

# Cobalt

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## SUMMARY

In 1996, the cobalt content of metal concentrates produced in Canada was 2267 t, an increase of 12.4% from 1995, while Canada's production of refined cobalt (including production from ore feed imported from Cuba) increased 12.5% to reach 3328 t. The value of mine production of cobalt in 1996, about \$174 million, was about 1% less than in 1995. The increase in mine production compared to 1995 is due to an improvement in capacity utilization at Inco Limited (Inco) and an even larger improvement at Falconbridge Limited (Falconbridge). In 1995, Falconbridge's production was 28% lower than in 1994 due to a number of production disruptions at surface plants and mine development projects.

World estimates from the Cobalt Development Institute and other sources put the 1996 production of refined cobalt at 26 842 t, an increase of about 17.6% from 1995. The improvement in output is attributed to production increases by all major producers, especially in Zambia and Zaire, in Canada at The Cobalt Refinery Company Inc. (Corefco) and at Inco, as well as in Norway and Finland. The only significant decrease in output was registered in Russia where continued production disruptions were experienced primarily due to a lack of working capital.

The lower value of Canadian production despite significantly higher output was due to a lower average price for cobalt during 1996. The free market price for cobalt spot cathode averaged US\$25.48/lb, a 12.8% decrease from 1995. The drop in price was the result of an increase in production from traditional sources, some of whom, such as La Générale des carrières et des Mines (Gécamines) and Zambia Consolidated Copper Mines Limited (ZCCM), managed to produce at levels unseen since the early 1990s, and from others who set new production records. Meanwhile, demand from world economies remained strong at a level similar to 1995. Judging by the price

decrease experienced during the year, the market appears to have balanced after being in deficit since 1993.

The outlook for 1997 calls for production in Zambia, Finland and Norway, as well as in Canada at Corefco, Inco, Falconbridge and Ego Resources Limited, to improve significantly relative to 1996, while production in Zaire and Russia will remain stable at 1996 levels. New production in Australia and Morocco will result in additional supplies. Further increases in demand are expected as world economies pursue the growth experienced in recent years, including the Japanese economy, which has improved of late on the strength of a devalued yen relative to the U.S. dollar. A supply surplus, pursuing the trend started in 1996, is expected to occur in 1997 with a corresponding general downward pressure on prices. Increased demand brought about by a more stable marketplace and lower prices will help balance the market in the long term.

## USES

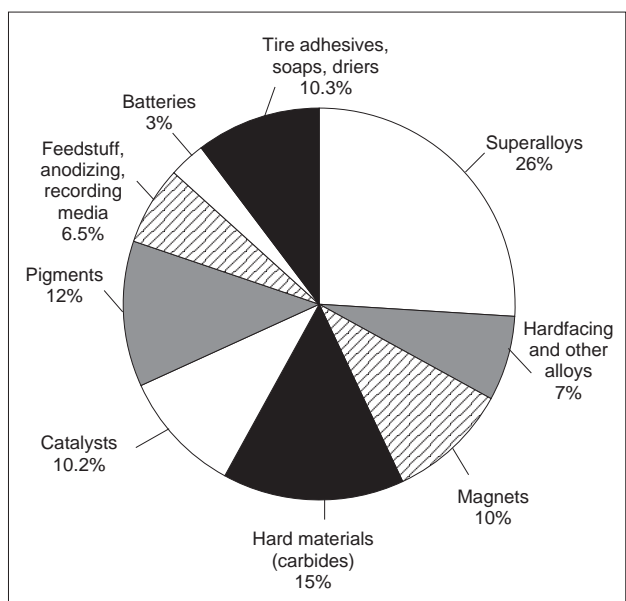
One of the major uses for cobalt is in superalloys where it improves the strength, wear and corrosion-resistant characteristics of alloys at elevated temperatures. The major uses of cobalt-based superalloys are in turbine blades for aircraft jet engines and in gas turbines for pipeline compressors. Cobalt-based 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 in instances where the specific advantages of reliability and good performance are required.

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. (Refer to Figure 1 for the importance of cobalt consumption per market segment.)

**Figure 1**  
**The Cobalt Market**



Source: Cobalt Development Institute.

## CANADIAN DEVELOPMENTS

Canada's mine production of cobalt in 1995 was 2016 t, while the preliminary estimate for 1996 is 2267 t. The output of refined cobalt in 1995 totalled 2958 t, and is estimated at 3328 t in 1996, an increase of 12.5%.

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. Corefco, a company owned 50% by Sheritt International Corp. and 50% by The Compania General de Niquel S.A. of Cuba, produces refined cobalt at its Alberta refinery from concentrates from its mining and mineral processing operation in Cuba and from other sources. Ego, a new Canadian producer and the world's largest primary cobalt producer, extracts cobalt from feedstock to produce cobalt carbonate.

## Inco Limited

Inco's 1996 mine production of cobalt was 1534 t, up 4.1% from the previous year, while its production of refined cobalt metal was 1220 t, up 10.7% from 1995. The production of cobalt in cobalt oxide totalled 320 t versus 1995's production of 280 t. The increased cobalt production in 1996 is related to increased nickel production.

Inco's cobalt production comes from several underground and a few open-cast mines located in the Sudbury and Thunder Bay area of Ontario, and in Manitoba's Thompson Nickel Belt. In 1996, the following mines were in operation: the Copper Cliff North and South, Crean Hill, Creighton, Froid, Stobie and Little Stobie, Coleman, Garson, McCreedy East and West, and Whistle open-pit, all located in the Sudbury area; Shebandowan in the Thunder Bay area; and the Thompson open-pit, as well as Thompson (T-1) and Birchtree, which are operated by Inco's Manitoba Division.

The nickel-copper-cobalt ores mined in Ontario are processed at the Clarabelle mill near Sudbury and at the Shebandowan mill near Thunder Bay. The concentrates are then sent to the Copper Cliff smelter for further processing to produce a variety of nickel and copper products, including nickel matte. An intermediate nickel-cobalt carbonate is shipped to Inco's refinery complex at Port Colborne, Ontario, where electrolytic cobalt rounds grading 99.9% pure are produced.

Ore from the Manitoba mines is concentrated and smelted in the local metallurgical complex. Cobalt oxide is a by-product of the electrolytic nickel refinery. The cobalt oxide is sent to Inco's Clydach refinery in Wales for final processing and packaging.

On August 21, 1996, Inco completed the \$4.3 billion acquisition of Diamond Fields Resources Inc. Through this deal Inco gained control of the Voisey's Bay project located 35 km southwest of Nain on the east coast of Labrador. Voisey's Bay Nickel Company Ltd. (VBNC), a 100%-owned subsidiary of Inco, will develop and operate the project.

The deposit, as outlined by the end of the year, is composed of three zones: the Ovoid, Eastern Deeps, and Western Extension. These zones are made up of massive and disseminated sulphides that include pyrrhotite, pentlandite and chalcopyrite mineralization hosted in an ultramafic sill. The deposit's total indicated mineral resources, as of June 1996, are estimated at 150 Mt. These include proven reserves of 31.7 Mt grading 2.83% nickel, 1.68% copper and 0.12% cobalt in the Ovoid Zone, 98 Mt of indicated resources in the Eastern Deeps, and 20 Mt of indicated resources in the Western Extension. VBNC plans to spend an average of \$20 million per year over the next four years to further explore the property.

VBNC completed a feasibility study on the project in 1996 and plans to develop the Ovoid Zone by open-pit methods, and the Eastern Deeps and Western Extension by underground methods. The ore will be processed into nickel-cobalt and copper concentrates in a 20 000-t/d on-site mill using conventional milling processes. The concentrates will then be trucked to storage facilities at the port site at Anaktalak Bay and shipped for smelting and refining to a new facility located at Argentia-Long Harbour, Newfoundland, 130 km west of St. John's.

The Voisey's Bay project is expected to generate 3500 direct and indirect jobs, and to produce about 123 000 t/y of nickel, 91 000 t/y of copper and 3200 t/y of cobalt. The capital cost to develop the project is US\$1.4 billion, split US\$350 million for the mine and mill, US\$640 million for the smelter, and US\$410 million for the refinery. VBNC registered the project for environmental review in the fourth quarter of 1996. This should allow sufficient time for the company to obtain the necessary environmental permits for the mine/mill complex and for the smelting and refinery complex to meet its schedule to start producing concentrate in late 1999 and a final refined product in late 2000.

### Falconbridge Limited

In 1996, Falconbridge's Canadian mineral production of cobalt was 725 t, up 34% from 1995, effectively returning to its customary production level. In 1995, the company had experienced difficulties in bringing the higher-capacity electric furnace at its Sudbury smelting facilities on line and had carried out important mine development projects at the Craig, Lockerby and Thayer Lindsley mines. Likewise, 1996 production of refined cobalt at Falconbridge's Nikkelverk refinery in Norway increased by 10.5% to 3099 t compared to 1995. This followed the two-stage capacity expansion of the refinery that was first increased to 3400 t/y by June 1, and then further expanded to 3700 t/y by the end of December 1996. In 1997, Falconbridge will concentrate on completing the plant's expansion program by increasing its nickel refining capacity to accommodate feed from the Raglan project.

During the year, Falconbridge operated five mines in the Sudbury, Ontario area, namely the Onaping, Craig, Fraser, Strathcona, and Thayer Lindsley mines. In addition, the company pursued the redevelopment of the Lockerby mine, which had been put on care and maintenance on June 1, 1994, for an indefinite period because of its high operating costs and market conditions. The company still expects to bring the mine back into production by mid-1998 when ore reserves at depth and to the east are developed. These reserves should ensure the mine a life of 10 years at its planned full output. The nickel-copper-cobalt ore extracted at these mines is concentrated at the Strathcona mill near Sudbury, Ontario, and is further processed at the Falconbridge smelter

to produce cobalt-bearing nickel matte. This matte, plus the feed the company obtains from outside sources (up to 75% for the production of cobalt), is sent by ship to the company's refinery at Kristiansand, Norway, to produce cobalt metal and nickel products.

Falconbridge also pursued exploration on a number of properties. Development work at its most advanced project, the Raglan property located on the Ungava Peninsula in northern Quebec, progressed and is said to be ahead of schedule with the start-up date now planned for the second half of 1997. Capital expenditures to bring the 21 000-t/y nickel (about 200 t/y cobalt) operation into production are estimated at \$500 million. Its estimated reserves, which were increased during the year to 19.3 Mt grading 3.18% nickel, 0.88% copper, 0.05% cobalt and precious metal credits, would permit a mine life of at least 25 years. Falconbridge is developing the property as an open-pit and underground operation, and plans to mill the ore on site and then truck the concentrate (grading, on average, 16% nickel and 4% copper) 65 km north to the port facility of Deception Bay, Quebec. The concentrate will then be shipped and railed to Falconbridge's Sudbury smelter where it will be processed into a nickel-copper-cobalt matte before being sent to the company's Nikkelverk refinery in Norway for further processing.

### The Cobalt Refinery Company Inc.

As of December 1994, Sherritt Inc.'s nickel and cobalt business came under the ownership of the joint venture between Sherritt and La Compania General de Niquel S.A. The three joint-venture companies formed were International Cobalt Company Inc. (ICCI), The Cobalt Refinery Company Inc. (Corefco), and Moa Bay Nickel S.A. In November 1995, Sherritt Inc. transferred its interests in the joint-venture to Sherritt International Corp. The latter is a new publicly traded Canadian company that owns a 50% share of the joint venture between Sherritt Inc. and La Compania General de Niquel S.A. of Cuba, Sherritt's international oil and gas business, and various other businesses including some nonmetal interests in Cuba.

On May 27, 1996, Sherritt Inc.'s fertilizer business and its Canadian oil and gas businesses were renamed Viridian Inc., while the specialty products business and its advanced industrial materials and technology groups became The Westaim Corporation (Westaim).

During 1996, Corefco produced about 2100 t of refined cobalt at its Fort Saskatchewan refinery located northeast of Edmonton, Alberta, an increase of about 20% over 1995. This increase was achieved through various debottlenecking exercises at the refinery. However, due to various maintenance issues, feed timing and management decisions, operation at capacity was not achieved over the full year. Modifications that were made to the refinery when it was

upgraded in 1993 will enable the company to plan cobalt production independently from that of nickel, making it less sensitive to price fluctuations for nickel and copper.

Corefco toll produces cobalt from feedstock owned by ICCI, which is purchased on a contract basis from Moa Bay Nickel S.A. In 1996, Corefco obtained the majority of its feed from ICCI, with a small amount coming from Australia and elsewhere. Moa Bay's better-than-expected production in 1995/96 will result in a further expansion at both the mine and the refinery. A project to double the present capacity of the refinery is in the planning stage but with no definite date for completion.

Corefco's nickel-cobalt refinery produces cobalt metal in powder form that can then be pressed and sintered into briquettes. Since 1990, as a result of importing feed from Cuba, Sherritt has not accessed the U.S. market because of the U.S. embargo that bans the import of materials originating in Cuba. This ruling has also affected the actions of the joint-venture companies, which are also restricted from selling their products in the United States. The U.S. policy is not expected to change in the near future.

Westaim's specialty products group produces ultra-fine 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. This ultrafine cobalt powder is produced in a separate production facility from that of Corefco's.

## Ego Resources Limited

Ego Resources Limited (Ego) joined the ranks of primary producers of cobalt on June 22, 1995, when it started operating its new recovery plant at Cobalt, Ontario. However, as a result of scale-up problems, it did not begin commercial cobalt shipments until the first quarter of 1996. Ego's production for the year amounted to 15 880 kg of cobalt carbonate containing 7861 kg of cobalt. This low production level is mostly attributed to design flaws at the plant that were corrected during the year.

In the last quarter of 1996, Ego phased out the use of ores mined locally and switched to cobalt-rich copper cake from Big River Minerals Corp. of Sauget, Illinois. This copper cake, containing 6% cobalt and 36% copper, is considered a waste product by that company because it is laced with high percentages of arsenic, which makes it impossible for the company to process it further. A second feed stream was being installed at the end of the year to enable Ego to process more of the new feed to reach its design capacity. This second feed stream will be integrated with the original Cobatec hydrometallurgical process and use various domestic and imported cobalt-bearing feedstock. It is expected to be fully operational in the first quarter of 1997.

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 544 t/y of cobalt carbonate compounds that contain about 49.5% metal, a value-added product sector. These products will be marketed by Amalgamet Inc. to end users. 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 enables the company to extract cobalt from feed with a high arsenic content, which before had posed a metallurgical barrier. By pressure leaching the feed 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. This process has been endorsed by the Ontario government as being consistent with its green industries strategy.

Ego cancelled the cobalt supply agreement reached in 1995 with H.C. Starck GmbH & Co. KG (H.C. Starck) of Goslar, Germany, because the latter company could not provide Ego with an initial date in 1997 for product delivery under the supply agreement, making it difficult for Ego to finalize its business plan. Under this agreement, Ego was to commit a large part of its production capacity to the manufacture of a high-purity cobalt intermediate to be supplied to H.C. Starck over a period of 10 years for the manufacture of electrode materials in high-performance rechargeable nickel-metal hydride batteries.

## Other Developments

Following up on last year's construction of a \$1 million pilot plant at its Key Lake facility, located about 550 km north of Saskatoon, Saskatchewan, **Cameco Corporation** hired Lakefield Research in 1996 to run the plant for six months to evaluate the technical feasibility of recovering cobalt and nickel from uranium tailings. The tests proved conclusive and enabled the company to confirm the design and the \$45 million cost of a commercial plant with a capacity to produce 263 t/y of cobalt and 3175 t/y of nickel from tailing reserves that could last 12 years. Once processed, the waste from the proposed plant would be placed in the nearby Deilman open pit, an environmentally friendlier location than the present site. The company expects to complete the financial analysis of the feasibility study and decide on how to proceed with development of the project in early 1997.

During the year, **Fortune Minerals Ltd.** proceeded to drill some of the zones of its NICO claim group

located 160 km northwest of Yellowknife, Northwest Territories, where impressive copper, cobalt, bismuth, and even tungsten and precious metal values had been reported in trenches. Of all the zones discovered, the best potential for cobalt appeared to rest in the Bowl Zone, the Nico Lake Zone and the Burke Lake Zone. Two drill programs carried out in 1996 outlined thick intersections of relatively low-grade mineralization. Further work is being planned on the claim group.

**Canmine Resources Corporation**, active in the Werner Lake Belt located 150 km northeast of Winnipeg, Manitoba, reported further intersections of significant copper-cobalt mineralization in its 1996/97 drilling program. Exploration and delineation drilling is planned on several properties while underground development work is planned at the Werner Lake Cobalt Deposits property.

In Quebec, the **Ministère des ressources naturelles** reported the discovery of a mineralized showing located about 60 km northeast of Sept-Îles in northeastern Quebec. Surface sampling of the Lac Volant showing, as it is known, returned assays averaging 2.0% nickel, 2.3% copper and 0.10% cobalt. The government secured a land position around its discovery and plans to explore the deposit before auctioning it away. The discovery sparked a staking rush in the area where numerous other showings have been identified.

Also in Quebec, **Tiomin Resources Inc.** and **SOQUEM** announced the discovery of surface showings on their ANNIC project located about 150 km northwest of Sept-Îles, in addition to previously announced results from the nearby Fortin claim block.

Numerous companies exploring properties in the vicinity of the Voisey's Bay discovery have reported significant nickel-copper-cobalt values from surface showings. However, few have drill-tested their findings. Companies reporting significant nickel-copper-cobalt drill intersections include **Canadian State Resources** on its 1514H claim group located 80 km northwest of Voisey's Bay, and **Consolidated Viscount Resources** and **Consolidated Magna Ventures** on their Tasisuak Lake property 50 km northwest of Voisey's Bay. In addition, drilling carried out by **Takla Star Resources** and **NDT Ventures** on their Project 44 near Nain, Labrador, has so far intersected only low-grade intervals of nickel-copper-cobalt.

Some 530 km northwest of Voisey's Bay, about midway to Falconbridge's Raglan project, **Troymin Resources Ltd.** pursued drilling on its Hawk Ridge property where a resource of 30 Mt grading 0.52% copper and 0.19% nickel has been outlined.

Other promising discoveries include that of **First Western Minerals Inc.** on its Mont Paul property in

Quebec's Gaspé Peninsula, where trench samples returned assays averaging 8.22% nickel and 0.07% cobalt over a 4-m section. The company started a 1500-m drilling program in December 1996 that should be completed by the end of January 1997.

Canada's most important cobalt export in 1996 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 \$344 million, an increase of 12.7% from 1995. Despite the fact that it registered a drop of 24% in value compared to 1995, the most important cobalt import on the basis of value was still "unwrought cobalt." The greater portion of these products was imported from Zaire for transformation and comprised 46% of total imports. As a general comment on trade, exports of cobalt products increased significantly in 1996 in terms of value compared to 1995, while the value of imports decreased by 6.4% compared to 1995. On the basis of tonnage, both exports and imports of cobalt products varied unevenly (Tables 1 and 2).

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 and is therefore not included in the cobalt statistics. For example, Canada imported 46 134 t of Cuban nickel-cobalt matte valued at \$316.8 million in 1996, while it exported 83 657 t of nickel-copper-cobalt matte worth \$950.8 million to Norway and the United Kingdom.

## WORLD DEVELOPMENTS

Using the Cobalt Development Institute's (CDI) estimates and other sources, world production of refined cobalt in 1996 appears to have been 26 842 t, or 17.6% more than in 1995. This figure includes 22 010 t supplied by producer members of the Institute, in addition to 4832 t estimated to be the combined production of Russia, Belgium, China, South Africa, Brazil, France and others. The production increase seen in 1996 confirms the 1995 perception of stabilizing cobalt supplies and brings the market close to balance. The market may even have experienced a small surplus if this year's price decrease is any indication. (Refer to Table 3 for the individual production of CDI producer members.)

### Australia

Australia's mine production of cobalt in 1996 is estimated at 2525 t, 1% more than in 1995. About 1425 t (down from 1500 t in 1995) of Australia's production came from the QNI Ltd. Yabulu refinery in Townsville, which produced an intermediate sulphide material grading 42% cobalt and 0.1% nickel from ore imported 63% from New Caledonia and 37% from

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. Construction began at the Yabulu refinery in January 1996 on an A\$33 million cobalt plant that will produce high-purity cobalt products – cobalt oxide and hydroxide – ideal feedstocks for the production of cobalt chemicals. The plant is scheduled to be completed in January 1997. QNI expects sulphide shipments to Finland to stop when the new plant comes on stream.

The balance of production came from Western Mining Corp.'s (WMC) nickel sulphide operations in Western Australia, which produced about 1100 t, including production from Mount Keith, and from Outokumpu Australia Pty's Forrestania mine located in the same area, which produced about 100 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 Corefco'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 0.4% cobalt.

Numerous projects under development are bound to boost Australia's cobalt production in the near future. Mining of the Ernest Henry copper-gold-cobalt deposit located in Queensland in northeastern Australia began in the last quarter of 1996. Owned by MIM Holdings Ltd. (51%) and Savage Resources Ltd. (49%), the project is expected to start producing at a rate of 1500 t/y of cobalt in late 1997 and rise to 3000 t/y by the end of the decade.

Other advanced projects include Annaconda Nickel NL's US\$615 million Murrin Murrin project located near Leonora in Western Australia where laterite resources estimated at 118 Mt grading 1.14% nickel and 0.07% cobalt could produce up to 3000 t/y of cobalt. Swiss-based Glencore International A.G., already a 19.99% owner of Annaconda, will acquire a 40% stake in the project for US\$220 million. Bank financing is expected to be finalized by March 1997 and production is to start in early 1998.

In September 1996, Resolute Samantha Ltd. completed the financing for the US\$145 million first-phase development of its Bulong laterite nickel-cobalt project located 30 km east of Kalgoorlie in Western Australia. The project has mineable reserves of 40 Mt grading 1.14% nickel and 0.09% cobalt, which are included in a resource of 140 Mt with slightly lower grades. Production will start at an initial rate of 500 t/y of cobalt cathode by March 1998 and is expected to be tripled at a cost ranging between US\$197 million and US\$236 million. The company will use a unique process flowsheet using high temperature, acid pressure leaching followed by solvent extraction/electrowinning to produce LME-grade nickel and cobalt metal.

Centaur Mining and Exploration Ltd. reached an agreement with SOGEM, a wholly owned subsidiary of Union Minière, for the US\$154 million first-stage development of the Cawse project located 40 km north of Kalgoorlie, Western Australia. The deposit contains a mineral resource of 193 Mt grading 0.7% nickel and 0.04% cobalt, including proven and probable reserves of 24.6 Mt grading 1.0% nickel and 0.08% cobalt. The project is slated to start producing at a rate of 2000 t/y of cobalt in late 1997.

Meanwhile, Dominion Mining completed a feasibility study on its Yakabindie project located adjacent to WMC's Mount Keith mine in Western Australia. The study estimated development costs of US\$386 million based on a production rate of 21 000 t/y of nickel and 600 t/y of cobalt. However, following a recent reserve upgrade, the company is investigating the possibility of mining the deposit at a faster rate (900 t/y cobalt). Reserves now stand at 193 Mt grading 0.51% nickel and 0.01% cobalt. The company plans to use the Activox hydrometallurgical process, which uses a combination of fine grinding and low pressure oxidative leaching to treat low-grade ores.

Other potential cobalt production from nickel ore deposits includes the Calliope Metals project to process New Caledonia ores, while production from copper ore deposits includes the Cloncurry, Maroochydore and White Range projects.

## Brazil

RTZ Mineração Ltda pursued the development of its Fortaleza nickel sulphide deposit located about 350 km southwest of Belo Horizonte in Minas Gerais State. The construction of a fully integrated mine-to-refinery complex is expected to cost about US\$183 million, plus an additional US\$50 million for the subsequent commissioning of the underground mine, both to come on stream in mid-1998. Ore reserves of 10.3 Mt grading 1.89% nickel, 0.36% copper, 0.2% cobalt and precious metal credits will result in a 20-year production life for the project with the first five by open-pit and the remainder by underground mining methods.

## Cuba

Cuba's mine production of cobalt in 1996, estimated at about 2400 t, was produced as nickel-cobalt mixed sulphide matte (with a 10:1 nickel-cobalt ratio) at the Moa Niquel S.A. mining and mineral processing plant and was exported for refining to Corefco's facilities in Canada. Cuba's other two nickel processing facilities, the Nicaro and Punta Gorda plants, also located in Cuba's eastern Holguin Province, did not recover the cobalt content of the ore despite their capacity to produce 2200 t/y since it is deliberately suppressed in order 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 those in Zaire.

The concessions allocated to Moa Niquel S.A. contain estimated reserves of 60 Mt grading 1.0% nickel and 0.12% cobalt, enough to supply the plant for 25 years, notwithstanding other surrounding deposits that could extend the life of the operation for an additional 25 years. On the strength of these reserves, the Canadian-Cuban joint venture announced its plans to expand the production capacity of the Moa Bay facilities. A first phase, to be realized by the end of 1999 at a cost of US\$165 million, will enable the plant to sustain a production level of 24 000 t/y of concentrate. A further US\$173 million may be invested up to and after the year 2000 to increase capacity to 46 000 t/y.

Aside from the joint venture with Sherritt discussed earlier, the Cuban government-owned Commercial Caribbean Nickel S.A. has agreed to form a joint stock-holding company with WMC of Australia to explore and develop the Pinares de Mayari West nickel deposit. This deposit, located in the Holquin Province about 200 km west of Moa Bay, is estimated to host reserves of 200 Mt grading over 1.0% nickel and 0.1% cobalt. The project is not expected to be in production until the year 2000.

Another important mining house active in Cuba, Gencor Ltd., a South African mining group, acquired in 1995 a 75% stake in the state-owned San Felipe nickel-cobalt deposit located in Camaguy Province about 500 km east of Havana. Estimated to be of similar size and grade to the Pinares de Mayari West deposit, the San Felipe deposit could be developed in the same time frame as the former. Gencor is also interested in completing the construction of the Las Camariocas plant in Holquin Province in conjunction with the development of a nearby nickel-cobalt deposit. Although it is two thirds completed, the project was abandoned in the early 1990s when financing from Russia was cancelled. It was still on hold in 1996 due to a lack of financing and pollution problems associated with the leaching process it uses.

## Finland

In August, Outokumpu Metals and Resources Oy commissioned a 500 to 700-t/y capacity plant to produce cobalt metal powders at its Harjavalta refinery. This follows the official inauguration of the refinery's new copper and nickel facilities in August 1995.

Finland's other cobalt refinery, operated by the OM Group Inc., produces cobalt metal powders, oxides and salts at its Kokkola Chemicals Oy plant from cobalt-bearing material imported from Zaire and Australia.

## Ivory Coast

Exploration work on the Biankouma-Touba and Sipilou nickel laterite deposits located close to the Ivory Coast's western border with Guinea continued

in 1996. The second phase of a 20 000-m drill program completed in March enabled the definition of a total indicated and inferred resource of 225.7 Mt grading 1.5% nickel and 0.1% cobalt split into about 10 deposits. Metallurgical testing done in Sudbury during the year confirmed that hydrometallurgical processing is the most suitable and cost-effective method of metal extraction, suggesting that cobalt would most likely be recovered.

Joint-venture partners have approved a 1996/97 US\$7.8 million follow-up exploration program consisting of 10 000 m of core definition drilling and 18 000 m of reverse circulation drilling at the Sipilou North deposit. The program also includes metallurgical tests on ore samples from four deposits in a mini-scale pilot plant, a scoping study, and initiation of an Environmental Impact Study. Results of a pre-feasibility study are expected by the end of 1997 or early 1998, which could signal a production start-up around 2003.

## Mexico

In 1996, International Curator Resources Ltd. pursued the evaluation of the Boleo copper-cobalt deposit located 3 km inland from the port city of Santa Rosalia, Mexico, on the Gulf of California. The mineralization at Boleo occurs in flat-lying seams averaging 1.2 m in thickness that contain both sulphide and oxide ore. Drill-indicated and inferred open-pit resources stand at 123.9 Mt grading 0.76% copper and 0.073% cobalt, while drill-indicated and inferred underground resources amount to 49.4 Mt grading 2.67% copper and 0.082% cobalt.

A pilot leach program on three bulk samples carried out during the year at the Colorado Minerals Research Institute in Denver achieved recoveries of 85% for copper and 75% for cobalt, confirming results from previous bench-scale metallurgical tests done by Lakefield Laboratories on oxide ore samples. The company was planning to complete a feasibility study on the project by the end of 1996 and was actively looking for financing.

## Morocco

La Compagnie de Tifnout Tiranimine, a primary cobalt producer that mines high-grade cobalt veins averaging 1.5% cobalt in the Bou-Azzer area, finalized the construction of a cobalt refinery in 1996. The plant, which was expected to be fully operational by July 1996, will have a capacity to produce 300 t/y of cobalt cathode. However, despite this development, the company plans to continue supplying China with as much as 700 t/y of cobalt contained in arsenic-rich concentrate for refining. In August 1996, the Government of Morocco sold its 40% interest in the company to ONA Group, the mine operator who already owned a minority interest in it.

## New Caledonia

Through Goro Nickel, an operating company owned 85% by Inco and 15% by France's Bureau de recherches géologiques et minières, Inco Limited carried out a feasibility study for the development of its Goro nickel-cobalt project in New Caledonia. The main goal of the study, expected to be completed by the end of 1996, was to ascertain the economic viability of pressure leaching, to be combined with solvent extraction, which would enable the recovery of cobalt from the lateritic ore. The process has successfully been tested on laterites from the Goro deposit on a continuous basis in a fully integrated pilot facility. Aside from Australia's QNI, Brazil's Tocantins, and Cuba's Moa Bay, all lateritic ore-based producers cannot economically recover cobalt. Goro's estimated reserves stand at 165 Mt grading 1.6% nickel and 0.16% cobalt amenable to open-pit mining.

## New Guinea

Joint-venture partners Highlands Gold Ltd. (65%) and Nord Pacific Ltd. (35%) completed a pre-feasibility study for the development of their Ramu and Frieda River projects in Papua New Guinea. Total inferred resources are estimated in the range of 100-130 Mt grading 0.9% nickel and 0.1% cobalt, which excludes resources of 24.2 Mt grading 0.9% nickel and 0.08% cobalt at Ramu central. The project has the potential to produce 30 000 t/y of nickel and 2770 t/y of cobalt oxides, and will cost over US\$500 million to develop. The partners are considering attracting a third party experienced in nickel mining to develop the deposit.

## Philippines

The Philippine's Asset Privatisation Trust accepted in May 1996 the US\$334 million offer from Pacific Nickel Holdings Ltd., a consortium composed of Filipino and Hong Kong investors, for the acquisition of the Nonoc nickel operation located near Surigao City on Mindano Island. The acquisition includes the nickel-cobalt-rich lateritic ore reserves estimated at 81.3 Mt grading 1.22% nickel, 0.11% cobalt and 37.3% iron; the refinery, which has a design capacity of about 35 000 t/y of nickel and 1500 t/y of cobalt; and the power plant located on site. The company plans to invest US\$275 million over two years to rehabilitate the facilities and build a modern cobalt refinery. The Nonoc operation had been foreclosed by the Philippine National Bank in 1986 after it defaulted on its loans.

Also active in 1996, Stellar Gold Corporation (Stellar) and BHP Minerals International Exploration Inc. pursued exploration of the Palawan laterite nickel project located on the southwestern island of Palawan. Current reserves on the Palawan property are estimated at 187 Mt grading 1.4% nickel and 0.1% cobalt, while at least 90 Mt of lateritic ore grading 1.14% nickel and 0.17% cobalt and proven

reserves of saprolite ore grading 2.29% nickel have been identified at Stellar's Surigao property.

## Russia

Russia's refined production of cobalt in 1996 is estimated at about 2770 t (not including tolled material), a decrease of about 36% compared to 1995 attributable mostly to reduced operations at two of the country's refineries. In Russia, cobalt is mined from nickel-copper-cobalt-rich sulphide deposits and processed at five locations. Norilsk Nickel Russian Joint Stock Society (Norilsk RJS), which accounted for 81.5% of Russia's production in 1994, produces from refineries at its Norilsk and Severonickel complexes, and from a smelter at its Pechenganickel complex. Matte from the smelter is sent for refining to the Severonickel plant or is exported to be treated on a tolling basis. The two other refineries based in the Urals are Ufaley Nickel, which produces cobalt oxide, and Yuzhural Nickel, which relies on Cuban matte imports to produce cobalt metal granules.

In step with lower production of nickel during the year, cobalt output is reported to have decreased due to the breakdown of the production apparatus caused by a lack of working capital for proper care and maintenance. Cobalt production at the Norilsk Nickel plant is reported at 1500 t, a decrease of only about 3.6% compared to 1995. Norilsk achieved this performance despite its difficult financial situation, which caused the workers to strike over unpaid wages and poor living conditions in June. Also affecting its production of cobalt, Norilsk RJS announced in August 1996 that it had stopped producing refined cobalt at its Severonickel refinery because of increased production costs (power and rail costs, and excessive taxes); however, production of low-grade cobalt would be pursued. Severonickel had been producing an average of about 800 t/y of refined cobalt in recent years.

The production of cobalt at Russia's Ufaley refinery was also affected by a financial crisis in 1996 that forced the closure of the plant for two months starting in early May. The plant's output was recently reported at 1000 t/y.

Cobalt exports in 1996 are estimated to have fallen by about 36% to a level of 1800 t. As of July 1996, Norilsk RJS's marketing arm, London-based Normaco Ltd., was reorganized. Interrosimpex, a financial-industrial group that includes Uneximbank, MFK Bank and Norilsk, will now act as exclusive exporter and foreign agent for all of Norilsk's production. Normaco's role will now be restricted to the distribution of the material.

## South Africa

South Africa's 1996 production of refined cobalt is estimated at 225 t, an increase of 18% over 1995. The country's production, which is in the form of



cobalt metal powder and cobalt sulphate, is a by-product of the mining of platinum group metals in the Bushveld Complex.

Anglo American Corp. and Angloval Ltd. decided to proceed with the development of the Massive Sulphide Zone, part of their Nkomati joint venture, while pursuing the evaluation of the other three mineralized zones identified on the Slaaihoek and Uitkomst farms located in the northeastern province of Mpumalanga. Containing geological reserves of 3 Mt grading 2.04% nickel, 1.13% copper, 0.09% cobalt and 6.17 g/t combined platinum, palladium, rhodium and gold, the zone is expected to be developed at a cost of US\$36.3 million and mining is to start at a rate of 10 000 t/m by June 1997.

## Tanzania

In 1996, BHP Minerals International Exploration Inc. (BHP) and Sutton Resources Ltd. (Sutton), a Canadian-based junior mining company, renegotiated their joint-venture agreement on the Kabanga and Kagera properties. BHP relinquished its interest in the Kabanga and South Kagera properties after preliminary studies for the development of the Kabanga deposit failed to meet its profitability criteria. According to the new agreement, BHP may obtain a 36% interest in the North Kagera property, a reconnaissance area, after spending US\$5 million on exploration. A surface exploration drill program was in progress at the end of the year. Sutton now plans to find a new partner to develop the project. A number of major companies have signed confidentiality agreements to review the Kabanga database, which may lead to various production alternatives being considered.

The Kabanga and neighbouring Kagera deposits in northwestern Tanzania are located in an extensive nickel belt similar in geology to the ones in Canada and Australia. Drill-estimated resources at the Kabanga deposit, including the North Zone, amount to 31.0 Mt grading 1.50% nickel, 0.22% copper and 0.13% cobalt amenable to production by open-pit mining.

## Uganda

Officials involved with the Kasese cobalt project in western Uganda expect to arrange US\$66 million in international bank financing for the development of this project early in 1997. Estimated to cost a total of US\$96 million, the project includes the construction of a cobalt-processing plant and an associated 10-MW hydro-electric plant. It will be developed by Kasese Cobalt Co. Ltd., which is owned by the Ugandan government (45%) and Canada's Banff Resources Ltd. (55%).

The cobalt plant will process cobaltiferous pyrite concentrates recovered from waste dumps from the old Kilembe copper mine located 10 km uphill. Through bio-oxidation, solvent extraction and electrowinning,

the plant is expected to produce 1000 t/y of cobalt cathode starting in 1998. The waste dumps are estimated to contain around 922 000 t of pyrite concentrate grading an average of 1.4% cobalt, which would give the project a 10-year life.

In conjunction with the tailings project, Banff Resources Ltd. is evaluating the feasibility of re-opening the Kilembe mine where Falconbridge milled 16.2 Mt of copper-cobalt ore grading 1.95% copper between 1956 and 1976.

## United States

In May 1992, the U.S. House of Representatives approved the disposal of 5897 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 of cobalt granules and rondelles in fiscal year 1993 (the sales frequency has changed several times since then). 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.

For fiscal year 1996, Congress approved the sale of up to 1815 t of cobalt. The cobalt was sold by the DLA through two negotiated sales, one of cobalt grading 99.99.29% pure and the other of cobalt grading less than 99% pure. Sales during fiscal year 1996 amounted to 1809 t and equated to an average price of US\$25.61/lb. This compares to 1995 fiscal year sales of 1888 t at an average price of US\$25.80/lb.

At year-end, the DLA received authorization to dispose of 11 794 t of cobalt through fiscal year 2006. Plans for fiscal year 1997 are for the sale of 2767 t of cobalt. Three negotiated sales for a total of 1406 t will be held in February, April and September 1997, while 1361 t will be sold through three sealed bids in December 1996 and in March and May 1997. About 1000 t of cobalt were sold during the 1996 calendar year.

At the end of fiscal year 1996, reserves at the National Defense Stockpile stood at 18 257 t of cobalt grading between 97.11% and 99.9% pure, split about 52% as granules, 29% as cathodes and 19% as rondelles.

Vancouver-based Formation Capital Corp. pursued the exploration of its Sunshine copper-cobalt deposit located 32 km southwest of Salmon in central Idaho. This property is adjacent to the Blackbird mine, which is a past copper-cobalt producer that Noranda Mining Inc. has agreed to help reclaim environmentally. In 1996, the company returned encouraging results from its Phase I 6125-m drill program that included 642 m on the Regina and Troll zones of the Black Pine property located 6 km southeast of the Sunshine property. A Phase II drill program will be undertaken in 1997 based upon a new interpretation of the data that will also result in new reserve calculations to be released in early 1997.

## Zaire

The economical and political situation in Zaire, the world's largest cobalt-producing country, was still unstable in 1996. However, the restructuring of La Générale des Carrières et des Mines (Gécamines), the refurbishment of production facilities carried out during the year, and the start-up of new mines may signal improvements to the situation. As proof, Zaire's cobalt output reached 6110 t in 1996, up 47% compared to 1995, pursuing the production improvement started during 1994. Production in Zaire had dropped to a 2200-t low in 1993 following political upheaval in 1992 and a serious cave-in at the Kamoto mine in 1990 that forced its closure.

The increased output in 1996 is said to have been reached mostly by processing hydrates grading 6-10% cobalt at Zaire's two hydrometallurgical plants at Luilu and Shituru. The prioritization of cobalt production over that of copper has allowed the reallocation of resources towards cobalt production. With cobalt hydrate material at Luilu exhausted by December 1995, Gécamines, the state-owned mining company, started operations at two new mines: the Kamoya mine, which has 2 Mt of ore grading 3% copper and 1% cobalt, and the high-grade Kasombo open-pit mine. Production in excess of 1000 t/y was expected at the latter following a joint investment from Union Minière and Gécamines early in 1996. Gécamines also planned to produce from the Kov and Kamoto mines, and from hydrates at Shinkolobwe.

The year 1996 was a turning point in Zaire's recent history. Gécamines entered into a number of joint-venture agreements with international mining companies to finance the development of new production capacity, effectively starting a partial privatization of its assets. In November the state-owned company granted a 55% interest in the Tenke and Fungurume concessions to Consolidated Eurocan Ventures (Eurocan), a Vancouver-based company. These concessions located about 175 km northwest of Lubumbashi, the Shaba Province capital, host two copper-cobalt deposits estimated to contain proven open-pit mineable reserves of 92.6 Mt grading 4.59% copper and 0.36% cobalt included in a larger resource estimate. A full feasibility study is expected to be completed by mid-1998, and production is to start in 2002 at a rate of 8000 t/y of cobalt through the leaching of oxide ores.

Also located in the Shaba Province, Vancouver-based International Panorama Resources Corp. signed a 51%-49% agreement with Gécamines for the development of the Kambove/Kakanda tailings project. Its total tailings reserves are estimated to exceed 61 Mt grading 0.98% copper and 0.19% cobalt. Plans are to start building a US\$190 million solvent extraction and electrowinning treatment facility in May 1997, and for production to start by the end of 1998. At a 5-Mt/y throughput rate and a 70% cobalt recovery rate, the plant could produce 6650 t/y of cobalt.

Finally, Gécamines asked for tenders to reprocess copper-cobalt-rich tailings located at Kolwezi, west of Lubumbashi. Reserves estimated at 107 Mt grading 1.34% copper and 0.26% cobalt could be treated similarly to Zambia's Colossal project. A decision is expected early in 1997 that could result in new cobalt production capacity of 5000 t/y.

## Zambia

As a result of the increased availability of high-grade ore from the Nchanga Division following the development of a new ore block at the end of 1995, the state-run Zambia Consolidated Copper Mines (ZCCM) produced 4799 t of cobalt during 1996, an increase of 64% over last year. This was just short of the recent high of 4844 t reached in 1990.

Zambia's production had been decreasing in the past few years because of a lack of capital to operate the plants properly, upgrade its operations, or develop ore deposits for production. Production is expected to remain at about 5000 t/y in the short term, but in order to stabilize production at that level, ZCCM needs a large influx of capital that would only be granted to it if the company is privatized. An example of this is the US\$600 million cost to develop the Konkola Deep deposit containing reserves of 340 Mt grading 3.8% copper and 0.07% cobalt, which is scheduled to replace the Nchanga operation when reserves at that location are exhausted at the turn of the century. Instead of waiting for the privatization to be finalized, ZCCM has awarded a development option to a consortium led by Anglo American Corp. of South Africa Ltd., which also includes Gencor Ltd. and Falconbridge Ltd., that is about to start a feasibility study on the project.

ZCCM also awarded an option to Anglovaal Ltd. to explore the Konkola North project that borders the producing Konkola mine to the north. Anglovaal Ltd. has committed to undertake a minimum of 50 000 m of drilling and to complete a pre-feasibility study within two years. If positive, a feasibility study would follow within another two years.

Since the Zambia Privatisation Agency was established in 1992, more than half of the earmarked state-owned companies have been privatized. The privatization of ZCCM that began in 1995 is now expected to be done in two stages. The first stage, due for completion in the second half of 1997, will correspond to the sale of an 80% share of ZCCM's assets in four groupings: (1) the Konkola mine with the mufulira concentrator, smelter and refinery; (2) the Nchanga mines, tailings leach plant and concentrator, together with the Nkana mines, concentrator, smelter and cobalt plant; (3) the Baluba and Luanshya mines and concentrator, plus the inactive Luanshya smelter, Ndola copper refinery and Chambishi cobalt plant; and (4) ZCCM's electricity generation and distribution assets. The second stage, which corresponds to the sale of the remaining 20% share of

ZCCM units, will be sold to the Zambian public by the first half of 1998.

Colossal Resources Corp. (Colossal) and Quasim Mining Enterprises Ltd. commissioned their first two 15-t electric arc furnaces on August 31 and September 28, 1996, at their Kabwe facility. The 60%-40% joint venture is recovering cobalt by processing slag by primary and reduction melting to produce a cobalt-rich cobalt-copper-iron granulated alloy suitable for processing to higher value-added cobalt products. The partners have an agreement with ZCCM for the processing of 8.6 Mt of slags from the Nkana dumps that grade between 0.70% and 0.82% cobalt. The slags will be railed 100 km to the Kabwe facilities where the electric furnaces will convert the cobalt-rich material to ferro-cobalt grading 60-65% cobalt. As a mid-term project, Colossal acquired a pilot hydrometallurgical processing facility, which it installed in Johannesburg, South Africa, where it plans to produce commercial-grade cobalt chemicals.

With the installation in November of an induction furnace for setting and granulating the cobalt-rich alloy, and the installation in December of an additional 10-t electric furnace, the companies were expecting to produce about 500 t in 1996. Plans are for production to increase to 1200 t/y in the second year of operation and to gradually expand to reach 3000 t/y in the fourth year of operation. Its reserves would give the project a 15- to 19-year mine life.

Also of interest in Zambia, Caledonia Mining Corp. outlined inferred resources of 295.5 Mt grading 0.029% cobalt on its Nama project located 10 km west of the Konkola mine on the northern boundary of the

Zambian copper belt. On the Kadola property, located 40 km south of Luanshya, inferred resources stand at 74 Mt grading 0.51% copper and 0.017% cobalt. These resources are suitable to open-pit mining and treating by heap leaching. Preliminary leach tests on a composite sample gave recoveries of 83% for cobalt and 50% for copper.

## Zimbabwe

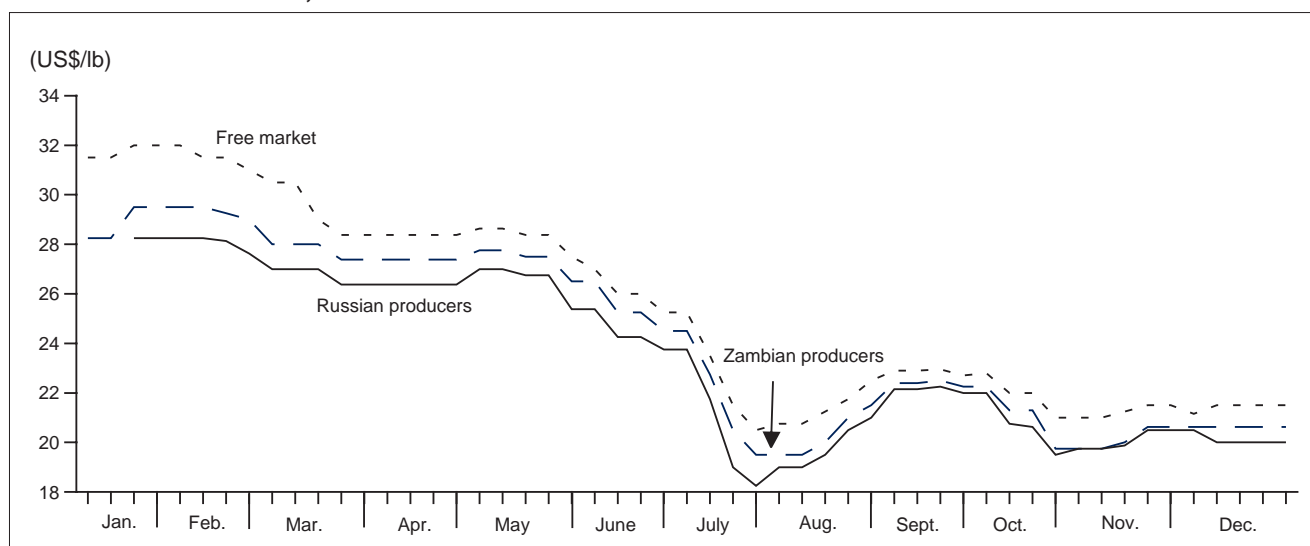
Commissioning of the Hartley Platinum operation located 80 km southwest of Harare started in mid-April 1996. Owned 67% by Broken Hill Pty Co. Ltd. and 33% by Delta Gold NL, the mine is expected to produce 35 t/y of cobalt as a by-product.

## PRICES

In 1996, the cobalt market was somewhat unstable. At the start of the year, in response to a perceived tightness in supplies of high-purity cathode used by the superalloy industry, prices remained high. However, with improving production levels from all of the industry's traditional suppliers, prices started retreating in February despite strong demand from the booming North American, European and some Asian economies.

The free market price for cobalt cathode started the year in the range of US\$31.00-\$33.00/lb, an historic high. However, in response to consumer perception that the market was well supplied, prices decreased steadily to reach a low of US\$20.50/lb at the end of July. They then firmed up to just under US\$23.00/lb in September following sizeable purchases from

**Figure 2**  
Cobalt Price Variations, 1996



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

China and news of unreliable supply from Russia, before retrenching to US\$21.50/lb where they stabilized for the rest of the year (Figure 2).

The African producer reference price, fixed at US\$27.50/lb in mid-February 1995, remained unchanged for the whole of 1996. However, both producers were said to be selling at prices following the market, noting that the reference price is not a selling price.

The price for Russian material followed the price of higher-grade Western-origin material throughout the year, although the price difference between the two diminished gradually. In response to a greater availability of higher-grade material, the price difference between the two decreased from a high of about US\$3.50/lb in early 1996 to a range of US\$0.70-\$1.25/lb. Russian material started the year at around US\$28.00/lb, fell to a low of US\$18.25/lb at the end of July, recovered in September to peak at US\$22.25/lb, and finished the year at US\$20.00/lb where it stabilized.

Improved output from major producers, new capacity coming on stream during the year and before 2000, and increased sales from the U.S. DLA stockpile will keep the market oversupplied for the short term. However, increased demand from the aerospace and battery industries, and a greater usage brought about by a more stable marketplace and lower prices, will gradually bring a balance back to the market. Prices will remain volatile in 1997, dropping further and settling back in the US\$15.00-\$20.00/lb range by the end of the year as the market finds its new balance.

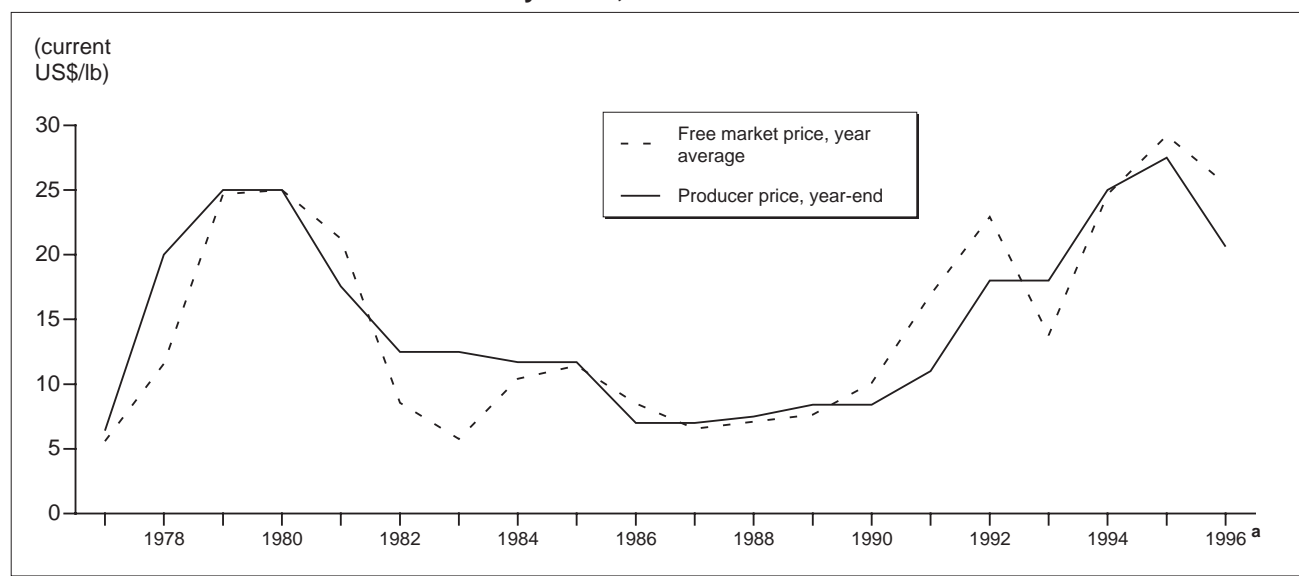
## OUTLOOK

In Canada, production of refined cobalt in 1997 is expected to increase by 26% to 4181 t. Inco is forecasting higher production of about 1650 t of cobalt as electro and oxide through increased nickel production. Falconbridge's world cobalt production is also expected to increase to about 3550 t following the expansion of its Nikelverk facility and the start-up of its Raglan project, while production at Corefco (Sherritt) should be about 2350 t, a 13% increase over 1996. Ego, through its wholly owned subsidiary Cobatec, should produce about 180 t of cobalt contained in carbonate compounds for its first full year of production. Following increases in nickel production through capacity utilization increases at Canada's principal producers and the start-up of the Raglan and Voisey's Bay mines, the country's production of refined cobalt is expected to rise to about 7400 t/y by the year 2000.

World production of refined cobalt is projected to reach 30 280 t in 1997, an increase of about 12.8% compared to 1996. This production increase, coupled with higher sales from the U.S. DLA, will result in cobalt availability reaching a new high.

The world's consumption of cobalt is expected to increase as the global economy experiences a period of moderate growth. The superalloy sector, which typically uses 26% of cobalt production, is expected to significantly increase its consumption as the commercial segment of the aircraft industry recovers and

**Figure 3**  
Cobalt Price Variations in the Past Twenty Years, 1977-96



Source: *Metals Week*.

<sup>a</sup> Producer price discarded in 1996. Zaire and Zambian prices were pegged to the market.

major airlines replace their ageing fleets of 747s. Increases in orders that started materializing in the second half of 1995 continued in 1996, specifically in the Asian market where domestic airlines are expanding. A major upturn in construction starts was experienced in 1996 with Boeing Co. planning to return, by the last quarter of 1997, to a production high last reached in September 1992. These new orders will start being delivered by 1998. Also, the demand for alloys for industrial gas turbines used in power generation and marine transport will remain strong with a 2-4% growth per year. Consumption in the chemical sector, the second most important segment of the market, has improved significantly of late and is also expected to grow substantially. This will be led by consumption in the rechargeable battery industry used for consumer electronics products, which is expected to increase from 700 t in 1996 to a 3000-4000-t/y range by the year 2000. Consumption in the magnet segment has declined slightly in recent years, but is slated for slow growth in the next few years. Consumption in the cemented carbides and hard-facing tool steel segments of the cobalt market increased in 1996 and is expected to grow at an average rate of 2% per year until 2000. Expanding international supplies of cobalt

and the resulting drop in prices are expected to fuel the growth of the cobalt industry and to cause more stability in the marketplace.

In the longer term, the use of cobalt in the chemical industry should expand with the growth of the battery industry, and 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 a tightening of air emission regulations.

In 1997, the increase in production is expected to outpace the increase in consumption, which will result in an oversupplied market, although there may be a certain tightness in supply for certain grades of cobalt during the year. This will cause prices to further decrease during 1997 until the market re-balances itself.

*Notes: (1) For definitions and valuation of mineral production, shipments and trade, please refer to Chapter 70. (2) Information in this review was current as of January 31, 1997.*

## TARIFFS

Item No.	Description	MFN	Canada	USA	United States
			GPT		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	Free	Free	Free	Free
2827.34	Cobalt chloride	4%	3%	Free	Free
2833.29.00.40	Cobalt sulphate	1.5%	Free	Free	Free
2836.99.90.20	Cobalt carbonates	3.5%	3%	Free	Free
2915.23	Cobalt acetates	10.4%	6%	Free	Free
8105.10.10	Cobalt mattes and other intermediate products; unwrought cobalt, alloyed; waste and scrap; powders, alloyed	4%	2%	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	4%	Free	Free	Free
8105.90.90	Cobalt and articles thereof, n.e.s.	4%	2%	Free	Free

Sources: Customs Tariff, effective January 1997, Revenue Canada; Harmonized Tariff Schedule of the United States, 1997. n.e.s. Not elsewhere specified.

**TABLE 1. CANADA, COBALT PRODUCTION AND TRADE, 1995 AND 1996, AND CONSUMPTION, 1993-95**

Item No.	1995		1996p		
	(kilograms)	(\$000)	(kilograms)	(\$000)	
<b>PRODUCTION<sup>1,2</sup> (all forms)</b>					
Ontario	1 602 127	140 516	1 894 145	145 628	
Manitoba	414 357	36 405	373 080	28 709	
Total	2 016 484	176 921	2 267 225	174 337	
<b>EXPORTS</b>					
2605.00	Cobalt ores and concentrates	-	-	-	
2822.00	Cobalt oxides and hydroxides; commercial cobalt oxides				
	United Kingdom	-	631 836	25 470	
	Total	-	631 836	25 470	
2915.23	Cobalt acetates	-	-	-	
8105.10	Cobalt, unwrought, matte and other intermediate products, waste, scrap and powders				
	Norway	1 242 743	94 928	1 388 591	113 154
	United States	1 064 068 <sup>f</sup>	84 672 <sup>f</sup>	979 211	74 673
	Japan	642 982 <sup>f</sup>	41 879 <sup>f</sup>	805 597	69 420
	Netherlands	330 707	30 027	509 529	39 693
	Singapore	213 801	14 107	206 176	16 959
	Belgium	160 050	12 894	241 986	16 390
	Other countries	330 215	26 911	200 190	13 771
	Total	3 984 566 <sup>f</sup>	305 418 <sup>f</sup>	4 331 280	344 060
8105.90	Cobalt and articles thereof, n.e.s.				
	Japan	141 183	10 446	59 344	5 541
	Netherlands	10 250	635	47 000	4 537
	Germany	9 345	1 424	8 753	1 510
	Singapore	13 000	1 066	15 000	1 464
	United States	14 669	1 418	7 972	1 148
	Other countries	54 213	1 638	7 186	753
	Total	242 660	16 627	145 255	14 953
<b>IMPORTS</b>					
2605.00	Cobalt ores and concentrates				
	United States	12 878	130	14 842	594
	Other countries	-	-	13 194	638
	Total	12 878	130	28 036	1 232
2822.00.10	Cobalt hydroxides				
	United States	6 985	406	14 242	546
	Belgium	15 502	817	6 346	261
	Finland	2 259	61	-	-
	Total	24 746	1 284	20 588	807
2822.00.90.10	Cobalt oxides				
	United States	739	17	9 755	583
	Belgium	1 403	35	1 181	30
	Finland	724	18	928	23
	Other countries	7 973	199	-	-
	Total	10 839	269	11 864	636
2822.00.90.20	Commercial cobalt oxides				
	United States	4 969	419	25	1
	Italy	-	-	42	1
	Total	4 969	419	67	2
2827.34	Cobalt chlorides				
	United States	2 512	35	1 555	22
	Belgium	1 327	19	1 367	21
	Germany	591	8	-	-
	Total	4 430	62	2 922	43
2833.29.00.40	Cobalt sulphate				
	United States	70 219	710	50 443	711
	Russia	-	-	38 125	642
	South Africa	13 451	93	31 000	617
	Other countries	6 092	98	8 615	159
	Total	89 762	901	128 183	2 129

TABLE 1 (cont'd)

Item No.	1995		1996 <sup>p</sup>	
	(kilograms)	(\$000)	(kilograms)	(\$000)
<b>IMPORTS (cont'd)</b>				
2836.99.00.20	Cobalt carbonates			
	United States	66 022	1 453	–
	Other countries	17 468	703	–
	Total	83 490	2 156	–
2836.99.90.20	Cobalt carbonates			
	United States	–	–	41 247
	Russia	–	–	19 074
	Finland	–	–	998
	Total	–	–	61 319
2915.23	Cobalt acetates			
	United States	3 842	92	16 193
	United Kingdom	47	1	–
	Total	3 889	93	16 193
8105.10.10.10	Unwrought cobalt; powders; mattes and other intermediate products, alloyed			
	United States	53 810	2 783	40 195
	Other countries	4 219	347	945
	Total	58 029	3 130	41 140
8105.10.10.20	Cobalt waste and scrap			
	Zaire	–	–	81 400
	Norway	–	–	21 102
	United States	153 941	962	56 043
	Zambia	19 250	1 583	–
	Other countries	330 886	7 225	42 563
	Total	504 077	9 770	201 108
8105.10.20.10	Unwrought cobalt, not alloyed			
	Zaire	443 512	36 102	175 999
	Belgium	30 399	2 309	106 690
	United States	18 110	1 284	40 195
	Russia	31 370	2 583	30 849
	Norway	16 000	1 365	24 000
	Other countries	21 299	1 490	36 654
	Total	560 690	45 133	414 387
8105.10.20.20	Cobalt powders, not alloyed			
	Finland	5 100	426	69 700
	South Africa	11 609	947	51 722
	United States	31 556	2 279	9 849
	Other countries	15 314	1 159	10 830
	Total	63 579	4 811	142 101
8105.90.10	Cobalt bars and rods, not alloyed			
	United States	432	41	5 768
	Other countries	227	10	159
	Total	659	51	5 927
8105.90.90	Cobalt and articles thereof, n.e.s.			
	United States	54 667	6 375	50 370
	Japan	775	39	760
	Other countries	3 679	425	203
	Total	59 121	6 839	51 333
		<b>1993</b>	<b>1994</b>	<b>1995<sup>p</sup></b>
			(kilograms)	
<b>CONSUMPTION<sup>3</sup></b>				
Cobalt contained in:				
	Cobalt metal and metallic compounds	49 889	63 565	51 538
	Cobalt pigments, feed and ground coat frit	6 751	7 323	7 426
	Cobalt salts and driers and other uses <sup>4</sup>	130 258	121 730	89 367
	Total	186 898	192 618	148 331

Sources: Natural Resources Canada; Statistics Canada.

– Nil; . . Not available; n.e.s. Not elsewhere specified; <sup>p</sup> Preliminary; <sup>r</sup> Revised.<sup>1</sup> Production includes recoverable cobalt in concentrates shipped. <sup>2</sup> Revised production numbers for 1996 were made available as of January 31, 1997. <sup>3</sup> Available data as reported by consumers. <sup>4</sup> 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 1980-96**

	Production <sup>1</sup>	Exports		Imports		Consumption <sup>4</sup>
		Cobalt Metal	Cobalt Oxides and Hydroxides	Cobalt Ores <sup>2</sup>	Cobalt Oxides and Hydroxides <sup>3</sup>	
(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	3 262	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	394	—	52	187
1994	1 846	3 922	204	—	81	193
1995	2 016	4 227 <sup>r</sup>	—	—	41	148
1996 <sup>p</sup>	2 267 <sup>a</sup>	4 477	632	—	33	..

Sources: Natural Resources Canada; Statistics Canada.

— Nil; .. Not available; <sup>p</sup> Preliminary; <sup>r</sup> Revised.<sup>a</sup> Revised production numbers for 1996 were made available as of January 31, 1997.<sup>1</sup> Production includes recoverable cobalt in concentrates shipped. <sup>2</sup> Cobalt content. <sup>3</sup> Gross weight.<sup>4</sup> Consumption of cobalt in metal, oxides and salts.**TABLE 3. WESTERN WORLD COBALT PRODUCTION, 1993-96**

	1993	1994	1995	1996
(tonnes)				
Falconbridge	2 414	2 823	2 804	3 099
Gécamines	2 200	3 300	4 146	6 110
Inco	1 410	1 130	1 362	1 544
OMG	2 200	3 000	3 610	4 160
ICCI	1 218	1 820	1 730	2 070
Sumitomo	190	161	222	228
ZCCM	4 211	2 639	2 934	4 799
Total	13 843	14 873	16 808	22 010

Source: Cobalt Development Institute.