, of wrought metal and cobalt articles valued at $31.3 million. Nearly 90% of these materials was sent to 10 countries—Germany (18%), France (17%), Belgium and the United Kingdom (12% each), China and the Republic of Korea (6% each), Canada (5%), and India, Japan, and Switzerland (4% each). The remainder was shipped to 33 other countries.

World Industry Structure

Refinery capacity by country is listed in table 7. Plants that processed refined cobalt, that used secondary materials (scrap) as their main source of feed or that produced a cobalt product that required further refining were not included.

World Review

Australia.—QNI Pty. Ltd. (a subsidiary of BHP Billiton Ltd.) processed lateritic ore imported from third party mining operations in Indonesia, New Caledonia, and the Philippines at its Yabulu nickel-cobalt refinery in Townsville, Queensland, and produced 1,800 t of cobalt as cobalt oxide hydroxide, a slight decrease compared with the 1,863 t produced in 2002. QNI planned to establish Yabulu as a Southeast Asian nickel-cobalt refining "center of excellence." As the first phase of this plan, QNI was to develop an integrated nickel-cobalt mine and front-end acid leaching plant at Ravensthorpe on the southern coast of Western Australia and to increase the refining capacity at Yabulu to 76,000 t/yr of nickel and 3,500 t/yr of cobalt to accommodate the intermediate nickel-cobalt hydroxide produced from Ravensthorpe. By yearend, QNI had completed the feasibility studies, and in early 2004, the company decided to proceed with the projects. The first shipment of nickel-cobalt hydroxide from Ravensthorpe to the expanded Yabulu refinery was expected to be in 2007. In the second phase of QNI's plan, Yabulu's ore-processing facility would be partially or totally shut down, and another ore-processing plant would be built at a world-class ore body in the region. Intermediate products from this plant, along with those from Ravensthorpe, would be sent to the Yabulu refining center (Cobalt Development Institute, 2004b; BHP Billiton, 2003§,[1] 2004§).

WMC produced cobalt in intermediate nickel-cobalt mixed sulfide at its Kwinana nickel refinery in Western Australia. The refinery processed matte from WMC's Kalgoorlie smelter, which was produced from nickel sulfide concentrates from ores mined in Western Australia by WMC and other companies. WMC's mixed sulfide was refined in Norway by Falconbridge Ltd. under a tolling agreement, and the resulting cobalt cathode was offered for sale by WMC on its Web site. In 2003, WMC sold 886 t of cobalt, 4% more than the 848 t sold in 2002. WMC also sold nickel concentrates, matte, and mixed sulfides (WMC Resources Ltd., 2004a, p. 9, 22; 2004b, p. 22-26).

Anaconda Nickel Ltd. produced 2,039 t of cobalt as metal powder and briquettes from its Murrin Murrin nickel-cobalt laterite pressure acid leaching operation east of Leonora in Western Australia, 11% more than the 1,838 t produced in 2002. During the year, the company focused on achieving steady state production, minimizing unplanned shutdowns, and reducing operating costs. At yearend, Anaconda changed its name to Minara Resources Ltd. (Anaconda Nickel Ltd., 2003, p. 4; Johnston, 2003, p. 6, 11-14; Cobalt Development Institute, 2004b).

OMG shipped intermediate nickel hydroxide produced from its Cawse plant, northwest of Kalgoorlie in Western Australia, to Finland for refining. Output from the plant, which used pressure acid leaching to treat lateritic ore, was expected to supply approximately 8,000 t/yr of nickel to Harjavalta and 800 t/yr of cobalt to Kokkola (OM Group, Inc., 2001; Reuters Ltd., 2002).

In late October, Barclays Bank plc withdrew financial support from Preston Resources Ltd.'s Bulong operation east of Kalgoorlie. Production from the nickel-cobalt laterite pressure acid leaching operation was expected to have ceased by mid-November (Matheson, 2003, p. 7).

In addition to the production discussed above, cobalt-bearing nickel sulfide concentrates produced in Australia were exported to OMG in Finland and Inco Ltd. in Canada to be refined. Inco and LionOre Mining International Ltd. expanded their life-of-mine agreement, under which Inco purchased concentrates from LionOre's Emily Ann Mine, to include concentrates from LionOre's nearby Maggie Hays Mine, which is scheduled to begin production in 2004 (LionOre Mining International Ltd., 2004, p. 21).

Titan Resources NL, West Perth, Western Australia, pursued opportunities for the commercial development of its BioHeap metallurgical process, which used bacterial oxidation to recover base metals from sulfide ores. In addition to studying the feasibility of using the heap-leach process on company ores from deposits in Western Australia, Titan was testing the process on ore samples from Jinchuan Group Ltd., WMC, and other companies (Titan Resources NL, 2003, p. 12-15).

Sally Malay Mining Ltd. began construction on the concentrator and associated infrastructure for its nickel sulfide mine in the East Kimberly District of Western Australia. All production from the mine was to be processed in Gansu Province, China, by Jinchuan Group Ltd. under a life-of-mine concentrate sales agreement. Open pit mining was expected to begin in early 2004, with the first shipment of nickel-copper-cobalt concentrates in August or September 2004. Mine output was forecast to be 7,500 t/yr of nickel, 3,600 t/yr of copper, and 370 t/yr of cobalt. In addition, Sally Malay planned to study the feasibility of producing a nickel-cobalt intermediate (mixed sulfide or carbonate) from the mine's low-grade flotation concentrates in 2004 (Sally Malay Mining Ltd., 2003, p. 5, 8-10, 15; 2004).

Belgium.—n.v. Umicore s.a. converted cobalt metal, residues, and other cobalt-bearing materials into a wide range of cobalt specialty products, including metal powders, oxides, salts, and compounds. According to the Cobalt Development Institute (2004b), Umicore's 2003 cobalt refinery production was 1,704 t, 50% more than the 1,135 t produced in 2002. This production took place in plants in Olen, Belgium; south central China; and Roodepoort, South Africa. In addition, Umicore

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

produced specialty cobalt products at processing plants in Arab, AL, and Laurinburg, NC, in the United States; Leduc and Fort Saskatchewan, Alberta, Canada; Guangzhou and Shanghai, China; Subic, Philippines; and Cheonan, Republic of Korea (Gellens, 2002, p. 7-8; n.v. Umicore, s.a., 2003a, p. 10; 2003b).

Botswana.—LionOre International Ltd. studied the feasibility of establishing a full-scale plant that would use the company's Activox hydrometallurgical processing technology on concentrates from the Phoenix Mine at its Tati Nickel Mining Co. (Proprietary) Ltd. operations. During the year, LionOre had a demonstration plant designed and constructed in Perth, Western Australia, which was then shipped to Botswana, where it was to be installed. The Activox process is a medium-temperature, medium-pressure process for the oxidation of sulfide minerals. It has been tested on a pilot scale on concentrates from various companies, including Tati Nickel and Inco (LionOre Mining International Ltd., 2004, p. 4, 38, 67).

Brazil.—Cia. Niquel Tocantins produced 1,097 t of cobalt cathode at its refinery in Sao Miguel Paulista, Sao Paulo State, 14% more than the 960 t produced in 2002 (Cobalt Development Institute, 2004b). The refinery used lateritic nickel-cobalt ore from Niquelandia, Goias State, as feed. Niquel Tocantins planned to increase the refinery's cobalt capacity to 1,200 t/yr during 2004 and possibly to 1,500 t/yr during 2005 (Matheson, 2003, p. 7).

Cameroon.—The Government of Cameroon granted Geovic Cameroon S.A. a mine permit for its laterite project in Est Province. Geovic estimated that resources in the permit area exceeded 1 billion metric tons grading approximately 0.6% nickel and 0.3% cobalt, which was present in absolane, a cobalt-nickel-manganese oxide. During the year, Geovic worked on a bankable feasibility study on the project, financed in part by the U.S. Trade and Development Agency. Geovic was considering producing 8,000 t/yr of cobalt and 4,000 t/yr of nickel by treating an upgraded cobalt concentrate with an atmospheric pressure sulfurous acid leaching, precipitation, solvent extraction-electrowinning process (Beling, 2004).

Canada.—Falconbridge produced 611 t of cobalt in concentrate from its Sudbury, Ontario, mines and 381 t of cobalt in concentrate from its Raglan Mine in Quebec. Nickel-copper matte produced at the Sudbury smelter was refined at the company's Nikkelverk refinery in Norway. In 2003, this matte contained 2,196 t of cobalt; 51% of the cobalt originated from ores produced at company mines, and 49% from custom feed materials, defined as feeds that did not originate from Falconbridge mines. The custom feed was primarily nickel-copper-cobalt secondary materials (scrap) with some intermediate feedstocks and smaller amounts of concentrates (Falconbridge Ltd., 2004a, p. 18; 2004b, p. 13, 17).

Inco produced cobalt cathode at its Port Colborne, Ontario, refinery, and cobalt oxide at its Thompson, Manitoba, refinery. Approximately 48% of the cobalt produced was from nickel sulfide ores from company mines in Sudbury; 34% was from nickel sulfide ores from company mines in Thompson; and 18% was from purchased feedstocks, including nickel sulfide concentrates from the Jubilee Mines NL's Cosmos nickel project and LionOre's Emily Ann Mine in Western Australia. In 2003, Inco's production was approximately 80% cathode and 20% oxide. The total output of 1,000 t of refined cobalt was a 32% decrease from the 1,480 t produced in 2002. The decrease was the result of a 3-month strike at Inco's Sudbury operations, which was followed by some problems with bringing the smelter and related facilities back up to planned production levels. In June, Inco declared a force majeure on cobalt from its Sudbury operations. The force majeure remained in effect until November 1 (American Metal Market, 2003; Jubilee Mines NL, 2003, p. 6; Cobalt Development Institute, 2004b; Inco Ltd., 2003b; 2004a, p. 18-19; LionOre Mining International Ltd., 2004, p. 18).

Inco completed a bankable feasibility study for Phase I of its Voisey's Bay project. This initial phase included a nickel-copper-cobalt-sulfide open pit mine, concentrator, and related facilities in northeastern Labrador and a research and development program on hydrometallurgical processing technologies for Voisey's Bay concentrates. During the year, Inco began construction on this phase of the project and tested the hydrometallurgical process it was developing for Voisey's Bay concentrates at a minipilot plant in Sheridan Park, Mississauga, Ontario. Inco planned to begin shipping concentrates from Voisey's Bay to its Ontario and Manitoba operations in 2006. Production from Voisey's Bay was expected to be 50,000 t/yr of nickel in concentrates containing 7,000 t/yr of copper and 2,300 t/yr of cobalt as well as 32,000 t/yr of copper in concentrates (Inco Ltd., 2004a, p. 2, 46-47).

The Fort Saskatchewan refinery of the Sherritt International Corp.-General Nickel Co. S.A. joint venture produced 3,141 t of cobalt in 2003, slightly more than the 3,065 t of cobalt produced in 2002. Most of the feed was in the form of nickel-cobalt mixed sulfides from the joint venture's operations at Moa Bay, Cuba. As a result of a United States embargo on imports of products originating from Cuba, nickel and cobalt produced by Sherritt cannot be sold to customers in the United States. Sherritt and General Nickel were considering a 60% expansion of their nickel-cobalt operations (Sherritt International Corp., 2004, p. 4, 21, 23).

Canmine Resources Corp.'s cobalt refinery in Cobalt, Ontario, was acquired by MFC Bancorp Ltd., an international merchant banking company with offices in Berlin, Germany, and Vienna, Austria. The company's Maskwa nickel property and Werner Lake cobalt property were acquired by Global Nickel Inc. of Halifax, Nova Scotia (MFC Bancorp Ltd., 2003; PacRim Resources Ltd., 2003).

China.—Refined cobalt production in China was reported to be 5,576 t. This cobalt, which was in the form of metal, metal powders, and compounds, was produced from domestically mined and imported raw materials. Chinese imports of cobalt-bearing raw materials have increased significantly in recent years, and countries providing these materials have included Australia, Congo (Brazzaville), Congo (Kinshasa), Cuba, Morocco, South Africa, and Zambia. In 2003, China imported more than 4,000 t of cobalt contained in concentrates from Africa alone (Aidong, 2004; Searle, 2004).

The number of Chinese cobalt refiners and processors was reported to be approximately 50 (Aidong, 2004). The leading refiners were Umicore, Jinchuan Group Ltd., and Ganzhou Cobalt & Tungsten Co., Ltd., listed in order of estimated cobalt capacity. Umicore refined cobalt-bearing materials in south central China. Some of the cobalt from the refinery was

processed into cobalt metal powders at Umicore's plant in Shanghai (Gellens, 2002, p. 7-8).

Jinchuan produced 1,509 t of cobalt as cathode and other products in 2003. Most of Jinchuan's cobalt production was from domestic nickel-copper-cobalt sulfide ores mined and refined at Jinchang, Gansu Province. Jinchuan has been steadily increasing its refinery capacity for nickel, copper, cobalt, and platinum-group metals and planned for cobalt capacity to reach 4,000 t/yr in 2006. Production is limited, however, by the amount of ore that can be produced from Jinchuan's mines. As a result, the company arranged for supplies of cobalt "concentrate" from Empresa Cubana Exportadora de Minerales y Metales (also known as Cubaniquel), nickel matte from WMC, and nickel concentrates from Sally Malay Mining Ltd. and continued to investigate additional sources of feed materials (China Metal Market, 2001, p. 13; Jinchuan Group Ltd., 2003, 2004; Sally Malay Mining Ltd., 2003, p. 10; WMC Resources Ltd., 2004b, p. 26).

Ganzhou, which produced cobalt cathode, metal powders, oxides, and salts at Ganzhou, Jiangxi Province, expanded its refining capacity to 1,000 t/yr of cobalt (Ganzhou Cobalt & Tungsten Co., Ltd., undated§).

Congo (Kinshasa).—The Cobalt Development Institute estimated Congo (Kinshasa)'s 2003 refined cobalt production to be 1,200 t, a 44% decrease from the 2,149 t refined in 2002 (Cobalt Development Institute, 2004b). Kababankola Mining Co. S.P.R.L. (KMC) mined copper-cobalt ores from open pit operations in La Générale des Carrières et des Mines' (Gécamines) Central Group and processed the ores at the nearby Kakanda concentrator, which it operated under lease from Gécamines. Ores and concentrates from KMC's mining operations were toll-treated at Gécamines' Shituru refinery in Likasi. KMC was a joint venture between Tremalt Ltd., a private company based in the British Virgin Islands (80%) and Gécamines (20%) (Kababankola Mining Co. S.P.R.L., undated a§, b§).

Gécamines and L'Enterprise Générale Malta Forrest S.P.R.L. produced copper-cobalt concentrates from the Luiswishi Mine, which were sold under a long-term supply contract to OMG. The mine was closed for maintenance work during the first 5 months of the year (Metal Bulletin, 2003b).

The Big Hill smelter at Lubumbashi, which was operated by Société pour le Traitement de la Terril de Lubumbashi (a joint venture between Gécamines, OMG, and S.A. Groupe George Forrest), reportedly operated at approximately one-half of its capacity during the early part of the year. The smelter processed stockpiled slag to produce a cobalt-copper alloy, which was shipped to OMG's Kokkola refinery. During the year, OMG worked on lowering the smelter's processing costs (Metal Bulletin, 2003d; OM Group, Inc., 2003, p. 12).

The Chemaf S.P.R.L. plant in Lumbumbashi had the capacity to produce 600 t/yr of cobalt as carbonate and 1,200 t/yr of copper as carbonate by direct leaching of rich copper-cobalt ores with sulfuric acid, followed by carbonation with soda ash (Cobalt Development Institute, 2002; Chemaf S.P.R.L., undated§).

In recent years, significant amounts of cobalt-rich concentrates have been produced illegally by artisanal miners and exported to China and elsewhere. Estimates of the amount of cobalt lost in 2003 from the export of illegally mined concentrates ranged from 3,600 t to more than 4,000 t (Metal Bulletin, 2003a; Searle, 2004).

America Mineral Fields Inc. (AMF) completed the first phase of the environmental and social impact assessment, concluded an option agreement with two leading international financial institutions, and renegotiated the terms of the Kolwezi tailings project with Gécamines and the Government of Congo (Kinshasa) so that the agreements would conform to Congo (Kinshasa)'s new Mining Code. Ownership of Kingamyambo Musonoi Tailings S.A.R.L. (KMT), the company which will own the mining title to the tailings and develop the project, would be 82.5% held by AMF's subsidiary Congo Mineral Developments Ltd., 12.5% held by Gécamines, and 5% held by the Government. This agreement received full government approval in early 2004, so that AMF could work towards completing the bankable feasibility study and environmental and social impact assessment and arrange project financing. The company hoped to make a go-ahead decision on the project in early 2005, so that production could begin in 2007. AMF was considering production levels of 42,000 t/yr of copper and 7,000 t/yr of cobalt, based on a tailings throughput level of 3 million metric tons per year (America Mineral Fields Inc., 2003, p. 16; 2004, p. 1-3, 7, 13-14).

Tenke Mining Corp. and Phelps Dodge Exploration Corp. submitted a formal proposal to the Government of Congo (Kinshasa) that amended existing agreements on the Tenke Fungurume project so that they would conform to Congo (Kinshasa)'s new Mining Code. The proposal was based on starting the project on a smaller scale than originally envisioned and developing it in phases. Although Tenke Mining was optimistic about progress towards sustainable peace and government stability in Congo (Kinshasa), the project remained under force majeure (Tenke Mining Corp., 2004).

Kumba Resources Ltd. had an agreement with Gécamines and held a presidential decree to rehabilitate and manage the Kamoto Mine. The mine, which is a large underground copper-cobalt mine, has had only limited production since it suffered a major collapse in 1990. Kumba was not able to resolve the legislative basis of the project and proceed during the year (Swindells, 2004).

Cuba.—Moa Nickel S.A. [part of the joint venture between Sherritt (50%) and General Nickel (50%)] mined nickel-cobalt laterites at Moa Bay in Holguin Province and produced mixed sulfides containing 32,042 t of nickel and cobalt, a 4% decrease from the 33,382 t produced in 2002. The decrease in production was attributed to lower ore grades and an increase in maintenance activities as compared with those of 2002. The mixed sulfides produced at Moa were sent to the joint venture's Fort Saskatchewan refinery in Canada. Sherritt and General Nickel were considering a 60% expansion of their nickel-cobalt operations (Sherritt International Corp., 2004, p. 4, 21, 23).

Unión del Níquel S.A. also mined and refined nickel-cobalt laterites in Holguin Province. Nickel-cobalt mixed sulfides produced at the Ernesto Che Guevara Mining and Metallurgical Combine at Punta Gorda were exported to China (McCutcheon, 2003, p. 38.44). Nickel and cobalt of Cuban origin cannot be imported into the United States because of a U.S. embargo on imports from Cuba.

Cubaniquel signed an agreement with China Minmetals Corp. whereby Minmetals would invest in the Cuban nickel industry

in return for exports of nickel-cobalt materials to China (Metal Bulletin, 2003c).

QNI held a 75% interest, and Unión Geológica Minera S.A. (Geominera) held a 25% interest in the San Felipe project in the Camaguey Province. Initial hydrometallurgical testing of ores from San Felipe resulted in good metal recoveries (BHP Billiton Ltd., 2003, p. 80).

Finland.—OMG's Kokkola Chemicals Oy refinery processed cobalt-bearing materials from Australia, the Big Hill smelter and the Luiswishi Mine in Congo (Kinshasa), and elsewhere. The company produced 7,990 t of cobalt in cobalt metal powders, briquettes, oxides, and compounds, slightly less than the 8,200 t produced in 2002. During the year, OMG restricted its refinery production to meet its customers' commitments. OMG continued to draw down its inventories, with a target of holding 4,500 t of cobalt by yearend compared with 5,700 t at yearend 2002 (OM Group, Inc., 2003, p. 18; OM Group, Inc., 2003§; Cobalt Development Institute, 2004b).

France.—The Eramet Group produced cobalt chloride at its refinery at Sandouville, near Le Havre. Feed for the refinery was nickel matte imported from the Eramet subsidiary Le Nickel-SLN's Doniambo smelter in New Caledonia.

India.—According to the Cobalt Development Institute (2001, 2004b), 255 t of cobalt was produced in India in 2003, 6% less than the 270 t produced in 2002. Three companies refined cobalt from imported raw materials. Nicomet Industries Ltd. produced cobalt oxide and salts at its plant in Cuncolim, Goa State; Rubamin Ltd. produced cobalt cathode, oxide, and salts at its plant in Vadodara, Gujarat State; and Conic Metals Ltd. produced cobalt sulfate and carbonate at its plant in Mumbai, Maharahtra State.

Indonesia.—State-owned P.T. Aneka Tambang (Antam) exported lateritic nickel-cobalt ore to QNI's Yabulu refinery in Australia. Antam and other companies worked on projects to explore and develop Indonesia's nickel-cobalt laterite resources.

Japan.—Sumitomo Metal Mining Co., Ltd., produced electrolytic cobalt, cobalt oxide, and cobalt compounds as a byproduct of nickel production at its Niihama nickel refinery in Ehime Prefecture. The Niihama refinery processed nickel matte from WMC in Australia and P.T. Inco in Indonesia. Sumitomo planned to increase the capacity of Niihama to approximately 45,000 t/yr of nickel and 1,100 t/yr of cobalt in 2004 to accommodate the output from the Coral Bay Nickel plant in the Philippines (Metal Bulletin, 2002a).

Madagascar.—Dynatec Corp. signed a joint-venture agreement with subsidiaries of Phelps Dodge Corp. to study the feasibility of developing the Ambatovy nickel laterite deposit, 130 km east of Antananarivo. The deposit has an estimated 190 Mt of mineralized material grading 1.1% nickel and 0.10% cobalt. As part of the agreement, Dynatec was to provide commercial licenses for its hydrometallurgical technology to the project. Dynatec planned to review the potential to produce 50,000 t/yr of nickel and 4,000 t/yr of cobalt (Dynatec Corp., 2004, p. 7-8).

Morocco.—Cie. de Tifnout Tiranimine (CTT) mined cobalt-arsenic deposits at Bou Azzer and produced concentrates. The company refined the concentrates and tailings generated by past mining at Bou Azzer to produce cobalt cathode. In late 2002, CTT began operating a pilot-scale unit to investigate the production of cobalt chemicals and developed a cobalt oxide product with physical and chemical properties suitable for the production of rechargeable batteries. CTT planned to begin sales of the cobalt oxide in 2004 (Cie. de Tifnout Tiranimine, 2001; Groupe ONA, 2002, p. 37; 2003, p. 46; Akalay, 2003).

New Caledonia.—Lateritic nickel-cobalt ore was exported to QNI's Yabulu refinery for processing. Nickel matte from Le Nickel-SLN's Doniambo smelter was sent to Eramet's refinery in Sandouville, France, where it was refined into nickel cathode, nickel chloride, and cobalt chloride, listed in decreasing order of magnitude.

At yearend 2002, Inco suspended construction at its Goro nickel-cobalt laterite project in southern New Caledonia and began a comprehensive review of the project. The review, which was expected to be completed by August 2004, was intended to evaluate information that suggested a possible 30% to 45% increase in Goro's capital cost estimate and to identify changes that could be made to maintain the project's economic feasibility. The project consisted of an integrated mining and pressure acid leaching-solvent extraction processing facility with a planned capacity of approximately 55,000 t/yr of nickel as oxide and 4,500 t/yr of cobalt as carbonate (Inco Ltd., 2004a, p. 2, 40-41).

Norway.—Falconbridge produced 4,556 t of cobalt at its Nikkelverk refinery, a 14% increase from the 3,994 t produced in 2002. During 2003, 25% of the cobalt produced at Nikkelverk originated from Falconbridge mines in Canada, and 75% originated from custom feeds. The custom feed included matte from Botswana, which Falconbridge processed under a long-term agreement with BCL Ltd. (Falconbridge Ltd., 2004a, p. 18; 2004b, p. 16-17).

Papua New Guinea.—Highlands Pacific Ltd. held discussions with potential joint-venture partners for the Ramu nickel-cobalt laterite project in Madang Province. The project was owned by Highlands Pacific (68.5%) and the Papua New Guinea Government's Mineral Resources Development Co. (31.5%). The project was to use pressure acid leaching technology to produce 32,800 t/yr of nickel cathode and 3,200 t/yr of cobalt cathode (Papua New Guinea Department of Mining, 2004, p. 4, 20-21).

Philippines.—Lateritic nickel-cobalt ore from the Philippines was exported to QNI's Yabulu refinery for processing.

Sumitomo was the major shareholder in a joint-venture company named Coral Bay Nickel Corp., which was constructing a plant that would use pressure acid leaching technology to process low-grade lateritic ores stockpiled at the Rio Tuba nickel mine on Palawan Island. The plant, which was being built adjacent to the mine, would produce a mixed nickel-cobalt sulfide intermediate product, which would be refined at Sumitomo's Niihama nickel refinery in Japan. Enough stockpiled ore was available to produce mixed sulfide containing 10,000 t/yr of nickel and 700 to 800 t/yr of cobalt for approximately 20 years. Initial production of mixed sulfide was expected to begin during the fourth quarter of 2004. Sumitomo's partners in the joint venture were Rio Tuba Nickel Mining Corp., Nissho Iwai Corp., and Mitsui & Co., Ltd. (Ryan's Notes, 2004).

Russia.—Total Russian cobalt production was 9.2% higher than that of 2002 (Interfax International Ltd., 2004). Nickel and cobalt

production in Russia involved a complex flow of ores, flotation concentrates, precipitates, and mattes between various production sites. The main feed materials were domestic nickel-copper sulfide and nickel-cobalt laterite ores and imported nickel- and cobalt-bearing secondary materials. Russia had the capacity to produce refined cobalt at four locations. OJSC MMC Norilsk Nickel, which was Russia's leading cobalt producer, had refineries at Monchegorsk on the Kola Peninsula and Norilsk in Siberia. The OJSC Ufaleynickel refinery was at Verkhniy Ufaley in the Ural Mountains, and the OJSC Yuzhuralnickel refinery was at Orsk, also in the Ural Mountains (Roskill Information Services Ltd., 2001, p. 71-74).

South Africa.—Cobalt was mined as a byproduct from six platinum-group metal mines and one nickel mine (Harding, 2003). Two South African companies produced refined cobalt as a byproduct of domestic platinum mining and refining. Rustenburg Base Metal Refiners Pty. Ltd. (a subsidiary of Anglo American plc) produced cobalt sulfate at its refinery near Rustenburg, Northwest Province, and Impala Platinum Ltd. produced cobalt metal powder at its base-metals refinery near Springs, Gauteng Province.

Anglovaal Mining Ltd. (Avmin) considered various options for expanding the Nkomati nickel sulfide mine in Mpumalanga Province. One option included combined open pit and underground mining and the construction of a new concentrator and a processing plant, which would use the Activox leach process. Production rates following expansion were estimated to be 16,000 t/yr of refined nickel, 9,000 t/yr of refined copper, 900 t/yr of cobalt oxide, and 80,000 troy ounces of platinum-group metals for toll refining. In recent years, production of cobalt in nickel concentrates has been approximately 50 to 60 t/yr (Angloval Mining Ltd., 2002; 2003, p. 25).

Umicore South Africa Pty. produced cobalt compounds from low-grade cobalt-containing residues in Roodepoort, near Johannesburg.

Spain.—Rio Narcea Gold Mines, Ltd. began construction on its Aguablanca open pit nickel sulfide mine, processing plant, and associated infrastructure in southwestern Spain. The copper-nickel-platinum-group-metal concentrate to be produced would contain an estimated 150 t/yr of cobalt (Rio Narcea Gold Mines, Ltd., 2004, p. 6-7).

Turkey.—In April, European Nickel PLC began trial mining at the Çaldağ nickel laterite deposit in western Turkey. The company agreed to initially supply ore to ferronickel smelters in Greece and Macedonia. European Nickel's longer-term plan was to process the ore onsite using an acid heap-leaching process and to produce a nickel-cobalt intermediate product, which could be sold to a refinery. European Nickel planned to raise the funds to complete a feasibility study on the heap-leaching process (European Nickel PLC, undated a§, b§).

Uganda.—In late 2002, in response to low cobalt prices, MFC Bancorp ceased production from the Kasese cobalt operation in southwestern Uganda and placed the refinery on care-and-maintenance status. By December 2003, cobalt prices had recovered, and MFC Bancorp announced that it had arranged to sell forward one-half of Kasese's 2004 production to an international trading company for $17.20 per pound. The Kasese refinery recovers cobalt from stockpiled pyrite concentrates by using a bacterial leaching and electrowinning process (Banff Resources Ltd., 2002; MFC Bancorp Ltd., 2003).

Zambia.—Mopani Copper Mines Plc [owned by Glencore International AG (73.1%), First Quantum Minerals Ltd. (16.9%), and Zambia Consolidated Copper Mines Ltd. (ZCCM) (10%)] produced 2,050 t of cobalt metal at its Nkana cobalt refinery, a 14% increase from the 1,800 t produced in 2002. The refinery processed concentrates from Mopani's Nkana underground copper-cobalt mine and Konkola Copper Mines PLC (KCM) operations (Metal Bulletin, 2002b; Cobalt Development Institute, 2004b).

Chambishi Metals plc produced 4,570 t of cobalt metal at its Chambishi cobalt refinery, a 5% increase from the 4,344 t produced in 2002. The refinery's main feed materials were metal-bearing solutions from the company's COSAC smelter and matte leach facility, which recovered cobalt and copper from slag stockpiled at Nkana, and concentrates from Mopani's Nkana Mine and KCM operations, which the refinery toll refined. During the year, Avmin sold its 90% interest in Chambishi to J&W Holdings AG of Switzerland (Platts Metals Week, 2002; Angloval Mining Ltd., 2003, p. 16; Cobalt Development Institute, 2004c).

KCM mined copper ores from the Nchanga open pit and underground mines and the Konkola Mine. Cobalt in concentrates produced by KCM was toll refined at the Chambishi and Nkana refineries. In 2003, production of cobalt cathode credited to KCM was 1,157 t, a 43% decrease from the 2,039 t of cobalt cathode credited to KCM in 2002. The decline in cobalt production was attributed to a planned downscaling of operations at the Nchanga open pit. KCM was owned by Zambia Copper Investments Ltd. (58%) and ZCCM Investments Holdings plc (42%). Following a competitive bidding process of potential strategic equity partners, KCM selected Vedanta Resources PLC (the holding company of Sterlite Industries Ltd.) as the preferred bidder and began detailed negotiations with Sterlite on the terms of their proposed investment (Metal Bulletin, 2002b; Zambia Copper Investments Ltd., 2004, p. 1-2; 2004§).

Roan Antelope Mining Corp.'s assets, which included the Baluba and Luanshya mines, were sold to J&W Holdings. The assets had been for sale since Roan Antelope was put under receivership in late 2000. Mining operations ceased in early 2001 as a result of flooding following heavy rains (Platts Metals Week, 2001; Metal Bulletin, 2004).

Metorex's tolling contract with Mopani's Nkana concentrator expired in September 2002. From that point onward, ores from Chibuluma West were processed at Metorex's Chibuluma South concentrator, which did not have the capability to produce cobalt concentrates (Metorex Ltd., 2003, p. 15).

Late in the year, Caledonia Mining Corp. was approached by a Zambian mining company regarding Caledonia's ability to supply copper-cobalt concentrates from its Nama licence area west of and adjacent to the Konkola mining area in northern Zambia. Caledonia planned to undertake a sampling and screening program in 2004 to determine whether it could meet the potential customer's smelter feed specifications. Subject to meeting the specifications and obtaining satisfactory economic terms, Caledonia expected to enter a long-term contract to supply approximately 300 metric tons per day of copper-cobalt concentrate from Nama (Caledonia Mining Corp., 2003, 2004).

Equinox Resources Ltd. completed a feasibility study on the Lumwana project in Zambia's North-Western Province.

Lumwana comprised two copper-cobalt-gold deposits, which could be mined by open pit mining methods. The study recommended developing the deposits sequentially. During years 1 through 5, the Malundwe deposit would be mined, and its concentrates would be transported offsite for smelting and refining to produce copper and gold. During years 6 through 20, the Chimiwungo deposit would be mined, and its concentrates would be processed onsite in a roast-leach-electrowin refinery to produce copper cathode, cobalt powder (1,000 t/yr), and sulfuric acid. Equinox signed a letter of intent with Phelps Dodge to acquire that company's interest in the project and began searching for a new joint-venture partner (Equinox Resources Ltd., 2003, p. 5-8).

Outlook

World production of refined cobalt is expected to continue to increase in coming years. Most of the increase is expected to come from various new nickel operations, which are being developed to satisfy projected growth in nickel demand during the next decade. African copper projects and primary cobalt projects are also expected to contribute to future cobalt supply. The first production from the larger of these projects, in terms of cobalt output—Goro in New Caledonia, Idaho Cobalt in the United States, Kolwezi in Congo (Kinshasa), Ramu in Papua New Guinea, Voisey's Bay in Canada, and Yabulu/Ravensthorpe in Australia—is not expected to begin before 2006 or 2007 (Cobalt Development Institute, 2003c; Inco Ltd., 2004a, p. 46; 2004b; Searles, 2004). In the meantime, production restarted from the Kasese cobalt refinery in Uganda in 2004, and some existing cobalt producers have announced plans to increase their production levels and/or capacities.

In addition to production, inventory releases and recycled cobalt will continue to contribute to supply. The DNSC cobalt inventory at the end of fiscal year 2004 was less than the amount listed in the AMP for fiscal year 2005. Therefore, the NDS cobalt inventory could be depleted during the fiscal year that began October 1, 2004.

World demand for cobalt is expected to increase in coming years. Industries that could show significant increases in cobalt demand include superalloys for civil aviation, catalysts for gas-to-liquid production of synthetic liquid fuels, and rechargeable batteries for portable electronic devices and hybrid electric vehicles. Some of the increase in demand might be dampened, however, by substitution of cobalt with other, less expensive metals in rechargeable batteries for portable electronic devices (Cobalt Development Institute, 2003c; Searle, 2004).

From 1995 to 2002, the general trend in cobalt prices was downward because supply was growing at a faster rate than demand. During the first quarter of 2003, cobalt prices increased sharply in response to reduced production and concerns over tightness in global supply. As 2003 progressed, demand improved and the market tightened further. The average price for cobalt cathode increased to $28 per pound by mid-January 2004, before softening to less than $23 per pound in late September (Cobalt Development Institute, 2003a-b, 2004a; Inco Ltd., 2003a, p. 18; Sherritt International Corp., 2003, p. 10; Falconbridge Ltd., 2004b, p. 36).

References Cited

Aidong, Xu, 2004, China—A growing cobalt market in the world: Cobalt News, no. 2, April, p. 5-7.

Akalay, Ismail, 2003, Moroccan cobalt—What's new?, *in* The Cobalt Conference, Shangri-La, Hong Kong, November 19-20, 2003, Presentation: Guildford, United Kingdom, Cobalt Development Institute, 2 p.

America Mineral Fields Inc., 2003, Prospectus: London, United Kingdom, America Mineral Fields Inc., September 19, 46 p.

America Mineral Fields Inc., 2004, Bringing world class assets to value—Annual report 2003: London, United Kingdom, America Mineral Fields Inc., 41 p.

American Metal Market, 2003, Inco sets Jan. 1 to lift lingering force majeure: American Metal Market, v. 111, no. 51-2, December 23, p. 1.

Anaconda Nickel Ltd., 2003, Annual report 2003: Perth, Australia, Anaconda Nickel Ltd., 72 p.

Anglovaal Mining Ltd., 2002, Reviewed results for the year ended 30 June 2002: Johannesburg, South Africa, Anglovaal Mining Ltd., 4 p.

Anglovaal Mining Ltd., 2003, Annual report 2003: Johannesburg, South Africa, Anglovaal Mining Ltd., 96 p.

Banff Resources Ltd., 2002, Schedule C—Management discussion and analysis for the quarter ended September 30, 2002: Toronto, Ontario, Canada, Banff Resources Ltd., 3 p.

Beling, D.C., 2004, Geovic's major cobalt development—Cameroon, Africa, *in* The Cobalt Conference, Toronto, Ontario, Canada, May 19-20, 2004, Presentation: Guildford, United Kingdom, Cobalt Development Institute, 9 p.

BHP Billiton Ltd., 2003, Form 20-F—2003: Securities and Exchange Commission, 177 p.

Caledonia Mining Corp., 2003, 2003 third quarter report: Toronto, Ontario, Canada, Caledonia Mining Corp., 10 p.

Caledonia Mining Corp., 2004, Caledonia updates its gold, platinum, cobalt & diamond activities: Toronto, Ontario, Canada, Caledonia Mining Corp. news release, February 26, 3 p.

China Metal Market, 2001, Extra—Jinchuan Co. built up stable trade relationship with Cuba: China Metal Market (Precious & Minor Metals), no. 23, November, 16 p.

Cie. de Tifnout Tiranimine, 2001, CMBA—A global reference for high grade cobalt cathodes: Casablanca, Morocco, Cie. de Tifnout Tiranimine brochure, 8 p.

Cobalt Development Institute, 2001, Cobalt in India: Cobalt News, no. 2, April, p. 9-11.

Cobalt Development Institute, 2002, Preminco Ltd.: Cobalt News, no. 4, October, p. 4.

Cobalt Development Institute, 2003a, Comment: Cobalt News, no. 2, April, p. 2.

Cobalt Development Institute, 2003b, Comment: Cobalt News, no. 3, July, p. 2.

Cobalt Development Institute, 2003c, Developments in the Cobalt Industry: Cobalt News, no. 2, April, p. 9-13.

Cobalt Development Institute, 2004a, Comment: Cobalt News, no. 2, April, p. 2.

Cobalt Development Institute, 2004b, Statistics review 2003: Cobalt News, no. 2, April, p. 3-4.

Cobalt Development Institute, 2004c, 2003 production statistics update: Cobalt News, no. 3, July, p. 11.

Defense National Stockpile Center, 2002, DLA-COBALT-001—Basic ordering agreement (BOA) for cobalt metal: Fort Belvoir, VA, Defense National Stockpile Center Basic Ordering Agreement, 41 p.

Defense National Stockpile Center, 2003a, Amendment no. 002 to basic ordering agreement for cobalt metal under DLA-COBALT-001: Fort Belvoir, VA, Defense National Stockpile Center amendment, 4 p.

Defense National Stockpile Center, 2003b, FY 2004 annual materials plan announced: Fort Belvoir, VA, Defense National Stockpile Center news release, October 1, 2 p.

Dynatec Corp., 2004, From a base of expertise—Building a strong mining company—Annual report 2003: Richmond Hill, Ontario, Canada, Dynatec Corp., 42 p.

Equinox Resources Ltd., 2003, Annual report 2003: West Perth, Australia, Equinox Resources Ltd., 52 p.

Falconbridge Ltd., 2004a, Annual report 2003: Toronto, Ontario, Canada, Falconbridge Ltd., 62 p.

Falconbridge Ltd., 2004b, 2003 annual information form: Toronto, Ontario, Canada, Falconbridge Ltd., May 10, 57 p.

Formation Capital Corp., 2002, Purchase of metals processing complex complete: Vancouver, British Columbia, Canada, Formation Capital Corp. press release, September 24, 1 p.
Formation Capital Corp., 2003, Formation raises $632,000 and appoints financial advisor: Vancouver, British Columbia, Canada, Formation Capital Corp. press release, March 6, 1 p.
Gellens, Luc, 2002, Cobalt in China, *in* The Cobalt Conference, Paris, France, May 14-15, 2002, Presentation: Guildford, United Kingdom, Cobalt Development Institute, 8 p.
Groupe ONA, 2002, Rapport annuel 2001: Casablanca, Morocco, Groupe ONA, 76 p.
Groupe ONA, 2003, Rapport annuel 2002: Casablanca, Morocco, Groupe ONA, 91 p.
Harding, A.J., 2003, Cobalt, *in* South Africa's mineral industry 2002/2003: Pretoria, South Africa, Mineral Economics Directorate, p. 72-75.
Holder, C.A., 2003, [untitled], *in* 2003 Ryan's Notes Ferroalloys Conference, Scottsdale, AZ, October 26-28, 2003, Presentation: Pelham, NY, Ryan's Notes, 42 p.
Inco Ltd., 2003a, Form 10-K—2002: Securities and Exchange Commission, 168 p.
Inco Ltd., 2003b, Inco Limited provides update on impact of post-strike ramp-up at Ontario operations on production and costs and net earnings for the third quarter of 2003 and guidance on production, costs and certain other factors: Toronto, Ontario, Canada, Inco Ltd. press release, October 15, 3 p.
Inco Ltd., 2004a, Form 10-K—2003: Securities and Exchange Commission, 203 p.
Inco Ltd., 2004b, Inco provides update on key preliminary findings to date of phase 2 of Goro project review—Company remains optimistic on Goro project: Toronto, Ontario, Canada, Inco Ltd. press release, May 25, 4 p.
Interfax International Ltd., 2004, Change in output: Mining & Metals Report, v. 13, issue 10 (619), March 6-12, p. 8.
Jinchuan Group Ltd., 2003, Jinchuan Group confirm the development targets for the coming three years: Jinchang, China, Jinchuan Group Ltd. news release, September 15, 1 p.
Jinchuan Group Ltd., 2004, The accomplished status of accumulative nickel products output of JNMC in 2003: Jinchang, China, Jinchuan Group Ltd. news release, January 12, 1 p.
Johnston, Peter, 2003, Presentation to the 10th annual general meeting by the chief executive officer: Perth, Australia, Anaconda Nickel Ltd., November 26, 14 p.
Jubilee Mines NL, 2003, Annual report for the year ended 30 June 2003: West Perth, Australia, Jubilee Mines NL, 53 p.
Kennecott Exploration Co., 2003, Eagle Prospect update 2: Negaunee, MI, Kennecott Exploration Co., November, 4 p.
Kennecott Exploration Co., 2004, Eagle Prospect update 3: Negaunee, MI, Kennecott Exploration Co., February, 4 p.
LionOre Mining International Ltd., 2004, 2003 annual report: Toronto, Ontario, Canada, LionOre Mining International Ltd., 112 p.
Matheson, P.J., 2003, The changing supply situation of cobalt as a by-product of nickel, *in* The Cobalt Conference, Shangri-La, Hong Kong, November 19-20, 2003, Presentation: Guildford, United Kingdom, Cobalt Development Institute, 16 p.
McCutcheon, Bill, 2003, Nickel: Natural Resources Canada Canadian Minerals Yearbook 2002, p. 38.1-38.58.
Metal Bulletin, 2000, Opening up the cobalt market: Metal Bulletin, no. 8474, May 11, p. 19.
Metal Bulletin, 2002a, SMM to raise Niihama nickel and cobalt capacity: Metal Bulletin, no. 8697, August 8, p. 6.
Metal Bulletin, 2002b, Zambian closure may have repercussions for cobalt: Metal Bulletin, no. 8644, January 28, p. 8.
Metal Bulletin, 2003a, Gécamines issues warning on raw materials: Metal Bulletin, no. 8799, August 18, p. 8.
Metal Bulletin, 2003b, Luiswishi restarts cobalt production: Metal Bulletin, no. 8777, May 29, p. 5.
Metal Bulletin, 2003c, Minmetals invests in Cubaniquel: Metal Bulletin, no. 8753, March 3, p. 4.
Metal Bulletin, 2003d, OM Group hunts for new cobalt: Metal Bulletin, no. 8776, May 26, p. 7.
Metal Bulletin, 2004, J&W defends Zambia copper purchase: Metal Bulletin, no. 8824.3, January 8, p. 1.
Met-Chem Technology, Inc., 2003, Met-Chem Technology acquires The Hall Chemical Company: Wickliffe, OH, Met-Chem Technology, Inc. press release, November 12, 1 p.
Metorex Ltd., 2003, Annual report 2003: Rosebank, South Africa, Metorex Ltd., 62 p.
MFC Bancorp Ltd., 2003, MFC Bancorp Ltd. declares distribution of cobalt related assets: New York, NY, MFC Bancorp Ltd. press release, December 31, 2 p.
n.v. Umicore, s.a., 2003a, Annual report 2002: Brussels, Belgium, n.v. Umicore, s.a., 96 p.
n.v. Umicore, s.a., 2003b, Quarterly update: Brussels, Belgium, n.v. Umicore, s.a., November 7, 8 p.
OM Group, Inc., 2001, OM Group, Inc. acquires Cawse: Cleveland, OH, OM Group, Inc. press release, December 27, 1 p.
OM Group, Inc., 2002, OM Group to exit tungsten carbide fine powders business and St. George site: Cleveland, OH, OM Group, Inc. press release, November 6, 1 p.
OM Group, Inc., 2003, 2003 third quarter conference call—October 30, 2004: Cleveland, OH, OM Group, Inc. press release, October 31, 27 p.
PacRim Resources Ltd., 2003, PacRim announces proposed business combination with Global Nickel Inc.: Toronto, Ontario, Canada, PacRim Resources Ltd. press release, October 15, 2 p.
Papua New Guinea Department of Mining, 2004, 4th quarter bulletin 2003: Port Moresby, Papua New Guinea, Papua New Guinea Department of Mining, January, 66 p.
Platts Metals Week, 2001, Roan Antelope assets to be sold off: Platts Metals Week, v. 72, no. 12, March 19, p. 15.
Platts Metals Week, 2002, Avmin to cut Zambia cobalt output: Platts Metals Week, v. 73, no. 51, December 23, p. 13-14.
PolyMet Mining Corp., 2004, Annual report for year ended January 2004: Vancouver, British Columbia, Canada, PolyMet Mining Corp., 51 p.
Reuters Ltd., 2002, OM Group shuts Cawse laterite nickel refinery: Perth, Australia, Reuters Ltd. press release, January 8, 1 p.
Rio Narcea Gold Mines, Ltd., 2004, 2003 annual report: Toronto, Ontario, Canada, Rio Narcea Gold Mines, Ltd., 54 p.
Roskill Information Services Ltd., 2001, The economics of cobalt (9th ed.): London, United Kingdom, Roskill Information Services Ltd., 189 p.
Ryan's Notes, 2000, DLA awards Co at $13.77-14.276 per lb—Spot market steady on little business: Ryan's Notes, v. 6, no. 18, May 1, p. 1.
Ryan's Notes, 2004, Ferroalloy notes—Coral Bay Nickel plans to start: Ryan's Notes, v. 10, no. 19, May 10, p. 4.
Sally Malay Mining Ltd., 2003, Annual report 2003: Perth, Australia, Sally Malay Mining Ltd., 56 p.
Sally Malay Mining Ltd., 2004, Quarterly report for the period ended 31 December 2003: Perth, Australia, Sally Malay Mining Ltd., 12 p.
Searle, Peter, 2004, A strategic view of the cobalt market, *in* The Cobalt Conference, Toronto, Ontario, Canada, May 19-20, 2004, Presentation: Guildford, United Kingdom, Cobalt Development Institute, 12 p.
Sherritt International Corp., 2003, First quarter report—March 31, 2003: Toronto, Ontario, Canada, Sherritt International Corp., 24 p.
Sherritt International Corp., 2004, Annual report—2003: Toronto, Ontario, Canada, Sherritt International Corp., 66 p.
Swindells, Steve, 2004, Kumba to hold copper-cobalt project talks: Metal Bulletin, no. 8829, February 16, p. 12.
Tenke Mining Corp., 2004, Annual report to shareholders—For the period ended December 31, 2003: Vancouver, British Columbia, Canada, Tenke Mining Corp., 33 p.
Titan Resources NL, 2003, Annual report 2003: West Perth, Australia, Titan Resources NL, 60 p.
U.S. Department of Defense, 2004, Strategic and critical materials report to the Congress—Operations under the Strategic and Critical Materials Stock Piling Act during the period October 2002 through September 2003: U.S. Department of Defense, 66 p.
WMC Resources Ltd., 2004a, Fact file—For the twelve months ended 31 December 2003: Southbank, Australia, WMC Resources Ltd., 34 p.
WMC Resources Ltd., 2004b, Form 20-F—2003: Securities and Exchange Commission, 122 p.
Zambia Copper Investments Ltd., 2004, Annual report 2003: Hamilton, Bermuda, Zambia Copper Investments Ltd., 44 p.

Internet References Cited

BHP Billiton, 2003 (September 25), BHP Billiton Stainless Steel Materials, Presentation to the Investment Community, accessed July 30, 2004, at URL http://www.bhpbilliton.com/bbContentRepository/Presentations/BHPBilliton250903.pdf.

BHP Billiton, 2004 (March), The Ravensthorpe nickel project and Yabulu Refinery expansion—Overview, accessed July 30, 2004, at URL http://www.bhpbilliton.com/bbContentRepository/News/RelatedContent/RYINOverviewPaper.pdf.
Chemaf S.P.R.L., [undated], Chemaf—About us, accessed July 2, 2004, at URL http://www.chemaf.com/about.htm.
European Nickel PLC, [undated]a, Çaldağ, accessed February 3, 2004, at URL http://www.enickel.co.uk/caldag.htm.
European Nickel PLC, [undated]b, Company history, accessed February 3, 2004, at URL http://www.enickel.co.uk/history.htm.
Ganzhou Cobalt & Tungsten Co., Ltd., [undated], Brief introduction, accessed June 30, 2004, at URL http://www.gzct.com/801ct1/jj.htm.
Kababankola Mining Co. S.P.R.L., [undated]a, Operations, accessed February 4, 2004, at URL http://www.kababankola.com/operations.html.
Kababankola Mining Co. S.P.R.L., [undated]b, Company profile, accessed February 4, 2004, at URL http://www.kababankola.com/profile.html.
OM Group, Inc., 2003 (October 30), 2003 third quarter, Conference Call, accessed August 2, 2004, at URL http://www.omgi.com/PressReleasesPDFs/3Q2003ConferenceCall.pdf.
Zambia Copper Investments Ltd., 2004, KCM performance for the month of December 2003, accessed August 5, 2004, at URL http://www.zci.lu/KCM%20Dec%2003.pdf.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Cobalt. Ch. in Metal Prices in the United States Through 1998, 1999.
Cobalt. Ch. in Mineral Commodity Summaries, annual.
Cobalt. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Cobalt. International Strategic Minerals Inventory Summary Report, Circular 930-F, 1987.
Cobalt. Mineral Industry Surveys, monthly.
Cobalt Recycling in the United States in 1998. Ch. in Flow Studies for Recycling Metal Commodities in the United States, Circular 1196-A-M, 2004.
Historical Statistics for Mineral and Material Commodities in the United States, Open File Report 01-006, 2003.
Recycling—Metals. Ch. in Minerals Yearbook, annual.

Other

American Metal Market, daily.
China Metal Market, Precious & Minor Metals, monthly.
Cobalt. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Cobalt Development Institute.
Company reports and media releases.
Defense National Stockpile Center, Defense Logistics Agency.
Engineering & Mining Journal, monthly.
Federal Register, daily.
Interfax International Ltd., Mining & Metals Report, weekly.
Materials Flow of Cobalt in the United States, The. U.S. Bureau of Mines Information Circular 9350, 1993.
Metal Bulletin, daily, weekly, and monthly.
Mining Journal Ltd:
Mining Journal, weekly.
Mining Annual Review.
Nickel. Ch. in Canadian Minerals Yearbook, Natural Resources Canada, Minerals and Metals Sector.
Platts Metals Week, weekly.
Roskill Information Services Ltd.
Ryan's Notes, weekly.
Strategic and Critical Materials Report to the Congress. U.S. Department of Defense.

TABLE 1
SALIENT COBALT STATISTICS[1]

(Metric tons, cobalt content, unless otherwise specified)

		1999	2000	2001	2002	2003
United States:						
Consumption:						
Reported		8,660	8,980	9,540	7,940 r	7,640
Apparent		10,700	11,600	11,800	9,860	10,000
Imports for consumption		8,150	8,770	9,410	8,450	8,080
Exports		1,550	2,630	3,210	2,080	2,710
Stocks, December 31:						
Industry[2]		738	820	852	917	699
U.S. Government[3]		13,200	10,200	7,200 e	6,680	4,290
Price, metal[4]	dollars per pound	17.02	15.16	10.55	6.91	10.60
World, production:						
Mine		32,700 r	38,300 r	47,800 r	50,300 r	48,400 e
Refinery		33,100	35,000	38,800 r	40,800 r	40,200 e

eEstimated. rRevised.
[1]Data are rounded to no more than three significant digits, except prices.
[2]Stocks held by cobalt processors and consumers.
[3]Defense National Stockpile Center. Includes material committed for sale pending shipment.
[4]Annual average U.S. spot price for minimum 99.8% cobalt cathode reported by Platts Metals Week.

TABLE 2
U.S. GOVERNMENT NATIONAL DEFENSE STOCKPILE
SALES AND SHIPMENTS[1]

(Metric tons, cobalt content)

	2002	2003
Sales:		
Fiscal year[2]	1,210	2,060
Calendar year	1,320	2,820
Shipments:[3]		
Fiscal year[2]	1,330	1,930
Calendar year	524	2,380

[1]Data are rounded to no more than three significant digits.
[2]Twelve-month period ending September 30 of year stated.
[3]Calculated from yearend inventory levels.

Source: Defense National Stockpile Center.

TABLE 3
U.S. REPORTED CONSUMPTION AND STOCKS OF COBALT[1, 2]

(Metric tons, cobalt content)

	2002	2003
Consumption by end use:		
Steels	560 r	565
Superalloys	3,700	3,400
Alloys, excludes steels and superalloys:		
Magnetic alloys	416	339
Other alloys[3]	634	632
Cemented carbides[4]	618 r	662
Chemical and ceramic uses	1,950	1,980
Miscellaneous and unspecified	63	63
Total	7,940 r	7,640
Consumption by form:		
Chemical compounds, organic and inorganic[5]	1,270	1,940
Metal	3,870	3,570
Purchased scrap	2,800	2,140
Total	7,940 r	7,640
Stocks, December 31:[6]		
Chemical compounds, organic and inorganic[5]	242	214
Metal	486	380
Purchased scrap	189	105
Total	917	699

rRevised.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes estimates.
[3]Includes nonferrous alloys, welding materials, and wear-resistant alloys.
[4]Includes diamond tool matrices, cemented and sintered carbides, and cast carbide dies or parts.
[5]Includes oxides.
[6]Stocks held by cobalt processors and consumers.

TABLE 4
U.S. IMPORTS FOR CONSUMPTION OF COBALT, BY FORM[1]

	2002			2003		
	Gross weight (metric tons)	Cobalt content[2] (metric tons)	Value (thousands)	Gross weight (metric tons)	Cobalt content[2] (metric tons)	Value (thousands)
Metal[3]	6,800	6,800	$114,000	6,700	6,700	$135,000
Oxides and hydroxides	1,300	936	20,000	1,370	983	23,000
Other forms:						
Acetates	349	84	1,790	294	71	1,600
Carbonates	131	60	1,120	231	106	2,700
Chlorides	86	22	799	106	26	866
Sulfates	2,020	545	6,780	716	193	3,180
Grand total	10,700	8,450	144,000	9,410	8,080	166,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Estimated from gross weights.
[3]Unwrought cobalt, excluding alloys and waste and scrap.

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

TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF COBALT, BY COUNTRY[1]

Country of origin	Metal[2]			Oxides and hydroxides			Other forms[3]			Total		
	Gross weight (metric tons)	Cobalt content[4] (metric tons)	Value[5] (thousands)	Gross weight (metric tons)	Cobalt content[4] (metric tons)	Value[5] (thousands)	Gross weight (metric tons)	Cobalt content[4] (metric tons)	Value[5] (thousands)	Gross weight (metric tons)	Cobalt content[4] (metric tons)	Value[5] (thousands)
2002:												
Australia	177	177	$2,490	--	--	--	--	--	--	177	177	$2,490
Belgium	437	437	9,090	528	380	$8,550	8	2	$52	973	819	17,700
Brazil	289	289	4,480	--	--	--	6	3	70	295	292	4,550
Canada	888	888	15,700	--	--	--	--	--	--	888	888	15,700
China	41	41	990	1	(6)	18	6	2	36	47	43	1,040
Congo (Kinshasa)	271	271	3,570	--	--	--	(6)	(6)	4	271	271	3,570
Finland	1,000	1,000	18,900	560	403	6,740	2,190	594	7,900	3,750	2,000	33,500
France	31	31	1,620	46	33	1,700	--	--	--	77	64	3,320
Germany	27	27	683	12	9	224	54	18	271	93	54	1,180
Japan	93	93	2,380	(6)	(6)	33	57	14	623	150	107	3,040
Korea, Republic of	1	1	50	--	--	--	--	--	--	1	1	50
Morocco	57	57	842	--	--	--	--	--	--	57	57	842
Netherlands	54	54	432	(6)	(6)	3	--	--	--	54	54	434
Norway	1,710	1,710	25,800	--	--	--	--	--	--	1,710	1,710	25,800
Philippines	--	--	--	--	--	--	85	34	601	85	34	601
Russia	1,040	1,040	16,600	--	--	--	--	--	--	1,040	1,040	16,600
South Africa	231	231	3,070	52	37	527	--	--	--	283	269	3,600
Sweden	31	31	757	--	--	--	--	--	--	31	31	757
Uganda	44	44	650	--	--	--	--	--	--	44	44	650
United Kingdom	45	45	365	101	73	2,170	180	44	927	326	162	3,460
Zambia	316	316	4,680	--	--	--	--	--	--	316	316	4,680
Other	17 r	17 r	637 r	(6)	(6)	6 r	--	--	--	17 r	17 r	643 r
Total	6,800	6,800	114,000	1,300	936	20,000	2,580	710	10,500	10,700	8,450	144,000
2003:												
Australia	298	298	5,040	--	--	--	--	--	--	298	298	5,040
Belgium	325	325	7,290	537	387	9,900	17	4	121	880	717	17,300
Brazil	262	262	4,780	--	--	--	4	2	42	266	264	4,820
Canada	508	508	9,440	--	--	--	--	--	--	508	508	9,430
China	161	161	3,440	128	92	1,560	46	13	297	335	267	5,300
Congo (Kinshasa)	178	178	2,820	--	--	--	--	--	--	178	178	2,820
Finland	582	582	13,600	381	274	5,720	832	255	5,150	1,800	1,110	24,500
France	31	31	1,430	38	27	1,350	--	--	--	69	58	2,780
Germany	29	29	489	2	1	173	--	--	--	31	31	662
India	--	--	--	--	--	--	50	14	195	50	14	195
Japan	128	128	3,320	--	--	--	60	15	597	189	144	3,910
Korea, Republic of	28	28	317	--	--	--	--	--	--	28	28	317
Morocco	20	20	353	--	--	--	--	--	--	20	20	353
Netherlands	20	20	412	--	--	--	--	--	--	20	20	412
Norway	1,770	1,770	36,500	--	--	--	--	--	--	1,770	1,770	36,500
Philippines	--	--	--	--	--	--	111	35	766	111	35	766
Russia	1,640	1,640	32,000	--	--	--	--	--	--	1,640	1,640	32,000
South Africa	103	103	1,540	26	18	301	--	--	--	129	121	1,840
Sweden	22	22	601	--	--	--	6	2	13	28	24	615
Uganda	5	5	66	--	--	--	--	--	--	5	5	66
United Kingdom	17	17	403	250	180	3,950	203	51	1,110	470	248	5,470
Zambia	555	555	9,920	--	--	--	--	--	--	555	555	9,920
Other	17	17	1,110	3	2	57	17	5	49	37	24	1,220
Total	6,700	6,700	135,000	1,370	983	23,000	1,350	396	8,350	9,410	8,080	166,000

rRevised. -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Unwrought cobalt, excluding alloys and waste and scrap; includes cobalt cathode and cobalt metal powder; may include intermediate products of cobalt metallurgy.
[3]Includes cobalt acetates, cobalt carbonates, cobalt chlorides, and cobalt sulfates.
[4]Estimated from gross weights.
[5]Customs value.
[6]Less than 1/2 unit.

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

TABLE 6
U.S. EXPORTS OF COBALT IN 2003, BY COUNTRY[1, 2]

Country of destination	Metal[3] Gross weight (metric tons)	Metal[3] Value[4] (thousands)	Oxides and hydroxides Gross weight (metric tons)	Oxides and hydroxides Value[4] (thousands)	Acetates Gross weight (metric tons)	Acetates Value[4] (thousands)	Chlorides Gross weight (metric tons)	Chlorides Value[4] (thousands)	Total Cobalt content[5] (metric tons)	Total Value[4] (thousands)
Argentina	14	$337	22	$304	(6)	$3	--	--	30	$643
Belgium	1,150	30,300	9	347	119	497	--	--	1,190	31,100
Brazil	43	849	16	221	90	555	--	--	76	1,620
Canada	164	2,170	28	625	33	269	62	$642	207	3,710
China	54	291	95	1,390	--	--	--	--	123	1,680
France	18	415	--	--	--	--	--	--	18	415
Germany	44	1,240	(6)	8	--	--	--	--	44	1,250
Ireland	293	4,070	--	--	--	--	--	--	293	4,070
Italy	5	227	13	106	--	--	--	--	14	333
Japan	195	4,200	59	1,520	--	--	--	--	238	5,720
Mexico	9	162	24	474	216	958	1	8	78	1,600
Netherlands	53	216	35	243	--	--	2	28	79	486
Philippines	--	--	16	33	--	--	--	--	11	33
Spain	2	156	13	106	58	214	--	--	25	476
Sweden	80	1,040	--	--	--	--	--	--	80	1,040
Switzerland	20	179	--	--	--	--	--	--	20	179
Taiwan	8	192	29	434	8	24	1	17	31	667
United Kingdom	123	1,830	(6)	25	18	106	(6)	10	127	1,970
Other	16	758	17	278	7	34	(6)	3	30	1,070
Total	2,290	48,600	375	6,110	550	2,660	66	708	2,710	58,100

-- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]In addition to the materials listed, the United States exports cobalt ores and concentrates and wrought cobalt and cobalt articles.
[3]Includes unwrought cobalt, powders, waste and scrap, and mattes and other intermediate products of cobalt metallurgy.
[4]Free alongside ship value.
[5]Estimated from gross weights.
[6]Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 7
WORLD ANNUAL COBALT REFINERY CAPACITY, DECEMBER 31, 2003[1, 2]

(Metric tons, cobalt content)

Country	Capacity
Australia[e]	4,950
Belgium	1,200
Brazil	1,100
Canada	5,200
China[e]	5,900
Congo (Kinshasa)	17,600
Finland	10,000
France	600
India	370
Japan	600
Morocco	1,350
Norway	4,600
Russia[e]	8,000
South Africa[e]	1,000
Uganda[e]	720
Zambia	9,700
Total	72,900

[e]Estimated.
[1]Data are rounded to no more than three significant digits; may not add to total shown.
[2]Refinery products include cobalt metal, metal powders, oxides, and/or salts.

TABLE 8
COBALT: WORLD MINE PRODUCTION, BY COUNTRY[1, 2]

(Metric tons, cobalt content)

Country[3]	1999	2000	2001	2002	2003[e]
Australia[e, 4]	4,100	5,600	6,200	6,700	6,900
Botswana[5]	331	308	325	269	362 [6]
Brazil[e]	700	900	1,100	1,200	1,300
Canada[7]	5,323	5,298	5,326	5,148 [r]	4,304 [6]
China[e]	250	90	150	1,000 [r]	1,000
Congo (Kinshasa)[e, 8]	7,000 [r]	11,000 [r]	15,000 [r]	14,500 [r]	12,000
Cuba[9]	2,537	2,943	3,411	3,124 [r]	3,000
Kazakhstan[e, 10]	300	300	300	300	300
Morocco[11]	863	1,305	1,242 [r]	1,335 [r]	1,278 [6]
New Caledonia[e, 12]	1,100	1,200	1,400	1,400	1,400
Norway[e, 11]	100	100	100	100	--
Russia[e]	3,900	4,000	4,600	4,600	4,800
South Africa[e]	450	580	550	540	400
Zambia[13]	5,640	4,600	8,000 [e]	10,000 [e]	11,300
Zimbabwe[14]	121	79	95	87	80
Total[e]	32,700 [r]	38,300 [r]	47,800 [r]	50,300 [r]	48,400

[e]Estimated. [r]Revised. -- 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 18, 2004. Figures represent recoverable cobalt content of ores, concentrates, or intermediate products from copper, nickel, platinum, or zinc operations. Morocco was the only country where cobalt was mined as a primary product.

[3]In addition to the countries listed, Bulgaria, Indonesia, the Philippines, and Poland are known to produce ores that contain cobalt, but information is inadequate for reliable estimates of output levels. Other copper-, nickel-, platinum-, or zinc-producing nations may also produce ores containing cobalt as a byproduct component, but recovery is small or nil.

[4]Quantities of cobalt contained in intermediate or refined metallurgical products produced from Australian and imported ores. Cobalt content of lateritic nickel ore, nickel concentrate, and zinc concentrate originating in Australia, in metric tons, was estimated to be as follows: 1999--7,000; 2000--5,100; 2001--6,100; 2002--6,500 (revised); and 2003--7,000.

[5]Reported cobalt content of pelletized nickel-copper matte.

[6]Reported figure.

[7]Assay content of cobalt in concentrates produced. The cobalt content, in metric tons, of all products derived from ores of Canadian origins, including cobalt oxide shipped to the United Kingdom for further processing and nickel-copper matte shipped to Norway for refining, was reported to be as follows: 1999--2,014; 2000--2,022; 2001--2,112; 2002--2,065 (revised); and 2003--1,743.

[8]Cobalt content of concentrates, tailings, and slags. Includes the following estimates, in metric tons, of illegal production by artisanal miners: 1999-2000--1,000; 2001-02--2,000; and 2003--4,000.

[9]Determined from reported nickel-cobalt content of sulfide production.

[10]Estimated cobalt content of only those ores from which it is assumed cobalt is recovered. Cobalt content of total ores mined is assumed to be 1,400 metric tons (1999-2003).

[11]Cobalt content of concentrates.

[12]Quantities of cobalt contained in intermediate or refined metallurgical products (cobalt chloride and cobalt oxide hydroxide) produced from New Caledonian ores exported to Australia and France. Cobalt content of total ores mined, in metric tons, is estimated to be as follows: 1999--11,000 and 2000-03--12,000.

[13]Cobalt content of concentrates and slags.

[14]Cobalt content of intermediate products produced in Zimbabwe from ores originating in Botswana and Zimbabwe.

TABLE 9
COBALT: WORLD REFINERY PRODUCTION, BY COUNTRY[1, 2]

(Metric tons, cobalt content)

Country[3]	1999	2000	2001	2002	2003
Australia, metal, metal powder, oxide hydroxide[e]	1,700	2,610	3,470	3,700	3,840
Belgium, metal powder, oxide, hydroxide[4]	950	1,110	1,090	1,135	1,704
Brazil, metal	651	792	889	960	1,097
Canada, metal, metal powder, oxide	4,196	4,364	4,378	4,625	4,233
China, metal[e]	300	410	680 [r]	980 [r]	1,000
Congo (Kinshasa), metal[5]	5,180	4,320	4,071	3,000 [e]	1,200 [e]
Finland, metal powder and salts[6]	6,200	7,700	8,100	8,200	7,990
France, chloride	181	204	199	176 [r]	181
India, metal and salts	120 [e]	206	250	270	255
Japan, metal	247	311	350	354	379
Morocco, metal	472	967	1,337	1,354 [r]	1,350 [e]
Norway, metal	4,009	3,433	3,314	3,994	4,556
Russia, unspecified[e]	4,300	4,400	5,000	5,100	5,500
South Africa, metal powder and sulfate	306	397	373	366	271
Uganda, metal	77	420	634	450 [e]	--
Zambia, metal	4,236	3,342	4,657	6,144	6,620
Total[e]	33,100	35,000	38,800 [r]	40,800 [r]	40,200

[e]Estimated. [r]Revised. -- 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 18, 2004. Figures represent cobalt refined from ores, concentrates, or intermediate products and do not include production of downstream products from refined cobalt.

[3]In addition to the countries listed, Germany and Slovakia may produce cobalt, but information is inadequate to make reliable estimates of production.

[4]Production reported by n.v. Umicore s.a.; includes production from China and South Africa that is not otherwise included in this table.

[5]Excludes production of cobalt in white alloy, matte, and slag that would require further refining.

[6]Production reported by OM Group, Inc.; may include production from outside Finland that is not otherwise included in this table.