

COBALT

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

The United States is the world's largest consumer of cobalt, but has no mine or refinery production, so it relies on imports to meet its primary cobalt needs. The U.S. Government maintains significant quantities of cobalt metal in the National Defense Stockpile (NDS) for military, industrial, and essential civilian use during a national emergency.

World cobalt production continued to increase in 1996. As in the past few years, cobalt sales from the NDS and exports from Russia contributed to supply. Demand remained strong, but prices decreased during the year.

With the exception of prices and reported production from foreign countries, all data in this report have been rounded to three significant digits. Totals and percentages were calculated from unrounded numbers.

Legislation and Government Programs

The U.S. Government continued its sales of cobalt from the NDS. During fiscal year 1996 (October 1, 1995, through September 30, 1996), the Defense Logistics Agency (DLA) sold 1,809 tons of cobalt valued at \$102 million. This equaled the quantity allowable for sale under the Annual Materials Plan (AMP) for the fiscal year and completed the disposal of the 5,779 tons (12.7 million pounds) of excess cobalt identified in the Department of Defense 1992 Report to the Congress on National Defense Stockpile Requirements.

In September 1996, the 1997 Defense Authorization Bill was signed into law. The bill gave DLA the authority to dispose of an additional 11,793 tons (26 million pounds) of cobalt. The AMP for fiscal year 1997 allowed for a maximum of 2,722 tons (6 million pounds) of cobalt to be sold during the year beginning October 1, 1996. In October, the DLA announced the following sales program: sealed bid sales in December 1996, March 1997, and May 1997; negotiated sales in February 1997, April 1997, and September 1997. Approximately 450 tons (1 million pounds) of 99.0% to 99.59% cobalt would be offered in each sale except the February sale, when 500 tons (1.1 million pounds) of less than 99.0%-pure cobalt would be offered.

The DLA held two cobalt offerings during calendar year 1996. Awards announced in June were made under a negotiated

bid basis, while awards made in December were on a sealed bid basis. Between January and December, the DLA sold 1,020 tons of cobalt valued at \$151 million. On December 31, the total uncommitted cobalt inventory held by the DLA was 18,176 tons (40.1 million pounds) and the quantity authorized for eventual disposal was 11,793 tons (26 million pounds). (*See tables 1 and 2.*)

Production

There was no domestic mine or refinery production of cobalt in 1996. Formation Capital Corp., of Vancouver, British Columbia, Canada, put its Black Pine copper-cobalt-gold project in Lemhi County, ID, on hold and concentrated on exploring the nearby Sunshine copper-cobalt-gold deposit. Double Creek Mining Corp., also based in Vancouver, acquired a 50% interest in Formation Capital's Salmon Canyon copper property and began an exploration program. The three properties are located in the Idaho Cobalt Belt, which contains Noranda Mining Inc.'s Blackbird Mine, which ceased production in 1959.

U.S. processors made cobalt chemicals and cobalt metal powders from cobalt metal and/or cobalt-bearing scrap. U.S. Geological Survey (USGS) data on chemical and metal powder production were developed from a monthly voluntary survey of U.S. cobalt processors. Six of the seven companies canvassed for this survey responded. Estimates were made for the nonresponding company. U.S. processors produced 960 tons of cobalt oxide and hydroxide, inorganic cobalt compounds, and organic cobalt compounds in 1996, 35% less than the 1,470 tons produced in 1995. Because this figure includes production of intermediate forms, it does not represent net production. Shipments are defined as sales, transfers, or consumption to make end-use products such as paint driers and catalysts. In 1996, shipments by U.S. processors included 1,350 tons of cobalt oxide and hydroxide, inorganic cobalt compounds, and organic cobalt compounds, an 8% decrease from 1995 shipments of 1,460 tons. Two processors made extra-fine cobalt metal powder in the United States. Carolmet, owned by Union Minière S.A. of Belgium, made cobalt metal powder from imported metal at its Laurinburg, NC, plant. Osram Sylvania Inc. made cobalt metal powder from recycled materials in Towanda, PA. Production and shipments of cobalt metal powder are withheld to avoid disclosing company proprietary data.

U.S. cobalt supply included secondary cobalt from alloy scrap, cemented carbide scrap, and spent catalysts. Spent petroleum catalysts were treated by at least four companies in 1996: AMAX Metals Recovery, Inc. in Braithwaite, LA;

Dakota Catalyst Products Inc. in Williston, ND; Gulf Chemical and Metallurgical Corp. in Freeport, TX; and OMG-Apex in St. George, UT.

Consumption

Apparent consumption (as calculated from net imports, consumption from purchased scrap, and changes in Government and industry stocks) was basically the same as apparent consumption in 1995. (See table 1.) Increases in imports, consumption of scrap, and consumption from stocks were offset by a significant increase in exports.

Reported consumption was developed 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 superalloy producers, magnetic alloy producers, and tungsten carbide producers. For this survey, more than 100 cobalt consumers were canvassed on a monthly or annual basis. The USGS also canvassed 13 superalloy scrap recyclers to determine the consumption of secondary cobalt in superalloy production. Reported consumption and stocks data in tables 1 and 2 contain estimates to account for nonrespondents.

U.S. reported consumption for 1996 was basically the same as reported consumption for 1995. As a whole, metallurgical industries consumed 2% more cobalt in 1996 than in 1995. On an industry-by-industry basis, superalloy melters consumed more cobalt in 1996 than in 1995; producers of welding materials consumed basically the same amount of cobalt during the 2 years; and producers of steel, magnetic alloys, other alloys, cemented carbides, and mill products from metal powder consumed less cobalt in 1996 than in 1995. Total reported cobalt consumption in chemical uses decreased 7% in 1996. Consumption in pigments, decolorizers, and feed materials increased in 1996 as compared with that in 1995, while consumption in catalysts, ground coat frit, and driers decreased. (See table 2.)

Prices

Market prices for cobalt decreased in 1996. In January, the U.S. spot cathode price reported by Platt's Metals Week was approximately \$32 per pound. By late July the spot cathode price had dropped to a low of \$20 per pound. The price increased to approximately \$23 per pound in September, but decreased again to \$21 to \$22 per pound by yearend. Platt's average annual U.S. spot cathode price for 1996 was \$25.50 per pound.

Platt's prices for Zambian and Russian cobalt paralleled the U.S. spot cathode prices. In January, the price differential between cathode and Zambian cobalt was minus \$2.50 per pound and the price differential between cathode and Russian cobalt was minus \$3.75 per pound. As prices decreased the price differentials narrowed. By September, Zambian cobalt was approximately \$0.50 per pound less than cathode and

Russian cobalt was approximately \$0.75 per pound less than cathode.

The reference price set by African producers La Générale des Carrières et des Mines (Gécamines) of Zaire and Zambia Consolidated Copper Mines Ltd. (ZCCM) remained at \$27.50 per pound throughout the year.

Foreign Trade

Seven countries supplied 95% of U.S. imports of unwrought cobalt and cobalt in chemicals. Norway was the leading supplier, followed by Finland, Zambia, Canada, Russia, Zaire, and Belgium. Cobalt imports in 1996 were 4% higher than imports in 1995. Imports of cobalt from Finland, Norway, and Zambia increased as compared with those of 1995; imports from Canada, Russia, and Zaire decreased; while imports from Belgium were unchanged from those of 1995. (See tables 4 and 5.)

In 1996, the United States imported 60 tons, gross weight, of unwrought cobalt alloys valued at \$3.8 million. Seven countries supplied nearly all of these materials: France (24%), Sweden (19%), Belgium (13%), the United Kingdom (12%), Canada and Germany (each 11%), and Japan (10%). The United States imported 566 tons, gross weight, of cobalt matte, waste, and scrap, valued at \$11.7 million. Eight countries supplied 92% of these materials: the United Kingdom (21%), Japan (13%), Germany (12%), South Africa (11%), Canada and Finland (each 10%), Brazil (9%), and Russia (7%). The United States also imported 178 tons, gross weight, of wrought cobalt and cobalt articles valued at \$11.5 million. The leading suppliers of these materials were Japan (30%), the United Kingdom (41%), France (16%), Germany (6%), and Canada (4%).

U.S. exports of unwrought cobalt and cobalt contained in chemicals increased 28% as compared with exports in 1995. More than three-fourths of 1996 cobalt metal and chemical exports was shipped to six countries: Belgium, Canada, Japan, Mexico, the Netherlands, and the United Kingdom. The remainder was shipped to 42 other countries. (See table 6.)

Exports also included 529 tons, gross weight, of wrought metal and cobalt articles valued at \$23.5 million. Eighty percent of these materials was sent to seven countries: Hong Kong (19%), the United Kingdom (18%), Canada, Japan, and the Netherlands (each 11%), Taiwan (6%), and France (5%). The remainder was shipped to 29 other countries.

World Review

World cobalt production continued its upward trend in 1996. Refinery production reported by the seven Cobalt Development Institute-member producers increased 31%, from 16,808 tons in 1995 to 22,010 tons in 1996 (Metal Bulletin, 1997).

Australia.—QNI Ltd. made a number of investments to expand production and improve metal recovery rates at its Yabulu nickel-cobalt refinery in Townsville, Queensland. In addition, the company began construction on a plant that would convert Yabulu's cobalt sulfide to cobalt oxide hydroxide. The

plant was expected to be operational in early 1997. The cobalt oxide hydroxide would be sold as feedstock for the production of cobalt chemicals.

Yabulu's production during the 12-month period ending June 30, 1996, was 1,425 tons of cobalt in cobalt sulfide, basically the same as production during the previous year. Nearly all of the laterite feed for the refinery was from PT Aneka Tambang in Indonesia and four mining companies in New Caledonia. QNI continued its search for additional sources of laterite ore. During the year, QNI signed a contract with Hinatuan Mining Corp. for the supply of trial ore shipments from the Philippines. In July, QNI, Gencor Ltd. of South Africa, and PT Aneka Tambang of Indonesia announced a study to evaluate the possibility of developing integrated nickel-cobalt processing facilities in Indonesia and Australia (QNI Ltd., 1996).

WMC Ltd. (formerly Western Mining Corp. Holdings Ltd.) produced approximately 1,000 tons of cobalt in intermediate products as a byproduct of mining, smelting, and refining nickel sulfide ores in Western Australia. The intermediate products were exported to Outokumpu Oy in Finland, Sumitomo Metal Mining Co. in Japan, and Sherritt International Corp. in Canada to be refined.

Outokumpu Australia Pty. Ltd. produced nickel sulfide concentrates from its Forrester Mine and concentrator southwest of Kalgoorlie, in Western Australia. The concentrates were exported to Finland for treatment by Outokumpu, where an estimated 100 tons of cobalt was recovered.

Anaconda Nickel NL completed a feasibility study and decided to move forward on its Murrin Murrin nickel-cobalt project. The Murrin Murrin deposit, located between Leonora and Laverton, Western Australia, consists of nickel laterites with a total resource of 117 million tons at 1.10% nickel and 0.08% cobalt. The study indicated that the deposit could be mined by open pit methods over a period of 30 years. Anaconda planned to produce nickel metal powder and cobalt metal powder using the following process: pressure acid leaching, mixed sulfide precipitation and re-leaching, solvent extraction, then hydrogen reduction. Initial production, forecast to begin in early 1998, would be at an annual rate of 45,000 tons of nickel and 3,000 tons of cobalt. Further expansion to 70,000 tons per year of nickel was being considered. At yearend, Anaconda entered into an agreement with Glencore International AG, whereby Glencore would increase its interest in the Murrin Murrin project to 40% (Anaconda Nickel NL, 1996; Anaconda Nickel Ltd., 1997).

Resolute Samantha Ltd. completed a feasibility study and made a commitment to develop its Bulong nickel-cobalt project. The deposit, located east of Kalgoorlie in Western Australia, is a nickel laterite with a resource of 140 million tons at 1.0% nickel and 0.1% cobalt. Mining would occur in several open pits over a period of 26 years. Ore would be refined by pressure acid leaching, followed by solvent extraction and electrowinning to produce nickel cathode and cobalt cathode. Resolute planned to develop the project in two stages: initial annual production of approximately 9,000 tons of nickel and 600 tons of cobalt, followed by an expansion to 22,000 tons of nickel and 1,800

tons of cobalt. Production was to begin during the first half of 1998 (Resolute Samantha Ltd., 1996; Metal Bulletin, 1996a).

Centaur Mining & Exploration Ltd. completed a feasibility study on its Cawse nickel laterite project north of Kalgoorlie in Western Australia. Exploration during the year upgraded the mineral resource estimate to 193 million tons at 0.7% nickel and 0.04% cobalt. Centaur planned to mine the deposit from a number of shallow pits, screen the ore, then process it with pressure acid leaching. An intermediate nickel-cobalt hydroxide would be produced, then re-leached in ammonia. Nickel would be recovered by solvent extraction and electrowinning. Cobalt would be produced as a sulfide, which would be sent elsewhere for further processing. Centaur planned to begin production in 1998 at an initial rate of 8,000 tons of nickel and 2,000 tons of cobalt (Centaur Mining & Exploration Ltd., 1996a, 1996b).

Calliope Metals Corp. worked on a feasibility study for a nickel-cobalt refinery to be built in Gladstone, Queensland. Calliope planned to use pressure acid leaching to treat limonitic ore imported from New Caledonia. The proposed refinery would be capable of processing 1.2 million dry tons of ore per year to produce a mixed sulfide containing 18,700 tons of nickel and 1,890 tons of cobalt. Calliope planned to begin production in 1999 (Calliope Metals Corp., 1996; Mattheson, 1996).

Mount Isa Mines Ltd. and Savage Resources Ltd. proceeded with the development of the Ernest Henry copper-gold deposit near Cloncurry, Queensland. The partners planned to begin production in late 1997. A project to recover cobalt from pyrite in Ernest Henry's flotation tailings was under consideration. Bench-scale testing of various oxidation process options began in 1996. Pilot plant scale testing was delayed until mine production begins and bulk concentrate samples become available (Wall, 1996).

The following nickel sulfide projects also have the potential to produce cobalt in the future: Dominion Mining Ltd.'s Yakabindie project, the CRA Ltd./Outokumpu Oy Honeymoon Well project, and the Mining Project Investors Pty. Ltd./Outokumpu Black Swan project. All three of these projects are north of Kalgoorlie in Western Australia. Two copper properties in the Cloncurry area of Queensland also have the potential to produce cobalt: Cloncurry Mining NL's Great Australia copper mine and Majestic Resources NL's White Range copper-cobalt project.

Belgium.—Union Minière S.A. converted cobalt metal, residues, and other cobalt-bearing materials into cobalt metal powders, oxides, hydroxide, and chloride at its facilities in Olen, Belgium.

Brazil.—Cia. Niquel Tocantins produced cobalt cathode at its refinery in Sao Miguel Paulista, Sao Paulo State. The refinery used lateritic nickel ore from Niquelandia, Goias State, as feed.

RTZ Mineração, a subsidiary of RTZ Corp. Plc. of the United Kingdom, worked on its Fortaleza de Minas nickel sulfide project in Minas Gerais State. The project was to include a mine, concentrator, smelter, and refinery. RTZ planned to begin production in early 1998. Byproduct cobalt would be refined elsewhere (Metal Bulletin, 1996b).

Canada.—Falconbridge Ltd.'s Sudbury Division produced 1,625 tons of cobalt contained in nickel-copper matte, a 3% increase from 1,574 tons produced in 1995 (Falconbridge Ltd., 1997). Forty-five percent of the cobalt smelted was from nickel-copper ores mined at the company's Sudbury, Ontario, operations. The remaining 55% was from custom feed materials. Matte from Falconbridge's Sudbury smelter was refined at the company's Nikkelverk plant in Norway.

Falconbridge continued with the development of its Raglan nickel-copper property in the Ungava region of northern Quebec. The company planned both open pit and underground mining. Concentrates milled at Raglan would be smelted at Sudbury and the matte produced would be refined in Norway. An estimated 20,800 tons of nickel, 5,200 tons of copper, and 330 tons of cobalt would be recovered annually from Raglan ores (Falconbridge Ltd., 1996). Production was scheduled to begin by late 1997.

Inco Ltd. produced cobalt oxide at its Thompson, Manitoba, refinery and cobalt cathode at its Port Colborne, Ontario, refinery. Feed materials for the two refineries originated from nickel mines in Thompson, Manitoba, and Sudbury, Ontario, respectively. In 1996, Inco produced 1,544 tons of cobalt, a 13% increase over the 1,362 tons produced in 1995 (Metal Bulletin, 1997).

In August, Inco purchased Diamond Fields Resources Inc. and became full owner of the world-class Voisey's Bay nickel-copper-cobalt-sulfide deposit in northeastern Labrador. Exploration at Voisey's Bay continued during the year. By yearend, at least three zones of mineralization had been identified: a near-surface ovoid-shaped body, the Eastern Deeps area, and the Western Extension. Inco reported an "inferred resource" of approximately 150 million tons (Inco Ltd., 1997). Inco hoped that permitting would be completed by May 1998 and initial concentrate production could begin in late 1999 (Inco Ltd., 1996).

In November, Inco selected Argentia, Newfoundland, as the site for the smelter and refinery complex that would process the nickel-cobalt concentrate from Voisey's Bay. Inco planned to have the complex built in time to begin smelting concentrate in the year 2000. At full production Voisey's Bay was expected to yield 122,000 tons of nickel, 90,000 tons of copper, and 3,000 tons of cobalt per year (Inco Ltd., 1997).

In November 1995, Sherritt Inc.'s 50% share in the Metals Enterprise joint venture with General Nickel Co. S.A. of Cuba was transferred to Sherritt International Corp. The Metals Enterprise included The Cobalt Refinery Co. Inc.'s nickel-cobalt refinery at Fort Saskatchewan, Alberta. In 1996, capacity at this refinery was increased to 27,200 tons of nickel and 2,270 tons of cobalt. Cobalt production was a record 2,074 tons, 20% higher than the 1,730 tons produced in 1995 (Sherritt International Corp., 1997). Most of the feed for the refinery was in the form of nickel-cobalt mixed sulfides from Metals Enterprise subsidiary Moa Nickel S.A. of Moa Bay, Cuba. As a result of a U.S. embargo on imports of products originating from Cuba, nickel and cobalt produced at The Cobalt Refinery Co. cannot be sold to U.S. customers.

Ego Resources Ltd. produced cobalt carbonate at its Cobatec refinery near the historic silver mining town of Cobalt, Ontario. The refinery used a hydrometallurgical process to treat ores from local mines and "copper cake" from electrolytic zinc production. During the year Ego reviewed its plant process and decided to discontinue processing ore in favor of cobalt-bearing residues. As a result of this decision, production from two local mines ceased and arrangements were made with outside sources for feedstock (Ego Resources Ltd., 1997).

Canmine Resources Corp. explored cobalt and nickel deposits in the Werner Lake Belt of southwestern Ontario-southeastern Manitoba. In May, Canmine announced that it was to acquire full titles to the Juan cobalt-copper-gold property in Ontario and the Maskwa-Dumbarton nickel-copper-platinum-group-metal property in Manitoba. Canmine planned to develop high-grade cobalt deposits at the Juan property and process the ore at a milling facility to be established at Maskwa. Approximately 300 tons of cobalt in concentrate would be produced from test milling during the first year. Full-scale annual production in later years was targeted at 900 tons of cobalt in concentrate. The mine was being developed on a 50% joint-venture basis with Red Engine Resources Corp. (Canmine Resources Corp., 1996).

China.—Cobalt was produced from both domestic and imported raw materials. At Jinchuan, Gansu Province, cobalt metal was produced as a byproduct of nickel from the refining of domestic nickel sulfide ores. The Ganzhou cobalt refinery in Jiangxi Province produced cobalt metal and salts from cobalt arsenide concentrates imported from Morocco. Minor production sites included the Zibo Cobalt Works in Shandong Province, where cobalt metal was produced from iron ore from Shandong Province and copper ore from Shanxi Province.

Côte d'Ivoire.—Falconbridge, Trillion Resources Ltd., and Société de Développement Minière de la Côte d'Ivoire continued exploration work on nickel laterite deposits in western Côte d'Ivoire. In December, Falconbridge signed a memorandum of understanding with the Government of Côte d'Ivoire that outlined a schedule for the Touba-Biankouma nickel laterite project. The schedule included completion of a study on hydrometallurgical ore treatment during the first quarter of 1997. Exploration identified a total resource of 226 million tons, grading 1.50% nickel and 0.10% cobalt (Falconbridge Ltd., 1997).

Cuba.—Moa Nickel S.A. mined nickel-cobalt laterites at Moa Bay and produced mixed sulfides containing 26,034 tons of nickel and cobalt. This 26% increase over 1995 production was attributed to improved management practices and the overhaul of two sulfuric acid plants at Moa. The mixed sulfides produced at Moa were refined by The Cobalt Refinery Co. in Fort Saskatchewan, Alberta, Canada (Sherritt International Corp., 1997.)

WMC continued negotiations with state-owned Commercial Caribbean Nickel S.A. to finalize detailed plans for a joint-venture project to evaluate and possibly develop the Pinares de Mayari West nickel laterite deposit in Holguín Province.

Nickel and cobalt of Cuban origin cannot be imported into

the United States because of a U.S. embargo on imports from Cuba.

Finland.—OM Group, Inc. produced a record 4,160 tons of cobalt in cobalt metal powders, oxides, and salts, 15% more than the 3,610 tons produced in 1995 (Metal Bulletin, 1997). In recent years, OM Group's Kokkola Chemicals Oy refinery has used cobalt sulfide from QNI in Australia, cobalt slag and cobalt-nickel hydrate from Gécamines in Zaire, and cobalt hydroxide sludge from Outokumpu's Harjavalta, Finland, refinery as its raw materials feed.

Outokumpu Metals and Resources Oy produced an estimated 500 tons of cobalt metal powder at its newly expanded and upgraded Harjavalta nickel refinery (Karpel, 1996). The cobalt was a byproduct of nickel produced from concentrates imported from the Nikkel og Olivin Mine in Norway and the Mount Keith and Forrestania Mines in Western Australia.

Japan.—Sumitomo produced electrolytic cobalt, cobalt oxide, and cobalt salts as a byproduct of nickel production at its Niihama Nickel Refinery in Ehime Prefecture. Sumitomo's cobalt metal production in 1996 was basically the same as that in 1995.

Mexico.—International Curator Resources Ltd. of Vancouver, British Columbia, continued its investigation of the Boleo copper-cobalt deposit near Santa Rosalia, Baja California. Exploration by the company expanded the "geological resource" to 395 million tons grading 0.88% copper and 0.075% cobalt at a 1% copper-equivalent cutoff grade (International Curator Resources Ltd., 1996). International Curator investigated a leaching-precipitation-flotation process to produce copper and cobalt concentrates, which would then be redissolved and electrowon to produce cathode copper and cobalt. Annual production was forecast at 55,000 tons of copper and 4,500 tons of cobalt beginning in late 1999 (McInnis, 1996).

Morocco.—Cie. de Tifnout-Tiranimine (CTT) began production of cobalt metal in mid-1996. Cobalt tailings from past mining operations at Bou-Azzer were leached in sulfuric acid, purified with solvent extraction, then electrowon to produce 99.9% cobalt cathode. Preliminary treatment of the tailings occurred at a newly constructed plant at the Bou-Azzer Mine. Final purification and cathode production occurred at a newly constructed plant at the Guemassa Mine. CTT planned to produce 220 tons of cobalt cathode per year. This production was to be in addition to the 300 to 400 tons of cobalt in concentrates that CTT exports to China for refining (M'Hamdi, 1996).

New Caledonia.—Lateritic nickel ore from J.C. Berton Mines, Nickel Mining Corp., Société Minière du Sud Pacifique, and Société des Mines de la Tontouta was exported to QNI's Yabulu nickel-cobalt refinery in Queensland, Australia, for processing. Nickel matte from Société Métallurgique Le Nickel's Doniambo smelter was sent to the Eramet Group's refinery in Sandouville-LeHavre, France, where it was refined into nickel cathode, nickel chloride, and cobalt chloride. Inco continued work on a feasibility study of its 85%-owned Goro nickel-cobalt property in southern New Caledonia.

Norway.—Falconbridge expanded the cobalt capacity of its Nikkelverk refinery to 3,700 tons per year. The expansion was to accommodate feed from the company's Raglan Mine in Quebec, Canada, and additional custom feed. The company produced 3,098 tons of cobalt cathode at Nikkelverk in 1996, a 10% increase over the 2,804 tons produced in 1995 (Falconbridge Ltd., 1997). Feedstock for the refinery was in the form of matte from company operations in Sudbury, Canada, BCL Ltd. in Botswana, and elsewhere.

Papua New Guinea.—Joint-venture partners Highlands Gold Ltd. and Nord Pacific Ltd. completed a prefeasibility study on their Ramu River laterite project. The study investigated the feasibility of open pit mining, then processing the ore with pressure acid leaching technology. A production rate of 33,000 tons of nickel and 2,800 tons of cobalt over a period of 20 years or more was considered, with initial production beginning in the first quarter of 2001. The partners planned to advance the project toward full feasibility and production (Nord Pacific Ltd., 1996).

Philippines.—At the end of 1995 a consortium of international investors named Pacific Nickel Holdings Ltd. reached an agreement with the Philippine Government to acquire Philnico Mining and Industrial Corp. and rehabilitate the Nonoc nickel mine and refinery complex. The complex, located in Surigao del Norte, Nonoc Island, was closed in 1986 following financial difficulties. It has the capacity to produce 30,000 tons of nickel metal and mixed sulfides containing 3,000 tons of nickel and 1,500 tons of cobalt. During 1996, Arboyne NL of Perth, Western Australia, secured an option to acquire 100% of Pacific Nickel Holdings. Arboyne planned to include alterations to the refinery to allow the use of higher grade imported ore and was considering adding a cobalt refinery to the complex (Mining Journal, 1997).

Russia.—Russian cobalt continued to contribute to Western supply in 1996. Russian cobalt is a byproduct of Russia's nickel industry. Nickel and cobalt production in Russia involves a complex flow of ores, flotation concentrates, precipitates, and mattes between various production sites. The main feed materials are domestic nickel-copper sulfide ores, nickel laterite ores from Russia and Kazakstan, and imported nickel- and cobalt-bearing secondary materials. Refined cobalt is produced at four locations: Norilsk Nickel Joint Stock Co. refineries at Norilsk in Siberia and Monchegorsk on the Kola Peninsula; the Ufaleynickel Joint Stock Co. refinery at Verkhniy Ufaley in the Ural Mountains; and the Yuzhuralnickel Joint Stock Co. refinery at Orsk, also in the Ural Mountains. In 1996, the Severonickel refinery in Monchegorsk stopped refining cobalt. Cobalt-bearing intermediate materials produced at Severonickel were sent to Ufaleynickel's refinery in the Urals to be toll refined (Sarykh, 1996).

South Africa.—Cobalt was produced as a byproduct of South Africa's platinum industry. Rustenburg Base Metal Refiners Pty. Ltd. produced cobalt sulfate, and Impala Platinum Ltd. produced cobalt metal powder. Western Platinum Ltd. produced nickel sulfate containing minor amounts of cobalt.

Colossal Resources Corp. of Vancouver, British Columbia,

began installation of a hydrometallurgical pilot plant to produce cobalt chemicals in Brakan, near Johannesburg. (*See Zambia section of this report.*)

Tanzania.—Sutton Resources Ltd. and BHP Minerals International Exploration Inc. renegotiated their exploration agreement regarding nickel-cobalt projects in northwestern Tanzania. Under the amended agreement, BHP relinquished its interest in the Kabanga deposit and in the southern portion of the Kagera reconnaissance area, but retained the right to earn an interest in the northern portion of Kagera. Sutton began discussions with prospective joint-venture partners for continued development of Kabanga and exploration of southern Kagera.

Uganda.—In July, Banff Resources, Ltd., of Vancouver, British Columbia, completed its acquisition of a 55% interest in Kasese Cobalt Co. Ltd. (KCCL). The remaining interest was held by Uganda's state-owned Kilembe Mines Ltd. KCCL has been involved in a project to build a refinery to recover cobalt from pyrite concentrates stockpiled during past production from the Kilembe copper mine. Banff planned to begin building the refinery at Kasese, southwestern Uganda, in early 1997 and begin cobalt production during the first quarter of 1998. The refinery was to use bioleaching followed by solvent extraction and electrowinning to produce 1,000 tons per year of cobalt cathode for about 10 years.

In addition to its interest in the Kasese project, Banff has an option agreement with Kilembe Mines Ltd. to earn a 65% interest in the Kilembe Mine by completing a feasibility study and arranging financing for production. During the year, Banff continued its exploration program at the mine and assessed the cobalt content of mine tailings in the Nyawamba River valley (Banff Resources Ltd., 1996).

Zaire.—During the year, Gécamines made several arrangements that would result in increased cobalt production from Zaire. In partnership with Union Minière, the Kasombo Mine west of Lubumbashi was reopened. Concentrates from Kasombo were toll refined at Gécamines Shituru refinery in Likasi. Approximately 3,000 tons of cobalt metal was expected to be produced from Kasombo over a 2-year period ending in late 1997 (Anyadike, 1996). Of this amount, more than 1,000 tons was expected to be produced in 1996 (Union Minière S.A., 1996).

Gécamines contracted with Union Minière's engineering subsidiary to improve cobalt recovery rates, improve some of the older purification methods, and upgrade the measuring and control equipment at the Shituru refinery. Once implemented, the improvements were expected to increase cobalt recovery by several hundred tons per year (Union Minière S.A., 1996).

In another project, Union Minière acquired approximately 28,000 tons of low-grade cobalt hydrates, containing an estimated 1,000 tons of recoverable cobalt. Union Minière shipped the hydrates to Union Mineral Concentrators Pty. in Roodepoort, near Johannesburg, South Africa, for initial processing. Once upgraded in South Africa, the hydrates would be refined at Union Minière's cobalt plant in Olen, Belgium (Union Minière S.A., 1996).

International Panorama Resource Corp. of Vancouver, British Columbia, purchased PTM Minerals Ltd. of the Cayman Islands and secured the rights to PTM's Kambove/Kakanda tailings project. The project is a joint venture with Gécamines to recover copper and cobalt from tailings located near Gécamines' Kambove and Kakanda concentrators. Gécamines estimated that the tailings were in excess of 61 million tons, with an average grade of 0.98% copper and 0.19% cobalt. This equates to nearly 600,000 tons of copper and 116,000 tons of cobalt. International Panorama was considering a leaching-solvent extraction-electrowinning process to treat the tailings. Production could begin within 2 years of completion of the feasibility study, which was scheduled for spring 1997 (International Panorama Resource Corp., 1996a, 1996b).

Consolidated Eurocan Ventures Ltd. of Vancouver, BC, Canada, acquired Lundin Holdings Ltd. and its joint-venture project with Gécamines to develop the Tenke Fungurume deposits northwest of Likasi in the Shaba Province's Copper Belt. Tenke Fungurume's "geological resources" reportedly total more than 222 million tons at 4.42% copper and 0.33% cobalt using a 1% copper equivalent cutoff grade. As part of the agreement with Gécamines, Tenke Fungurume Mining S.A.R.L. (TFM) was established to conduct the exploration, development, and mining of the Tenke Fungurume project. Ownership of TFM is 55% Lundin Holdings and 45% Gécamines. Consolidated Eurocan planned to complete a full feasibility study by the spring of 1997 and begin production within 4 years at an initial annual rate of 100,000 tons of copper and 8,000 tons of cobalt. The company proposed increasing annual production in three additional stages to a final 400,000 tons of copper by the year 2008 (Consolidated Eurocan Ventures Ltd., 1996).

In September, Gécamines received bids from six companies for a joint-venture project to recover copper and cobalt from flotation tailings accumulated during past production at Kolwezi. The economic viability of recovering copper and cobalt using a solvent extraction-electrowinning process would be investigated. An estimated 107 million tons of tailings averaging 1.34% copper and 0.70% cobalt was available for the project (South Atlantic Diamonds Corp., 1996). Two of the bidders were America Mineral Fields, Inc., of Hope, AR, and South Atlantic Resources Ltd. of Vancouver, British Columbia. America Mineral Fields and South Atlantic Resources each also qualified to bid on Gécamines' Ruashi-Etoile copper-cobalt project. The Ruashi-Etoile deposits, near Lubumbashi, were estimated to contain 62.5 million tons of ore at 3.45% copper and 0.46% cobalt (South Atlantic Diamonds Corp., 1996).

Zambia.—ZCCM produced 4,799 tons of cobalt metal between January and December 1996, an increase of 64% from the 2,934 tons produced in calendar year 1995 (Metal Bulletin, 1997). This return to more typical production levels was the result of mining higher grade ores at the Nchanga open pit.

In mid-1996, ZCCM adopted the recommendation of one of its advisors to privatize the company in two stages. In the first stage, majority interests in ZCCM assets would be sold to mining companies and other investors. ZCCM would retain

minority interests in the operations, which would be managed by the incoming investors. The assets were grouped into nine packages for the sale, which was scheduled to be completed by the second half of 1997. In the second stage, all or part of the Government's shares in ZCCM would be offered to the Zambian public and to financial institutions worldwide. The second stage of privatization was scheduled for the first half of 1998.

In September, Colossal Resources Corp. of Vancouver, British Columbia, and Qasim Mining Enterprises Ltd. (QME) of Lusaka, Zambia, began treating smelter slag from ZCCM's Nkana division at its newly constructed pyrometallurgical plant in Kabwe. At the plant, electric arc furnaces were used to upgrade the slag to "white alloy" containing 8% to 10% cobalt, 25% copper, and 60% to 70% iron. The slag was being processed under a 25-year agreement with ZCCM. The agreement gives QME access to approximately 8.6 million tons of slag containing approximately 56,000 tons of cobalt and 80,000 tons of copper. In October, Colossal announced that it had acquired a hydrometallurgical pilot plant that would be used to convert white alloy to cobalt chemicals. The pilot plant was being installed and upgraded on a leased site in Brakpan, near Johannesburg, South Africa. Colossal established a new subsidiary, named SACOLCo Pty. Ltd., to operate the plant. After the process was tested in South Africa, Colossal planned to install a similar chemical facility at its Kabwe plant (Colossal Resources Corp., 1996a, 1996b).

Caledonia Mining Corp. of Toronto, Canada, explored for copper and cobalt in the southern extension of the copper belt. At its Nama cobalt oxide project, Caledonia increased the "inferred and indicated mineral resource" to 953 million tons at a 0.029% cobalt equivalent grade. Caledonia initiated a prefeasibility study on mining the Nama deposit using open pit methods, then treating the ore with an acid leach, solvent extraction, electrowinning process. Caledonia also announced a copper-cobalt oxide discovery in its Kadola licence area. The initial "inferred mineral resource" at Kadola West was calculated as 74 million tons at a grade of 0.95% copper equivalent (Caledonia Mining Corp., 1997).

Outlook

Cobalt supply is expected to continue to increase in the next few years. U.S. Government sales of cobalt from the NDS are expected to continue at the rate set each year under the annual materials plan until the amount authorized for disposal has been sold. Current producers are expected to expand their output, and many new producers hope to come on-stream in the next 5 to 10 years. The increased production will come from both newly mined ore and from the refining of stockpiled intermediate materials such as tailings and slags.

World cobalt demand is also expected to increase. Cobalt consumption by the superalloy industry will rise with the growth in production of commercial jet aircraft and land-based gas turbines for power generation. Significant growth is also expected for cobalt used to make rechargeable batteries.

However, the growth in supply is expected to exceed the

growth in demand. If that occurs, an oversupply situation would develop and prices would decrease. Lower prices would limit some of the potential future supply by discouraging production from higher cost operations and from projects where cobalt production is discretionary (dependent on cobalt price).

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TABLE 1
SALIENT COBALT STATISTICS 1/

(Metric tons cobalt content unless otherwise specified)

	1992	1993	1994	1995	1996
United States:					
Consumption:					
Reported	6,400 r/	6,430 r/	7,020 r/	7,030 r/	7,010
Apparent	6,590	7,310	8,470	8,640 r/	8,810
Imports for consumption	5,760	5,950	6,780	6,440	6,710
Exports	1,420	795	1,360	1,300	1,660
Stocks, December 31:					
Industry 2/	831 r/	810 r/	910 r/	818 r/	762
U.S. Government 3/	24,100	23,800	22,300	20,700	18,700
Price: Metal, per pound					
Average U.S. spot cathode 4/	\$22.93	\$13.79	\$24.66	\$29.21	\$25.50
Yearend producer 5/	\$18.00	\$18.00	\$25.00	\$27.50	\$27.50
World production:					
Mine	28,000 r/	21,900 r/	17,800 r/	23,800 r/	27,000 e/
Refinery	21,500 r/	16,600 r/	19,000 r/	22,100 r/	25,400 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to three significant digits, except prices.

2/ Stocks held by cobalt processors and consumers.

3/ Defense Logistics Agency. Includes material committed for sale pending shipment.

4/ Price for 1992 is weighted average of weekly prices reported by Metals Week; prices for 1993-96 are annual average prices reported by Platt's Metals Week.

5/ Price established by La Générale des Carrières et des Mines and Zambia Consolidated Copper Mines Ltd.

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

(Metric tons cobalt content)

	1995	1996
Sales:		
Fiscal year 2/	1,890	1,810
Calendar year	2,740	1,020
Shipments:		
Fiscal year 2/	1,360	2,200
Calendar year	1,550	2,050

1/ Data are rounded to three significant digits.

2/ Twelve-month period ending Sept. 30 of year stated.

Source: Defense Logistics Agency.

TABLE 3
U.S. REPORTED CONSUMPTION AND STOCKS OF COBALT 1/ 2/

(Metric tons cobalt content)

	1995	1996
Consumption by end use:		
Steel:		
Stainless and heat resisting	38	38
Tool	146	95
Superalloys	2,940	3,230
Alloys (excludes steels and superalloys):		
Magnetic alloys	757	728
Welding materials (structural and hard-facing) 3/	287	284
Other alloys 4/	75 r/	65
Cemented carbides 5/	748	722
Chemical and ceramic uses:		
Catalysts	732	652
Driers in paints or related usage	770	733
Ground coat frit	196 r/	159
Pigments	172	191
Miscellaneous and unspecified 6/	164 r/	119
Total	<u>7,030 r/</u>	<u>7,010</u>
Consumption by form:		
Chemical compounds (organic and inorganic) 7/	1,830 r/	1,710
Metal	3,660	3,640
Purchased scrap	1,540	1,670
Total	<u>7,030 r/</u>	<u>7,010</u>
Stocks, December 31: 8/		
Chemical compounds (organic and inorganic) 7/	305 r/	275
Metal	384 r/	305
Purchased scrap	129 r/	182
Total	818 r/	762

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes estimates.

3/ Includes wear-resistant alloys.

4/ Includes nonferrous alloys.

5/ Includes diamond bit matrices, cemented and sintered carbides, and cast carbide dies or parts.

6/ Includes feed or nutritive additive, full-alloy steel, glass decolorizer, mill products made from metal powder.

7/ Includes oxides.

8/ Stocks held by cobalt processors and consumers.

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

(Metric tons, unless otherwise specified)

	1995	1996
Metal: 2/		
Gross weight	5,530	5,760
Cobalt content 3/	5,530	5,760
Value	\$325,000	\$327,000
	thousands	
Oxides and hydroxides:		
Gross weight	808	824
Cobalt content 3/	582	593
Value	\$34,300	\$36,200
	thousands	
Other forms:		
Acetates:		
Gross weight	129	124
Cobalt content 3/	31	30
Value	\$1,650	\$1,760
	thousands	
Carbonates:		
Gross weight	80	61
Cobalt content 3/	37	28
Value	\$2,310	\$785
	thousands	
Chlorides:		
Gross weight	24	10
Cobalt content 3/	6	3
Value	\$361	\$102
	thousands	
Sulfates:		
Gross weight	940	1,070
Cobalt content 3/	254	288
Value	\$11,500	\$12,100
	thousands	
Total:		
Gross weight	7,510	7,850
Cobalt content 3/	6,440	6,710
Value	\$376,000	\$378,000
	thousands	

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Unwrought cobalt, excluding alloys and waste and scrap.

3/ Estimated from gross weight.

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

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

Country of origin	Metals 2/			Oxides and hydroxides			Other forms 3/			Total		
	Gross weight (metric tons)	Cobalt content 4/ (metric tons)	Value (thousands)	Gross weight (metric tons)	Cobalt content 4/ (metric tons)	Value (thousands)	Gross weight (metric tons)	Cobalt content 4/ (metric tons)	Value (thousands)	Gross weight (metric tons)	Cobalt content 4/ (metric tons)	Value (thousands)
1995:												
Belgium	189	189	\$13,500	217	156	\$10,600	35	8	\$552	441	354	\$24,600
Brazil	30	30	1,660	--	--	--	--	--	--	30	30	1,660
Canada	993	993	60,700	66	47	3,070	18	8	486	1,080	1,050	64,300
China	18	18	1,090	12	8	149	--	--	--	30	27	1,240
Finland	658	658	41,300	266	192	10,900	898	241	11,100	1,820	1,090	63,300
France	34	34	2,970	19	14	1,600	(5/)	(5/)	3	54	48	4,580
Germany	147	147	9,430	2	1	83	--	--	--	149	148	9,520
Japan	14	14	841	10	7	280	(5/)	(5/)	8	24	21	1,130
Norway	1,510	1,510	93,700	--	--	--	--	--	--	1,510	1,510	93,700
Russia	649	649	30,900	90	65	2,450	177	59	3,260	915	772	36,600
South Africa	33	33	1,980	14	10	606	1	(5/)	14	48	43	2,600
United Kingdom	22	22	1,240	79	57	3,920	40	10	340	141	88	5,500
Zaire	656	656	34,800	--	--	--	--	--	--	656	656	34,800
Zambia	569	569	31,300	--	--	--	--	--	--	569	569	31,300
Other	3	3	146	33	24	623	3	1	16	39	27	786
Total	5,530	5,530	325,000	808	582	34,300	1,170	327	15,800	7,510	6,440	376,000
1996:												
Belgium	204	204	16,000	213	153	10,100	3	1	42	421	359	26,100
Brazil	47	47	2,200	--	--	--	--	--	--	47	47	2,200
Canada	927	927	54,300	60	43	2,580	28	13	585	1,010	983	57,500
Finland	561	561	34,100	408	294	16,700	1,160	311	13,500	2,130	1,170	64,300
France	29	29	3,040	20	14	1,760	--	--	--	49	43	4,800
Germany	100	100	7,640	2	1	152	--	--	--	102	102	7,790
Hong Kong	--	--	--	--	--	--	7	2	60	7	2	60
Japan	8	8	377	22	16	950	(5/)	(5/)	7	30	24	1,330
Norway	1,710	1,710	99,900	--	--	--	(5/)	(5/)	3	1,710	1,710	99,900
Russia	630	630	28,100	5	3	94	40	17	259	676	651	28,500
South Africa	10	10	601	4	3	182	--	--	--	14	13	783
United Kingdom	17	17	965	43	31	1,840	20	5	313	81	53	3,120
Zaire	396	396	21,200	--	--	--	--	--	--	396	396	21,200
Zambia	1,130	1,130	58,800	--	--	--	--	--	--	1,130	1,130	58,800
Other	(5/)	(5/)	45	47	34	1,730	4	1	23	51	35	1,800
Total	5,760	5,760	327,000	824	593	36,200	1,260	349	14,800	7,850	6,710	378,000

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Unwrought cobalt, excluding alloys; includes cobalt cathode and cobalt metal powder.

3/ Includes cobalt sulfates, cobalt chlorides, cobalt carbonates, and cobalt acetates.

4/ Estimated from gross weights.

5/ Less than 1/2 unit.

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

TABLE 6
U.S. EXPORTS OF COBALT IN 1996, BY COUNTRY 1/ 2/

Country of destination	Metal 3/		Oxides and hydroxides		Acetates		Chlorides		Total	
	Gross weight (metric tons)	Value 4/ (thou-sands)	Gross weight (metric tons)	Value 4/ (thou-sands)	Gross weight (metric tons)	Value 4/ (thou-sands)	Gross weight (metric tons)	Value 4/ (thou-sands)	Cobalt content 5/ (metric tons)	Value 4/ (thou-sands)
Australia	37	\$370	6	\$231	5	\$195	--	--	42	\$796
Belgium	189	14,700	9	170	--	--	--	--	196	14,900
Brazil	17	557	14	618	12	220	1	\$16	30	1,410
Canada	145	5,360	44	855	19	173	1	13	182	6,400
Chile	(6/)	7	10	216	--	--	--	--	8	223
Colombia	--	--	3	103	3	82	--	--	3	185
Dominican Republic	--	--	--	--	1	14	3	43	1	58
France	12	700	9	298	--	--	--	--	19	999
Germany	47	2,370	3	128	--	--	--	--	50	2,500
Grenada	--	--	--	--	--	--	(6/)	5	(6/)	5
Guatemala	--	--	1	9	(6/)	3	4	44	2	57
Hong Kong	57	2,920	22	608	--	--	--	--	73	3,520
Indonesia	(6/)	4	5	331	--	--	--	--	4	335
Jamaica	--	--	(6/)	10	(6/)	4	1	10	(6/)	24
Japan	323	16,700	63	1,540	24	575	--	--	374	18,800
Korea, Republic of	18	837	14	352	4	95	2	28	30	1,310
Mexico	24	1,210	61	2,530	331	2,110	--	--	147	5,850
Netherlands	239	11,900	44	1,270	6	85	--	--	272	13,300
Taiwan	1	90	8	123	11	196	--	--	10	409
United Kingdom	134	5,180	4	56	10	13	--	--	138	5,250
Venezuela	--	--	5	221	3	41	--	--	4	262
Other	62	2,590	20	514	5	76	(6/)	3	77	3,180
Total	1,310	65,500	346	10,200	433	3,880	13	162	1,660	79,800

1/ Data are rounded to 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 (f.a.s.) value.

5/ Estimated from gross weight.

6/ Less than 1/2 unit.

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

TABLE 7
WORLD ANNUAL COBALT REFINERY CAPACITY
DECEMBER 31, 1996 1/

(Metric tons, cobalt content)

Country	
Belgium 2/	1,200
Brazil	300
Canada 2/	4,400
China e/	500
Finland e/ 2/	4,700
France 3/	600
Japan 2/	480
Morocco	300
Norway	3,700
Russia e/	8,000
South Africa e/ 4/	750
United States 5/	900
Zaire	18,000
Zambia	5,000
Total	48,800

e/ Estimated.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes oxide and salts.

3/ Cobalt chloride.

4/ Includes sulfate.

5/ Standby capacity.

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

(Metric tons, cobalt content)

Country 3/	1992	1993	1994	1995	1996 e/
Albania e/ 4/	20	10	10	--	--
Australia e/ 5/	1,600	1,800	2,200	2,200 r/	2,300
Botswana 6/	208	205	225	270 r/	410 7/
Brazil e/	400	400	400	400	400
Canada 8/	5,102	5,108	4,265	5,339 r/	5,803 p/
China e/	260	240	270	980	800
Cuba e/ 9/	1,150	1,060	972	1,561 7/	1,968 7/
Kazakstan e/ 10/	1,000	600	300	300	300
Morocco 11/	461	397	440	548 r/	565 7/
New Caledonia e/ 12/	800	800	800	800	800
Russia e/	4,000	3,500	3,000	3,500	3,300
South Africa e/	350	350	370 r/	290 r/	350
Zaire 11/	5,700	2,459	826 e/	1,647	2,000
Zambia 11/ 13/	6,910	4,840	3,600 r/	5,908 r/	7,900
Zimbabwe e/	80	90	100	100	90
Total	28,000 r/	21,900 r/	17,800 r/	23,800 r/	27,000

e/ Estimated. p/ Preliminary. r/ Revised.

1/ World totals and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through June 18, 1997. 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, Germany, Indonesia, 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/ Calculated from reported and estimated weight of nickeliferous ore.

5/ Figures represent quantities of cobalt contained in intermediate metallurgical products (cobalt sulfide, nickel-cobalt sulfide, nickel concentrate, and nickel matte) produced from Australian and imported ores. Cobalt content of lateritic nickel ore, nickel concentrate, and zinc concentrate originating in Australia was estimated as follows, in metric tons: 1992--1,270; 1993--1,320; 1994--1,270; 1995--800 (revised); and 1996--900 (reported).

6/ Reported cobalt content of pelletized nickel-copper matte.

7/ Reported figure.

8/ Figures represent the assay content of cobalt in concentrates produced. The cobalt content of all products derived from ores of Canadian origins, including cobalt oxide shipped to the United Kingdom for further processing and nickel-copper-cobalt matte shipped to Norway for refining, was reported as follows, in metric tons: 1992--2,223; 1993--2,150; 1994--1,846; 1995--2,016 (revised); and 1996--2,190.

9/ Determined from reported nickel-cobalt content of sulfide production. Data not comparable with those prior to 1990.

10/ Figures represent 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 as follows, in metric tons: 1992-93--not available; 1994--1,394; 1995--1,400; and 1996--1,400.

11/ Cobalt content of concentrates.

12/ Series represents estimated recoverable content of ores and intermediate metallurgical products exported from New Caledonia to France. Estimated cobalt content of total ores mined is 6,000 metric tons per year.

13/ Fiscal year beginning Apr. 1 of that stated. Cobalt content of ore milled was as follows, in metric tons: 1992--11,370; 1993--9,480; 1994--6,747; 1995--8,849 (revised); and 1996--12,000 (estimated).

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

(Metric tons, cobalt content)

Country 3/	1992	1993	1994	1995	1996
Albania: Oxide e/	3	1	--	--	--
Brazil: Metal e/	240	240	240	180	180
Canada: Metal (including metal powder and oxide)	2,210	2,695	2,971	3,269 r/	3,552 p/
China: Metal e/	220	190	200	240 r/	200
Finland (metal powder and salts)	2,100	2,200	3,000	3,610	4,160
France: Chloride	120	144	146	161	174
Japan: Metal	105	191	161	227	222
Norway: Metal	2,293	2,414	2,823	2,804	3,098
Russia: Unspecified	4,100 r/	3,700 r/	4,340 r/	4,450 r/	4,200
South Africa:					
Metal (powder) e/	65	71 r/	44 r/	32 4/	42
Sulfate e/	169	172 r/	214 r/	158 4/	200
Total	234	243 r/	258 r/	190	242
Zaire: Metal 5/	5,049	831	2,329	3,441	4,200 e/
Zambia: Metal 6/	4,797	3,705	2,482	3,577	5,126
Grand total	21,500 r/	16,600 r/	19,000 r/	22,100 r/	25,400 r/
Of which:					
Metal	15,000	10,300	11,300 r/	13,800 r/	16,600
Salts 7/	292	317 r/	360 r/	319	374
Unspecified	6,200 r/	5,900 r/	7,340 r/	8,060 r/	8,360

e/ Estimated. p/ Preliminary. r/ Revised.

1/ World totals and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data through June 18, 1997. 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, Belgium, Germany, and Slovakia may recover cobalt from imported materials, but production is not reported; available information is inadequate to make reliable estimates of production.

4/ Reported figure.

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

6/ Fiscal years beginning Apr. 1 of that stated.

7/ Includes oxide.