NICKEL

By Peter H. Kuck

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Producers continued to commission new mines and add capacity because of optimistic forecasts for long-term growth in demand for stainless steel and nickel-based batteries. More than 280,000 metric tons (t) of capacity (on a contained nickel basis) were scheduled to come on-stream between 2001 and 2007. In Western Australia, three new laterite mines were commissioned between 1998 and 2000, and at least three others were in various stages of development (Western Australian Department of Resources Development, 1999, p. 3-18; Griffiths, 2000). The three new laterite mines were refining the nickel on-site. However, two new sulfide mines in Western Australia were shipping concentrates or matte to Outokumpu Oyj's recently expanded smelting and refining complex in Finland. In addition to the expansion in Australia, new mining projects were at various stages of development in Brazil, Canada, Indonesia, New Caledonia, the Philippines, and Venezuela. Exports of primary nickel from Russia were up about 6% from 1999 levels. Russian exports exceeded demand inside the country by more than 9 to 1. Russian consumption of nickel has been severely depressed for the past 4 years largely because the former Soviet stainless steel industry has had problems shifting to a market-economy mode.

Stainless steel accounted for more than 60% of nickel consumption in the world. In the United States, however, this percentage was considerably lower and was closer to 40% because of the relatively large number of specialty metal industries in the country. Specialty uses included superalloys and other aerospace alloys, high-temperature nickel-chromium alloys, electrolytic plating, electroless plating, cupronickel alloys, and naval brasses.

Nickel in excess of 8% is needed to produce the austenitic structure in 300-series stainless steels. The nickel content of some austenitic grades can be as high as 22%. Duplex (ferritic-austenitic) steels generally contain only 2.5% to 5.0% nickel (Ni). Sometimes, smaller amounts of nickel (0.2% to 3.8%) are incorporated into low alloy steels to improve their resistance to atmospheric corrosion.

Legislation and Government Programs

Decontamination of Radioactive Nickel Metal.—For more than a decade, the U.S. Department of Energy (DOE) has been exploring ways of reusing nickel metal scrap contaminated with trace amounts of natural and manmade radioactive isotopes. DOE has some 6,000 t of volumetrically contaminated nickel stored at the East Tennessee Technology Park in Oak Ridge, TN. "Volumetrically contaminated" describes metal that has radioactive contamination dispersed throughout the mass of the

Nickel in the 20th Century

In 1900, refineries in New Jersey and New York recovered a total of 4 metric tons of nickel from byproduct matte produced at the Mine Lamotte lead smelter in Missouri. The bulk of U.S. nickel consumption, however, was met by cobalt-copper-nickel matte imported from Canada and processed into nickel oxide or metallic nickel at Bayonne and Camden, NJ. The nickel smelter at Sudbury, Ontario, shipped 23,287 tons of ore and matte, containing about 3,100 tons of nickel, to the United States in 1900. France and the German Empire were Canada's biggest competitors for nickel production between 1890 and 1905. Both European producers were heavily dependent on matte and ore from New Caledonia, where nickel laterite mining had begun in 1875. The most important use was the manufacture of nickel steel, a family of alloy steels containing 3% to 25% nickel. By 1900, nickel steel was being fabricated into armor plate, gun turrets, propeller shafts, crank shafts, and a variety of other parts for naval vessels. Shipbuilders also found that nickel-bronzes and nickel-brasses were relatively resistant to saltwater corrosion and made good vessel parts. Other important end uses were coins, cutlery, and plating. Most of the cutlery was being fabricated from German silver, a family of copper-zinc-nickel alloys.

Nickel had been a strategic and critical material in every major conflict fought by the United States since 1900, with the U.S. Government having to allocate or ration the metal in almost every instance. World War I caused world production of nickel steel to soar. The development of stainless steel between 1905 and 1912 further accelerated demand for nickel. Nickel had become a vital aerospace material. The discovery of nickel-base superalloys during the 1930s permitted the development of jet aircraft engines and rocket engines during World War II. In the 1980s, soaring sales of mobile telephones, the invention of the laptop computer, and a resurgence of interest in electric vehicles led to the development of the nickel-metal hydride battery. In 2000, Russia, Canada, and Australia were the largest nickel-mining countries. The United States had never been a major source of nickel ore. Japan was the largest nickel-consuming country in the world, followed by the United States and Germany. The United States used 60,300 tons of primary nickel, or about 39% of the 156,000 tons imported, to produce a variety of stainless and alloy steels. Production of superalloys and various nickel-base alloys accounted for another 36% of primary nickel. The remaining 25% was divided largely between batteries, catalysts, coinage, and plating.

metal, as opposed to a surface coating of contamination. The principal contaminants in the Oak Ridge nickel are reportedly technetium-99 (a beta emitter with a half-life of 211,000 years) and uranium-235. The nickel is a vestige of the U.S. Government's nuclear weapons programs.

In 1996, DOE awarded a contract to British Nuclear Fuels Ltd. (BNFL) to clean up a defunct gaseous diffusion plant at the Oak Ridge site in the technology park. As part of the contract, BNFL was to decontaminate nickel metal used in the plant operations so that it could be commercially recycled. The DOE plan, however, ran into opposition from several industry and community groups. The American Iron and Steel Institute (AISI), other members of the Metals Industry Recycling Coalition, and the Nickel Development Institute (NiDI) all opposed the release of any decontaminated scrap into the marketplace. On December 21, 1999, NiDI presented a 15-page brief to the U.S. Nuclear Regulatory Commission (NRC) opposing the entry of any "low-level" radioactive nickel scrap into the commercial recycling stream (Nickel Development Institute, 1999a, b). On January 6, 2000, the Specialty Steel Industry of North America issued a similar statement opposing the DOE plan and reaffirming its "zero tolerance" policy toward potentially radioactive scrap metals (Nuclear News, 2000). Because of the strong opposition from the metals industry, the U.S. Secretary of Energy decided on January 12 to prohibit the release of decontaminated nickel scrap into the marketplace until national treatment standards could be developed (U.S. Department of Energy, 2000; Washington Post, 2000). The prohibition also applied to at least 10,000 t of nickel-bearing scrap stored at other DOE facilities (Nuclear News, 2000; U.S. Department of Energy, 2000).

The NRC has begun developing national treatment standards for all volumetrically contaminated materials, including the DOE nickel. Public hearings were held to give concerned citizens an opportunity to participate in developing the new standards.

National Toxicology Program.—The U.S. Department of Health and Human Services was evaluating evidence on the toxicity and carcinogenicity of nickel metal and its alloys. The scientific review was being carried out as part of the National Toxicology Program (NTP). The NTP is funded by the National Institute of Environmental Health Sciences under various Congressional mandates.

From December 13 to 15, 2000, the NTP Board of Scientific Counselors met in Washington, DC, to review the evidence on nickel and seven other nominations. The Board was composed of scientists from the public and private sectors and had been providing primary scientific oversight to the NTP Executive Committee. J&L Specialty Steel Inc., the Specialty Steel Industry of North America, Inco US Inc., the Nickel Producers Environmental Research Association (NiPERA), and the U.S. Food and Drug Administration all made presentations to the Board. The NiPERA representative pointed out that two alloys with the same nickel content can have completely different nickel release rates and, thus, different levels of carcinogenicity. After the presentations, the Board voted to include metallic nickel in the 10th Edition of the Report on Carcinogens. The Board recommended that metallic nickel be treated in the future as a "reasonably anticipated carcinogen." However, the Board voted not to list nickel alloys without more conclusive research and test data.

Environmental Programs.—The Portable Rechargeable Battery Association, a nonprofit trade association comprised of about 90 manufacturers, distributors, assemblers, users, and sellers of small rechargeable batteries, continued to expand its nationwide battery collection and recycling system. The nonprofit, public service recycling program was being administered by Rechargeable Battery Recycling Corp. (RBRC) of Atlanta, GA. The RBRC was supported by more than 285 manufacturer/marketer licensees and a network of 26,000 collection locations across the United States and Canada. The program was made possible by the passage of "The Mercury-Containing and Rechargeable Battery Management Act" (Public Law 104-142) in 1996. The bulk of the spent nickel-cadmium (NiCd) and nickel-metal hydride (NiMH) batteries was being shipped to a pyrometallurgical reclamation facility at Ellwood City, PA. The facility was operated by the International Metals Reclamation Co. Inc. (Inmetco), a subsidiary of Inco Ltd.

New Coinage.—The European Union (EU) and the United States were in the process of issuing new coinage. The two Governments, however, have taken different positions with respect to nickel. The EU has limited nickel in its new coinage to minimize the potential risk of hypersensitive members of the public contracting nickel dermatitis. The U.S. Mint continued to use the cupronickel cladding previously in circulation and apparently has received few complaints about the cladding causing nickel dermatitis.

Commemorative Quarters.—The U.S. Mint produced 6.47 billion quarters (25-cent coins) in 2000, up from 4.43 billion in 1999. The cupronickel-cladded coins were part of the popular 50 State Quarters^{TM} Program launched in December 1998. Between 40 and 60 billion quarters will have been minted when the program ends in 2008. Each State was being honored with its own coin showing George Washington on the obverse (front) and a unique statehood design on the reverse. The five States honored in 2000 were Massachusetts, Maryland, South Carolina, New Hampshire, and Virginia (in order of minting). Since each coin weighs 5.67 grams and contains 8.33% Ni, the total quantity of nickel ending up in the five commemoratives released in 2000 was about 3,060 t.

The U.S. Mint also began releasing the new Golden Dollar coin in March. The dollar coin has an overall composition of 88.5% copper (Cu), 6.0% zinc, 3.5% manganese, and 2.0% Ni.

Euro Coinage.—The European Monetary Union (EMU) was scheduled to have its new euro coinage in circulation by January 1, 2002. After July 1, 2002, coins of the individual member States would no longer be legal tender and were to be scrapped. Because of health considerations, the EMU was using a nickel-free alloy called Nordic Gold for the 10-, 20-, and 50-eurocent pieces and copper-covered steel for the 1-, 2-, and 5-eurocent pieces (Outokumpu Oyj, 1998b). Only the 1- and 2-euro coins contained nickel (Outokumpu Oyj, 1998a). EuroCoin AG, a group of companies within Vereinigte Deutsche Nickel-Werke AG, was one of several contractors making blanks for the German mint. Since 1998, the participating mints have built up huge stockpiles of the new coins at undisclosed locations throughout the EU in anticipation of the 2002 exchange period. The old national coins—many of which contain significant nickel—will be defaced and stockpiled until they can be melted down by contractors into remelt alloys.

National Defense Stockpile.—On June 10, 1999, the U.S. Government sold the last of the nickel in the National Defense Stockpile.

Production

Primary Production.—The United States did not produce any primary nickel in 2000. The Glenbrook Nickel Co. was in the process of decommissioning its mining and smelting complex at Riddle, OR. All of the electric arc furnaces have been dismantled and scrapped. The calciner has been moved to another location and will not be used for ferronickel production. Glenbrook, a subsidiary of Teck Cominco Ltd., permanently closed the smelter in March 1998 after the world ferronickel price fell below $6,000 per metric ton ($2.72 per pound) of contained nickel. The recent startup of a greenfield ferronickel operation in Venezuela and the expansion of existing capacity in Colombia, Indonesia, and New Caledonia have discouraged potential ferronickel producers from building facilities elsewhere in the Western United States.

Secondary Production.—Inmetco continued to produce nickel-chromium-iron remelt alloy at its metals recovery facility in Ellwood City, PA. The facility was set up in 1978 to reclaim chromium and nickel from wastes generated by the stainless steel industry. Because of subsequent improvements to the facility, Inmetco can accept a broad spectrum of other recyclable nickel- and/or chromium-bearing wastes, including filter cakes, plating solutions and sludges, catalysts, refractory brick, and spent batteries (Barozzi, 1997).

Inmetco is the only facility in North America that can thermally recover cadmium from NiCd batteries. The cadmium circuit employs a technology that the U.S. Environmental Protection Agency (EPA) has determined to be the best demonstrated available technology for cadmium reclamation. The RBRC program has been encouraging consumers to return their spent NiCd and NiMH batteries to commercial outlets where they are stockpiled and eventually shipped to Ellwood City. The small rechargeable cells are used in a variety of devices, including cellular telephones, transceivers, portable power tools and appliances, medical equipment, and emergency lighting systems. Inmetco also reclaims large industrial cells that are used by railroads, electric utilities, the military, and telecommunication companies for backup power. An estimated 1,600 t of NiCd batteries were collected in the United States and Canada in 2000. Although the tonnage of nickel-based batteries being recycled has increased dramatically since 1996, a significant number still end up in landfills. The RBRC is hoping that future improvements in its program will significantly reduce the tonnage being landfilled.

Byproduct Production.—Limited quantities of nickel were recovered at some copper and precious-metals refineries and at a few plants that reclaim spent catalysts.

The Stillwater Mining Co. has been mining platinum-group metals (PGM) and gold since 1986 from the Stillwater Complex at Nye in Montana's Beartooth Mountains. The ore is associated with the 45-kilometer (km) long J-M Reef. Concentrates from the Stillwater Mine were being trucked to the company's smelting and refining complex at Columbus, MT, where a filter cake containing approximately 60% palladium and platinum was being produced. In 2000, the refinery also produced a byproduct nickel-cobalt solution, which was trucked to Canada where the two metals were recovered. Other byproducts were copper, rhodium, selenium, silver, and tellurium (Stillwater Mining Co., 2001a, p. 18-21; b, p. 3-10).

Stillwater was in the process of expanding the Columbus smelter and has begun construction of a centralized concentrate sampling and drying facility. A second top blown rotary converter was scheduled to come on-stream in late 2001. The expansion was needed to accommodate concentrates from the new East Boulder Mine under development in the western half of the J-M Reef. Several improvements also were made to the refinery in 2000. Copper, selenium, and tellurium are now being recovered on-site by pressure leaching. After removal of the selenium and tellurium, the copper-rich solution is fed to an electrowinning circuit. A nickel sulfate crystallizer circuit, still in the final stage of construction at yearend, became operational in mid-2001. The new crystallizer circuit allows the company to ship its nickel sulfate byproduct as a solid rather than a liquid, minimizing environmental risks and reducing shipping costs.

The Nye mill processed a total of 686,000 t of ore in 2000, with a mill head grade of 20 grams per ton (g/t) of palladium plus platinum. All of the ore came from the Stillwater Mine at the eastern end of the reef. Development of the East Boulder Mine near Big Timber has been underway since mid-1998. The first of two tunnel boring machines intersected the J-M Reef on June 25, 2000. The second boring machine reached the reef on August 24. The East Boulder Mine was scheduled to begin production in 2002 (Stillwater Mining Co., 2001a, p. 2-17).

Spent catalysts are another U.S. source of byproduct nickel. In early 2000, CS Metals of Louisiana, LLC commissioned a spent catalyst reclamation facility on the Mississippi River at Convent, LA. The plant was designed to recover vanadium oxide and molybdenum oxide from spent catalysts used in oil refining and petrochemical operations. The facility also produces a nickel-cobalt byproduct. CS Metals is a joint venture of Strategic Minerals Corp. (Danbury, CT) and CRI International Inc. (Houston, TX), a wholly owned member of the Royal Dutch/Shell Group of companies. The fully permitted plant is in the Baton Rouge/New Orleans refining corridor and uses a patented hydrometallurgical process that produces no solid waste (Strategic Minerals Corp., 1999).

Gulf Chemical and Metallurgical Corp. of Freeport, TX, also processes spent catalysts. The Freeport facility can treat nickel/molybdenum and cobalt/molybdenum hydrotreating catalysts with or without vanadium present. The principal products are oxides of molybdenum and vanadium, fused alumina, and a crude nickel-cobalt alloy byproduct. The nickel-cobalt alloy is produced in an electric furnace and available for sale to nickel refineries. Several of the metals recovered from the spent catalysts are used to manufacture fresh hydrotreating catalyst.

Encycle/Texas, Inc. of Corpus Christi, TX, and U.S. Filter Recovery Services, Inc. of Roseville, MN, have been recovering limited amounts of nickel from electronic scrap and electroplating sludge. Encycle, a wholly owned subsidiary of ASARCO Inc., is now using an innovative electrowinning process to fully reclaim metals from wastes brought to the facility. U.S. Filter recently launched an EPA-approved pilot program that uses ion exchange resins to treat waste waters at electroplating operations.

Consumption

In 2000, demand for primary nickel in the Western World was estimated to have reached an alltime high of 1,029,000 t, surpassing the previous record of 1,004,000 t (revised) set in

1999 (International Nickel Study Group, 2001b, p. 3-17). U.S. apparent consumption of primary nickel was 147,000 t, or about 14% of Western demand. U.S. industry consumed an additional 84,000 t of nickel in scrap. Within the United States, the share of primary nickel consumed in the production of stainless and alloy steels fell from 44% in 1999 to 39% in 2000. The drop was attributed to higher prices for primary nickel, the increased availability of scrap, and increased demand for superalloys and other nickel-base alloys. The estimated value of apparent primary consumption in the United States in 2000 was $1.27 billion. Even though consumption declined slightly due to increased prices for primary nickel, the $1.27 billion figure was 51% higher than that of 1999.

Stainless Steel and Low-Alloy Steels.—In 2000, the United States and world demand for nickel continued to be driven by the stainless steel industry. Stainless steel producers accounted for 33% of primary nickel demand in the United States and more than 60% of primary demand in the world. The percentage for the United States was lower because its stainless steel producers operated with higher scrap ratios than some of its foreign competitors.

Production of raw stainless steel in Western countries has doubled in the past 14 years, growing to 17.28 million metric tons (Mt) in 1999 from 7.92 Mt in 1985 (Inco Ltd., 2000f, p. 3-25). Utilization of stainless melt capacity in the Western World has climbed from an estimated 74% in 1996 to 87% in 2000. Because of the high utilization rate, additional melt capacity will have to be brought on-stream by 2005 to accommodate the projected growth in demand for stainless. Between 2002 and 2005, additional capacity is expected to start up in the EU, the Republic of Korea, Taiwan, and the United States. In the interim, reduced growth in demand in East Asia and other overseas markets since 1997 has encouraged foreign stainless steel producers to increase their exports to the United States. Total U.S. imports of stainless steel mill products have grown by 35% since 1996, but domestic production has risen by only 17%.

Production of raw stainless and heat-resisting steel in the United States totaled 2.19 Mt in 2000, almost the same tonnage as in 1999. The tonnage was the highest on record, even higher than that of 1974 when the EPA first required automobiles to have emission control systems. Nickel-bearing grades accounted for 1.24 Mt, or 56% of the total stainless production for 2000 (American Iron and Steel Institute, 2001b). Net shipments of all types of stainless totaled 1.93 Mt, an 11-year high (American Iron and Steel Institute, 2001a, p. 26-29). Shipments of sheets and strip increased 4% to 1.53 Mt, breaking the previous record of 1.47 Mt set in 1999. Shipments of plate, the next largest category, were 188,000 t, or 2% less than that of 1999. Although U.S. stainless steel production and net shipments were practically unchanged from 1999 levels, stainless steel imports increased 6% to 1.07 Mt.

North American Stainless, a subsidiary of Acerinox SA (Madrid, Spain), was building a melt shop at its steel rolling operations in Ghent, KY. The new melt shop was expected to be a major consumer of primary nickel and stainless steel scrap. The facility is designed to produce about 800,000 metric tons per year (t/yr) of hot metal and should be operational by yearend 2001.

Superalloys and Related Nickel-Base Alloys.—About 30% of the primary nickel consumed in the United States was used to make high-performance superalloys and related nickel-base alloys for the aerospace, electric power, and petrochemical industries. U.S. production of nickel-base alloys was up from 1999 because of a strengthening of sales to aircraft manufacturers and manufacturers of turbines for land-based powerplants.

Demand for superalloys is partially reflected in the production backlog and new orders for jet aircraft. Turbine blades, discs, and other critical parts of jet engines are fabricated from superalloys. In 2000, the U.S. aerospace industry earned $9.4 billion on sales of $144 billion—the second highest profits on record (Napier, 2000). Total sales were 4.9% less than those of 1999, when profits peaked at $10.2 billion. The U.S. Government accounted for only 46% of domestic aerospace products and services compared with 70% a decade ago (Napier, 2000). Boeing Co. and its McDonnell Douglas Corp. subsidiary increased their backlog of orders for civil jet transports. A total of 585 net orders for large civil jet transports was received in 2000, compared with 346 in 1999 (Aerospace Industries Association of America, Inc., 2001). Between 1999 and 2000, actual shipments decreased, falling from 620 aircrafts to 485. On December 31, 2000, Boeing had a backlog of 1,612 aircrafts, up from 1,512 at yearend 1999.

Mergers, Acquisitions, and Closures.—The specialty steel industry of the United States continued to restructure in the face of growing imports of stainless steel. U.S. superalloy producers, which have close ties to some of the specialty steel producers, also restructured. The principal force driving the mergers and acquisitions has been the financial synergies created by the integration of similar specialty metals operations.

On November 29, 1999, the management of Allegheny Teledyne Inc. completed its reconfiguration of the company. Only operating units involved in the production and marketing of specialty materials were retained. After the consumer-oriented units were spun off, Allegheny Teledyne changed its name to Allegheny Technologies Inc. The retained units had combined sales of $2.46 billion in 2000, up from $2.30 billion in 1999. The aerospace, automotive, and electrical energy markets accounted for 17%, 13%, and 12%, respectively, of sales. Allegheny Technologies also supplied advanced materials, nickel-based alloys, titanium alloys, and specialty steels to the oil and gas industry for use in drill holes, drilling rigs, and refining plants (Allegheny Technologies Inc., 2001, p. 1-15).

In November 1999, Allegheny Ludlum Corp., the company's specialty steel unit, offered Bethlehem Steel Corp. $20.5 million in cash for its closed stainless steel sheet and strip mill at Washington, PA. Bethlehem accepted and the sale was completed on December 22, 1999. Allegheny Ludlum announced that it would restart the plant's Sendzimir mills together with its annealing and pickling lines (Allegheny Technologies Inc., 1999a, b).

In June 2000, Slater Steel Inc. of Mississauga, Ontario, purchased two Canadian specialty steel operations from Atlas Steels Inc. for C$122 million in cash and the assumption of long-term debt of about C$16 million. The acquisition of Atlas Specialty Steels and Atlas Stainless Steels was finalized on August 1. Shortly afterward, Slater launched a long-term program designed to integrate its U.S. and Canadian specialty steel operations with those of the two former Atlas subsidiaries (Slater Steel Inc., 2000a, b, c). The newly consolidated company now owns and operates the following five minimills in North America:

(1) the Fort Wayne Specialty Alloys division in Indiana—a leading producer of stainless steel bar products and the only producer of stainless steel angle in North America;
(2) the Hamilton Specialty Bar division at Hamilton, Ontario—a producer of alloy steel bar and grinding balls which Slater owned prior to the acquisition;
(3) the Atlas Specialty Steels complex at Welland, Ontario;
(4) Atlas Stainless Steels—a stainless steel strip, sheet, and plate operation at Tracy, Quebec; and
(5) Sorel Forge Inc.—a producer of carbon, alloy and stainless steel forgings at Sorel, Quebec, which Slater owned prior to the acquisition.

On August 7, Slater announced that it would close its melt shop at Fort Wayne, IN, in early 2001. The closure would directly affect about 90 employees. Slater was planning to consolidate melting operations at its newly acquired facilities in Welland, Ontario. The Welland melt shop was newer and had significantly more capacity than the Fort Wayne shop. Modernizing the Fort Wayne melt shop would have cost an estimated $30 million (Slater Steel Inc., 2000c). Slater's management believed that the consolidation would make the company more competitive and help ward off growing imports of stainless steel into North America. (See Foreign Trade.)

Advanced Castings and Forgings Industry.—Nickel is used in a variety of brass, stainless steel, and superalloy castings. Nickel also is added to gray-iron castings to toughen the iron, promote graphitization, and improve machinability. The U.S. castings industry shipped an estimated 1.3 Mt of steel castings and 2.5 Mt of nonferrous castings in 1999. Iron castings were about 9.4 Mt. The U.S. foundry industry has consolidated dramatically over the past 40 years. The number of foundries in North America has declined from approximately 6,000 in the 1960s to 3,000 in 2000. Since 1985, Caterpillar Inc., Deere and Co., Gardner Denver Inc., General Electric Co., General Motors Corp. (GM), Siemens Westinghouse Power Corp., and several other major manufacturers of machinery or vehicles have closed one or more of their in-house foundries. In 1999, there were only 400 steel foundries and 700 iron foundries in the United States. At the same time, capacity utilization has increased from 45% to 85%. Cast components are becoming increasingly complex, especially those going to the aerospace and power generation sectors (Atchison Casting Corp., 2000, p. 6-8; Atchison Casting Corp., 2001 inside front cover and p. 1-18).

On June 20, Alcoa Inc. completed its acquisition of Howmet International Inc. Howmet is the largest manufacturer of investment cast turbine engine components in the world and a significant consumer of nickel. Many of the advanced superalloy castings produced by the company are incorporated into jet aircraft engines or industrial gas turbines (Alcoa, 2000c). Many of the nickel-base and other high-temperature alloys used as starting material are produced at the company's metallurgical complex in Dover, NJ. Alloy production from the Dover facility supports several casting plants in the United States, Europe, and Japan. Howmet's corporate headquarters are in Greenwich, CT. The purchase strengthened Alcoa's ties to the U.S. automotive industry and was expected to bring Alcoa closer to Airbus Industrie S.A.S. because of Howmet's business in both new-generation and after-market jet engine components. The purchase also provided Alcoa with an entry into the fast-growing industrial gas turbine market.

On April 18, Alcoa made a cash tender offer of $20 per share to Howmet shareholders after direct negotiations with Howmet's Board of Directors stalled. At that time, about 15.4 million shares of Howmet common stock were outstanding. On June 2, Alcoa raised its offer to $21 per share and ended up paying about $324 million for the stock (Alcoa Inc., 2000a). The Howmet acquisition came less than a month after Alcoa acquired Howmet's parent—Cordant Technologies, Inc. of Salt Lake City, UT. The acquisition of Cordant was completed on May 25 after Alcoa received clearance from antitrust authorities in the EU and the United States (Alcoa Inc., 2000b). Cordant owned 84.7% of Howmet's outstanding shares prior to the May transaction (Alcoa Inc. and Cordant Technologies, Inc., 2000).

On January 12, 2000, Precision Castparts Corp. (PCC) of Portland, OR, completed its acquisition of the Wyman-Gordon Co. The acquisition was made through a cash tender valued at $731 million (Precision Castparts Corp., 2000, p. 1-5, 25-28). The acquisition, which ended up costing $784 million, broadened PCC's capabilities in the aerospace industry and also gave the Oregon-based company a niche in the aluminum castings business. Wyman-Gordon is a leading producer of forgings for the aerospace, industrial gas turbine (IGT), and energy markets. PCC makes superalloy investment castings for the aerospace, power generation, and general industrial sectors. Many of these castings contain significant nickel. PCC also makes investment castings for automotive and medical applications. The acquisition offered considerable synergies, cost reduction, and manufacturing improvements. PCC now has a much stronger presence in the booming IGT market. For the time being, Wyman-Gordon will operate as a separate Precision Castparts business while maintaining its own forging business identity.

During the year, PCC also acquired Drop Dies & Forgings Co. of Cleveland, OH, and UEF Aerospace of Lincoln, England. Drop Dies & Forgings specializes in the production of high-quality forgings from difficult-to-forge metals, including aluminum, titanium, and high-temperature nickel superalloys. UEF Aerospace, a unit of the British automotive specialist United Engineering Forgings, Ltd., was made a division of Wyman-Gordon. UEF Aerospace (renamed Wyman-Gordon Lincoln Ltd.) produces forged engine discs, engine shafts, and airframe and landing gear components, primarily for British jet engine maker Rolls-Royce plc (Precision Castparts Corp., 2001, p. 1-3).

Nickel-Based Batteries.—U.S. demand for nickel in rechargeable batteries may now exceed U.S. demand for several other important end uses, such as copper-nickel alloys and coinage.

Battery Manufacturing.—Texaco Ovonic Battery Systems LLC (formerly GM Ovonic LLC) manufactures NiMH batteries for electric, hybrid electric, and fuel cell electric vehicles. The main plant is at Kettering, OH. Some key battery components, though, are produced in development facilities operated in Troy, MI, by Ovonic Battery, Inc.—one of Texaco Ovonic's parents. Ovonic Battery and GM formed the joint venture in 1994 to manufacture electric vehicle (EV) batteries using proprietary NiMH technology developed by Ovonic Battery. Prior to 2000, GM had a 60% interest in the joint venture; Ovonic Battery, 40%.

On May 1, 2000, Texaco Inc. purchased a 20% equity interest in Energy Conversion Devices, Inc. (ECD) of Troy, MI, for $67.4 million. ECD, in turn, has a 91.4% interest in Ovonic Battery. ECD is a leading developer of advanced energy technologies and is perhaps best known for its patents on the NiMH battery (Texaco Inc. and Energy Conversion Devices, Inc.; 2000 Energy Conversion Devices, Inc., 2001, p. 7-18). In early October, ECD, GM, and Texaco restructured GM Ovonic. Texaco took over GM's interests in the Kettering operation and is now an equal partner with Ovonic Battery. GM has since designated Texaco Ovonic as a preferred supplier for its NiMH battery requirements and is collaborating on a development program with the battery manufacturer. The sale of GM's interests to Texaco was completed on July17, 2001.

Texaco formed two other joint ventures with ECD in 2000 that were aimed at further developing and eventually commercializing fuel cells for automobile propulsion. (See Current Research and Technology.)

Electric and Hybrid Electric Vehicles.—Although EVs were being commercially manufactured in the EU, Japan, and the United States, production and sales were still limited. Fewer than 6% of the 2002-model automobiles and trucks arriving at U.S. dealerships were able to get more than 7.8 liters per 100 kilometers (L/100km) or about 30 miles per gallon (mpg). Of the 491 passenger car models evaluated in combined city and highway driving by the EPA in 2001, the average fuel economy was only 9.84 L/100km or 23.9 mpg. The best achievers were two hybrid gas- and electric-powered vehicles. The hybrids—the two-seat Honda Insight coupe and the five-seat Toyota Prius sedan—were rated at 3.7 L/100km (or 64 mpg) and 4.9 L/100km (or 48 mpg), respectively (Heilprin, 2001).

At yearend 2000, at least six EV models equipped with NiMH batteries were being sold or leased in the United States. A total of 1,270 battery electric light-duty passenger vehicles and trucks were reported leased or sold in 1999. A significant number of the 1,270 vehicles, especially trucks, used lead-acid batteries as a cost savings measure. The new Generation I NiMH battery made by Texaco Ovonic can store twice the energy of a conventional lead-acid battery for the same weight and volume. At yearend 2000, more than 4,000 EVs were on U.S. highways. Sales of hybrid electric vehicles (HEVs) were growing at a much faster rate—4,402 Honda Insight coupes and 8,052 Toyota Prius sedans were sold or leased between October 1999 and March 2001 (Electric Vehicle Association of the Americas, 2001).

On December 22, 1999, the United States Postal Service ordered 500 electric mail delivery vehicles from the Ford Motor Co. and its partner, Baker Electromotive, Inc., of Rome, NY. The postal service had an option to order 5,500 additional vehicles. The design of the delivery vehicle was based largely on Ford's Ranger EV. Production began in the fall of 2000 and was to continue through 2001 at the rate of 45 vehicles per month. The purchase will increase the Federal electric vehicle fleet by more than 400% (Ford Motor Co. and Baker Electromotive, 1999).

Stocks

On December 31, 2000, U.S. consumer stocks of primary nickel (cathode, pellets, briquets, powder, etc.) totaled 6,490 t—34% greater than the 4,850 t (revised) at yearend 1999. Stocks in London Metal Exchange (LME) warehouses worldwide, in contrast, plummeted 79% during 2000 to 9,678 t. LME stocks at yearend 1999 and 1998 were 46,962 t and 65,964 t, respectively. Data collected by the International Nickel Study Group indicated that, at yearend 2000, world nickel producers (excluding those in Austria, China, the former Yugoslavia, and the Ural area of Russia) had approximately 87,500 t of nickel in primary products in stock (International Nickel Study Group, 2001b, p. 10-11).

Prices

The monthly average cash price for 99.8% pure metal on the LME peaked in March at $10,280 per metric ton ($4.663 per pound) and then gradually declined throughout the rest of the year. (See figure 1.) By yearend, the monthly average price had fallen to $7,314 per ton ($3.318 per pound). The cash prices for January and February 2001 were even lower—$6,995 per ton ($3.173 per pound) and $6,524 per ton ($2.959 per pound), respectively. The weakening of prices was attributed primarily to the economic slowdown in the United States and parts of East Asia. The end of strikes at Canadian nickel mines, the ramping up of three new pressure-acid-leach complexes in Australia, and the startup of the Loma de Niquel ferronickel operation in Venezuela also helped to lower prices in the second half of 2000 by firming up Western World supplies. The supply increase was partially offset by a strengthening of demand for stainless steel in East Asia, which kept nickel prices from collapsing in the fourth quarter. Japanese production of austenitic stainless steel increased from 1.84 Mt gross weight in 1999 to 2.07 Mt in 2000, an increase of 12% (International Nickel Study Group, 2001b, p. 18). The East Asian recovery also led to increases in stainless steel production in the Republic of Korea and Taiwan (World Bureau of Metal Statistics, 2000, p. 8).

In 2000, the last weekly price (for the 4 days ending December 29) was $7,158 per ton ($3.247 per pound). The average annual price was $8,638 per ton ($3.918 per pound). The annual price was 44% higher than the 1999 average of $6,011 per ton ($2.727 per pound).

Foreign Trade

U.S. net import reliance as a percentage of apparent consumption was 56% in 2000—significantly less than the 63% for 1999 because of increased scrap usage. Imports accounted for 100% of primary supply. The United States imported 156,000 t of primary nickel in 2000, 12% more than the 139,000 t for 1999. Class I materials accounted for 86% of total primary imports received. Canada, as usual, supplied most of the primary imports. The second largest source was Russia, recapturing the position from Norway. RAO Norilsk Nickel has become an important source of nickel metal for the United States since the dissolution of the Soviet Union. Almost all of the Norwegian nickel was produced from foreign matte processed at Falconbridge Ltd.'s refinery in Kristiansand. Australia was in fourth place, with shipments from Murrin Murrin and the two other new pressure-acid leach plants near Kalgoorlie entering the United States for the first time. (See Australia.)

Prices for nickel-bearing scrap tracked those for primary nickel, decreasing almost continuously during the second half of 2000 because of the deteriorating economic outlook in the EU, the United States, and parts of East Asia. Increased exports of Russian scrap added to the downward pressure on primary and secondary prices. Most of the Russian scrap was consumed in the EU and did not enter the U.S. market. The EU imported 344,000 t (gross weight) of stainless steel scrap from Russia in 2000, the second highest tonnage in the past 5 years and 36% more than the 253,000 t in 1999 (International Nickel Study Group, 2001b, p. 64-65). U.S. exports of stainless steel scrap to the EU totaled 55,300 t (gross weight), up 59% from 1999 levels.

U.S. producers of specialty steels concerned about the country's continuing high level of specialty steel imports filed additional antidumping and countervailing duty petitions with the U.S. Department of Commerce and the U.S. International Trade Commission (ITC). In 2000, specialty steel imports reached a record 811,000 t (gross weight). Stainless steel accounted for 628,000 t, or 77% of the 811,000 t total. Electrical steel constituted 14%, and tool steel, 9% (Specialty Steel Industry of North America, 2001). Imports had slackened slightly in 1999 to 757,000 t because of the ongoing trade investigations, but began rising again in the first half of 2000, outpacing growth in U.S. consumption (Specialty Steel Industry of North America, 2000). Japan, the Republic of Korea, and Taiwan were cited in several of the U.S. producers' petitions. In 2000, total imports of all stainless steel long products (bar, rod and wire) captured 52% of the U.S. market.

On August 18, 2000, Slater Steels Corp. (the U.S. subsidiary of Slater) and the United Steelworkers of America filed an antidumping petition with the U.S. Government. The petition alleged that Japanese, South Korean, and Spanish producers were selling stainless steel angle in the United States at less than fair value. Stainless steel angle (a length of steel with a cross section resembling the letter L) is used to reinforce the interiors of stainless steel tanks commonly found in the food, dairy, and chemical processing industries. On September 28, the ITC determined preliminarily in a 6-0 vote that unfair trade practices had indeed injured domestic stainless steel producers. The stainless steel angle case was subsequently referred to the U.S. Department of Commerce for determination of antidumping margins (Slater Steels Corp.., 2000a, b).

World Review

The world's largest nickel producer was Norilsk Nickel, followed by Inco. Other major producers were Billiton plc of the United Kingdom, the Eramet Group of France, Falconbridge Ltd. of Canada, and WMC Ltd. of Australia. The six companies accounted for about 66% of world primary production in 2000. More than 30 medium to small companies supplied the remaining 34%. The nickel industry has become highly competitive as a result of recent corporate alliances and new developments in extractive metallurgy.

In December 2000, Anglo American plc commissioned its mining and smelting complex in Venezuela at Loma de Niquel. The mining giant increased or retained its holdings in several other medium-sized nickel producers. At yearend 2000, Anglo American had interests in the following six producers: Anaconda Nickel Ltd. of Australia (26%), BCL Ltd. of Botswana (23%), Bindura Nickel Corp. Ltd. of Zimbabwe (53.11%), Codemin S.A. of Brazil (90%), Minera Loma de Niquel, C.A. of Venezuela (85.5%), and Tati Nickel Mining Co. (Pty.) Ltd. of Botswana (43.35%). Anglo American also was involved in the Barro Alto Project (Brazil) and the Kabanga Project (Tanzania).

OM Group Inc. (OMG) of Cleveland, OH, has taken a number of steps since 1998 to transform the chemical company into a fully integrated nickel producer. OMG already had chemical production operations in the Congo, France, Germany, Malaysia, Thailand, and the United States before these actions were taken. In April 2000, OMG bought the nickel refinery at Harjavalta, Finland, from Outokumpu Oyj (Juusela, 2000). (See European Union—Finland.) OMG also formed a partnership with Weda Bay Minerals Inc. to evaluate the Halmahera laterite deposits in Indonesia. (See Indonesia.)

Global competition among stainless steel producers intensified in 2000. The increased competition and associated antidumping actions led to at least one key merger. On January 22, 2001, Avesta Sheffield AB and Outokumpu Steel Oyj merged their stainless steel manufacturing operations. The new consolidated company, AvestaPolarit Oyj Abp, became the world's second largest producer of stainless steel slabs. AvestaPolarit now has about 8,900 employees and was expected to have net sales of more than EUR 3.5 billion (about $3.2 billion) in 2001. Key production plants are located in Finland, Sweden, the United Kingdom, and the United States. The company's melt shop facilities in the four countries have a combined stainless steel slab capacity of about 1.7 million metric tons per year (Mt/yr) (Avesta Sheffield AB, 2001; Outokumpu Oyj, 2001; Outokumpu Oyj and Avesta Sheffield AB, 2000).

Avesta Sheffield and Outokumpu announced their intention to merge in September 2000, but first had to obtain approval from antitrust authorities in the European Commission and five foreign governments, including the United States (Avesta Sheffield AB, 2000). The new company is incorporated in Finland and has its head office in Stockholm. The merger had the full support of the Finnish State, which owned 40% of Outokumpu Oyj at the time. Exchanging of shares of Avesta Sheffield for shares of Outokumpu Steel began on December 21, 2000, and continued until February 2, 2001. Outokumpu Steel was renamed AvestaPolarit during the exchange period. The two largest shareholders in AvestaPolarit were Outokumpu Oyj (55.3% equity) and Corus Group plc (23.2%). Outokumpu Oyj agreed to reduce its holdings to 40% within 3 years so that AvestaPolarit's stock would be more liquid.

Outokumpu Steel's Kemi-Tornio complex is the only fully integrated stainless steel production operation in the world, starting with chromite ore and ending with finished stainless steel products. The new company was expecting to spend more than EUR 680 million (about $615 million) on expansion of its Tornio operation. Most of the money was being used to construct a new melt shop and expand rolling capacity (Outokumpu Oyj and Avesta Sheffield AB, 2000; AvestaPolarit Oyj Abp, 2001). The merger allowed Outokumpu Oyj, the parent of Outokumpu Steel, to focus on developing its remaining nonferrous businesses—copper and zinc.

***Australia*.**—Australia is now the third largest nickel producing country in the world and is beginning to rival Canada. Most of the nickel properties under development are in Western Australia. By 2002, nickel production capacity of Western Australia is projected to reach 200,000 t/yr. WMC was still the largest nickel producer in the State, recovering 107,458 t of nickel in sulfide concentrate in calendar year 2000, up from 88,275 t in 1999 (WMC Ltd., 2001b).

Australian Sulfide Operations.—In early 2000, WMC increased production at its operations in Western Australia because of strengthening nickel prices. All three mining operations—Kambalda, Leinster, and Mount Keith—produced more in 2000 than in 1999. The Kambalda Mines showed the biggest gain, with output of concentrate increasing to 19,202 t of contained nickel in 2000 from 11,114 t. Production at the huge Mount Keith Mine northwest of Leinster resumed its upward trend, rising to 47,532 t from 41,208 t. Production at the Leinster Mines increased to 40,724 t from 35,953 t (WMC Ltd., 2001b). WMC's smelter at Kalgoorlie produced 103,000 t of Ni in matte, up from 79,668 t in 1999. During the year, WMC acquired the Yakabindie deposit, 25 km south of Mount Keith. The Yakabindie deposit contains an estimated 292 Mt of resources averaging 0.52% Ni (WMC Limited, 2001a, p. 16-17).

Australian Laterite Projects.—Pressure acid leach (PAL) production capacity continued to grow in Western Australia at a rapid rate. Three nickel laterite mining and processing operations have been commissioned in the Kambalda-Goldfields region since mid-1998—Bulong, Cawse, and Murrin Murrin (Mining Journal, 1999b). Together, the three initially should eventually add about 60,000 t/yr of nickel to world production capacity. By May 2000, however, only Cawse had approached design capacity. The other two continued to experience ramp-up problems.

Murrin Murrin.—Anaconda Nickel Ltd. began producing nickel metal at its new Murrin Murrin refinery in May 1999 (Anaconda Nickel Ltd., 1999d). The metal reportedly had a chemical purity of greater than 99.80% Ni and was being marketed as briquets (Hagopian, 1999). Briquets produced in the fourth quarter of 2000 reportedly averaged 99.93% Ni, 0.026% cobalt (Co), and 0.002% Cu, fully meeting LME specifications (Anaconda Nickel Ltd., 2001).

The development plan originally called for production to be gradually increased during the second half of 1999 to the full Stage I design capacity of 45,000 t/yr of nickel and 3,000 t/yr of cobalt (Anaconda Nickel Ltd., 1999e). Nickel production for 1999 was supposed to have been about 16,000 t (Platt's Metals Week, 1999a, b) but startup problems resulted in an actual output of only 1,000 t. In July 1999, Anaconda began a 100-day campaign to rectify several technical problems that had constrained production. Some of the problems were attributed to design flaws in the flash vessels of the plant's four autoclave systems. The flash vessels have since been converted from bottom entry to top entry. Stainless steel piping in some of the autoclave circuits was unable to withstand the corrosiveness of the acidic solutions and had to be replaced by titanium alloy pipe.

The Murrin Murrin refinery produced about 4,100 t of nickel in the fourth quarter of 2000. The complex is now scheduled to reach the original target of 45,000 t/yr of nickel in the first half of 2002. Anaconda was already preparing to launch Stage II and expand the capacity of Murrin Murrin to 106,000 t/yr of nickel and 7,600 t/yr of cobalt. Stage II would use a process developed in-house instead of the original Sherritt process (Anaconda Nickel Ltd., 2001). The expansion could make Murrin Murrin the largest nickel mine in Australia, surpassing Mount Keith. According to Anaconda officials, the resources of the Murrin Murrin project (including the Abednego property) now total more than 355 Mt of ore grading 0.99% Ni and 0.07% Co.

Mount Margaret Project.—Anaconda also was preparing to develop its Mount Margaret property, 100 km northwest of Murrin Murrin. Test work on the Marshall Pool and Lawlers ore bodies indicates a resource of at least 170 Mt grading 0.78% Ni and 0.045% Co (Anaconda Nickel Ltd., 1999f). Total resources in the Mount Margaret region reportedly exceed 585 Mt and average 0.67% Ni. Drilling was underway to better delineate the resources at Mount Margaret and a feasibility study was in progress.

The proposed centralized Mount Margaret nickel refinery would have an initial design capacity of 63,600 t/yr of nickel. The development of the Murchison properties northeast of Meekatharra would allow the Mount Margaret refinery to be expanded to 130,000 t/yr. The refinery would be fed by two modular PAL plants—one at Marshall Pool and the other at Murchison.

Bulong and Cawse.—Like Murrin Murrin, Bulong and Cawse experienced startup problems associated with the new PAL technology but eventually overcame the bulk of the problems and are now in production. The two also were using solvent extraction technology to separate the cobalt from the nickel. All three, however, had somewhat different circuits.

In March 1999, Preston Resources Ltd. began continuously producing nickel metal at Bulong (Mining Journal, 1999c). Preston was also stockpiling cobalt sulfides (Mining Journal, 1999a), although the Bulong cobalt refinery was still in the final stages of commissioning. The Bulong complex was originally designed to produce 9,000 t/yr of nickel and 700 t/yr of cobalt. In October 1999, Anaconda and Preston agreed to jointly expand Bulong's production capacity and were considering raising the nickel output of the complex to 40,000 t/yr. Anglo American—Anaconda's partner—was reportedly backing Anaconda's involvement. Anaconda agreed to manage Bulong for Preston and review existing work. Anaconda can earn up to a 60% interest in Bulong. Preston's largest shareholder, Resolute Ltd., reportedly agreed to support the joint venture under certain conditions. The expansion feasibility study was scheduled to be completed by August 2001.

The Cawse complex is in the Eastern Goldfields region, 60 km northwest of Kalgoorlie. The complex produced its first cobalt sulfide concentrate, assaying 40% Co, on December 25, 1998, and the first nickel cathode was made on January 20, 1999 (Western Australian Department of Resources Development, 1999). The complex is owned and operated by Centaur Mining and Exploration Ltd. When fully operational, Cawse is expected to produce 8,700 t/yr of nickel and 1,300 t/yr of cobalt.

In November 1999, Anaconda formed a strategic alliance with Centaur Mining to expand the Cawse operation (Anaconda Nickel Ltd., 1999a). Anaconda and Centaur proposed raising the capacity of Cawse to more than 50,000 t/yr. The two companies were expecting to complete an expansion feasibility study by mid-2001. Anaconda was to be responsible for the financing, construction, commissioning, and operation of the expanded plant. Anaconda could earn as much as a 60% interest in Cawse.

Marlborough.—Preston also was preparing to develop the Marlborough laterite deposit on the central Queensland coast, about 75 km northwest of Rockhampton. Marlborough Nickel Pty. Ltd., the project manager, was in the process of securing the permits required for development and construction. Marlborough Nickel is a wholly owned subsidiary of Preston. The proposed hydrometallurgical complex would produce 25,000 t/yr of nickel metal and 2,000 t/yr of cobalt metal. Sufficient resources have been identified to permit the plant to operate for at least 22 years and possibly 100 years. According to company officials, Marlborough has about 210 Mt of resources grading 1.02% Ni and 0.06% Co (Preston Resources Ltd., 1999).

Ravensthorpe Project.—Comet Resources Ltd. (formerly Comet Resources NL) and BHP Billiton plc were preparing to develop the Ravensthorpe nickel property, 150 km from the southern port of Esperance. Comet's latest plan called for the complex to have a design capacity of 35,000 t/yr of nickel metal and 1,400 t/yr of cobalt sulfide (Comet Resources NL, 1999; Comet Resources Ltd., 2000). Construction of the Halleys cut—the proposed initial open pit on Bandalup Hill—was scheduled to begin in early 2001. The first of three pits would have a projected life of 10 to 15 years. Like Marlborough, the ore would be beneficiated before being fed into an autoclave. The beneficiated ore would have a nickel content of 2.0%. The PAL plant would adjoin the ore beneficiation plant.

In November 1999, QNI Pty. Ltd., the Queensland subsidiary of BHP Billiton, paid Comet $22 million for a 40% interest in the project. The proposed Ravensthorpe PAL plant would ship an intermediate nickel and cobalt concentrate to QNI's existing Yabulu plant near Townsville, Queensland (Mining Journal, 1999d). In September 2000, QNI acquired an additional 10% from another venture partner. On March 9, 2001, QNI agreed to purchase Comet's remaining interest in Ravensthorpe for $14.3 million plus the cancellation of its 19.9% interest in Comet (Billiton plc, 2001a).

Processing of Intermediates and Refining.—QNI produced 25,208 t of nickel metal at its Yabulu refinery during fiscal year 1999-2000 (Billiton plc, 2000). Laterite feed for the refinery was being supplied by PT Aneka Tambang (Persero) Tbk. (AnTam) in Indonesia, Hinatuan Mining Corp. in the Philippines, and four mining companies in New Caledonia.

Canada.—Key events of 2000 are summarized in the nickel chapter of the Canadian Minerals Yearbook (McCutcheon, 2001).

Labrador.—Inco Ltd. and its subsidiary Voisey's Bay Nickel Co. Ltd. (VBNCL) remained committed to developing the huge nickel-copper-cobalt deposit at Voisey's Bay. An impasse between Inco and the Provincial Government of Newfoundland and Labrador over the scope of the project continued to delay development (Inco Ltd., 1999). On January 11, 2000, Inco and the Provincial Government mutually agreed to suspend negotiations on the Voisey's Bay Project. Spokespersons for Inco and the Provincial Government were not willing to predict when negotiations might resume.

Inco has decided to recover the nickel using a new hydrometallurgical process developed in-house instead of using flash smelting technology as originally planned. On November 14, 1999, Inco delivered a new development proposal for Voisey's Bay to the Provincial Government (Whyte, 1999). In the proposal, Inco offered to build a hydrometallurgical pilot plant in the Province but did not want to commit to building a full-scale facility until the new process was determined to be technically and economically feasible. The proposed pilot plant and associated research and development program would have cost about $125 million (Inco Ltd., 2000f). Inco also would have spent about $65 million on underground exploration at the mine site.

Despite the impasse, Inco was permitted to push ahead with its surface exploration program. According to Inco, the Voisey's Bay deposit has 32 Mt of proven reserves averaging 2.83% Ni and 1.68% Cu. All of these reserves reportedly can be recovered by open pit mining. In addition to these reserves, geologists have calculated that there are 95 Mt of indicated resources averaging 1.28% Ni and 0.60% Cu plus 14 Mt of inferred resources averaging 0.98% Ni and 0.66% Cu (Inco Ltd., 2001, p. 26-27). The bulk of these resources would have to be recovered using underground mining techniques. A minihydrometallurgical pilot-plant program was scheduled to begin in 2001 at the company's Sheridan Park research center.

Inco was working with the Labrador Inuit Association to establish baseline metal concentrations in meadows and other sensitive areas near the proposed mine site. The baseline environmental data will be used to ensure that metal concentrations do not rise when commercial mining begins.

On December 14, Inco redeemed the Class VBN shares that were issued when Diamond Fields Resources Inc. and the Voisey's Bay deposit were acquired in 1996. Each VBN share was exchanged for C$7.50 in cash and a fraction, 0.45, of an Inco common share purchase warrant. The warrant can be used to purchase one Inco common share for C$30.00 on or before August 21, 2006.

South Voisey's Bay, Labrador.—Donner Minerals Ltd. and its partners had planned to spend C$2.75 million exploring their claims in the South Voisey's Bay (SVB) project area during the 1999 field season. However, on July 6, 1999, Donner announced that the company had been unable to reach an agreement with the Innu Nation, which was still conducting land claims negotiations with the Federal and Provincial Governments. Donner was unwilling to risk a confrontation at its SVB exploration camp and decided to cancel its 1999 exploration program (Donner Minerals Ltd., 1999). Donner kept the exploration program on hold throughout 2000 while it negotiated with the Innu Nation.

Ontario.—The Sudbury region of Ontario, northwest of Lake Nipissing, has been the principal nickel-producing district in Canada since 1883. Inco operates a smelting complex at Copper Cliff, on the western edge of the City of Sudbury. Falconbridge Ltd. has a somewhat smaller smelter near the town of Falconbridge. Concentrates for the two smelters come from a number of underground mines ringing the perimeter of the Sudbury Basin. Ore production at Falconbridge's four Sudbury mines totaled only 1.79 Mt and was down 35% from 2.75 Mt in 1999 because of a prolonged labor strike and the impact of a rockburst in the Fraser Mine. The ore averaged 1.54% Ni and 1.37% Cu (Falconbridge Ltd., 2001, p. 18-19).

Falconbridge and Inco have continued to find additional resources along the basin rim. Inco and two major producers of PGM recently accelerated their exploration efforts in the region. Higher nickel prices, improved PGM fundamentals, and two recent discoveries of nickel-copper sulfides on the southern perimeter of the Sudbury Basin all contributed to the expansion of exploration activities.

Kelly Lake and Totten Deposits.—Inco management was expected to decide in 2001 when the Kelly Lake deposit should be brought into production. The deposit is 2 km south of Copper Cliff and Highway 17 and reportedly is accessible from existing mine workings near Inco's Copper Cliff South Mine.

Inco geologists continued to evaluate a new area of mineralization in and around the Totten Mine, near Worthington on the Canadian Pacific Railway. The mineralization was discovered in late 1999. Subsequent drilling indicated that the

Totten deposit has at least 8.4 Mt of resources averaging 1.42% Ni, 1.90% Cu, and 4.7 g/t of PGM (Inco Ltd., 2000d). If the necessary environmental permits can be obtained in 2001, production could begin as early as 2005.

The Kelly Lake and Totten deposits both have average nickel and PGM concentrations higher than those being mined by Inco's Ontario Division. The average ore grade for the Division currently is 1.41% Ni, 1.40% Cu, and 1.8 g/t of PGM. Because of the two new finds, Inco decided to spend $7.7 million in 2000 exploring several high potential targets in the region. This was Inco's highest annual exploration expenditure (in nominal dollars) in Ontario since the 1970s.

Other Nickel-PGM Targets.—Anglo American Platinum Corp. Ltd. of Johannesburg, South Africa, has teamed up with Pacific Northwest Capital Corp. (PNWC) of Vancouver, BC, to evaluate the River Valley mafic intrusion, 50 km east of Sudbury. The intrusion is a layered gabbro-anorthosite complex, with elevated PGM values near its contact with the country rock. Mustang Minerals Corp. of Toronto, ON, and Impala Platinum Corp. of Johannesburg, South Africa, have joined forces to explore parts of the intrusion adjoining PNWC's license area (Mining Journal, 2000c).

Mustang also was exploring a second gabbro-anorthosite complex at East Bull Lake, 80 km west of Sudbury. Again, PGM values appear to be enriched at the margins of the intrusion (Mining Journal, 2000a).

Quebec.—Exploration activities have increased dramatically in parts of Quebec since the discovery of the Voisey's Bay deposit in neighboring Labrador and the startup of Falconbridge's Raglan Mine on the Ungava Peninsula.

The Raglan mining and milling complex completed its second full year of operation. The new nickel-copper mine is in the Nunavik region of northern Quebec—near Katinniq, at the tip of the Ungava Peninsula. Falconbridge spent C$25 million in 2000 to increase annual milling capacity from 800,000 t of ore to 1 Mt. In 2000, Raglan recovered 936,000 t of ore averaging 2.94% Ni and 0.86% Cu. This equated to a mine production of 23,089 t of nickel in concentrate. The nickel concentrate also contained 6,308 t of copper and 289 t of cobalt (Falconbridge Ltd., 2001, p. 18-19).

Falconbridge was hoping to eventually raise production capacity to 30,000 t of nickel in concentrate. At yearend 2000, Raglan had 19.5 Mt of proven and probable reserves, averaging 2.85 % Ni and 0.78% Cu. In addition to the reserves, Raglan had 2.74 Mt of indicated resources averaging 1.86% Ni and 0.69% Cu (Falconbridge Ltd., 2001, p. 13).

Manitoba.—Inco's Manitoba Division produced about 45,000 t of nickel, up 33% from 34,000 t in 1999 (McCutcheon, 2001). There were two principal mines—the Birchtree and Thompson. Inco has decided to deepen the Birchtree over the next 5 years and has begun resurveying the entire Thompson Nickel Belt (Inco Ltd., 2000b).

Canmine Resources Corp. continued to evaluate 2,000 square kilometers (km^2) of claims northeast and west of the Thompson Belt (Canmine Resources Corp., 1999b). In early 2000, Canmine transferred its interests in the BINCO project to a wholly owned subsidiary named BINCO Resources Corp. In March 1999, Canmine obtained 21-year renewable surface and mineral right leases on its Maskwa property in Nopiming Provincial Park from the Province of Manitoba (Canmine Resources Corp., 1999a).

Alberta.—Sherritt International Corp. continued to improve operations at its Fort Saskatchewan refinery. Finished nickel production was 28,070 t, slightly below the record of 28,643 t set in 1999 (Sherritt International Corp., 2001, p. 7). The bulk of the feedstock—nickel-cobalt sulfide precipitate—came from Metals Enterprise, a mining and concentrating operation at Moa in Cuba. Metals Enterprise is a 50-50 joint venture between Sherritt and the Government of Cuba.

China.—Recent advances in nickel and rare-earth electrochemistries have spurred several joint battery manufacturing projects in mainland China and Taiwan.

Evercel, Inc. of Danbury, CT, and Xiamen Three Circles Battery Co. have formed a joint venture to mass produce rechargeable nickel-zinc batteries in Fujian Province, China. The nickel-zinc batteries were being used to power bicycles, scooters, and small automobiles. The joint venture developed from a licensing agreement signed in February 1998 between Energy Research Corp. (ERC) and its two partners—the Formosa Plastics Group of Taiwan and the City of Xiamen, China (Energy Research Corp., 1998). Evercel was spun off from ERC on February 22, 1999, and shortly after opened its corporate headquarters along with a pilot production line at Danbury. The pilot production facility was producing sample quantities of the new batteries for field testing by prospective customers (Evercel, Inc., 1999a).

In August 1999, the joint venture, Xiamen Three Circles - ERC Battery Corp. Ltd., began manufacturing nickel-zinc batteries for electric bicycles at its brand-new facilities in Xiamen (Evercel, Inc., 1999b). The joint venture's first production order came from the Xiamen Bicycle Co. The Chinese post office department was using the electric bicycles to deliver mail. Evercel also assumed responsibility for the original licensing agreement with the Xiamen City government and Formosa Plastics. The original agreement allows Xiamen City and Formosa Plastics to jointly manufacture patented nickel-zinc batteries for electric and hybrid automobiles. Xiamen City's automotive company produces 30,000 conventional cars and trucks annually (Energy Research Corp., 1997).

Nan Ya Plastics Group, a Formosa Plastics subsidiary, has been developing new markets for nickel-zinc batteries on Taiwan. Xiamen Three Circles-ERC was hoping to sell a significant part of its production to Taiwanese electric scooter manufacturers. Taiwanese electric scooters are currently powered by lead-acid batteries. Comparison road testing of an Evercel scooter battery with an equivalent lead-acid battery was carried out by Taiwan Sanyang Industry Co., Ltd., one of the island's leading scooter manufacturers. The total life distance of the nickel-zinc-powered scooter was reportedly twice that of the lead-acid alternative (Evercel, Inc., 1999c). Recent environmental regulations adopted by the Taiwan Authorities require that, starting in 2000, 2% of the scooters manufactured on the island must be electrically powered. Electric scooter manufacturers were expecting to sell 33,000 battery packs in 2000.

On August 26, 1999, ECD and its subsidiary, Ovonic Battery, signed a cooperation and licensing agreement with Rare Earth High-Tech Co. Ltd. of Baotou. Rare Earth High-Tech is the largest producer of rare-earth elements in China and has mining and extraction operations in the Nei Mongol Autonomous Region. The company is a subsidiary of Baotou Iron and Steel Ltd. Rare Earth High-Tech and Ovonic Battery have agreed to jointly produce key materials for NiMH batteries. Proprietary rare-earth alloys are used as anodes in certain types of NiMH batteries. Several joint projects were planned, including production of hydrogen storage alloy powders, production of advanced nickel-hydroxide materials, and development of battery production equipment (Energy Conversion Devices, Inc., 1999).

Colombia.—On January 1, 2001, Billiton plc commissioned a second ferronickel production line at its Cerro Matoso S.A. (CMSA) subsidiary in northwestern Colombia. The commissioning marked the turning point in a 5-year project to expand operations and reduce production bottlenecks at the mining and smelting complex near Montelibano. Startup was achieved 3 months ahead of schedule, while costs were kept below the $353 million budgeted. Production on the second line was to be gradually increased over the next 18 months until the design capacity of 27,000 t/yr of contained nickel was reached. When the ramp-up is completed in July 2002, the two lines will have a combined production capacity of 55,000 t/yr of Ni in ferronickel (Billiton plc, 2001b). Each line has its own ore dryer, kiln, and smelting furnace, so that the ferronickel plant can now be operated continuously. The expanded plant reportedly has been designed so that intermediate products can be exchanged between the two lines if one of the kilns or furnaces should require repair or maintenance (Nacken, 2000).

Billiton launched the expansion project in February 1999 when the nickel market began to recover from 2 years of depressed prices. In December 1999, the company closed on a $240 million loan, completing financing of the project. ABN AMRO Bank N.V., Barclays Capital (a division of Barclays plc), and four other banks participated in arranging the loan syndication. The syndicated loan, technically termed a debt facility, will mature in mid-2005 (Billiton plc, 1999).

In 2000, CMSA produced 27,720 t of Ni in ferronickel and exported 26,192 t, building up stocks in the process. Only 2,016 t, or 8% of CMSA's total exports, went to the United States. About 70% of the ferronickel exports went to Europe (International Nickel Study Group, 2001b, p. 30).

Cuba.—Metals Enterprise, the joint venture of the Cuban Government and Sherritt, produced 29,520 t of nickel-plus-cobalt in mixed sulfides at Moa in 2000—a record high output. The material provided about 90% of the feed for the venture's Fort Saskatchewan refinery in Alberta (Sherritt International Corp., 2001, p. 7). Mixed sulfide production at Moa has increased 126% since 1994, the year when the joint venture was formed.

European Union.—Finland.—On April 5, 2000, OMG bought the Harjavalta nickel plant in Finland from Outokumpu Oyj. OMG paid Outokumpu EUR 180 million in cash, which was equivalent at the time to about $172 million (Outokumpu Oyj, 2000a, b). (On April 6, 1 EUR was quoted at US$0.9583). OMG wanted to integrate the nickel plant with its Kokkola cobalt and nickel chemicals plant. The Kokkola plant was spun off from Outokumpu in 1991 when Mooney Chemicals, Inc. and Outokumpu merged their chemical businesses to form OMG. The nickel smelter at Harjavalta was not part of the April 5 transaction. Outokumpu continued to operate the smelter, processing nickel-copper concentrates from Outokumpu's mines in Australia. Outokumpu was also toll processing concentrates for OMG.

In 2000, the Harjavalta nickel plant produced about 50,600 t of refined nickel. The bulk of the nickel was recovered from matte produced at Outokumpu's smelter. The Outokumpu matte was supplemented with matte imported from Australia (8,982 t gross weight) and Brazil (15,835 t gross weight). The nickel was leached from the matte and separated from the other transition metals by solvent extraction. Most of the nickel was recovered as cathode by electrowinning. Some of the nickel, however, was reduced with hydrogen and made into briquets.

The 180 employees working at the Harjavalta plant were transferred to OMG. OMG has begun to more closely integrate the nickel plant with its Kokkola chemical operations. OMG will continue to supply nickel to Outokumpu's stainless steel melt shop at Tornio. Outokumpu will remain a copper and zinc producer but is planning to eventually give up nickel production when ore reserves at its mines in Finland and Australia are depleted.

European Union.—Netherlands.—ELG Haniel GmbH handled about 1.2 Mt of stainless steel scrap and related materials in 1999. Approximately 790,000 t were processed in Europe, mostly in Germany. The company recently moved the scrap processing facilities of Jewometaal Stainless Processing B.V., its Dutch subsidiary, to a new location in the Port of Rotterdam. The relocation and upgrading cost EUR 8 million and will allow Jewometaal to recycle and transship 220,000 t/yr of stainless steel scrap (ELG Haniel GmbH, 2000, p. 32-33).

Indonesia.—PT International Nickel Indonesia Tbk. (PT Inco) and AnTam continued to add mining and smelting capacity to their operations on the island of Sulawesi. Total mine production in 2000 for all of Indonesia was 98,200 t of contained nickel. All of the ore came from laterite deposits. Several joint ventures have been formed to explore and/or develop promising properties in Maluku.

Sulawesi.—PT Inco completed its 4-year expansion project, increasing the production capacity of its Soroako smelter by 50% to 68,000 t/yr of Ni in matte. The company added a fourth electric furnace smelting line and upgraded the existing three lines. At the end of 2000, PT Inco had 101 Mt of proven and probable reserves in the Soroako area averaging 1.82% Ni. The company has an additional 130 Mt of indicated resources averaging 1.80% Ni and 171 Mt of inferred resources averaging 1.82% Ni (Inco Ltd., 2001, p. 26).

In July 1999, AnTam announced that it would begin building a third line at its ferronickel smelter at Pomalaa. The third line would raise the capacity of the smelter from 11,000 t/yr of Ni in ferronickel to 24,000 t/yr. Money for the expansion was to come from funds raised in the company's initial public offering of November 1997. If all goes well, the third line could be operational by 2002 (PT Aneka Tambang (Persero) Tbk., 1999).

Gag Island.—On July 12, Falconbridge Ltd. and BHP Ltd. of Melbourne, Australia, announced that they had tentatively formed a joint venture to further evaluate nickel laterite deposits on Gag Island. Several matters, however, had to be resolved before the joint venture could become effective (Falconbridge Ltd., 2000). Commercial arrangements with AnTam, BHP's Indonesian partner, needed to be clarified. There were also some outstanding issues involving management of the island's forests. When these matters are resolved, Falconbridge will be able to acquire a 37.5% interest in the nickel project by contributing $75 million for a feasibility study. Falconbridge would be responsible for managing the 2-year study. BHP's current 75% interest would be reduced to 37.5% upon completion of the feasibility study. AnTam would retain its current 25% interest in the project.

Gag Island is about 40 km southeast of Gebe Island, Maluku, where AnTam has one of its two principal nickel mines. BHP and AnTam have been working together on the Gag Island project since August 1996. BHP mining experts estimate that the Gag Island concession has 240 Mt of combined oxide and silicate resources averaging 1.35% Ni and 0.08% Co (BHP Ltd., 2000).

Halmahera Island.—Weda Bay Minerals Inc. of Vancouver, British Columbia, and AnTam have been jointly evaluating laterite deposits on Halmahera Island since May 1996. At least 11 areas between Cape Ulie and the Jira River were under investigation. The project is held under a contract of work between the Government of Indonesia and PT Weda Bay Nickel. PT Weda Bay Nickel is a joint venture of Weda Bay Minerals (90%) and AnTam (10%).

In February 2000, OMG agreed to work with Weda Bay Minerals and AnTam on the Halmahera project (OM Group Inc., 2000). OMG was to provide $18 million for a feasibility study in exchange for a 19.9% interest in Weda Bay Minerals. The feasibility study was scheduled to be completed in early 2002. If the feasibility study is positive, some of the Halmahera deposits could be in production as early as 2004. The nickel and cobalt would be recovered by pressure acid leaching. According to Weda Bay officials, the Halmahera deposits can supply the proposed PAL plant with 4 Mt/yr of ore for 30 years (Weda Bay Minerals Inc., 2000a, b). The PAL plant would produce some 30,000 t/yr of nickel and 3,000 t/yr of cobalt in value-added intermediate products (Metal Bulletin, 2000).

On August 16, Weda Bay Minerals announced that it had revised upward its estimates of nickel resources on the Halmahera concession by 73%. The total aggregate resource was now estimated to be 202 million dry tons of laterite averaging 1.37% Ni and 0.12% Co. The estimate included both indicated and inferred resources. The Santa Monica and Pinto deposits reportedly have an indicated resource, at a 1% nickel cutoff grade, of 60 million dry tons averaging 1.51 % Ni and 0.09% Co (Weda Bay Minerals Inc., 2000b).

New Caledonia.—Société Métallurgique le Nickel (SLN) accounted for 47% of New Caledonian mine production in 2000. The other 53% of mine production was divided among J.C. Berton Mines, Nickel Mining Corp., Société des Mines de la Tontouta (SMT), Société Minière du Sud Pacifique S.A. (SMSP), and several other independent mining companies. Mine production totaled 127,493 t on a contained nickel basis, up 16% from 110,062 t (revised) in 1999. In 2000, the French overseas territory exported 59,240 t of nickel in ore, which included 40,174 t of nickel in garnierite shipped to Japan and 19,066 t in limonitic laterites shipped to Australia. The remaining 68,300 t of nickel in ore was processed at the SLN smelter outside Doniambo (International Nickel Study Group, 2001b, p. 46-47).

SLN's Mining and Smelting Operations.—SLN operated the following four nickel mines: Thio, Kouaoua, Népoui-Kopéto, and Tiébaghi. (See figure 2.) A fifth mine, Kaala-Gomen (also known as Etoile du Nord), was operated by an SLN contractor. SLN's ore production was 5% greater than that of 1999. SLN and its subcontractors mined 3.71 Mt of wet lateritic ore, up from 3.52 Mt (revised). Garnierite ore accounted for 3.43 Mt or 92% of total production. The remaining 278,000 t was limonitic laterite. Eramet's management was evaluating a proposal to expand the new Tiébaghi Mine. In October, preparatory work was begun to resume mining laterites at Bonini in the Poro region. The Bonini mine site was abandoned in the early 1980s (Eramet Group, 2001, p. 30-35).

In 2000, the Doniambo smelter produced 43,914 t of nickel in ferronickel and 13,549 t of nickel in matte. The combined output of 57,463 t was an alltime high for Doniambo, edging out the previous record of 56,642 t set in 1999. A labor strike in February and March kept SLN from reaching its original production goal of 61,000 t. The refining capacity of the plant was 49,000 t/yr, while matte capacity was about 14,000 t/yr of contained nickel. SLN was planning to increase the annual capacity of Doniambo to 75,000 t sometime in 2004 or 2005 (Eramet Group, 2001, p. 30-35). Expansion of the smelter and improvement of operations at Tiébaghi were expected to cost a total of $180 million (Reuters Ltd., 2001).

The Paris-based Eramet Group controlled 60% of the shares of SLN, down from 90% in 1998. Eramet also had a 38.45% interest in Special Metals Corp.

Inco's Goro Project.—On December 13, Inco announced that it was hoping to complete its feasibility study of the Goro nickel-cobalt project by April 2001. The Goro deposits are at the southeastern tip of La Grande Terre, the main island. The mining and extraction project had advanced through several stages of planning and review since its inception in mid-1992. The Toronto-based nickel producer already had invested $50 million in an on-site pilot plant. The pilot-plant was being used to validate an advanced PAL process developed in-house to extract nickel and cobalt from lateritic ores. The plant was commissioned on October 22, 1999, and can process 12 metric tons per day of ore (Inco Ltd., 2000a, p. 24). Pilot-plant work to date indicates that the Inco process can be used successfully on a commercial scale. If financing can be arranged immediately after completion of the feasibility study, a full-size commercial facility could be operational by late 2004 or early 2005. The proposed mining and processing complex would have a production capacity of 54,000 t/yr of Ni in nickel oxide and 5,400 t/yr of Co in cobalt carbonate. A joint venture of Bechtel Overseas Corp. and Technip France S.A. would act as prime contractor during construction.

Inco was in the process of securing the necessary permits and clearances from the Government of New Caledonia to construct and operate the commercial facility. Inco and the Government have been discussing future taxes and financing arrangements for some time. The project's operating company, Goro Nickel S.A., is a wholly owned subsidiary of Compagnie Minière de Xere (CMX). CMX is a joint venture of Inco (85% equity) and Bureau de Recherches Géologiques et Minières—an agency of the French Government (15% equity).

Inco would continue to operate the Goro pilot plant after construction began and use the plant to train its future New Caledonian work force. The company has allocated $5 million for training and will build a training center near the pilot plant as part of the program. According to company officials, the Goro concession has more than 200 million dry tons of laterite ore, averaging 1.6% Ni and 0.17% Co. The initial mining zone has 47 Mt of proven and probable reserves (Inco Ltd., 2000e).

Inco was reportedly seeking a partner to help finance the $1.4 billion project and offset the investment risks (Platts Metals Week, 2001). Eramet has acknowledged that it has been contacted by Inco and has been evaluating the Canadian proposal. The Government of France, a stockholder in Eramet, has already committed $350 million for the Goro project.

Nakéty PAL Project.—Argosy Minerals Inc. and SMT were considering building a PAL plant at Nakéty on the east-central coast of La Grand Terre. SMT, an independent New Caledonian mining company, has been operating on the island for more than a decade. Argosy, an Australian-Canadian exploration and development company, was created on May 7, 1999, when Argosy Mining Corp. and Calliope Metals Corp. merged. The new company was headquartered in Vancouver, British Columbia.

In 1995, Calliope agreed to purchase ore from SMT, which holds several mining concessions at Nakéty. In 1998, Calliope Metals shelved plans to build a PAL facility in the Australian State of Queensland. The PAL facility was to have used New Caledonian ore supplied by SMT. A feasibility study by Kvaerner Metals ASA, however, indicated that the cost of exporting wet, unbeneficiated ore to Queensland—about $1.00 per pound Ni—would make the project uneconomical. The study concluded that it would be more cost effective to build the same facility adjacent to SMT's concessions at Nakéty. Over the long term, the savings in ore shipping charges would outweigh any additional costs incurred in building and operating the PAL plant on La Grand Terre (Russell, 2001). In May 1998, Argosy Mining Corp. and SMT tentatively agreed to form a joint venture to explore the feasibility of a PAL plant at Nakéty (Argosy Minerals Inc., 2000b). Ore for the plant would come from four of SMT's concessions: Barbouille, Belle Asashi 2, Lucienne 2, and Lucienne 2H. Argosy has continued to honor the agreements of its two predecessors. In August 1999, Argosy formed a joint venture with SMT to evaluate the Nakéty concessions. More than 675 holes have been drilled within the Nakéty deposit to date.

Dynatec Engineering Corp. has performed extensive metallurgical tests on the Nakéty ores, and Kvaerner has completed a preliminary engineering study of the deposit. According to Resources Service Group (an Argosy contractor), the Nakéty deposit has measured, indicated, and inferred resources in excess of 48 million dry tons that are estimated to average 1.42% Ni and 0.12% Co. Measured and indicated resources consist of 21.0 million dry tons of limonitic ore averaging 1.33% Ni and 0.14% Co and an additional 13.5 million dry tons of underlying, magnesium-rich saprolitic ore averaging 1.83% Ni and 0.06% Co. SMT is currently mining the saprolite zone on a small scale for export. The limonitic ore is reportedly better suited than the saprolite for pressure acid leaching (Argosy Minerals Inc., 2001b).

On July 24, 2000, Argosy and SMT agreed to include SMT's concessions at Bogota in the joint-venture agreement. The Bogota concessions are in the Canala area, about 3 km northwest of the proposed plant site near Nakéty. The 40 Bogota concessions cover 53.9 km^2, compared with only 10.4 km^2 for Nakéty. Reconnaissance drilling carried out by SMT in 1995 suggests that laterite mineralization underlies much of the iron-rich cap rock that trends northwest along the entire 18-km length of the Bogota Peninsula. Exploration efforts to date have focused on an 11-km^2 target area in the southern part of the peninsula (Argosy Minerals Inc., 2000b). The additional resources may allow Argosy to increase the design capacity of the proposed refinery. A total of 196 holes were drilled on 8 of the 40 Bogota concessions between 1982 and 1995. In some places, the thickness of the limonitic zone exceeded 35 meters (m). The number of drill holes to date is insufficient to make a rigorous resource estimate for the Bogota area (Argosy Minerals Inc., 2001b).

Argosy, like Inco, was actively seeking a partner for its project. On July 25, 2001, Argosy announced that the Norilsk Nickel Mining and Metallurgical Co. of Russia had agreed to participate in the evaluation (Argosy Minerals Inc., 2001a). Norilsk Nickel would provide the $20 million needed for a new bankable feasibility study of the Nakéty-Bogota laterites and would reimburse Argosy for part of the development company's expenditures to date. In exchange, Norilsk Nickel would earn a 50% to 70% interest in the joint venture.

Koniambo Project.—In 1998, Falconbridge, SMSP, and Société de Financement et d'Investissement de la Province Nord formed a joint venture to develop a nickel mining and smelting complex in the North Province. The smelter would have a capacity of 54,000 t/yr of nickel in ferronickel and use lateritic ores from the Koniambo massif as feedstock. Falconbridge would be allowed to earn up to a 49% interest in the project. The diamond drilling program on the Koniambo massif was completed during 2000. A total of 70,600 m of rock were drilled between August 1998 and December 2000. Based on this latest drilling, geologists now estimate that the massif has 151 Mt of inferred resources averaging 2.58% Ni and 0.07% Co (Falconbridge Ltd., 2001, p. 27-28).

Philippines.—Three companies mined laterite ore in 2000—Hinatuan Mining Corp., Rio Tuba Nickel Mining Corp., and Taganito Mining Corp. Combined production amounted to 20,208 t of contained nickel, 63% more than in 1999. None of the ore was smelted in the Philippines. About 50% of the material was exported to Japan; another 25% went to Australia. The remaining 25% was stockpiled in anticipation of the construction of a proposed PAL operation (International Nickel Study Group, 2001a; b, p. 48).

Mindoro Island.—Crew Development Corp. of Vancouver, Canada, has been evaluating a large nickel laterite deposit on the island of Mindoro. Mindoro is separated from Luzon on the north by the Verde Island Passage and is about 120 km south of Manila. According to company officials, the laterite deposit has at least 72 million dry tons of resources grading 0.94% Ni and 0.06% Co (Crew Development Corp., 2000a, b). Crew acquired the 110-km^2 concession when it merged with Mindex ASA, a Norwegian exploration company, in 1999. The proposed $700 million mining and hydrometallurgical extraction complex could produce as much as 40,000 t/yr of nickel and 3,050 t/yr of cobalt over its 30 years of operation.

The nickel and cobalt would be recovered using PAL technology similar to that employed in Western Australia. Natural gas for the project would come from a pipeline proposed by Philippine National Oil Co. and Royal Dutch/Shell Group. The pipeline would transport gas to Batangas from a new offshore field being developed near Palawan Island. The pipeline would pass within 6 km of Crew's proposed plant site. The sulfur needed for leaching the nickel would come from the Pamplona sulfur deposit on the island of Negros, 300 km to the southeast. Crew already holds all of the rights to the Pamplona concession (Northern Miner, 2000a, b). Cash costs for the Mindoro operation potentially could be reduced by selling 126,000 t/yr of byproduct ammonium sulfate. The Philippine rice and sugar cane industries currently consume about 400,000 t/yr of imported ammonium sulfate.

Palawan Island.—On April 20, Sumitomo Metal Mining Co. Ltd. of Japan and Rio Tuba announced that they were launching a joint study to determine if high pressure acid leach technology could economically recover nickel at Rio Tuba's mine on Palawan Island (Reuters Ltd., 2000). The 500,000-t/yr open pit operation currently exports the bulk of its ore to Japan. The Rio Tuba ore typically grades 2.4% Ni. Philippine interests own 60% of Rio Tuba, while Japanese interests led by Pacific Metals Co. Ltd. (PAMCO) control the remaining 40%.

Sumitomo was hoping to complete the feasibility study by yearend 2000 and will be assisted by PAMCO. Sumitomo, the largest nickel producer in Japan, produces cathode and nickel salts at its Niihama refinery in Ehime Prefecture. PAMCO operates a ferronickel smelter at Hachinohe in Aomori Prefecture.

Russia.—The Russian Federation produced more more than 221,000 t of nickel in refined products (International Nickel Study Group, 2001b, p. 49-50). Norilsk Nickel was by far the largest producer in Russia, accounting for at least 218,000 t of nickel in metal or limited amounts of ferronickel, as well as 391,000 t of copper metal, and 4,650 t of cobalt. Norilsk Nickel produced 23% more nickel in 2000 than in 1996, when the company had a reported output of 177,185 t (Platt's Metals Week, 1998; Interfax International Ltd., 1999; RAO Norilsk Nickel, 1999a). A 1997 amendment to the Federation's Law on State Secrets prohibits Norilsk Nickel from divulging detailed production figures for its different subsidiaries.

RAO Norilsk Nickel.—In 2000, RAO Norilsk Nickel was the largest producer of nickel in the world, accounting for about 19% of total refinery production (RAO Norilsk Nickel, 2000a, b). The company was restructured in 2000 but continued to subsidize housing, the importation of food, and municipal services in the cities of Norilsk, Monchegorsk, and Zapolyarny. On January 4, 2000, officials of the LME agreed to accept two major nickel products made by Norilsk—full-size nickel cathode sheet (H-1) and full-size sheet with uncut edges (H-1Y).

In 1998, RAO Norilsk Nickel launched a 10-year development program aimed at modernizing operations on both the Kola Peninsula and the Taimyr Peninsula. The program required raising $3 billion to $5 billion from foreign investors. Norilsk Mining Co. was created to manage the A.P. Zavenyagin Norilsk Mining and Metallurgical Combine on the Taimyr Peninsula. The Kola Metallurgical and Mining Co, a second new entity, was to oversee the Pechenganickel Mining and Metallurgical Combine, the Severonickel Combine, and related activities on the Kola Peninsula (RAO Norilsk Nickel, 1999b).

The International Finance Company Bank, Norilsk's financial consultant, was to be responsible for developing the necessary market instruments needed to attract the initial $200 million. INTERROS Holding Co. of Russia would guarantee the investments under a "repo" agreement that could give INTERROS a 37.9% stake in Norilsk Mining Co. (Budrys, 2000). An additional $800 million would have to be raised before January 2003 if the program was to keep on schedule. The initial $200 million would be used to expand Norilsk Nickel's product line, improve sales to Russian consumers, create an overseas sales network, and improve the company's transport infrastructure.

The 10-year development program would allow Norilsk Mining Co. and Kola Metallurgical and Mining Co. to develop new levels in existing underground mines, construct new mines, and carry out local exploration work designed to transform inferred resources into measured reserves. If the plans are fully implemented, the Kola Combine would remain open past 2007 and possibly continue to operate until 2015 (RAO Norilsk Nickel, 2000b).

Expansion of Operations on the Taimyr Peninsula.—Mine development work to replace declining reserves has intensified, even though some 50 years of reserves still exist. The bulk of the Taimyr ores comes from the Oktyabr and the Talnakh deposits. The two deposits reportedly contain more than 35% of the world's nickel reserves (RAO Norilsk Nickel, 2000a). Production from the new Skalisty Mine will help offset declining output at some of the older mines. Increased production of disseminated "impregnation" ores and high-grade copper ores should compensate for declining production of high-nickel, massive sulfide ores.

The first stage in the development of the Pelyatka gas condensate field was completed in 2000. Construction of a pipeline from the field to Norilsk was well underway and was critical to the Taimyr expansion program. By yearend, 123 km of pipelines had been installed. The first gas was scheduled to reach Norilsk sometime in 2001. The initial gas flow was to be about 1.4 million cubic meters per day (RAO Norilsk Nickel, 2001, p. 10).

Questions About the Legitimacy of Norilsk's Privatization.—On June 20, 2000, a Moscow city prosecutor filed a lawsuit seeking to overturn the privatization of Norilsk Nickel (Mining Journal, 2000b). The lawsuit could complicate future company plans to raise capital for modernization and development. The lawsuit questioned the legality of the 1995 loans-for-shares program that preceded privatization of the giant parastatal enterprise. Under the program, the Russian Government used its equity in Norilsk Nickel as collateral to obtain a $170 million loan from United Export-Import Bank Open Joint Stock Co. (UNEXIM Bank). The original agreement gave UNEXIM Bank, now part of INTERROS, control of 51% of Norilsk Nickel's voting stock. The Russian Government never repaid the loan and Norilsk Nickel was subsequently sold at auction to ZAO SVIFT, an affiliate of UNEXIM Bank, for about $250 million.

UNEXIM Bank is rescheduling its foreign debt, undergoing restructuring, and may merge with ROSBANK, another INTERROS financial institution. On May 22, holders of UNEXIM Bank eurobonds ratified key parts of the restructuring plan. Fleming UCB is serving as financial adviser to UNEXIM Bank (INTERROS Holding Co., 2000).

Enterprises in the Ural Mountains.—The board of directors of RAO Yuzhural Nickel were considering turning over key assets—a nickel smelter and a hydrometallurgical plant used to produce cobalt—to Uraltransgaz, the company's gas supplier, in exchange for a forgiveness of debts. Uraltransgaz is already the largest shareholder in Yuzhural Nickel. The Orenburg Copper-Nickel Co., which has a 20% interest in the nickel producer, opposed the asset-debt swap. The Orenburg Copper Nickel Co. is a parastatal controlled by the Orenburg Regional Administration (Interfax International Ltd., 2000).

Venezuela.—The new Loma de Niquel mining and smelting complex was in the final stages of construction begun in October 1997. The site (formerly Loma de Hierro) is about 80 km southwest of Caracas. For more than 50 years, a string of companies had been evaluating the laterite deposit. The complex was designed to produce 17,500 t of Ni in ferronickel and began smelting ore in December 2000. Full capacity should be reached by 2001 (Minera Loma de Niquel, C.A., 2000).

***Yemen*.**—Canadian Mountain Minerals (Yemen) Ltd. (CMMY), a wholly owned subsidiary of Cantex Mine Development Corp., has been exploring a 40,000-km^2 area on the western margin of the Rubh al-Khali (*English* Great Sandy Desert) since January 1996 (Cantex Mine Development Corp., 1999a). In late 1999, CMMY drilled two holes into a portion of the Suwar ultramafic complex where the overlying soils were anomalously high in copper and nickel (Cantex Mine Development Corp., 1999b). On February 22, 2000, Cantex announced that both drill holes had intersected massive nickel and copper sulfide mineralization (Cantex Mine Development Corp., 2000a). The complex is located in the Maswar district of Hajjah Governorate, about 60 km west of Sana'a, the capital of Yemen. The principal rock types in the ultramafic complex are gabbro-norite, peridotite, and olivine gabbro.

The bulk of the sulfide mineralization in the two discovery holes was at depths of 40 to 70 m. The first hole intercepted 18.7 m of mineralization averaging 0.89% Ni, 0.67% Cu, and 0.046% Co. The second hole intercepted 22.1 m of mineralization averaging 1.41% Ni, 0.91% Cu, and 0.07% Co (Cantex Mine Development Corp., 2000a). The sulfide-rich sections also contained anomalous amounts of silver and PGM (Cantex Mine Development Corp., 2000d).

In the first half of 2000, CMMY drilled eight additional holes near the two discovery holes in an area now referred to as the Suwar north zone. Seven of the eight holes also intersected significant sulfide mineralization, with peak nickel values ranging from 0.43% to 1.64%. Mineralization was subsequently found in a second area, 1.6 km southwest of the two discovery holes. This second area is now referred to as the Suwar south zone. Three holes were drilled in the south zone where anomalous values of palladium and platinum as well as copper, nickel, and cobalt were present in soil and rock chips. One drill hole intersected a 6.7-m-thick sulfide section assaying 1.23% Ni, 0.45% Cu, 0.113% Co, and 2.02 g/t of silver (Cantex Mine Development Corp., 2000c).

On July 4, CMMY and Falconbridge International (Investments) Ltd. formed a joint venture to evaluate the Suwar discovery. Falconbridge International (Investments) is a wholly owned subsidiary of Falconbridge Ltd., one of the five largest nickel producers in the world. Under the joint-venture agreement, Falconbridge can earn up to a 60% working interest in the Suwar mining lease. The two Canadian partners are hoping to construct a mine and mill within 4 years if a proposed feasibility study is positive (Cantex Mine Development Corp., 2000b). In November, Falconbridge International was finishing up a ground electromagnetic survey of the Suwar complex but decided to suspend surveying until after the Ramadan holiday. The geophysical data were to be used to generate targets for the 2001 drilling program.

The Prime Minister of Yemen reportedly has commissioned the surveying and planning of a 42-km-long access road to the Suwar property. The access road would tie into an existing highway at a point 145 km from the Red Sea port of Hodeidah.

Current Research and Technology

Researchers Synthesize Organo-Nickel Compound that Behaves Like a Metal.—Japanese researchers have synthesized an organo-nickel compound that behaves like a metal. The new crystalline material reportedly is the first synthetic metal built from a single, neutral molecular component (Chemical and Engineering News, 2001). Previously synthesized molecular metals have had two or more components. The compound is referred to as $Ni(tmdt)_2$, where tmdt is trimethylene-tetrathiafulvalene-dithiolate. Resistivity and magnetic susceptibility measurements indicate that $Ni(tmdt)_2$ is metallic over a temperature range from 0.6 K (Kelvin) to room temperature, 296 K. Single crystal diffraction analysis revealed that $Ni(tmdt)_2$ has a triclinic crystal structure (Tanaka and others, 2001).

A conventional metal typically has good electrical and thermal conductivities, ductility, and reflectivity and usually exhibits high strength. These properties are related to a structure in which the positively charged ions are bonded through a field of free electrons (i.e., electron gas) which surrounds them. The $Ni(tmdt)_2$ molecule has 12 sulfur atoms bonded to carbon, forming a string of five-membered, heterocyclic rings. Because of this complex resonating ring structure, the new compound exhibits some of the characteristics of graphite and benzene.

The Japanese research team was composed of scientists from the Institute for Molecular Science in Okazaki and the Research Centre for Spectrochemistry at the University of Tokyo. The team focused on $Ni(tmdt)_2$ after finding in 1999 that an analogous nickel molecule, propylene-dithiotetrathiafulvalene-dithiolate [$Ni(ptdt)_2$], behaved like a semiconductor. The latest discovery may open new avenues for the preparation of molecule-based metals and novel superconductors.

Commercialization of Fuel Cells.—On September 21, Texaco Energy Systems, Inc. and ECD formed a 50-50 joint venture to commercialize regenerative fuel cells. ECD will provide proprietary technology and fuel cell development expertise. ECD has been developing an advanced automotive fuel cell that utilizes low-cost, nonnoble metal catalytic materials (Texaco Energy Systems, Inc. and Energy Conversion Devices, Inc., 2000).

In a fuel cell-powered automobile, hydrogen gas is used in place of gasoline. The fuel cell generates electric power for the automobile motor by combining the hydrogen with oxygen to form water vapor. The oxygen is in air drawn into the cell from the outside atmosphere. ECD has proposed storing the hydrogen in a metal hydride system the size of a conventional gasoline tank. The metal hydride matrix minimizes the possibility of a hydrogen explosion. For additional information, see Dunn (1999), Goes (1999), and Mangan (1999).

Outlook

There is little chance that ferronickel production in the United States can be revived in the near term. The use of PAL technology to recover nickel from lateritic ores in New Caledonia, the Philippines, and Western Australia is expected to keep nickel prices in check for at least a decade. The combined rate of refined nickel production for the three existing Australian PAL operations passed the 9,000 t/yr mark at the beginning of 2001 and was expected to keep growing for at least another 3 years, eventually surpassing 100,000 t/yr. Plans to develop additional lateritic nickel deposits in the Kalgoorlie region of Western Australia have accelerated since the Goldfields natural gas pipeline was completed in late 1996 (Griffiths, 2000). The availability of inexpensive natural gas from offshore fields on the North West Shelf of the Indian Ocean has made it economically possible to produce refined nickel at several other laterite deposits previously rejected because of their remote locations. At least part of the new ferronickel production from Cerro Matoso (Colombia) and Loma de Níquel (Venezuela) has begun to come to the United States. The proposed Goro and Koniambo projects in New Caledonia would put additional material into the U.S. supply line.

The immense resources of the Voisey's Bay nickel-copper-cobalt deposit in northeastern Labrador (Canada) continue to overshadow the market. Inco and the Provincial Government of Newfoundland could reach an agreement at any time on developing the sub-Arctic deposit. Depending on market conditions, the proposed Voisey's Bay mining and milling complex would be capable of producing from 60,000 to 123,000 t/yr of nickel in sulfide concentrates. In Ontario, Falconbridge and Inco continue to find new ore along the edges of the Sudbury Basin. In Manitoba and Quebec, exploration crews have identified several promising occurrences for future followup.

The long-term outlook for increased nickel consumption is extremely positive, despite the recent economic crises in East Asia. Several forces are helping to sustain long-term growth in nickel consumption. The population of the world continues to grow. Faster transport, the explosive expansion of telecommunications systems, and the globalization of markets are making society as a whole increasingly dependent on products fabricated from sophisticated starting materials, many of which contain significant quantities of nickel. A technologically advancing society is continually demanding new materials with improved resistance to corrosion and heat, again favoring nickel.

Demand for austenitic stainless steel will continue to drive the world nickel market for at least another 20 years. For the present, growing demand for stainless steel in China, Europe, and the Western Hemisphere has offset weak demand in Japan. Beginning in 2002, world stainless steel consumption is forecast to grow between 2% and 5% per year to the year 2007. After 2007, the growth rate could rise even more, perhaps reaching 9% at some point, if the Russian economy turns around. The outlook for stainless steel production in the United States remains positive despite the growth in steel imports. Stainless steel production in the United States could exceed 2.6 Mt in 2002—an all time high for the country. The austenitic share of the production is expected to remain unchanged at 59%. This percentage is lower than corresponding austenitic percentages reported by other member countries of the Organization for Economic Cooperation and Development because the U.S. automobile manufacturing industry consumes more than 500,000 t/yr of ferritic stainless, about 18% of total U.S. stainless consumption.

Demand for nickel-bearing superalloys is expected to grow. The aerospace industry has been gradually shifting from a defense-oriented market to one that is more evenly balanced between commercial and Government purchases. Advanced nickel and titanium alloys are increasingly being incorporated in aircraft.

Batteries now constitute a bigger market for nickel in the United States than either coinage or traditional copper-nickel alloys. The use of nickel in batteries is growing at a much faster rate than the use of nickel in steel, although the tonnages going into batteries are still small. The market for nickel-based batteries is expected to grow at least 6% per year during the next 10 years even if American and Japanese automobile manufacturers decide to substitute lithium-ion cells for nickel-metal hydride cells in their third-generation EVs or second-generation hybrid vehicles. Automobile manufacturers are considering replacing the current 12-volt electrical systems in vehicles with 42-volt systems. If adopted, the change could drastically change the types of metals used in batteries for conventional automobiles. A NiMH battery has a higher energy density and longer cycle life than its advanced lead-acid counterpart. Performance and environmental requirements favor the NiMH battery, but problems starting the automobile at low temperatures need to be resolved (Jouhanneaud, 2001).

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TABLE 1
SALIENT NICKEL STATISTICS 1/

(Metric tons of contained nickel, unless otherwise specified)

	1996	1997	1998	1999	2000
United States:					
Mine production	1,330	--	--	--	--
Plant production	15,100	16,000	4,290	--	--
Secondary recovery from purchased scrap:					
From ferrous scrap	48,800	58,200	52,700	58,600	71,700
From nonferrous scrap	10,500	10,200	10,400	12,400 r/	12,200
Shipments of purchased scrap 2/	84,900	97,600	89,700 r/	93,000 r/	123,000
Exports:					
Primary	13,100	16,400	8,440	7,440 r/	8,150
Secondary	33,600	40,200	35,100	31,400	49,900
Imports for consumption:					
Ore	15,000	17,600	1,420	--	--
Primary	142,000	147,000	148,000	139,000	156,000
Secondary	8,060	11,000	8,500	9,480	10,700
Consumption:					
Reported:					
Primary	118,000 r/	120,000 r/	116,000 r/	116,000 r/	115,000
Secondary (purchased scrap) 3/	59,300	68,400	63,100 r/	71,000	84,000
Total	177,000 r/	188,000 r/	179,000 r/	187,000 r/	199,000
Apparent:					
Primary	146,000	154,000 r/	149,000 r/	140,000 r/	147,000
Secondary (purchased scrap) 4/	33,700	37,700	36,900 r/	49,400 r/	42,000
Total	180,000	192,000 r/	186,000 r/	190,000 r/	189,000
Apparent primary plus reported secondary	206,000	222,000 r/	212,000 r/	211,000 r/	231,000
Stocks, yearend:					
Government	15,900	8,530	2,600	--	--
Producers and traders	13,300	12,600	13,100	12,700	12,300
Consumer, primary	9,270	10,400 r/	10,500 r/	4,850 r/	6,490
Consumer, secondary	4,230	5,770	5,460 r/	5,070	7,860
Total	42,700	37,300	31,700 r/	22,600 r/	26,600
Employment, yearend:					
Mine	8	7	7	1	1
Smelter	253	264	6	6	(5/)
Port facility	23	22	1	1	--
Price, cash, London Metal Exchange:					
Per metric ton, average annual	$7,501	$6,927	$4,630	$6,011	$8,638
Per pound, average annual	$3	$3	$2	$3	$4
World, mine production	1,060,000	1,120,000 r/	1,130,000 r/	1,120,000	1,250,000

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits, except prices; may not add to totals shown.
2/ Defined as scrap receipts less shipments by consumers plus exports minus imports plus adjustments for consumer stock changes.
3/ More nearly represents amount consumed than does apparent secondary consumption.
4/ Internal evaluation indicates that apparent secondary consumption is considerably understated.
5/ The smelter at Riddle, OR, was decommissioned in 2000.

TABLE 2
NICKEL RECOVERED FROM PURCHASED SCRAP IN THE UNITED STATES,
BY KIND OF SCRAP AND FORM OF RECOVERY 1/

(Metric tons of contained nickel)

	1999	2000
Kind of scrap:		
Aluminum-base 2/	4,450	4,290
Copper-base	2,860	3,310
Ferrous-base 3/	58,600	71,700
Nickel-base	5,120 r/	4,620
Total	71,000	84,000

See footnotes at end of table.

TABLE 2--Continued
NICKEL RECOVERED FROM PURCHASED SCRAP IN THE UNITED STATES,
BY KIND OF SCRAP AND FORM OF RECOVERY 1/

(Metric tons of contained nickel)

	1999	2000
Form of recovery:		
Aluminum-base alloys	4,450	4,290
Copper-base alloys	5,160 r/	5,300
Ferrous alloys	58,600	71,800
Nickel-base alloys	2,780 r/	2,610
Miscellaneous and unspecified	2	1
Total	71,000	84,000

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Primarily borings and turnings of wrought alloys such as 2218, 2618, 4032, and 8280, or special casting alloys such as 203.0.
3/ Primarily stainless and alloy steel scrap consumed at steel mills and foundries.

TABLE 3
REPORTED U.S. CONSUMPTION OF NICKEL, BY FORM 1/

(Metric tons of contained nickel)

Form	1999	2000
Primary:		
Metal	95,600 r/	94,600
Ferronickel	12,800 r/	13,500
Oxide and oxide sinter 2/	5,160	3,610
Chemicals	1,660	1,340
Other	1,200 r/	1,590
Total	116,000 r/	115,000
Secondary (scrap) 3/	71,000	84,000
Grand total	187,000 r/	199,000

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes chemical-grade oxide.
3/ Based on gross weight of purchased scrap consumed and estimated average nickel content.

TABLE 4
U.S. CONSUMPTION OF NICKEL IN 2000, BY USE 1/

(Metric tons of contained nickel)

Use	Metal	Ferro-nickel	Oxide and oxide sinter	Chemicals	Other forms	Total primary	Secondary (scrap)	Grand total 2000	Grand total 1999
Cast irons	54	W	--	--	60	114	54	168	495 r/
Chemicals and chemical uses	347	W	W	644	--	991	--	991	1,580 r/
Electric, magnet, expansion alloys	479	--	--	--	--	479	W	479	525 r/
Electroplating (sales to platers)	15,600	--	--	39	W	15,700	--	15,700	15,400 r/
Nickel-copper and copper-nickel alloys	5,570	W	W	--	16	5,590	4,370	9,960	10,500
Other nickel and nickel alloys	15,500	67	W	--	89	15,700	2,510	18,200	15,200
Steel:									
Stainless and heat resistant	21,100	13,200	3,360	W	153	37,800	70,400	108,000	102,000 r/
Alloys (excludes stainless)	5,370	85	147	--	776	6,370	1,330	7,700	8,100 r/
Superalloys	18,900	--	W	W	441	19,400	W	19,400	18,900 r/
Other 2/	11,600	68	107	651	59	12,500	5,350	17,800	15,200 r/
Total	94,600	13,500	3,610	1,330	1,590	115,000	84,000	199,000	187,000 r/
Total all companies, apparent	XX	XX	XX	XX	XX	147,000	42,000	189,000	190,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Other." XX Not applicable. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes batteries, catalysts, ceramics, coinage, other alloys containing nickel, and data indicated by symbol "W."

TABLE 5
NICKEL IN CONSUMER STOCKS IN THE UNITED STATES, BY FORM, DECEMBER 31 1/

(Metric tons of contained nickel)

Form	1999	2000
Primary:		
Metal	3,610 r/	4,720
Ferronickel	430 r/	768
Oxide and oxide sinter	390	610
Chemicals	224 r/	188
Other	194 r/	202
Total	4,850 r/	6,490
Secondary (scrap)	5,070	7,860
Grand total	9,920 r/	14,300

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 6
U.S. EXPORTS OF NICKEL PRODUCTS, BY CLASS 1/

	1999		2000	
Class	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Unwrought primary (contained nickel):				
Cathodes, pellets, briquets, shot	831	$6,610	1,690	$15,100
Ferronickel	59	161	37	202
Powder and flakes	909	14,200	1,260	18,700
Metallurgical-grade oxide	1,470	2,730	1,930	6,350
Chemicals (contained nickel):				
Catalysts	3,360	110,000	1,880	70,100
Salts 3/	803	6,860	1,350	13,800
Total	7,440	140,000	8,150	124,000
Unwrought secondary (contained nickel):				
Stainless steel scrap	19,500	151,000	35,100	310,000
Waste and scrap	12,000	40,300	14,800	60,900
Total	31,400	192,000	49,900	371,000
Grand total	38,900	332,000	58,100	495,000
Wrought (contained nickel):				
Bars, rods, profiles, wire	382	4,300	520	9,200
Sheets, strip, foil	280	4,700	741	13,000
Tubes and pipes	260	2,550	147	1,550
Total	922	11,500	1,410	23,700
Alloyed (gross weight):				
Unwrought alloyed ingot	9,140	76,100	9,850	91,400
Bars, rods, profiles, wire	6,360	101,000	7,270	120,000
Sheets, strip, foil	7,430	90,500	7,930	112,000
Tubes and pipes	828	20,400	1,010	23,900
Other alloyed articles	3,550	82,400	2,670	86,500
Total	27,300	371,000	28,700	433,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ The nickel contents are as follows: metallurgical-grade oxide, 77%; waste and scrap, 50%; and stainless steel scrap, 7.5%. The salts category contains the following: chemical-grade oxide, sesquioxide, and hydroxide, 65%; chlorides, 25%; and sulfates, 22%. Other salts and various catalysts are assumed to be 22% nickel.
3/ Excludes nickel carbonate (see Schedule B 2836.99.9050).

Sources: U.S. Census Bureau and Journal of Commerce.

TABLE 7
U.S. EXPORTS OF NICKEL PRODUCTS IN 2000, BY COUNTRY 1/

(Metric tons of contained nickel) 2/

Country	Cathodes, pellets, briquets (unwrought)	Powder and flakes	Ferro-nickel	Metallurgical grade oxide 3/	Waste and scrap	Stainless steel scrap	Chemicals	Total 2000	Total 1999	Wrought nickel 4/
Australia	--	1	--	--	11	1	3	16	28	28
Belgium	--	6	--	11	794	923	66	1,800	874	28
Brazil	3	19	--	6	--	74	47	149	38	9
Canada	347	456	31	1,820	8,770	3,500	551	15,500	13,400	239
China	1	3	--	--	149	1,770	64	1,980	732	17
Colombia	46	49	--	--	--	--	8	103	44	1
Finland	--	--	--	--	--	--	10	10	(5/)	--
France	295	86	--	--	16	10	37	444	130	15
Germany	1	99	6	1	623	97	126	953	627	54
India	--	5	--	1	73	1,230	28	1,340	296	4
Italy	1	27	--	17	13	11	9	78	25	25
Japan	22	48	--	(5/)	1,380	3,450	471	5,370	3,310	13
Korea, Republic of	6	29	--	1	1,580	13,500	92	15,200	8,080	34
Mexico	920	97	--	24	11	172	336	1,560	1,310	424
Netherlands	--	17	--	16	90	1,150	71	1,340	246	4
South Africa	--	(5/)	--	3	336	944	14	1,300	1,320	--
Spain	--	9	--	--	93	1,510	3	1,620	2,030	--
Sweden	--	5	--	(5/)	323	384	47	759	144	3
Taiwan	1	42	--	(5/)	12	5,970	180	6,210	4,050	18
United Kingdom	13	68	--	--	267	65	27	440	743	192
Venezuela	--	1	--	--	--	5	52	58	29	4
Other	33	192	--	34	266	319	989	1,830	1,460 r/	296
Total	1,690	1,260	37	1,930	14,800	35,100	3,230	58,100	38,900	1,410

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ The nickel contents are assumed to be as follows: metallurgical-grade oxide, 77%; waste and scrap, 50%; and stainless steel scrap, 7.5%. The chemicals category contains the following: chemical-grade oxide, sesquoxide, and hydroxide, 65%; chlorides, 25%; and sulfates, 22%. Other salts and various catalysts are assumed to be 22% nickel.
3/ Chemical-grade oxide is included in the "Chemicals" category.
4/ Excluded from "Total."
5/ Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 8
U.S. IMPORTS FOR CONSUMPTION OF NICKEL PRODUCTS, BY CLASS 1/

Class	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Unwrought primary (contained nickel):				
Cathodes, pellets, briquets, shot	109,000	$607,000	119,000	$1,020,000
Ferronickel	14,300	73,000	16,400	125,000
Flakes	206	1,200	942	9,320
Powder	9,170	84,700	13,500	146,000
Metallurgical-grade oxide	3,270	20,500	2,540	27,200
Chemicals (contained nickel):				
Catalysts	996	47,600	1,690	61,700
Salts 3/	1,810	20,200	2,000	25,400
Total	139,000	854,000	156,000	1,410,000
Unwrought secondary (contained nickel):				
Stainless steel scrap	4,960	27,700	4,220	35,500
Waste and scrap	4,520	27,100	6,530	56,400
Total	9,480	54,800	10,700	91,900
Grand total	149,000	909,000	167,000	1,500,000
Wrought (contained nickel):				
Bars, rods, profiles, wire	535	4,950	438	6,370
Sheets, strip, foil	540	12,600	503	13,600
Tubes and pipes	11	382	51	452
Total	1,090	17,900	992	20,400

See footnotes at end of table.

TABLE 8--Continued

U.S. IMPORTS FOR CONSUMPTION OF NICKEL PRODUCTS, BY CLASS 1/

Class	1999 Quantity (metric tons)	1999 Value (thousands)	2000 Quantity (metric tons)	2000 Value (thousands)
Alloyed (gross weight):				
Unwrought alloyed ingot	2,360	26,400	4,710	61,800
Bars, rods, profiles, wire	6,320	70,700	7,270	85,000
Sheets, strip, foil	2,560	35,500	3,470	58,900
Tubes and pipes	1,230	21,500	2,040	32,400
Other	818	29,600	1,550	32,400
Total	13,300	184,000	19,000	270,000

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ The nickel contents are as follows: metallurgical-grade oxide from Australia, 90%; elsewhere, 77%. The salts category contains the following: chemical-grade oxide, sesquioxide, and hydroxide, 65%; chlorides, 25%; sulfates, 22%; and other salts, which are assumed to be 22% nickel. The typical catalyst is assumed to have a nickel content of 22%. Waste and scrap is assumed to be 50% nickel, and stainless steel scrap, 7.5% nickel.

3/ Excludes nickel carbonate (see Harmonized Tariff Schedule of the United States 2836.99.5000).

Sources: U.S Census Bureau and Journal of Commerce.

TABLE 9

U.S. IMPORTS FOR CONSUMPTION OF NICKEL PRODUCTS, BY COUNTRY 1/

(Metric tons of contained nickel) 2/

Country	Cathodes, pellets, briquets (unwrought)	Powder and flakes	Ferro-nickel	Metal-lurgical grade oxide 3/	Waste and scrap	Stainless steel scrap	Chemicals	Total 2000	Total 1999	Wrought nickel 4/
Australia	10,200	5,240	--	53	28	--	--	15,500	14,600	--
Austria	--	143	--	--	--	--	--	143	657	103
Belgium	--	8	--	--	121	--	380	509	488	--
Brazil	5,960	2	--	--	--	46	71	6,080	5,680	26
Canada	53,500	6,510	--	2,480	2,550	2,350	103	67,500	59,400	34
China	--	--	--	--	21	--	140	161	681	9
Colombia	--	--	2,020	--	--	13	--	2,030	1,840	--
Dominican Republic	--	--	7,990	--	--	17	--	8,010	7,550	--
Finland	3,400	841	--	--	--	--	630	4,870	5,010	--
France	2,280	1	--	--	1,100	3	262	3,640	2,720	61
Germany	43	28	--	--	800	8	309	1,190	785	513
Japan	2	30	--	4	88	70	1,110	1,300	843	130
Mexico	--	--	--	--	319	1,440	15	1,770	1,690	1
Netherlands 5/	1,570	40	--	--	40	9	386	2,050	315	--
New Caledonia	--	--	6,390	--	--	--	--	6,390	4,960	--
Norway	18,400	--	--	--	27	--	--	18,400	22,700	--
Russia	19,500	1,290	--	--	10	--	--	20,800	13,800	--
South Africa	144	60	--	--	--	--	40	244	826	--
United Kingdom	2,340	174	--	--	826	18	103	3,460	2,320	64
Zimbabwe	1,600	--	--	--	--	--	--	1,600	1,190	--
Other	188	76	--	--	603	245	140	1,250	670	50
Total	119,000	14,400	16,400	2,540	6,530	4,220	3,690	167,000	149,000	992

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ The nickel contents are assumed to be as follows: metallurgical-grade oxide from Australia, 90%; elsewhere, 77%. The chemicals category contains the following: chemical-grade oxide, sesquioxide and hydroxide, 65%; chlorides, 25%; sulfates, 22%. Other salts and various catalysts are assumed to be 22% nickel. Waste and scrap is assumed to be 50% nickel, and stainless steel scrap, 7.5% nickel.

3/ Primarily oxide, rondelles and sinter.

4/ Excluded from "Total."

5/ The different nickel metal products (cathode, powder, etc.) are apparently material that has transited through bonded warehouses in the Netherlands including warehouses overseen by the London Metal Exchange.

Source: U.S. Census Bureau.

TABLE 10
NICKEL: WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons of nickel content)

Country	1996	1997	1998	1999	2000
Australia (content of concentrate)	113,134	123,372	143,513	127,000 r/	168,300
Botswana (content of ore milled)	21,910	19,860 r/	21,700 r/	33,733 r/	34,465
Brazil (content of ore)	25,245	31,936	36,764	41,522 r/	45,317
Burma (content of ore)	35 r/	38 r/	30 r/	76 r/	40
Canada (content of concentrate)	192,649	190,529	208,201	186,236 r/	190,728 p/
China e/	43,800	46,600	48,700	49,500 r/	51,100
Colombia (content of laterite ore)	27,700	31,230	29,422	39,274 r/	58,927
Cuba (content of oxide, oxide sinter, oxide powder, sulfide, ammoniacal liquor) 3/	51,220 r/	58,881 r/	64,752 r/	63,627 r/	68,305
Dominican Republic (content of laterite ore)	45,168	49,152	40,311 r/	39,997 r/	39,943
Finland (content of concentrate)	2,136	3,252	1,967	70 r/	2,600
Greece (content of laterite ore)	21,600 r/	18,419 r/	16,985 r/	16,050 r/	19,535
Indonesia (content of ore)	87,911	71,127	74,063	89,111 r/	98,200
Kazakhstan e/	7,000	7,000	-- r/	-- r/	3,000
Macedonia (content of ferronickel produced) e/	3,000	5,300	5,800	1,900	--
New Caledonia (content of ore)	122,486	136,467	125,319	110,062 r/	127,493
Norway (content of concentrate)	3,135	2,454	2,959	2,965 r/	2,538
Philippines	14,539	18,137 r/	12,840	14,300 r/ e/	23,500 e/
Russia e/	230,000	260,000	250,000	260,000	270,000
Serbia and Montenegro (content of ferronickel produced)	2,556	2,440	466	--	--
South Africa (content of concentrate)	33,861	34,830	36,679 r/	36,200 r/	36,616
Ukraine (content of ferronickel produced) e/	500	--	--	--	--
United States (content of local ore processed)	1,330	--	--	--	--
Venezuela (content of laterite ore)	--	--	--	--	2,472
Zimbabwe (content of concentrate)	11,561	12,963	12,872	11,164	8,160
Total	1,060,000	1,120,000 r/	1,130,000 r/	1,120,000	1,250,000

e/ Estimated. p/ Preliminary. r/ Revised. -- Zero.
1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.
2/ Insofar as possible, this table represents recoverable mine production of nickel. Where actual mine output is not available, data related to a more highly processed form have been used to provide an indication of the magnitude of mine output and this is noted parenthetically. North Korea may have an active nickel mine, but information is inadequate to make reliable estimates of output. Table includes data available through July 27, 2001.
3/ The Government of Cuba reports plant production on a contained nickel plus cobalt basis. The tonnages shown in this table for Cuba have been adjusted downward to correct for the cobalt. The cobalt content was determined to be 1.16% for granular and powdered oxide, 1.21% for oxide sinter, 7.56% for sulfide precipitate, and 25% for ammoniacal leach precipitate.

TABLE 11
NICKEL: WORLD PLANT PRODUCTION, BY COUNTRY AND PRODUCT 1/ 2/

(Metric tons of nickel content)

Country and product 3/	1996	1997	1998	1999	2000
Albania, metal e/	50	--	--	--	--
Australia:					
Metal	61,377	58,824	64,322	75,952 r/	102,660
Unspecified	12,636	14,762	15,256	7,648 r/	9,155
Total	74,013	73,586	79,578	83,600 r/ 4/	111,815 4/
Austria, ferronickel e/	2,000	2,000	1,800	1,700	1,700
Brazil: 5/					
Ferronickel	9,091	9,350	8,077	6,502	6,347
Metal	7,849	8,849	13,006	16,429	16,906
Total	16,940	18,199	21,083	22,931	23,253
Canada, unspecified 6/	130,136	131,639	146,715	124,260 r/	134,224 p/
China, metal e/	44,600	43,300	40,100	44,400 r/	50,900
Colombia, ferronickel	22,934	25,171	28,143	28,345	27,720
Cuba, oxide sinter and oxides 7/	26,730 r/	33,571 r/	38,192 r/	37,510 r/	39,892
Dominican Republic, ferronickel	30,376	32,558	25,220	24,449	27,832

See footnotes at end of table.

TABLE 11--Continued
NICKEL: WORLD PLANT PRODUCTION, BY COUNTRY AND PRODUCT 1/ 2/

(Metric tons of nickel content)

Country and product 3/	1996	1997	1998	1999	2000
Finland:					
Metal	28,815	34,228	46,200 r/	51,948 r/	50,619
Chemicals	4,508	4,990	4,518	4,143	3,711
Total	33,323	39,218	50,718 r/	56,091 r/	54,330
France:					
Metal	9,070	8,750	9,778	9,458	10,100
Chemicals	2,101	1,952	2,000 e/	2,244	2,200
Total 8/	11,171	10,702	11,778	11,702	12,300
Greece, ferronickel	17,801	17,610	15,005	12,964	17,470
Indonesia, ferronickel	9,553	9,999	8,452	9,205	10,111
Japan:					
Ferronickel	66,796	72,079	69,202	67,166 r/	73,448
Metal	26,564	26,889	29,397	30,481	36,230
Oxide sinter	34,772	26,899	25,435	34,482 r/	48,325
Chemicals	2,323	2,536	2,511	2,570	2,700
Total	130,455	128,403	126,545	134,699 r/	160,703
Korea, Republic of, metal	(9/)	(9/)	(9/)	(9/)	(9/)
Macedonia, ferronickel e/	3,000	5,300	5,800	1,900	--
New Caledonia, ferronickel	42,173	44,312	44,491	45,289	43,914
Norway, metal	61,582	62,702	70,152	74,137 r/	58,679
Poland, chemicals 10/	359	364	376	396	430
Russia: e/ 11/					
Ferronickel	10,000	10,000	10,000	11,000	11,000
Metal	170,000	210,000	205,000	215,000	225,000
Oxide sinter	8,000	8,000	10,000	10,000	10,000
Chemicals	2,000	2,000	2,000	2,000	2,000
Total	190,000	230,000	227,000	238,000	248,000
Serbia and Montenegro, ferronickel	2,556	2,440	466	--	--
South Africa:					
Metal	27,861 r/	28,830 r/	29,039	28,345	29,616
Chemicals 12/	6,000 r/	6,000	7,640 r/	7,855 r/	7,000
Total	33,861 r/	34,830 r/	36,679 r/	36,200 r/	36,616
Taiwan, metal	(9/)	(9/)	(9/)	(9/)	(9/)
Ukraine, ferronickel e/	500	--	--	--	--
United Kingdom, metal	38,561	36,091	41,994 r/	39,467 r/	37,976
United States, ferronickel	15,100	16,000	4,290	--	--
Venezuela, ferronickel	--	--	--	--	40
Zimbabwe, metal:					
Refined from domestic materials 13/	9,694	10,300	8,732	9,106 r/	6,678
Toll refined from imported materials 14/	6,518	7,346	8,709	10,676	12,937
Total	16,212	17,646	17,441	19,782	19,615
Other, metal 15/	-- r/	-- r/	-- r/	-- r/	--
Grand total:	954,000 r/	1,020,000 r/	1,040,000 r/	1,050,000	1,120,000
Of which:					
Ferronickel	232,000	247,000	221,000	209,000 r/	220,000
Metal	493,000 r/	536,000 r/	566,000 r/	605,000 r/	638,000
Oxide sinter	69,500	68,500 r/	73,600 r/	82,000 r/	98,200
Chemicals	17,300 r/	17,800	19,000	19,200 r/	18,000
Unspecified	143,000	146,000	162,000	132,000 r/	143,000

See footnotes at end of table.

TABLE 11--Continued

NICKEL: WORLD PLANT PRODUCTION, BY COUNTRY AND PRODUCT 1/ 2/

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

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through July 27, 2001.

3/ In addition to the countries listed, North Korea is believed to have produced metallic nickel and/or ferronickel, but information is inadequate to make reliabl estimates of output levels. Several countries produce nickel-containing matte, but output of nickel in such materials has been excluded from this table to avoid double counting. Countries producing matte for export are listed in table 12.

4/ Includes estimated production of pressure acid leach operations.

5/ Brazil produced nickel carbonate (an intermediate product), in metric tons: 1996--9,210; 1997--10,487; 1998--13,133; 1999--17,153; and 2000--17,223.

6/ Nickel contained in products of smelters and refineries in forms, which are ready for use by consumers. Figures include the nickel content of nickel oxide sinter exported to the Republic of Korea and Taiwan. See footnote 8.

7/ Cuba also produces nickel sulfide but, because it is used as feed material elsewhere, it is not included to avoid double counting. Combined output of processed sulfide and ammoniacal liquor precipitate was, as follows, in metric tons of contained nickel: 1996--24,490 (revised); 1997--25,310 (revised); 1998--26,561 (revised); 1999--26,118 (revised); and 2000--28,413. See table 12.

8/ Reported by Eramet for Sandouville. Excludes secondary production from spent rechargeable batteries.

9/ Nickel metal production for the Republic of Korea and Taiwan are not included because the production is derived wholly from imported metallurgical-grade oxides and to include them would result in double counting. Metal estimates are as follows, in metric tons: the Republic of Korea: 1996--18,000 (revised); 1997--18,452 (revised); 1998--20,183; 1999--20,235; and 2000--29,890; and Taiwan: 1996--10,000; 1997-1998--10,5000; and 1999-2000--10,000.

10/ Nickel content of nickel sulfate ($NiSO_4 \sim 6H_2O$). Most of the nickel sulfate was a byproduct of the concentrating, smelting, and refining of domestically mined copper ores. Some production, however, may have been derived from imported nickeliferous raw materials that were blended with the domestic copper concentrates.

11/ Includes production from sulfidized concentrates shipped from Cuba for toll refining.

12/ Include nickel sulfate plus exported metal in concentrate.

13/ Data represent production from domestic nickel ore.

14/ Previously published as "Other, metal." Data represent production from imported Botswanan matte and South African nickel sulfate.

15/ See "Zimbabwe, metal, toll refined from imported materials."

TABLE 12

NICKEL: WORLD PRODUCTION OF INTERMEDIATE PRODUCTS FOR EXPORT, BY COUNTRY 1/ 2/

(Metric tons of nickel content)

Country	1996	1997	1998	1999	2000
Matte:					
Australia 3/	28,768	37,010	47,459	28,190	41,771
Botswana	22,095 r/	20,157	22,851	22,898 r/	24,218
Brazil 4/	--	1,180	4,670	9,306	8,475 p/
Canada e/ 5/	50,000	45,000	48,000 r/	52,000	37,000
Indonesia	49,000	33,654	35,697	45,400 r/	59,200
New Caledonia	11,239	10,580	12,011	11,353	13,549
Russia e/ 6/	320	366	98	114 r/	480
Total	161,000 r/	148,000	171,000 r/	169,000 r/	185,000
Other:					
Cuba: 7/					
Sulfide precipitate	24,066 r/	24,507 r/	25,176 r/	24,999 r/	27,288
Ammoniacal liquor precipitate	425	803	1,385	1,119	1,125
Total	24,491	25,310	26,561	26,118	28,413

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

1/ Table includes data available through July 27, 2001. Data represent nickel content of matte and other intermediate materials produced for export.

2/ World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

3/ Total matte production on a contained nickel basis, in metric tons, was as follows: 1996--74,000; 1997--85,800; 1998--100,071 (revised); 1999--79,668 (revised); and 2000--103,000.

4/ The Fortaleza smelter was commissioned in December 1997. All output is being shipped to Finland for further processing.

5/ Estimated nickel content of reported exports.

6/ Export figures reported by importing countries: primarily France and Norway. Exports to Norway were estimated to have a nickel content of 40%.

7/ Corrected for coproduct cobalt.

FIGURE 1
NICKEL: LONDON METAL EXCHANGE CASH PRICE AND STOCKS

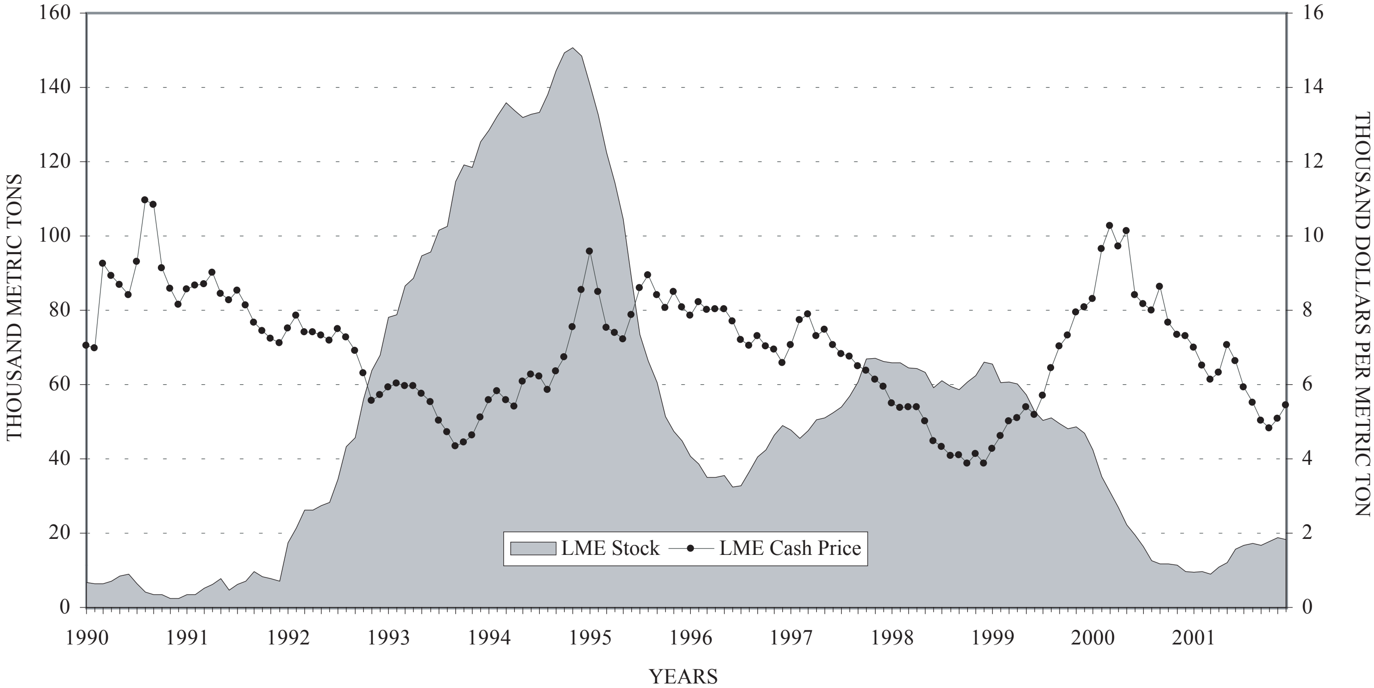

FIGURE 2
NICKEL: OPERATIONS AND PROJECTS IN NEW CALEDONIA