

Cobalt

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SUMMARY

In 1994, the cobalt content of metal concentrates produced in Canada was 1709 t, a decrease of 21% from 1993, while Canada's production of refined cobalt (including production from ore feed imported from Cuba) increased 16% to reach 2710 t. The value of 1994 mine production of cobalt, about \$124 million, was 51% greater than in 1993.

The drop in mine production is mostly due to extended shut-downs at Inco and Falconbridge, which were necessary to help lower nickel stocks accumulating on the London Metal Exchange (LME). The higher earnings are due to a major price hike for cobalt at the end of 1993 which lasted throughout 1994, where the free market price for cobalt spot cathode hovered around US\$24.67/lb. The price hike was a result of increased demand from economies coming out of a long recession, and a shortage of supplies on the market. The gap between supply and demand was compounded by low consumer inventories following de-stocking in 1993. Further cobalt price increases at the end of the year, which closed in the range of US\$29.50-\$30.50/lb, seemed to indicate a continued tightness in supply in early 1995 as a result of low production levels in Zaire, Zambia and Russia.

World production estimates from the Cobalt Development Institute's six-month production figure and other sources put the 1994 production of refined cobalt at 18 940 t, an increase of about 2.4% from 1993. The output improvement is mostly attributed to production increases in Zaire, in Canada at Sherritt Inc. (Sherritt), in Norway, in Belgium, and in Finland. These increases exceeded a decrease in output at Inco Limited (Inco) and persisting production disruptions in Zambia and Russia.

The outlook for 1995 calls for production in Zaire, Zambia and at Inco to improve significantly relative

to 1994, while production in Russia should remain stable at the 1994 level. Further increases in demand are expected as world economies improve, particularly the Japanese economy, which is now coming out of a recession. A small supply shortage, especially for higher-grade material, is expected in the first half of 1995 with corresponding general pressure on prices and a widening of the premium for good-quality Western-origin cobalt. Sales from the U.S. stockpile, a greater supply of scrap cobalt, and the commissioning of new production capacity in 1995 in Australia and in Canada, as well as a general improvement in production at many facilities, will help balance the market in the second half of the year.

USES

One of the major uses for cobalt is in superalloys where it improves the strength, wear and corrosion-resistant characteristics of alloys at elevated temperatures. The major uses of cobalt-based superalloys are in turbine blades for aircraft jet engines and in gas turbines for pipeline compressors. Cobalt-based superalloys normally contain 45% or more cobalt, while nickel- and iron-based superalloys contain 8-20% cobalt.

The demand for cobalt in the production of magnets has been declining in recent years. The substitution of neodymium-iron-boron magnets for cobalt-rare earth magnets has been a major factor. However, the use of cobalt-rare earth permanent magnets will continue where the specific advantages of reliability and good performance are required. In addition, Alnico magnets are staging a comeback, especially in automobile anti-lock braking systems.

Cobalt-based alloys are also used in specialized applications such as in machining very hard materials or where high abrasion-resistant qualities are required. In such applications, the most important group of cobalt-based alloys is the stellite group, which contains cobalt, tungsten, chromium and molybdenum as principal constituents. The hard-facing or coating of tools with cobalt alloys provides greater resistance to wear, heat, impact and corrosion.

Cobalt metal powder has an important application as a binder in the production of cemented tungsten

carbides for heavy-duty and high-speed cutting tools. In chemical applications, cobalt oxide is an important additive in paint, glass and ceramics. Cobalt is also used to promote the adherence of enamel to steel for applications such as appliances, and steel to rubber for the construction of steel-belted tires. A cobalt-molybdenum-alumina compound is used as a catalyst in hydrogenation and for petroleum desulphurization.

CANADIAN DEVELOPMENTS

Canada's mine production of cobalt in 1993 was 2150 t, while the preliminary estimate for 1994 is 1709 t. The output of refined cobalt in 1993 totalled 2337 t, while it is estimated at 2710 t in 1994 for a possible increase of 16%.

In Canada, Inco and Falconbridge produce cobalt as a by-product of their nickel-copper operations and from purchased concentrates. Inco refines its concentrates in Canada to produce cobalt metal and oxide, while Falconbridge sends nickel-cobalt matte to its refinery in Norway. Sherritt produces refined cobalt at its Alberta refinery from concentrates purchased domestically and abroad.

Inco Limited

Inco's 1994 mine production of cobalt was 1089 t, down 21% from last year, while its production of refined cobalt was 844 t, down 25% from 1993. The company's production in 1994 was affected by planned shut-downs and accidents, the worst one being the fall of a new skip down the main mine shaft at the Manitoba Division T-1 mine while it was being installed. This rendered the shaft out of commission until mid-September and caused a production loss of about 27 t of cobalt valued at over \$1.3 million. Because the incident occurred during the summer shut-down, no injuries were suffered.

Inco's cobalt production comes from several underground mines located in the Sudbury area of Ontario and in Manitoba's Thompson Nickel Belt. In 1994, Inco operated the Copper Cliff North and South mines, the Crean Hill, the Creighton No. 9, the Froid, the Stobie and Little Stobie, the Lower Coleman, the Garson, and the McCreedy West mines, all located in the Sudbury area, while it operated the Thompson open-pit and Thompson (T-1) mines in the Manitoba Division.

The nickel-cobalt ores from these operations are processed at the Clarabelle and Copper Cliff mills near Sudbury and at the mill and concentrator complex in Thompson. The Sudbury concentrate is then sent to the nearby Copper Cliff smelter for further processing to produce a variety of nickel and copper products, including nickel matte. Some of this matte is sent by rail to Inco's refinery complex at Port

Colborne, Ontario, where cobalt metal is produced as a by-product. An electrolytic cobalt refinery further upgrades the material to 99.9% pure cobalt rounds.

In Thompson, a local plant smelts and refines the concentrate to produce electrolytic nickel and by-product cobalt oxide. The cobalt oxide is sent to Inco's Clydach refinery in Wales for re-processing.

The Port Colborne, Ontario, nickel-cobalt refinery closed for a six-week period in January-February and for four weeks in July, while the Clydach refinery in Wales closed for a five-week period between July 25 and September 1, 1994.

The Lower Coleman mine in Ontario, after coming into production in early 1993, started working at full capacity in 1994, while the rich Garson mine, also located near Sudbury, started producing in the late spring of 1994. Finally, the Shebandowan mine, which closed in 1992, will be re-opened in 1995. These opening mines will replace existing operations at the Little Stobie, Crean Hill, McCreedy West, and Froid mines, which will soon be exhausted. In Manitoba, development of the Thompson 1-D mine moved ahead toward initial production in 1995, while full production is scheduled for 1998. Reserves are estimated at 20.9 Mt grading 2.51% nickel.

In November 1994, Inco announced it was planning a global production expansion of 20% from its 1994 production level by the year 2000. Half of the production increase would come from existing facilities and half from new projects, probably in Indonesia or at the Goro property in New Caledonia. To realize this expansion project, Inco is investing \$570 million for mine development of its Canadian operations. Of this, \$116 million will be spent to complete the first production phase at the McCreedy East mine located 50 km west of Sudbury. This will enable the mining of 15 Mt of ore grading 4.32% copper and 1.44% nickel. Production start-up is planned for late 1996 and full production, at a rate of 10 000 t/y of nickel, is planned by 1999. Also in the Sudbury Division, Inco is planning to spend \$72 million on exploring the Victor deposit located on the northeast rim of the Sudbury igneous complex. Mineral reserves outlined so far, mostly between 2100 and 2400 m deep, are split in two zones: the upper zone with 6 Mt grading 0.54% copper and 2.26% nickel, and the lower zone with 7 Mt grading 5.1% copper and 1.9% nickel. The exploration program to be realized over the next three years includes sinking a 1770-m-deep shaft and 1675 m of exploration drift from which 38 100 m of diamond drilling will be done.

Two other projects will also be completed. At the Creighton mine, \$18.3 million will be spent to develop a new ore-handling system to recover 2.6 Mt of ore grading 2.45% copper and 2.9% nickel located beneath the current floor of the mine. And finally, at the Manitoba Division, exploration will continue on the recently discovered Pipe Deep deposit located

32 km from Inco's processing facilities and 1.6 km from the mine shaft of the Pipe 2 mine. Reserves outlined to date are 4 Mt grading 2.3% nickel located between 800 and 1500 m deep. Engineering work aimed at assessing the orebody's economic feasibility will start once the 1994 drilling program is completed.

Falconbridge Limited

In 1994, Falconbridge's Canadian mineral production of cobalt was 620 t, down 19% from 1993.

During the year, Falconbridge operated six mines in the Sudbury, Ontario area, namely the Lockerby, Onaping, Craig, Fraser, Strathcona, and Thayer Lindsley mines, although this last one is still classified under exploration. The Lockerby mine, however, was put on care and maintenance starting June 1, 1994, for an indefinite period because of its high operating costs and market conditions.

The nickel-copper-cobalt ore extracted at these mines, plus the feed the company obtains from outside sources (up to 60% for the production of cobalt), is concentrated at the Strathcona mill near Sudbury, Ontario, and further processed at the Falconbridge smelter to produce cobalt-bearing nickel matte. This matte is sent by ship to the company's refinery at Kristiansand, Norway, to produce cobalt metal and nickel products.

Through a \$1.4 billion share offering in June 1994, Falconbridge went public. The company is now held 46% by Noranda Inc., 28% by Trelleborg AB of Sweden, and the rest is held widely. Proceeds from the sale will be used to pay down Falconbridge's debt and to finance expansion and exploration programs. Included in these, the company is expanding operations at the Craig mine at Sudbury where a \$250 million investment has been completed, at the Nikkelverk refinery in Norway, and at the Strathcona mill where a plant upgrade has enabled the production of a higher-grade concentrate.

On the exploration front, Falconbridge is pursuing work on the Raglan property located on the Ungava Peninsula in northern Quebec. Following a positive feasibility study completed in 1993, the company expects the project to be put in production within five years at a capital cost of \$486 million. Negotiations with the provincial government for both infrastructure and environmental permitting are already under way. Reserve estimates of 18.1 Mt grading 3.13% nickel, 0.88% copper, 0.05% cobalt and precious metal credits would permit the production of 20 000 t of nickel annually (or about 330 t/y of cobalt).

Falconbridge also spent \$8.3 million on exploration work in the Sudbury area and plans to spend a further \$10.5 million in 1995. On the Nickel Rim property hosting the down-dip extension of the Victor deposit, the company has outlined reserves of 0.5 Mt

grading 25.53% copper, 4.13% nickel, 9.8 g/t platinum and 8.5 g/t palladium at a depth of around 2600 m. At the Craig mine, exploration work on the down-dip extension of the deposit was a success. A drill hole intersected a 99.7-m section grading 1.23% nickel, 0.47% copper and 0.05% cobalt at a depth of 2040 m.

Falconbridge closed its Sudbury division for one week in January for the holiday period and for two weeks in July for the summer vacation, but it did not close its operations for the Christmas period.

Sherritt Inc.

In 1994, the preliminary estimate of Sherritt's production of refined cobalt is 1867 t, 53% more than in 1993. The large production increase results from the start of the redesigned processing system, modernized at a cost of \$60 million, which includes a new cobalt refinery employing Sherritt's proprietary ammonia leach-hydrogen reduction process. The completion of the construction of the cobalt refinery (Phase II of the upgrading plan) in early 1993 increased the cobalt production capacity of the refinery to 1361 t (3 million lb). Phase III of the upgrading plan to gradually increase the cobalt production capacity of the refinery to 2000 t (4.4 million lb) was completed at the end of 1993, and the plant reached full operating capacity by the end of March 1994. The production level reached each year will depend on the nature of the feed.

Sherritt produces cobalt from feedstock purchased mostly on a contract basis, both domestic and foreign. It does not operate any Canadian base-metal mines. In 1994 Sherritt was obtaining 70% of its feed from Union del Niquel in Cuba, with the balance coming from North America, Australia and South Africa.

Sherritt's nickel-cobalt refinery located at Fort Saskatchewan, northeast of Edmonton, Alberta, produces cobalt metal in the form of briquettes pressed from the powder form and is the Western World's only producer of Standard (S) grade cobalt powder. Since 1992, Sherritt has also produced ultrafine cobalt powder used as a bonding agent in the manufacture of tungsten carbide cutting tools and parts, as well as in the manufacture of diamond saw segments. Since 1990, as a result of importing feed from Cuba, Sherritt lost the U.S. market because of the U.S. embargo that bans imports of materials originating in Cuba. This stance is not expected to change in the near future.

On June 24, 1994, Sherritt and La Compania General de Niquel S.A. announced the establishment of a 50-50 joint venture to mine, refine and market cobalt and nickel. The joint venture includes three corporations: Moa Nickel S.A., which includes the mining operations and processing plant at Moa Bay, Cuba; the Cobalt Refinery Company Inc., which includes the metals refining facilities at Fort Saskatchewan, Alberta; and The International Cobalt Company Inc.,

which will be responsible for sales and marketing. Under the terms of the deal, approximately \$150 million will be spent over the next three years to upgrade and expand the Moa facilities by about 20%. This will increase its production capacity to 24 000 t/y of matte, which will include 2200 t of cobalt. In addition, the Cuban government has granted mining concessions to the new venture sufficient to supply the Moa Bay plant for around 25 years, with further concessions offering the possibility of extending the plant's production life to 50 years.

Other Developments

Ego Resources (Ego), a junior mining company, is set to become the world's largest primary producer of cobalt when it starts operating its new \$5 million milling facility located in Cobalt, Ontario, at the end of February 1995. Through its wholly owned private company Cobatec, which has developed a low-cost process to recover cobalt from high-grade feedstock, Ego expects to produce 300 t/y of cobalt in salts, a value-added product sector. The company principally will produce the following chemicals: cobalt carbonate, containing 49.5% metal; cobalt oxide, containing 70.5% metal; and cobalt sulphate, containing 22.4% metal. These products will be marketed by Amalgamet Inc. to end users within a 960-km radius of the plant. Contracts will be made on a "negotiated basis" although Amalgamet will buy the material at spot prices from Cobatec if it remains unsold for 30 days.

The Cobatec process will enable the company to extract cobalt from ores with a high arsenic content, which before had posed a metallurgical barrier. By pressure leaching the ore in the presence of oxygen, arsenides are oxidized to arsenates and react with iron to produce stable ferric arsenate. Sulphides, oxidized to sulphates, react with limestone to form gypsum which, together with the ferric arsenate and other insoluble materials, is separated from the cobalt-rich liquid phase and sent to a landfill or holding pond. The pregnant liquor is then stripped of its metal values in a solvent extraction unit and the loaded organic phase is selectively stripped of first nickel and then cobalt. These strip solutions are then electrolyzed to recover cobalt and nickel cathode.

Ego has sufficient feedstock to ensure about four years of production. It has acquired the Pansilver mine in Cobalt, Ontario, and is preparing it for production. The Teledyne mine, also purchased recently, will be dewatered starting in February 1995. The company plans to operate these mines at a high cut-off grade of 1% cobalt during winter months.

Diamond Fields Resources Inc. announced, in November 1994, the discovery of a significant nickel-copper-cobalt find on its Voisy Bay property located 35 km southwest of Nain, on the east coast of

Labrador. The deposit, outlined so far over a strike length of 800 m, corresponds to a massive and disseminated sulphide zone including pyrrhotite, pentlandite and chalcopyrite mineralization hosted in an ultramafic norite dyke. Of the five holes drilled by the end of the year, the best intersection was a 41.2-m section grading 2.96% nickel, 1.89% copper and 0.161% cobalt. Preliminary metallurgical tests done by Lakefield Research on composite material from the drill holes indicate that good recoveries of copper and nickel can be obtained using standard flotation methods. Test work on cobalt recovery is under way. A development plan intended to take the Voisy Bay discovery to full feasibility is being prepared.

Fortune Minerals discovered numerous polymetallic occurrences on its NICO claim group northwest of Yellowknife, Northwest Territories. The most significant occurrences are three parallel zones less than 150 m apart. The best known, the No. 1 zone, was traced over 300 m along strike at surface and yielded 0.53% cobalt, 0.62% bismuth and 1.32 g/t gold in chip samples over 3 m, and 0.19% cobalt and 0.32% bismuth over 17 m. A scientist at the Geological Survey of Canada commented that the geological setting of the claim area was similar in nature to the Olympic Dam deposit in Australia.

Additional new base- and precious-metal occurrences with associated cobalt values were reported during the year and were the site of preliminary evaluation. Noranda Inc. and Rhonda Mining Corp. discovered sediment-hosted copper mineralization in the Epworth area of the Northwest Territories about 120 km south of Coppermine. The copper is associated with silver, cobalt, lead and zinc in quartzites and dolomites. Diamond drilling is planned for 1995.

Flag Resources Ltd. of Calgary, Alberta, announced it would start a diamond drill program in early 1995 on a number of base-metal showings with associated precious metals and cobalt. These showings, located on Aboriginal lands near Sudbury, Ontario, had been frozen by land claims until recently.

Canada's most important cobalt export in 1994 was in the form of matte and "other intermediate products." This trade, directed mostly to Norway, the United States, Japan and the Netherlands, generated revenues of \$211 million, up 59% from 1993. By extension, the most important cobalt import on the basis of value was "unwrought cobalt." The greater portion of these products was imported from Zaire for transformation, and made up 47% of total imports. As a general comment on trade, Canada's imports and exports of cobalt products increased significantly in 1994 both in quantity and value compared to 1993. (Refer to Tables 1 and 2 for details.)

Canada's cobalt trade is significantly greater than indicated in the statistics because much of the cobalt imported or exported in ore, concentrates and matte

is counted as nickel and copper imports/exports (therefore, it is not included in the cobalt statistics). For example, in 1994, Canada imported 23 931 t of Cuban nickel-cobalt matte valued at \$112 million, while it exported 42 598 t of nickel-copper-cobalt matte worth \$324 million to Norway.

WORLD DEVELOPMENTS

Estimating from the Cobalt Development Institute's six-month production figure, and from other sources, world production of refined cobalt in 1994 will be about 18 940 t, or 2.4% more than in 1993. This figure includes 16 400 t supplied by member countries of the Institute (15 060 t from primary producers and 1340 t from secondary producers), and 2540 t estimated to be the combined production of Russia, China, South Africa and Brazil. The production increase seen in 1994 halts the downward trend experienced in the past six years and may signal the stabilization of cobalt supplies to the market to help balance it. (Refer to Table 3.)

Zaire

The economical and political situation in Zaire, until recently the world's largest cobalt-producing country, was still unstable in 1994. However, the election of a new government headed by Prime Minister Wadondo Kengo, although it has not yet been recognized by Western countries, may signal improvements to the situation. Because of political wrangling, social unrest, and a lack of investment damaging the metal industry's infrastructure, Zaire's cobalt output is expected to be about 3500 t in 1994 compared to 2200 t in 1993 and 6625 t in 1992.

The 1994 output is said to have been reached mostly by processing hydrates grading 6-10% cobalt at Zaire's two hydrometallurgical plants at Luilu and Shituru, and from cobaltiferous backfill material at Groupe Ovest. This was achieved after resolving the sulphuric acid shortage which hampered production in the first quarter of the year. The missing supplies were acquired through a US\$10 million per year transaction that has been financing the export of cobalt in all forms from Zaire to China. This deal, organized with the commodity finance bank Mees Pierson in early 1994, allows Générale des Carrières et des Mines (Gécamines), the state-owned mining company, to secure cash for the payment of vital spare parts for the maintenance of its rolling stock, and the purchase of supplies for its production facilities. The exported cobalt is sold to consumers in China, while the proceeds of the sales are transferred to South African companies for the purchase of spare parts.

To help resolve the situation in the longer term, Zaire is said to require between US\$500 million and \$1 billion to renovate and upgrade its mining con-

cerns. However, experts agree that even after banks put the necessary financial packages back in place, Gécamines will need three to five years before it can produce at "normal" levels. In the short term, Gécamines expects to increase its production in 1995 to about 5000 t of cobalt.

Zambia

Production from neighbouring Zambia was also reduced in 1994 and is estimated from nine-month figures to be around 2700 t. The lower production is attributed to stress problems at the Mufulira mine leading to reduced levels of production, smelter problems at the Nkhana division, and continuing low concentrator recovery at the Nchanga operations. These problems having been addressed, the state-run Zambia Consolidated Copper Mines (ZCCM) expects production in 1995 to return to near 5000 t as high-grade ore from the Nchanga open-pit becomes available. The Konkola Deep deposit, which contains reserves of 340 Mt grading 3.8% copper and 0.07% cobalt, is scheduled to replace the Nchanga operation when reserves at that location are exhausted at the turn of the century.

Zambia's production has been decreasing in the past few years because of a lack of capital to operate the plants properly, to upgrade its operations, and to develop ore deposits for production. To help solve the problems it is facing, ZCCM has embarked on a restructuring program to improve efficiency, boost the output of copper and cobalt, reduce operating costs, and reduce its long-term debt. The program includes a reduction of 10 000 employees, which is about 20% of its workforce, the cancellation of employee incentives, the fusion of Memaco (the trading arm of ZCCM) with the company's own marketing department, and the sale of the Chambishi and Kansanshi copper mines which are on care and maintenance.

Russia

Russian production of cobalt, in step with nickel production, was reported to be decreasing due to the breakdown of production apparatus caused by mechanical problems and the lack of spare parts. It was also due to shortages of coking coal and feed at smelters and refineries, the latter coming from domestic sources and imports for tolling. As usual, exact production figures were not released during the year but observers estimate 1994 production in Russia to be around 1800 t of cobalt, a decrease of 10% compared to last year. Exports of cobalt are also estimated to have fallen by as much as 30% to a level of about 1500 t. The reduced exports result partly from the implementation of a decree, at the start of August, which tightened up licensing conditions. Cobalt and other nonferrous metals will now be exported by state-registered companies who will have to register all export contracts.

In another development, the Norilsk Nickel Concern, which accounts for about 70% of Russian cobalt, was privatized in June 1994 according to the plan adopted in 1993.

Cuba

Cuban cobalt mine production in 1994, estimated at about 1500 t, was produced as nickel-cobalt sulphide matte at the Moa Bay smelter and exported for refining to Sherritt's facilities in Canada. The Nicaro and Punta Gorda plants, also located in Cuba's eastern Holquin Province, did not recover the cobalt content of the ore since it is deliberately suppressed to be able to produce on-spec nickel sinter. Cuba's lateritic deposits contain an average of 0.11% cobalt and are the world's second largest reserves after Zaire.

Aside from the agreement with Sherritt discussed earlier, the Cuban government-owned Commercial Caribbean Nickel (CCN) has agreed to form a joint venture with Western Mining Corp. (WMC) of Australia to explore and develop the Pinares de Mayari West nickel deposit located in the Holquin Province. WMC will earn a 65% stake in the project by financing further infill drilling and a feasibility study. The deposit is estimated to host reserves of 200 Mt grading over 1% nickel and 0.1% cobalt.

In other developments, Union Empresas de Niquel (UEN), Cuba's state-owned agency responsible for all nickel production, will undertake in 1995 the upgrade of the Punta Gorda smelter to reduce dust and increase energy efficiency. This will be realized through a US\$20 million loan from the Netherlands Caribbean Bank. Finally, the construction of the Las Camariocas plant, although two thirds completed, was still on hold for lack of financing and pollution problems associated with the leaching process it uses.

United States

In May 1992, the U.S. House of Representatives approved the disposal of 5810 t of cobalt from excess reserves in the National Defense Stockpile by the end of fiscal year 1996. Following this decision, the Defense Logistics Agency (DLA) started bi-monthly sales offering each month 113 t (250 000 lb) of cobalt granules and 45 t (100 000 lb) of cobalt rondelles in fiscal year 1993. Cobalt rondelles grading 98.87% cobalt can be used in the chemical industry, while cobalt granules grading 99.23% cobalt are suitable for the magnet and tool steel industries.

In fiscal year 1994, as in the previous year, the maximum amount of cobalt authorized to be sold under the Annual Materials Plan was 2087 t. Bi-monthly sales, conducted in the same manner as in 1993, were very popular in 1994 because of a certain tightness in supplies. About 1777 t of cobalt were sold during the calendar year. On average, stockpiled material sold at a discount of about US\$3/lb compared to Russian material grading 99.3% cobalt. During fiscal year 1994, i.e., up to September 30, 1994, sales were worth

US\$71.4 million, equating to an average price of US\$17.99/lb. DLA sales helped stabilize the North American domestic cobalt market, balancing fears of a supply shortage from African suppliers.

Beginning with fiscal year 1995, the DLA is offering for sale only cobalt grading 99.22% or lower to protect national defense interests. The agency has also separated sales into two categories: "A," for domestic use only; and "B," for general use. Congressional approval for fiscal year 1995 was 1725 t of cobalt to be sold either through long-term contracts or spot sales as in past years. The DLA will offer approximately 450 t of cobalt under a negotiated bid process for long-term contracts while the balance will be offered under the bi-monthly sealed bid process as before, except that quantities offered will be 181.5 t (400 000 lb) of granules and 68.0 t (150 000 lb) of rondelles per month.

Black Hawk Mining Inc. of Toronto, Ontario, is at the permitting stage for its Knox deposit located near Warren, Maine, in the United States. The company has kept the project on care and maintenance, and may proceed with the permitting stage in 1995 in light of improving metal prices. This should take two years to complete, after which a production decision would be made. Reserves at the Knox deposit, estimated at close to 4.0 Mt grading 1.40% nickel, 0.64% copper and 0.12% cobalt, are, in part, amenable to open-pit mining. The company expects to produce 340 t of cobalt in concentrates annually. These concentrates would be sent to a smelter in Canada or abroad for processing.

Australia

Australia's mine production of cobalt in 1994 is estimated at 2150 t. About 1400 t of this production came from the Queensland Nickel Joint Venture's (QNJV) Yabulu refinery in Townsville, which produced an intermediate sulphide material grading 42% cobalt and 1% nickel from ore imported from New Caledonia and Indonesia. This cobalt sulphide was sent to the Kokkola Chemicals Oy plant in Finland where it was processed into metal and salts by the Outokumpu Mooney Group. However, QNJV is continuing trial runs on a cobalt treatment pilot plant and a feasibility study is under way for a full-scale plant.

The balance of production came from WMC's nickel sulphide operations in Western Australia, which produced about 500 t, and from Outokumpu Australia Pty's Forrestania mine located in the same area, which produced about 250 t. The ore from WMC's mining operations was smelted at Kalgoorlie and refined at the nearby Kwinana plant before it was exported as a nickel-cobalt matte to Sherritt's plant in Canada for further refining. The Forrestania mine's output was exported for refining to Outokumpu Oy's Harjavalta refinery in Finland in the form of a nickel concentrate grading 0.3% cobalt.

New mines coming on stream, like the Mt. Keith mine commissioned at the end of 1994 by WMC which will add 600 t of cobalt to the company's output, or mining projects under development, like the Yakabindie Project which hosts reserves of 181 Mt grading 0.59% nickel and associated cobalt, or the Annaconda Project, are bound to boost the country's production in the near future.

Tanzania

In 1994, BHP Minerals International Exploration Inc. (BHP) and Sutton Resources Ltd. concentrated their efforts on the investigation of other showings north of Kabanga. BHP, the project operator, reported the intersection of a new mineralized zone located about 1 km north of the Kabanga deposit. The two holes drilled in the structure intersected similar grades of about 2.50% nickel, 0.35% copper, and 0.20% cobalt over a true width of 25 m.

BHP has agreed to finance all exploration costs up to the completion of a positive feasibility study in exchange for a 52.2% interest in the nickel-copper-cobalt-rich Kabanga deposit and a 60% interest in the Kagera deposit, both located in northwestern Tanzania. Sutton Resources Ltd., a British Columbia-based junior mining company, will retain a 37.8% interest in the Kabanga deposit and 30% in Kagera, while the Government of Tanzania holds the remaining 10% in each deposit.

The Kabanga and neighbouring Kagera deposits are located in an extensive nickel belt similar in geology to the ones in Canada and Australia. Drill-estimated resources at the Kabanga deposit amount to 25.5 Mt grading 1.19% nickel, 0.20% copper and 0.10% cobalt amenable to production by open-pit.

Uganda

Following a positive feasibility study for the Kasese cobalt project, the start of construction of a combined biological oxidation, solvent extraction and electrowinning plant was announced in January 1994. The plant is expected to permit the extraction of 1000 t/y of cobalt cathode from cobaltiferous pyrite concentrates recovered from waste dumps at the old Kilembe copper mine in western Uganda. These dumps are said to contain around 1.1 Mt of pyrite concentrate grading an average of 1.4% cobalt.

Mexico

International Curator Resources Ltd. (International Curator) is studying the possibility of re-opening the Boleo copper-cobalt mine located 3 km inland from the port city of Santa Rosalia, Mexico, on the Gulf of California. The mineralization at the Boleo deposit occurs in flat-lying seams averaging 1.2 m in thickness, which contain both sulphide and oxide ore.

As a result of the 1993/94 drill program on the property, International Curator has calculated new reserves oriented more towards open-pit mining. Drill-indicated and inferred open-pit resources now stand at 91.5 Mt grading 0.7% copper and 0.08% cobalt, while drill-indicated and inferred underground resources are 49.4 Mt grading 2.67% copper and 0.082% cobalt. At the end of September 1994, International Curator started a \$1.7 million exploration program consisting of at least 8000 m of drilling designed to upgrade the reserves and to conduct additional metallurgical tests.

Ivory Coast

Exploration work on the Biankouma-Touba nickel laterite project, located east of the Sipilou deposit close to the Ivory Coast's western border with Guinea, was a success in 1994. The 79-hole drill program revealed indicated reserves of 54 Mt grading 2.0% nickel and 0.07% cobalt split in three closely located deposits. These reserves are in addition to 51 Mt grading 1.8% nickel and 0.1% cobalt in the Sipilou deposit located on the same concession. Preliminary metallurgical test results indicate that the ore is suitable for ferronickel production; hence, cobalt would not be produced as a by-product.

A follow-up US\$3.5 million 1994/95 drilling program aimed at increasing reserves at the three deposits, exploring additional geochemical targets, and conducting metallurgical tests was started in October 1994. Falconbridge, the project operator, can earn a 60% interest in the project by funding and completing a feasibility study. Joint-venture partners are Trillion Resources Ltd., a junior company listed on the Toronto Stock Exchange with a 15% interest in the project, and SODEMI, the Ivory Coast state mining corporation with a 25% interest.

Finland

Outokumpu Metals and Resources Oy is preparing to re-enter the cobalt refining business in 1995 once the expansion and upgrade of its Harjavalta nickel refinery is completed. The company left the business in 1993 when it sold its share of the OM Group Inc., which produces cobalt metal powders, oxides and salts at its Kokkola Chemicals Oy plant from cobalt-bearing material imported from Zaire and Australia.

In 1993, because of a change in feedstock to its Harjavalta refinery following a decline in the supply of domestic ore, Outokumpu decided to change the design of the facility to treat more imported feed. A cobalt circuit, to produce metal powder, has been added to the plant to refine 250 t/y of cobalt, which was formerly sent to the Kokkola refinery as a hydroxide sludge, plus additional input from imports. Plant output is expected to double to 500 t/y.

Belgium

Union Minière AS recently upgraded its Olen plant, doubling the capacity of the facilities to recycle cobalt from scrap and residues to produce cobalt salts, oxides, and powders. A large part of the company's primary production of cobalt, expected to be around 1200 t/y, will come from the treatment of waste products from the zinc refining industry.

Philippines

Panorama Resources Corp., a Canadian company, entered into a Memorandum of Understanding with Philnico Mining and Industrial Corp. of the Philippines to acquire a 60% stake and rehabilitate the Nonoc nickel plant located near Surigao City on Mindano Island. The acquisition includes the nickel-cobalt-rich lateritic ore reserves; the refinery, which has a design capacity of about 34 000 t/y of nickel and 1500 t/y of cobalt; and the power plant located on site. Once the deal is approved, complete rehabilitation of the facilities could take a little more than a year.

Albania

Albania's Enterprise Restructuring Agency announced the closure of the country's only nickel-cobalt plant because it has become uneconomical to operate. Albania had been producing nickel and cobalt as by-products of its iron ore mining operations at Kukes in the northeast part of the country and at Kouka in southern Albania. The lateritic ores grade, on average, 15% iron, 1% nickel and 0.06% cobalt. A recent mineral production estimate identified the country's output at about 600 t of cobalt.

PRICES

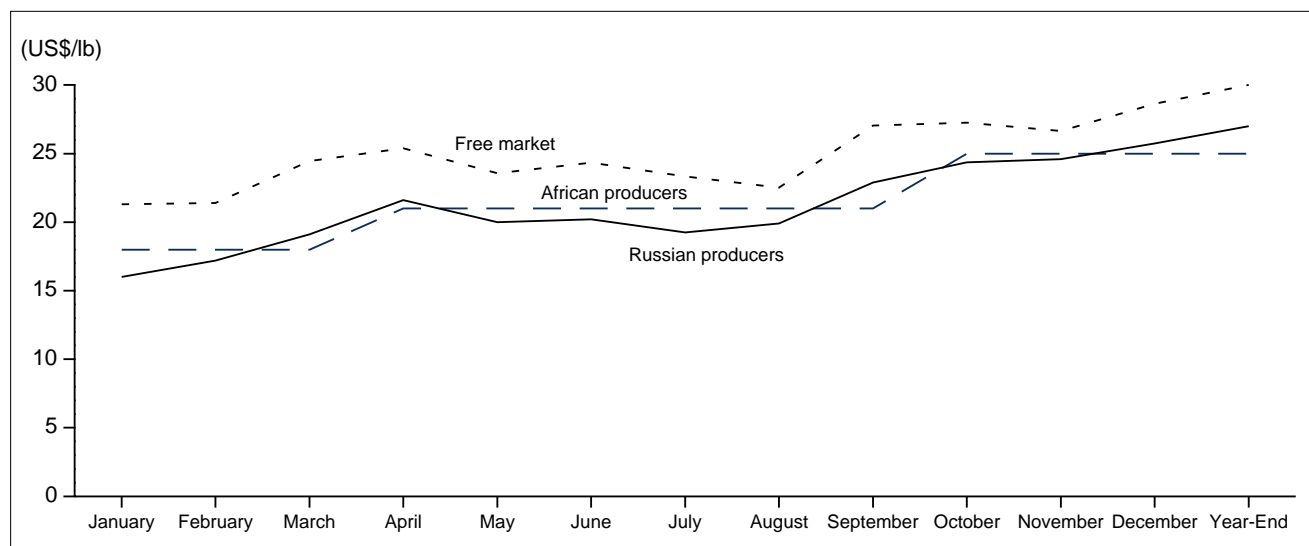
In 1994, the cobalt market was somewhat unstable in response to a perceived tightness in supply. Increases in demand from the booming North American economies, and from Europe and Japan coming out of the recession, coupled with production disturbances in major producing countries, pushed prices up, ending the downward trend which began in early 1992.

The free market price for cobalt cathode increased rapidly in the first quarter of the year to peak at US\$26.75/lb near the end of March. It then backtracked gradually to a low of US\$21.50/lb in mid-August, only to embark on a strong rally in mid-September with a US\$3.75/lb one-week hike. After experiencing some weakness in the first week of December, with prices decreasing to US\$25.75/lb, cobalt prices picked up again to finish the year near the US\$30.00/lb level. (Refer to Figure 1 for details.)

The price for Russian material followed the price of higher-grade Western-origin material, starting the year under US\$16.00/lb and finishing at US\$27.00/lb. The US\$5.00/lb discount for Russian material compared to Western-origin cobalt observed at the start of the year was reduced to less than US\$3.00/lb in the last quarter of the year. This spread reduction probably resulted from the tightness in supply for higher-grade material.

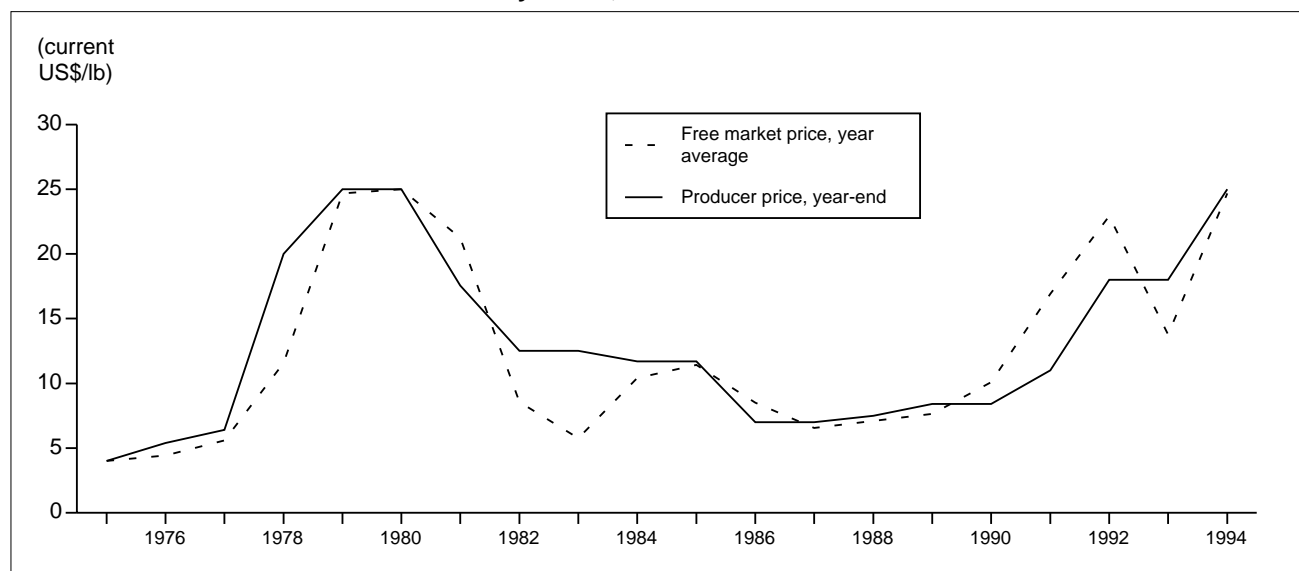
Although a price increase had been expected for a while because of a developing tightness in supply, the rapid movement was felt to result from the activity of merchants stockpiling while on the lookout for rising prices. Producers were quick to point out that the

Figure 1
Cobalt Price Variations, 1994



Sources: *Metals Week*; *Mining Journal*; *American Metal Market*.

Figure 2
Cobalt Price Variations in the Past Twenty Years, 1975-94



Source: *Metals Week*.

price hike was too rapid and would result in big consumers looking at other materials to replace cobalt.

The African producer price, fixed at US\$18/lb since November 1992, was kept at that level until April 1992 when ZCCM announced it was raising its price to US\$21.00/lb, which was matched shortly thereafter by Gécamines. In October, ZCCM and Gécamines announced a new reference price of US\$25.00/lb applicable to Zambian Grade B (qualities 3 and 4) and Zairean granules products grading 99.6% cobalt, and not the typical 99.8%. This release came after ZCCM had unilaterally announced in the previous month that it was raising its October sale price. Given Gécamines' reduced control of the market, these events may signal Zaire's interest in moving away from the established fixed price contracts toward free market pricing.

Improved output from major producers, new capacity coming on stream during the year, greater cobalt supplies generated from scrap metal and secondary material, and sales from the U.S. DLA stockpile will gradually bring balance back to the market in 1995. Prices should peak in the first quarter of the year and settle back to a level of around US\$20.00/lb by the end of 1995.

OUTLOOK

In Canada, production of refined cobalt in 1995 is expected to increase by 25% to 3400 t. Inco is forecasting production at 1200 t of refined cobalt through a reduction in shut-down time. Inco has announced that its Port Colborne refinery will close for a three-week period during the summer. However, the com-

pany is contemplating keeping its Canadian mining and smelting operations running on a 12-month basis to save on shut-down costs. Production at Falconbridge is expected to remain stable at 1994 levels, keeping its world cobalt output at 2800 t. Production at Sherritt should approach its capacity of 2000 t after the first full year of operation since the expansion of its refinery. Finally, Ego Resources, through its wholly owned subsidiary Cobatec, should produce about 200 t following the start-up of its operations in February 1995.

In 1995, because of improved production levels in Zaire, Zambia and Canada, and despite production disruptions in Russia, world production of refined cobalt is projected to reach 22 500 t, an increase of about 19% compared to 1994. This production increase, coupled with a greater supply of scrap cobalt that was previously uneconomic to recycle, sales from the U.S. DLA, and additional cobalt output from new producers like the Mt. Keith mine in Australia, will ensure the market is adequately supplied.

The world's consumption of cobalt is expected to increase as the economies of the European countries and Japan improve after a lengthy recession. The superalloy sector, which typically uses 40% of cobalt production, is not expected to significantly increase its consumption until the commercial segment of the aircraft industry recovers as major airlines replace their ageing fleets of 747s. Orders have started to increase, but a major upturn in deliveries is not expected until 1997/98. Meanwhile, the strong demand for alloys for industrial gas turbines used in power generation and marine transport should replace some of the aircraft industry's business.

Consumption in the chemical sector, the second most important segment of the market, has already improved significantly, mostly in the recording tape industry in Japan, while consumption in the magnet segment is decreasing because of substitution in uses. Finally, consumption in the cemented carbides and hard facing tool steel segments of the cobalt market should increase as the world economy improves. Continued tight supply in the market and the lack of price stability, however, hampers the growth of the cobalt industry and favours the switch to substitutes. This is particularly true concerning the use of cobalt in the superalloy, magnet, and wear-resistance industries.

In the longer term, the use of cobalt in the chemical industry should expand as new applications are found in the tire and medical industries. Likewise,

consumption of cobalt in the catalyst industry is estimated to increase by as much as 60% by the year 2000, following an increase in air emission regulations.

In 1995, the increase in production is expected to match the increase in consumption and help balance the market, although there may be a certain tightness in supply in the first half of the year. This will send prices up until the market slowly re-balances.

Notes: (1) For definitions and valuation of mineral production, shipments and trade, please refer to Chapter 60. (2) Information in this review was current as of January 14, 1995.

TARIFFS

Item No.	Description	Canada			United States
		MFN	GPT	USA	Canada
2605.00	Cobalt ores and concentrates	Free	Free	Free	Free
2822.00.10	Cobalt hydroxides	Free	Free	Free	Free
2822.00.90	Cobalt oxides, commercial cobalt oxides	8.9%	Free	Free	Free
2827.34	Cobalt chloride	11.8%	8%	Free	Free
2833.29.00.40	Cobalt sulphate	8.5%	6%	Free	Free
2836.99.00.20	Cobalt carbonates	11.8%	8%	Free	Free
2915.23	Cobalt acetates	11.8%	8%	Free	Free
8105.10.10	Cobalt mattes and other intermediate products; unwrought cobalt, alloyed; waste and scrap; powders, alloyed	8.8%	6.5%	Free	Free
8105.10.20	Unwrought cobalt, not alloyed; powders, not alloyed	Free	Free	Free	Free
8105.90.10	Cobalt bars and rods, not alloyed	6%	Free	Free	Free
8105.90.90	Cobalt and articles thereof, n.e.s.	8.8%	6.5%	Free	Free

Sources: Customs Tariff, effective January 1995, Revenue Canada; Harmonized Tariff Schedule of the United States, 1995. n.e.s. Not elsewhere specified.

TABLE 1. CANADA, COBALT PRODUCTION AND TRADE, 1993 AND 1994, AND CONSUMPTION, 1991-93

Item No.	1993		1994p	
	(kilograms)	(\$000)	(kilograms)	(\$000)
PRODUCTION¹ (all forms)				
Ontario	1 697 502	64 884	1 556 917	113 115
Manitoba	452 685	17 303	359 340	26 107
Total	2 150 187	82 187	1 916 257 ^a	139 222
EXPORTS				
2605.00	Cobalt ores and concentrates	—	—	—
2822.00	Cobalt oxides and hydroxides; commercial cobalt oxides			
	United Kingdom	388 604	14 147	150 795
	Singapore	—	—	51 000
	Other countries	5 350	187	1 962
	Total	393 954	14 335	203 757
2915.23	Cobalt acetates	—	—	—
8105.10	Cobalt, unwrought, matte and other intermediate products, waste, scrap and powders			
	Norway	1 628 193	63 932	1 489 091
	United States	760 252	28 719	663 385
	Netherlands	268 258	11 653	442 716
	Japan	262 052	10 908	627 913
	Belgium	156 124	6 050	162 000
	Other countries	276 740	11 403	387 214
	Total	3 351 619	132 665	3 772 319
8105.90	Cobalt and articles thereof, n.e.s.			
	Netherlands	130 520	4 334	54 176
	United States	8 055	1 239	12 241
	Japan	78 215	2 443	15 200
	Germany	6 499	508	7 719
	Other countries	6 094	380	20 625
	Total	229 383	8 904	109 961
IMPORTS				
2605.00	Cobalt ores and concentrates			
	United States	12 781	170	70 658
	Total	12 781	170	70 658
2822.00.10	Cobalt hydroxides			
	Belgium	14 000	477	52 000
	United States	19 773	648	5 792
	Japan	—	—	3 460
	Other countries	11 400	497	—
	Total	45 173	1 622	61 252
2822.00.90.10	Cobalt oxides			
	United States	6 685	181	18 174
	Belgium	—	—	993
	Other countries	—	—	760
	Total	6 685	181	19 927
2822.00.90.20	Commercial cobalt oxides			
	United Kingdom	74	1	39
	United States	529	13	—
	Total	603	15	39
2827.34	Cobalt chlorides			
	Belgium	1 062	13	1 777
	United States	272 566	1 552	1 175
	Germany	—	—	124
	Total	273 628	1 565	3 076
2833.29.00.40	Cobalt sulphate			
	United States	32 303	305	39 354
	Mexico	—	—	13 054
	People's Republic of China	20 000	270	3 024
	Other countries	5 683	112	—
	Total	57 986	688	55 432

TABLE 1 (cont'd)

Item No.	1993		1994P	
	(kilograms)	(\$000)	(kilograms)	(\$000)
IMPORTS (cont'd)				
2836.99.00.20	Cobalt carbonates			
	United States	27 713	797	54 590
	Russia	12 474	282	12 900
	Other countries	22 812	500	4 397
	Total	62 999	1 586	71 887
2915.23	Cobalt acetates			
	United Kingdom	—	—	2 799
	United States	3 160	36	2 456
	Total	3 160	36	5 255
8105.10.10.10	Unwrought cobalt; powders; mattes and other intermediate products, alloyed			
	United States	22 172	806	39 760
	Other countries	3 011	134	622
	Total	25 183	942	40 382
8105.10.10.20	Cobalt waste and scrap			
	Zambia	—	—	131 840
	United States	167 400	849	200 687
	United Kingdom	133	5	18 222
	Other countries	29 437	477	21 495
	Total	196 970	1 334	372 244
8105.10.20.10	Unwrought cobalt, not alloyed			
	Zaire	164 850	7 118	322 899
	Russia	8 455	301	8 634
	Netherlands	—	—	14 950
	Other countries	34 710	484	7 382
	Total	208 015	7 905	353 865
8105.10.20.20	Cobalt powders, not alloyed			
	United States	32 074	1 619	67 122
	United Kingdom	19 598	954	15 012
	Other countries	19 528	948	45 851
	Total	71 200	3 524	127 985
8105.90.10	Cobalt bars and rods, not alloyed			
	Germany	307	20	760
	United States	1 550	115	501
	Other countries	167	14	—
	Total	2 024	150	1 261
8105.90.90	Cobalt and articles thereof, n.e.s.			
	United States	37 360	3 665	52 627
	United Kingdom	1 433	63	1 319
	Other countries	3 737	178	544
	Total	42 530	3 908	54 490
		1991	1992	1993P
			(kilograms)	
CONSUMPTION²				
Cobalt contained in:				
	Cobalt metal and metallic compounds	72 554	67 381	49 889
	Cobalt pigments, feed and ground coat frit	9 039	5 801	6 751
	Cobalt salts and driers and other uses ³	84 315	131 542	130 258
	Total	165 908	204 724	186 898

Sources: Natural Resources Canada; Statistics Canada.

— Nil; . . . Amount too small to be expressed; n.e.s. Not elsewhere specified; P Preliminary.

^a A revised production figure in the amount of 1709 t was made available as of February 28, 1995.¹ Production (cobalt content) from domestic ores. ² Available data as reported by consumers. ³ Other uses include glass and chemicals.

Note: Numbers may not add to totals due to rounding.

TABLE 2. CANADA, COBALT PRODUCTION, TRADE AND CONSUMPTION, 1975 AND 1980-94

	Production ¹	Exports			Imports	Consumption ⁴
		Cobalt Metal	Cobalt Oxides and Hydroxides	Cobalt Ores ²	Cobalt Oxides and Hydroxides ³	
(tonnes)						
1975	1 354	431	561	123
1980	2 118	325	1 091	2	26	105
1981	2 080	677	601	24	20	101
1982	1 274	585	212	2	30	81
1983	1 410	885	192	45	30	101
1984	2 123	1 487	373	14	27	113
1985	2 067	1 551	268	36	192	101
1986	2 297	1 805	374	20	31	96
1987	2 490	1 875	440	45	38	120
1988	2 398	3 062	953	98	37	159
1989	2 344	3 236	371	22	33	147
1990	2 184	3 039	391	–	73	194
1991	2 171	3 456	459	–	42	166
1992	2 223	2 963	489	–	64	205
1993	2 150	3 581 ^r	394	–	52	187
1994 ^p	1 916 ^a	3 882	204	–	81	..

Sources: Natural Resources Canada; Statistics Canada.

– Nil; .. Not available; ^p Preliminary; ^r Revised.

¹ Production from domestic ores and cobalt content of intermediate products exported, including cobalt content of Inco Limited and Falconbridge Limited shipments to overseas refineries. ² Cobalt content. ³ Gross weight.

⁴ Reported consumption of cobalt in metal, oxides and salts.

^a A revised production figure in the amount of 1709 t was made available as of February 28, 1995.

TABLE 3. WESTERN WORLD COBALT PRODUCTION, 1991-94

	1991	1992	1993	1994
(tonnes)				
Falconbridge	1 983	2 300	2 414	2 800
Gécamines	8 790	6 625	2 200	3 500
Inco	1 385	1 465	1 410	1 100
OMG	1 503	2 100	2 200	2 900
Sherritt	823	686	1 218	1 870
Sumitomo	185	105	190	190
ZCCM	4 817	4 610	4 211	2 700
Total	19 486	17 891	13 843	15 060

Source: Cobalt Development Institute.