NICKEL

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For the past 20 years, nickel producers have had to deal with price fluctuations, which have deviated as much as 100% from the cumulative average. The spot price of nickel metal declined by 51% between March 1997 and October 1998, but began to improve in early 1999. By December, the price had recovered substantially from the October 1998 low of $3,872 per metric ton—the lowest level for the century in terms of constant dollars. Several analysts attributed the 1999 price recovery to a weakening of recessionary forces in East Asia and a strengthening of the economies of North America and Western Europe.

Producers continued to bring on new capacity because of optimistic forecasts for long-term growth in demand. Development projects were launched even during the worst months of the 1998 price downturn. More than 320,000 metric tons (t) of capacity (on a contained nickel basis) were scheduled to come on-stream between 2000 and 2006. In Western Australia, three new laterite mines were commissioned in 1998-99 and at least three others were in various stages of development (Griffiths, 2000; Western Australian Department of Resources Development, 1999, p. 3-18). The three new laterite mines were refining the nickel on-site; two new sulfide mines in Western Australia, though, were shipping concentrates or matte to Outokumpu Oyj's recently expanded refinery in Finland. In addition to the expansion in Australia, new mining projects were at various stages of development in Brazil, Indonesia, New Caledonia, Ontario, and Venezuela. Exports of primary nickel from Russia have remained firm, but consumption inside the country has been severely depressed for the past 3 years. The recent financial crisis in Asia created problems for several major stainless steel producers and discouraged some commodity funds and banking houses from investing in nickel.

Stainless steel accounts for more than 60% of nickel consumption in the world. In the United States, however, this percentage is considerably lower and is closer to 40% because of the relatively large number of specialty metal industries in the country. Specialty uses include 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). Smaller amounts of nickel (0.2% to 3.8%) sometimes are incorporated into low alloy steels to improve their resistance to atmospheric corrosion.

Legislation and Government Programs

***U.S. Department of Energy*.**—On January 12, 2000, the U.S. Secretary of Energy announced that he had forbidden 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 U.S. Department of Energy (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 metal, as opposed to a surface coating of contamination. The Oak Ridge material is a vestige of the U.S. Government's nuclear weapons programs. The prohibition also applied to at least 10,000 t of volumetrically contaminated scrap stored at other DOE facilities (Nuclear News, 2000; U.S. Department of Energy, 2000).

In 1996, DOE awarded a contract to British Nuclear Fuels Limited (BNFL) to clean up the defunct Oak Ridge Gaseous Diffusion Plant at the former K-25 Site (now the East Tennessee Technology Park). BNFL has been removing equipment containing large amounts of nickel as part of the cleanup of the uranium enrichment plant. Under the original contract, BNFL had the option of melting and decontaminating the nickel before releasing the material into commerce under a State of Tennessee license (U.S. Department of Energy, 2000). Because of the Secretary's order, a new contract may have to be negotiated. The principal contaminants in the K-25 nickel are reportedly technetium-99 (a beta emitter with a half-life of 211,000 years) and uranium-235.

As the project approached startup, several industry and community groups began protesting the Government recycling plan. Opposition continued to grow and on November 30, 1999, the Metals Industry Recycling Coalition (MIRC) sent a letter to the Secretary of Energy expressing the coalition's opposition to the recycling project.

On December 21, the Nickel Development Institute (NiDI) presented a 15-page brief to the U.S. Nuclear Regulatory Commission (NRC) opposing the entry of "low-level" radioactive nickel scrap into the commercial recycling stream (Nickel Development Institute, 1999c). 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. On January 6, 2000, the Specialty Steel Industry of North America issued a statement opposing the DOE plan and reaffirming its "zero tolerance" policy toward potentially radioactive scrap metals (Nuclear News, 2000).

Even if the decontaminated metal meets dose-based clearance levels established by the NRC, NiDI was opposed to "free release" (McKean, 1999; Nickel Development Institute, 1999c, d). NiDI, MIRC, and their member companies were concerned that introduction of decontaminated scrap into the commercial recycling stream would negatively affect the marketability of metal products made from scrap and, more broadly, the marketability of all metal products. They were also concerned that unrestricted use of decontaminated scrap would tarnish the positive image developed over the years by the metals recycling industry. In addition, many steelmakers were worried that increased use of scrap with above-background levels of radioactivity would complicate operations at melting facilities and increase costs (Reid, 1999a, b).

Spokespersons for the metals industry said that the industry might support a "restricted use" program (Nickel Development Institute, 1999c). Under this concept, the contaminated metal would be processed at a dedicated, licensed facility. The decontaminated metal would then be shipped to an NRC-licensed nuclear facility or to a DOE nuclear facility for on-site use only. For example, DOE could refabricate the metal into shielding or into storage containers for radioactive waste.

Environmental Regulations.—The Portable Rechargeable Battery Association, a nonprofit trade association comprising 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 the Rechargeable Battery Recycling Corporation (RBRC) of Gainesville, FL. 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 bulk of the spent nickel-cadmium and nickel-metal hydride 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 Limited.

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.—On December 7, 1998, the U.S. Mint began producing the first of some 20 billion to 30 billion quarters (25-cent coins) commemorating each of the 50 States of the Union. Each State was to be honored with its own coin showing George Washington on the obverse (front) and a unique statehood design on the reverse. The redesigned quarters were being issued in the order in which the States ratified the U.S. Constitution or were admitted into the Union, with the minting of each commemorative limited to about 10 weeks. Like the previous "Eagle" quarter, the new coin contained 8.33% Ni and 91.67% copper (Cu). The coin had a core of pure copper and outer layers composed of a 25% Ni and 75% Cu alloy. The popular program was expected to earn from $3 billion to $5 billion for the Treasury. The U.S. Mint estimated that 100 million to 160 million people will collect the special-edition quarters.

Golden Dollar Coin.—The U.S. Mint was planning to put its new Golden Dollar coin into general circulation in March 2000. The new coin was a significant setback for the Mint's nickel suppliers because manganese and zinc replaced much of the nickel traditionally used in the alloy layer. The coin was authorized by the United States Dollar Coin Act of 1997 (Section 4 of Public Law 105-124) and replaces the Susan B. Anthony (SBA) dollar that has been in circulation since 1979. The Golden Dollar coin will coexist with the traditional one-dollar bank note. In early December 1999, the Mint released samples of the new coin to manufacturers of vending machines and other stakeholders for full field testing (U.S. Mint, 1999e).

The construction and electromagnetic properties of the Golden Dollar are very similar to those of the SBA coin. Both the Golden Dollar and the SBA dollar are clad coins, constructed by sandwiching a pure copper core between outer layers of an alloy. In the case of the Golden Dollar, the alloy layers on each side of the core are manganese brass, a golden-colored material. Table 13 compares the chemical composition of Golden Dollar alloy with that of the SBA dollar. It was extremely important that the electromagnetic signature and density of the new alloy closely match the signature and density of the cupronickel alloy used in the SBA dollar. Because the two coins are identical in size and weight, thousands of vending and mass transit machines that now accept SBA dollars will not have to be reprogrammed or refitted (U.S. Mint, 1999a).

The Philadelphia Mint began full-scale production of the Golden Dollar on November 18, 1999 (U.S. Mint, 1999d). The coin weighs 8.1 grams and has an overall composition of 88.5% Cu, 6.0% zinc, 3.5% manganese, and 2% Ni. The mint will have to produce more than 100 million per year of the coins if demand projections based on market research are correct. More than 16 tons per year (t/yr) of nickel would be consumed to make the coins.

The mint is producing the Golden Dollar for four reasons. First, demand for dollar coins in commerce is increasing (U.S. Mint, 1999b). Second, the coin will last longer than the banknote. The average life span of the coin should be about 25 years. Third, the Government's stocks of SBA dollars are nearly exhausted. Fourth, the Golden Dollar will be easily distinguishable from the traditional quarter, unlike the SBA coin (U.S. Mint, 1999c).

Euro Coinage.—The European Monetary Union (EMU) was planning 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. Because of health considerations, the EMU was using a nickel-free alloy called Nordic Gold for the 10-, 20-, and 50-eurocent coins (Outokumpu Oyj, 1998b). The 1-, 2-, and 5-eurocent coins were being made from copper-covered steel and were also nickel free. Only the 1- and 2-euro coins contained nickel.

The blanks for the two-color, bimetallic coins were formed by joining together thin layers of cupronickel and nickel-brass (Outokumpu Oyj, 1998a). Minting of the first euro coinage began in 1998. Stockpiles of the new coins were being built up throughout the EU in anticipation of the 2002 exchange period.

National Defense Stockpile.—On June 10, the U.S. Government sold the last of the nickel in the National Defense Stockpile (NDS). The Government had 33,760 t of nickel in inventory when the sales program began on March 24, 1993. The sales have been part of a major downsizing of the stockpile approved under the Defense Authorization Act of 1992 (Public Law 102-484). The final nickel sale was made to Considar, Inc., a trading company based in New York City (Defense National Stockpile Center, 1999). Considar paid $1.219 million for 231.224 t (509,761 pounds) of cathode. The unit price was $5,273 per ton ($2.3917 per pound). In the 1980's, the NDS goal for nickel was about 180,000 t of metal but actual stocks never exceeded 34,000 t. The breakdown of shipments and sales over the 7-year life of the program are shown in table 14.

Production

Primary Production.—The United States did not produce any primary nickel in 1999. On March 30, 1998, Cominco Ltd. permanently closed its ferronickel smelter at Riddle, OR, when the world price fell below $6,000 per metric ton ($2.72 per pound). The Glenbrook Nickel Co., a Cominco subsidiary, had operated the smelter since its acquisition from The M.A. Hanna Co. in 1989. Cominco was keeping the smelter, the only primary nickel producer in the United States, on care-and-maintenance status while the company searched for a prospective buyer.

After 43 years of mining, the bulk of the ore reserves on Nickel Mountain have been depleted. By yearend 1996, reserves had dwindled to 230,000 t grading 1.25% Ni (Cominco Ltd., 1997, p. 22). Additional resources of similar grade were available at other laterite deposits in the Klamath Mountains, which extend from southwestern Oregon into northern California, but trucking low-grade ore from these isolated and scattered pockets would not have been profitable at 1998-99 nickel prices. The 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, an Inco subsidiary, 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). The company can accept four types of spent nickel-based batteries—nickel-cadmium, nickel-iron, nickel-metal hydride, and nickel-zinc.

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 Company operated a base-metals refinery adjacent to its precious-metals smelter at Columbus, MT. In 1997 and 1998, the refinery produced a byproduct copper-nickel-cobalt solution, which was shipped by truck to Canada where the three metals were recovered (Stillwater Mining Company, 1998b, p. 1-17). The company has been mining platinum-group metals (PGM) and gold since 1986 from the Stillwater Complex at Nye in Montana's Beartooth Mountains. The Nye mill was expanded in 1998 and was processing almost 2,000 metric tons per day (t/d) of ore at yearend 1999 (Stillwater Mining Company, 2000a, p. 2; 2000b, p. 13-15 and 42). All of the ore was coming from the Stillwater Mine, an underground complex developed in the eastern half of the J&M Reef. The PGM- and nickel-bearing sulfides in the ore were being recovered by flotation and shipped as concentrate 74 kilometers (km) to Columbus for smelting. In 1999, the company spent $38 million expanding its Columbus metallurgical complex and adding a second, larger electric furnace to the smelter. The smelter can now process more than 100 t/d of concentrate. The PGM are recovered using a matte leach process developed by Sherritt International Corporation.

In 1998, Stillwater began to construct a copper-nickel-cobalt recovery circuit at its Columbus complex (Stillwater Mining Company, 1998a, p. 16-17; 1999, p. 22-23; 2000b, p. 8). The second stage of the $6 million circuit came on-stream in mid-1999, allowing the copper to be separated on-site from the nickel and cobalt. The copper byproducts are now shipped directly to a copper smelter. The base metals refinery expansion was scheduled to be completed by late 2000.

In August 1998, Stillwater began to develop its new East Boulder underground mine near Big Timber (Alexander, 1999). The company was boring two 5,600-meter-long adits to access the western half of the J&M Reef. The East Boulder Mine could be in production by late 2001. According to company officials, the reef has 33.6 million metric tons (Mt) of proven and probable reserves averaging 25 grams per ton (g/t) PGM. Recent exploration activities indicate an additional 38 Mt of resources of similar grade, but major portions of the reef have not yet been drilled. The reef has a strike length of about 45 km.

Consumption

In 1999, demand for primary nickel in the West was estimated to have reached an alltime high of 1,004,000 t (revised), surpassing the previous record of 943,800 t (second revision) set in 1997 (International Nickel Study Group, 2000a; 2000b, p. 3-12; 2000c, p. 3-8). U.S. apparent consumption of primary nickel was 140,000 t, or about 14% of Western demand. U.S. industry consumed an additional 71,000 t of nickel in scrap.

Stainless Steel and Low-Alloy Steels.—In 1999, U.S. and world demand for nickel continued to be driven by the stainless steel industry. Stainless steel producers accounted for 38% 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. A large part of the nickel consumed in the United States was used to make high-performance superalloys and related nickel-base alloys for the aerospace and petrochemical industries.

Production of raw stainless steel in Western countries has doubled in the past 13 years, growing to 16.25 Mt in 1998 from 7.92 Mt in 1985 (Inco Limited, 1999f, p. 3-13). Since 1990, new production facilities have been started up in the Republic of Korea, South Africa, and Taiwan. At the same time, existing capacity has been expanded in Finland, France, Germany, Spain, Sweden, and several other members of the EU. This expansion of capacity was followed by the 1997-98 economic slowdown in Japan, the Republic of Korea, several other East Asian countries, and Russia. Reduced growth in demand in East Asia and other overseas markets 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 153% since 1992, but domestic production has risen by only 21%.

Production of raw stainless and heat-resisting steel in the United States increased in 1999 by 9% to 2.19 Mt, surpassing the near-record high of 2.16 Mt reached in 1997. Nickel-bearing grades accounted for 1.28 Mt, or 42% of the total stainless production for 1999 (American Iron and Steel Institute, 2000b). Net shipments of all types of stainless totaled 1.89 Mt, a 10-year high (American Iron and Steel Institute, 2000a, p. 24-29). Shipments of sheets and strip increased 7% to 1.47 Mt, breaking the previous record of 1.38 Mt set in 1998. Shipments of plate, the next largest category, were 192,000 t, or 12% less than that of 1998.

***Superalloys and Related Nickel-Base Alloys*.**—U.S. production of nickel-base alloys was down from December 1998 to March 1999 because of a softening of key markets and a labor dispute at the Inco Alloys International (IAI) plant in Huntington, WV. United Steelworkers of America Local 40 struck the facility on December 11, 1998, halting production (Sacco, 1999b). The strike ended on February 24, 1999, with labor and management agreeing to a 3-year contract that will expire on February 22, 2002 (Special Metals Corporation, 1999). Special Metals Corporation bought IAI from Inco Limited on October 28, 1998. The merger made Special Metals the world's largest and most-diversified producer of high-performance nickel-base alloys.

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 1999, the U.S. aerospace industry earned a record $10.8 billion on sales of $151 billion (Napier, 2000). Total sales were 2.1% greater than those of 1998. The U.S. Government accounted for only 46% of domestic aerospace products and services compared with 70% a decade ago. For the first time in 5 years, The Boeing Company and its McDonnell Douglas Corporation subsidiary reduced their backlog of orders for civil jet transports. A total of 346 net orders for large civil jet transports was received in 1999, compared with 601 (revised) in 1998 (Aerospace Industries Association of America, Inc., 2000). Between 1998 and 1999, actual shipments increased, rising from 559 aircraft to 620. On December 31, 1999, the combined firms had a backlog of 1,512 aircraft, down from 1,786 at yearend 1998.

***Mergers, Acquisitions, and Closures*.**—The specialty steel industry of the United States has undergone a major restructuring since mid-1996. U.S. superalloy producers, which have close ties to some of the specialty steel producers, also have restructured. The principal force driving the mergers and acquisitions has been the financial synergies created by the integration of similar specialty metals operations. Growing imports of stainless steel have forced company executives to accelerate their plans.

Allegheny Teledyne.—On January 19, 1999, Allegheny Teledyne Inc. announced that it would reconfigure the company. The reconfiguration was completed on November 29. The operating units involved in the production and marketing of specialty materials were retained. The remainder of the company was split in two.

Four business units in the Aerospace and Electronics Segment were spun off and welded into a new company called Teledyne Technologies Inc.; these units, which had been part of Teledyne Inc., were absorbed when Teledyne merged with Allegheny Ludlum Corporation in August 1996. The new company focused on high-technology products for the aerospace and communications industries. Allegheny Teledyne's Consumer Segment was also spun off, forming a third freestanding company—WaterPik Technologies Inc. (Allegheny Teledyne Inc., 1999; Boselovic, 1999c).

After the spinoffs were completed, Allegheny Teledyne changed its name to Allegheny Technologies Inc. The retained units had combined sales of $2.3 billion in 1999. The downsized company now has the following eight principal operating units: Allegheny Ludlum, Allvac, Casting Service, Metalworking Products, Oremet-Wah Chang, Portland Forge, Rome Metals, and Titanium Industries. Allegheny Ludlum is a leading producer of flat-rolled stainless steel, while Allvac makes superalloy bar, rod, and wire. Rome Metals specializes in the machining and finishing of nickel alloys, titanium, and zirconium.

Bethlehem Steel Corporation.—In late March, Bethlehem Steel closed two operations that produced stainless steel sheet and strip—Washington, PA, and Massillon, OH. Bethlehem had acquired the two steel mills in May 1998 as part of its $800 million purchase of Lukens Inc. (Kuck, 2000, p. 5). The two facilities had been operating on an intermittent basis since November 1998. About 340 workers were laid off at the Washington facility and another 200 at Massillon (Sacco, 1999a; Boselovic, 1999b). Bethlehem decided to close the two facilities because of their recent operating cash losses and the company's concerns over unprecedented levels of foreign steel imports. The stainless sheet and strip operations also did not fit well into Bethlehem's core strategy of producing carbon and alloy steel products (Bethlehem Steel Corporation, 1999).

Bethlehem Steel acquired Lukens' melt shop and hot rolling facilities at Houston, PA, as part of the 1998 transaction. At that time, the Houston facility was being operated in tandem with the Washington mill. In November 1998, Allegheny Teledyne Inc. paid Bethlehem $175 million for the Houston facility and other assets. Under a related conversion services agreement, Bethlehem began providing Allegheny Teledyne exclusive access to the melt shop and stainless slab caster at Coatesville, PA—a fourth steel mill that Bethlehem acquired from Lukens (Boselovic, 1999a). Bethlehem and Allegheny Teledyne also agreed to jointly upgrade Bethlehem's 110-inch Steckel mill at Conshohocken, PA. Upgrading of the Steckel mill, which rolls stainless steel slabs and different types of nickel alloys, was expected to cost $25 million.

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

KBAlloys, Inc.—On September 28, 1998, KBAlloys purchased Reading Alloys, Inc. (KBAlloys, Inc., 1998). Both companies are based in the Reading area of Pennsylvania and manufacture a broad spectrum of aerospace-quality master alloys. KBAlloys has been a leading supplier of master alloys to the aluminum industry for more than 25 years. The company also has manufacturing facilities in Henderson, KY, and Wenatchee, WA—two areas with relatively inexpensive power and a concentration of aluminum smelters and fabrication plants. One of the binary master alloys produced by KBAlloys contains 20% Ni and 80% aluminum (Al).

Reading Alloys makes ferrous and nonferrous master alloys at Robesonia, a Reading suburb. The bulk of Reading's customers are in the titanium and superalloy industries. Reading also makes metal powders and special alloys for the petrochemical, medical equipment, and electronic markets. The company's nickel products include nickel aluminum powder (69% Ni, 31% Al), vacuum-grade nickel columbium (niobium) (33% to 38% Ni, 60% to 65% Nb), nickel vanadide (40% Ni, 60% V), and nickel molybdide (50% Ni, 50% Mo). Reading has about 100 employees.

***Advanced Castings and Forgings Industry*.**—The U.S. castings industry shipped an estimated 1.4 Mt of steel castings, 2.7 Mt of nonferrous castings, and 10.8 Mt of iron castings in 1998. The castings industry has consolidated dramatically over the past 20 years. In 1982, the United States had approximately 465 steel foundries and 1,400 iron foundries. In 1998, there were 400 steel foundries and only 700 iron foundries (Atchison Casting Corp., 2000, p. 6-8). At the same time, capacity utilization has increased from 45% to 85%. Cast components were becoming increasingly complex, especially those going to the aerospace and power generation sectors. In addition, the chemical composition and metallurgical characteristics of the alloys were becoming increasingly sophisticated.

On May 17, 1999, Precision Castparts (PCC) of Portland, OR, offered to buy all of the outstanding shares of Wyman-Gordon Co. for $20 per share. The tender closed in November 1999 and the merger was finalized on January 12, 2000. The cash tender was valued at $731 million (Precision Castparts Corp., 2000, p. 1-5, 25-28). Wyman-Gordon is a leading producer of forgings for the aerospace, industrial gas turbine, and energy markets. PCC makes superalloy investment castings for the aerospace, power generation, and general industrial sectors. The Wyman-Gordon acquisition required approval from the Federal Trade Commission (FTC). To gain FTC approval and alleviate antitrust concerns, PCC agreed to divest itself of two key Wyman-Gordon operations—(1) an operation producing large castings in Groton, CT, and (2) a titanium casting operation at Albany, OR. PCC also assumed $53 million of debt, raising the total cost of the acquisition to $784 million.

***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. Demand for nickel-cadmium and nickel-metal hydride batteries has grown significantly in North America, thanks to a joint U.S. and Canadian recycling program that has made the use of nickel-based household and industrial batteries more environmentally acceptable. Both battery types are widely used in handheld power tools and a myriad of portable electronic devices.

Although electric vehicles (EVs) were being commercially manufactured in the EU, Japan, and the United States, production and sales were still limited. At yearend 1999, the following seven models equipped with nickel-metal hydride (Ni-MH) batteries were being sold or leased in the United States: the EV Plus (American Honda Motor Co., Inc.), the Electric Powered Interurban Commuter (EPIC) minivan (DaimlerChrysler), the Ranger EV pickup truck (Ford Motor Company), the EV1 (General Motors Corporation), the S-10 electric pickup truck (General Motors), the Force (Solectria Corporation), and the RAV4-EV sports utility vehicle (Toyota Motor Corporation, USA). Nissan North America also was leasing its Altra, an EV equipped with a lithium-ion battery. A total of 4,017 battery electric light-duty passenger vehicles and trucks were leased or sold between January 1996 and December 2000 (Electric Vehicle Association of the Americas, 2001). A significant number of the 4,017 vehicles, especially those manufactured in 1996 and 1997, used lead-acid batteries as a cost savings measure. The new Generation I Ni-MH battery made by GM Ovonic L.L.C. can store twice the energy of a conventional lead-acid battery for the same weight and volume.

In April, General Motors and Toyota announced that they would collaborate on developing advanced technology vehicles. The 5-year program will pool efforts on electric, hybrid electric, and fuel cell technologies. One of the first projects will be to develop a common set of electric traction and control components for future battery, hybrid, and fuel cell EVs (General Motors Corporation, 1999).

On December 22, the United States Postal Service ordered 500 electric mail delivery vehicles from Ford and its partner, Baker Electromotive, Inc. of Rome, NY. The postal service has an option to order 5,500 additional vehicles. The design of the delivery vehicle is based largely on Ford's Ranger EV. Production was scheduled to begin in the fall of 2000 and 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 Company and Baker Electromotive, Inc., 1999).

Earlier in the year, Ford purchased a controlling interest in Norwegian-based Pivco Industries Ltd., the manufacturer of the two-passenger *TH!NK city* EV. Since then, Ford has been helping Pivco introduce *TH!NK* in North America and Scandinavia. Pivco began producing the *TH!NK city* in November in Norway. The lightweight, plastic-bodied car is designed for commuting and stop-start urban driving. The EV has a range of about 80 km and uses nickel-cadmium batteries. On December 1, Ford announced that it would make available up to 100 *TH!NK* EVs for use in California at the Presidio of San Francisco (Ford Motor Company, 2000). On December 15, Honda introduced its Insight—the first gasoline-electric hybrid car vehicle to be sold in North America. The hybrid was priced competitively with conventional model year 2000 automobiles. An electric motor augments the 1.0-liter, 3-cylinder gasoline engine. The electric motor is powered, in turn, by a Ni-MH battery pack. The battery pack is automatically recharged during braking and does not normally require an outside source of electric power. The Insight has a U.S. Environmental Protection Agency mileage rating of 26 kilometers per liter (km/l) in the city and 30 km/l on the highway. Honda was planning to sell about 6,500 of the vehicles in calendar year 2000 (American Honda Motor Co., Inc., 2000).

At yearend, DaimlerChrysler delivered 10 EPIC minivans to Xpress Shuttle at Los Angeles World Airport. Each of the minivans will be expected to log 160,000 km per year. The EPIC can carry 79 kilograms of cargo in addition to five passengers and can go up to 130 km per hour. The 28, 12-volt Ni-MH batteries can deliver up to 130-140 km per charge and be fast charged in about 30 minutes. The batteries are supplied by SAFT America Inc. The vehicle has no transmission. Like the Insight, a regenerative braking system recharges the battery when the vehicle decelerates (DaimlerChrysler, 2000).

Stocks

On December 31, U.S. consumer stocks of cathode, pellets, briquets, and powder totaled 3,470 t—53% less than the 1998 high of 7,450 t reached on December 31, 1998. Stocks in London Metal Exchange (LME) warehouses worldwide decreased 29% during the year to 46,962 t. LME stocks at yearend 1998 were 65,964 t. Data collected by the International Nickel Study Group indicated that, at the end of December, world nickel producers (excluding those in Austria, China, the former Yugoslavia, and the Ural area of Russia) had approximately 83,800 t of nickel in primary products in stock.

Prices

The spot price of nickel metal increased almost continuously throughout 1999. By yearend, the monthly average price had recovered from its lowest level for the century in terms of constant dollars and was still climbing.

The monthly average cash price for 99.8% pure metal on the LME bottomed out at $3,872 per ton ($1.756 per pound) in October 1998. The cash prices for December 1998 and January 1999 were somewhat higher—$3,878 per ton ($1.759 per pound) and $4,269 per ton ($1.936 per pound), respectively. Growing Western demand, the threat of strikes at Canadian nickel mines, and startup problems at three new pressure-acid-leach complexes in Australia all helped to boost prices in 1999. Production of austenitic stainless steel in the EU increased 7% between 1998 and 1999, rising from 5.57 Mt to 5.95 Mt. The economic recovery in East Asia was another key factor. Japanese production of austenitic stainless steel dropped from 2.35 Mt gross weight in 1997 to 1.98 Mt in 1998, a decline of 16%. Japanese production declined again in 1999, but at a significantly slower rate, dropping 7% to 1.84 Mt (International Nickel Study Group, 2000b, p. 18). The East Asian recovery also led to increases in stainless steel production in the Republic of Korea and Taiwan, further strengthening nickel prices (World Bureau of Metal Statistics, 2000, p. 8).

In 1999, the last weekly price (for the 4-days ending December 30) was $8,395 per ton ($3.808 per pound). The average annual price was $6,011 per ton ($2.727 per pound). The annual price was 30% higher than the 1998 average of $4,630 per ton ($2.100 per pound).

Foreign Trade

U.S. net import reliance as a percentage of apparent consumption was 63% in 1999—slightly less than the percentage for 1998. Imports accounted for 100% of primary supply in 1999, if sales of the last material in the Defense National Stockpile are excluded. The United States imported 139,000 t of primary nickel in 1999, 6% less than the 148,000 t for 1998. Class I materials accounted for 85% of total primary imports received. Canada, as usual, supplied most of the primary imports. The second largest source was Norway, recapturing the position from Russia. Almost all of the Norwegian nickel was produced from foreign matte processed at Falconbridge Limited's refinery in Kristiansand. Australia edged out Russia for the first time since 1994. U.S. imports of Russian Class I material were down 40% from those of 1998, but were still a major market factor. RAO Norilsk Nickel has become an important source of nickel metal for the United States since the dissolution of the Soviet Union. In 1999, the United States imported 12,900 t of cathode and 873 t of powder and flakes directly from Russia.

Prices for nickel-bearing scrap tracked those for primary nickel, increasing almost continuously during 1999 because of improved global demand and a lessening of economic problems in East Asia. Reduced exports of Russian scrap added to the upward 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 253,000 t (gross weight) of stainless steel scrap from Russia in 1999, down 22% from a near-record 324,000 t in 1998 (International Nickel Study Group, 2000c, p. 76).

Antidumping Petitions.—In mid-1997, four of the larger U.S. producers of specialty steels—Allegheny Teledyne, Armco Inc., J&L Specialty Steel Inc., and Lukens—expressed concern about the country’s continuing high level of specialty steel imports and filed a number of antidumping and countervailing duty petitions with the U.S. Department of Commerce and the U.S. International Trade Commission (ITC). Additional petitions were filed in 1998 when specialty steel imports continued to rise. North American Stainless of Ghent, KY—a subsidiary of ACERINOX, S.A.—was also a petitioner in this second round of filings. In 1998, specialty steel imports reached a record 774,000 t (gross weight) and were 7% greater than those of 1997. Stainless steel accounted for 599,000 t, or 77% of the 774,000 t total. Electrical steel constituted 15% and tool steel, 8% (Specialty Steel Industry of North America, 1999). Imports 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, 2000a). Japan, the Republic of Korea, and Taiwan were cited in several of the U.S. producers' petitions.

Three major investigations of imported stainless steel products were instituted by the ITC in 1998. On March 27, petitions were filed dealing with round wire; on March 31, with plate in coils; and on June 10, with sheet and strip in coils. The ITC ruled on all three cases in 1999. The rulings were mixed (U.S. International Trade Commission, 1999a, b, c). On April 22, 1999, the ITC issued an affirmative decision on imports of hot-rolled plate in coils, triggering the imposition of antidumping and countervailing duties for that material. Final antidumping duties ranged between 7% and 45%; countervailing duties, between 2% and 15%. However, the ITC made a negative determination in the case of cold-rolled plate. On May 10, the ITC issued a negative determination in the case of round wire, but, on July 7, made an affirmative decision in the case of sheet and strip.

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 Limited of Canada, and WMC Limited of Australia. The six companies accounted for about 66% of world primary production in 1999. 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.

Anglo American Plc. (Anglo) illustrates the ongoing globalization of nickel interests. The company was formed in 1998 when Anglo American Corporation of South Africa Ltd. merged with its sister company, Minorco SA of Luxembourg. In 1999, Anglo had interests in at least five nickel producers: Anaconda Nickel Ltd. of Australia (26%), BCL Ltd. of Botswana (23%), Bindura Nickel Corporation Ltd. of Zimbabwe (53.11%), Codemin S.A. of Brazil (90%), and Tati Nickel Mining Company (Pty.) Ltd. of Botswana (43.35%). The mining giant was also constructing a mining and smelting complex in Venezuela at Loma de Niquel and had interests in the Barro Alto Project (Brazil) and the Kabanga Project (Tanzania).

The 1997 merger of Billiton Nickel (a division of Billiton Plc.) and QNI Limited brought together two established nickel operations under a single-management structure. The assets of Billiton's new nickel business group—QNI Pty. Limited (the new QNI)—included the Yabulu refinery in Queensland, Australia, the Cerro Matoso mining and smelting complex in Colombia, and a 40% interest in the Ravensthorpe project in Western Australia. QNI is now a wholly owned subsidiary of London-based Billiton Plc.

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 latest actions were taken. At the end of 1999, the company had about 1,100 employees worldwide. Late in the year, OMG offered to buy the nickel refinery at Harjavalta, Finland, from Outokumpu Oyj. Negotiations were underway at yearend. The copper-nickel smelter at Harjavalta would not be part of the proposed transaction. Outokumpu would continue to operate the smelter, processing nickel-copper concentrates from Outokumpu's mines in Australia (Outokumpu Oyj, 2000a, b). OMG also became a partner in a mine development project. OMG and Weda Bay Minerals Inc. agreed to jointly evaluate the Halmahera laterite deposits in Indonesia (OM Group Inc., 2000).

Australia.—Australia is rapidly becoming one of the leading nickel-producing countries in the world. 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 Limited is still the largest nickel producer in the State, recovering 88,275 t of nickel in sulfide concentrate in calendar year 1999 (WMC Limited, 2000a, p. 18-19).

Australian Sulfide Operations.—In late 1998, WMC had begun cutting back on production at its operations in Western Australia because of weak nickel prices. The three mining operations—Kambalda, Leinster, and Mount Keith—produced less in 1999 compared with that of 1998. The Kambalda operations bore the brunt of the cutbacks, with output of concentrate dropping to 11,114 t of contained nickel in 1999 from 33,381 t. Mining was suspended at three of Kambalda's seven mining complexes—Blair, Otter/Juan, and Wannaway, the higher cost operations in the group. Production at the huge Mount Keith Mine northwest of Leinster declined for the first time in 5 years, slipping to 41,208 t from 42,037 t. Production at the Leinster operations dropped to 35,953 t from 44,313 t (WMC Limited, 2000b).

Australian Laterite Projects.—Pressure acid leach (PAL) production capacity continued to grow in Western Australia at a rapid rate. PAL technology had been pioneered at Moa in Cuba during the late 1950's, but the technology was not commercially adapted to Australian laterites until 1997. 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, 1999c). Development was spurred by the construction of the Goldfields natural gas pipeline from the Pilbara coast to

Kalgoorlie. Together, the three initially should add about 60,000 t/yr of nickel to world production capacity. By May 2000, however, only Cawse had reached design capacity.

Murrin Murrin.—On May 7, 1999, Anaconda Nickel Limited began producing nickel metal at its new Murrin Murrin refinery, 50 km east of Leonora. The first day's output—some 35 t of nickel metal—reportedly had a chemical purity of greater than 99.80% Ni and satisfied other LME contract rules required to place nickel on warrant (Anaconda Nickel Limited, 1999d). The metal was being marketed as briquets (Hagopian, 1999). The mining and refining complex had about 400 full-time employees.

Construction of the $670 million greenfield project began in June 1997. The project was initially a 60-40 joint venture between Anaconda and Glencore International AG of Switzerland. Fluor Daniel Australia Ltd. was responsible for the overall design and engineering. The development plan 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 Limited, 1999e). Nickel production for 1999 was supposed to have been about 16,000 t (Platt's Metals Week, 1999a, c), but unforseen startup problems resulted in an actual output of only 1,000 t.

On July 1, 1999, Anaconda began a 100-day campaign to rectify several technical problems that had constrained production at Murrin Murrin. As part of the campaign, the flash vessels in three autoclave systems were converted from bottom entry to top entry. The campaign was completed on October 9. Retrofitting of the plant's fourth autoclave was completed in mid-December. 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.

Anaconda was already preparing to launch Stage II and expand the capacity of Murrin Murrin to 115,000 t/yr of nickel and 8,500 t/yr of cobalt. Plans for Stage II were undergoing final review at yearend 1999 (Anaconda Nickel Limited, 1999g). Stage II was originally scheduled to be commissioned in the fourth quarter of 2000 (Anaconda Nickel Limited, 1999c, f). Anaconda's management, however, was reluctant to fully implement Stage II until de-bottlenecking of the existing plant could be completed and the capabilities of the individual operating units fully analyzed. Project managers and engineering teams recommended that each operating unit be expanded incrementally between 2000 and 2003 until the Stage II target capacity of 100,000 t/yr of nickel metal was reached. This expansion could make Murrin Murrin the largest nickel mine in Australia, surpassing Mount Keith.

The Murrin Murrin ore was being crushed, milled, slurried, and then fed into an autoclave circuit where it was pressure leached with sulfuric acid and steam. Three of Murrin Murrin's four autoclaves were operational by the fourth quarter of 1999. The autoclaves were designed to handle a total of 3.8 million metric tons per year (Mt/yr) of ore averaging 1.34% Ni, 0.091% cobalt (Co), and 4.6% magnesium (Anaconda Nickel Limited, 1999d). The autoclaving produces a nickel-cobalt-rich slurry, which is later pumped into a counter-current-decantation washing circuit and neutralized. If the ore slurry were leached at ambient temperature, a large part of the iron in the ore would dissolve along with the nickel and cobalt, complicating downstream separation. Instead, under pressure, the iron forms insoluble jarosites [$KFe_3(SO_4)_2(OH)_6$, etc.].

When hydrogen sulfide is injected into the nickel-cobalt leach liquor, the two metals precipitate out as mixed sulfides. The existing system is designed to produce about 50 t/d of sulfides. The sulfides are subsequently filtered, pressure leached with oxygen, and later fed into an ammonia-based solvent extraction circuit where the nickel is separated from the cobalt. The oxygen converts the metal sulfides to water-soluble sulfates. At the end, the nickel is reduced to metal with hydrogen gas and briquetted.

In February 1999, Anaconda acquired Abednego Nickel Limited, a company that controlled sizable resources on an adjoining property. The Abednego acquisition reportedly added 68 Mt of indicated resources, of which 22 Mt were considered to be high grade. The 68-Mt estimate was later increased to 75 Mt. According to Anaconda officials, the combined resources of the Murrin Murrin project now total more than 310 Mt of ore grading 0.99% Ni and 0.07% Co (Anaconda Nickel Limited, 1999b, e, f). (See table 15.)

Mount Margaret Project.—Anaconda also was preparing to develop its Mount Margaret property, 100 km northwest of Murrin Murrin. Test work to date indicates a resource of at least 170 Mt grading 0.78% Ni and 0.045% Co (Anaconda Nickel Limited, 1999f). Inferred resources in the Mount Margaret region reportedly exceed 500 Mt. Drilling was underway to better delineate the resources at Mount Margaret. In August 1999, Anaconda had five drill rigs operating in the Mount Margaret area (Anaconda Nickel Limited, 1999f). Infill drilling at the Marshall Pool tenements has sizable identified resources reportedly grading 1.29% to 1.65% Ni, with cobalt values ranging from 0.068% to 0.162%. Anaconda has drilled more than 1,000 holes at a second location called Lawlers. According to company officials, preliminary data from the Lawlers drilling suggest a 9-meter (m)-thick resource of 125 to 200 Mt, above a cutoff of 0.5% Ni. The Goldfields Gas Transmission pipeline, which brings Northwest Shelf natural gas to Leinster, Kambalda, and Kalgoorlie, passes through the area. The Mount Margaret properties could be developed as early as 2002 if nickel prices do not deteriorate.

Anaconda's Financial Backing.—The ownership structure of Anaconda changed dramatically in 1999, with Anglo and Sherritt buying into the company. On May 14, Sherritt announced that it had purchased approximately 9% of the outstanding common shares of Anaconda (Sherritt International Corporation, 1999). Glencore retained its holdings and briefly remained Anaconda's major shareholder, with about 19% of the shares. Sherritt—a Canadian public company—reportedly paid C$51 million for its Anaconda stock (Northern Miner, 1999d). Sherritt developed much of the acid-leach technology employed at Murrin Murrin and had been providing technical support to the project since its inception. On August 1, Anglo agreed to acquire a 23% interest in Anaconda Nickel. Anaconda and Anglo were to work together on nickel projects throughout the Australasian region

(Anaconda Nickel Limited, 1999g). The acquisition, which cost Anglo at least A$244 million, was approved by the Australian Foreign Investment Review Board (Mining Journal, 1999b). Anglo paid A$3.15 per share for 43.2 million shares of Anaconda Nickel—47% more than Anaconda's closing price of A$2.15 on July 30.

***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. At Bulong and Cawse—in the final stage—nickel is recovered by electrowinning rather than by hydrogen reduction. At the beginning of 1999, Bulong was owned by Preston Resources Limited, while Cawse was owned by Centaur Mining and Exploration Limited. Again like Murrin Murrin, their ownerships changed substantially during the year.

On May 5, 1999, Preston restarted its autoclave at Bulong. The failure of a mechanical seal forced Preston to shut down the autoclave at the very end of 1998 (Mining Journal, 1999b, d, e). In March, the company began producing nickel metal. Preston Resources also had been stockpiling cobalt sulfides since mid-February (Mining Journal, 1999a). The Bulong cobalt refinery was still in the final stages of commissioning.

The Bulong complex was designed to produce 9,000 t/yr of nickel and 700 t/yr of cobalt. The mines and processing plant partially encircle the historic gold mining town of Bulong, 30 km east of Kalgoorlie. The ore occurs at depths of 5 to 40 m over a strike length of some 20 km. According to the Western Australian Government, the group of more than 40 ore bodies contains 140 Mt of ore grading 1% Ni and 0.1% Co (Western Australian Department of Resources Development, 1999).

In October, 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—Anaconda's new partner—was reportedly backing Anaconda's involvement. Anaconda agreed to manage Bulong for Preston and review existing work. Preston had just launched a recapitalization program and was hoping to raise A$50 million in new equity (Mining Journal, 1999a). Anaconda agreed to subscribe to the new equity issue, encouraging other potential investors to participate. Anaconda can earn up to a 60% interest in Bulong. Preston's largest shareholder, Resolute Limited, reportedly agreed to support the joint venture under certain conditions. Resolute purchased an interest in Bulong from WMC in 1987 and spent the next 8 years determining if nickel could be recovered economically from Bulong ores using PAL technology. Resolute sold Bulong to Preston for A$319 million in July 1998 and now has a 48% interest in Preston.

The expansion feasibility study was scheduled to be completed by August 2001. Bulong was commissioned in December 1998 and produced its first LME-grade metal in March 1999. The deposit was being mined at a rate of 500,000 t/yr of ore. Preston expected marketable production for the fiscal year ending June 30, 2000, to be about 5,440 t of nickel and 340 t of cobalt metal (Mining Journal, 1999b; Platt's Metals Week, 1999a).

The Cawse complex is in the Eastern Goldfields region, 60 km northwest of Kalgoorlie. The nickel occurs with cobalt in limonite clays associated with the Norseman-Wiluna greenstone belt. The mineralization extends from the surface to a maximum depth of 60 m. The complex produced its first cobalt sulfide concentrate, assaying 40% Co, on December 25, 1998. The first nickel cathode was made on January 20, 1999 (Western Australian Department of Resources Development, 1999). When fully operational, Cawse is expected to produce 8,700 t/yr of nickel and 1,300 t/yr of cobalt.

Cawse Expansion Project.—On November 18, Anaconda announced that it had formed a strategic alliance with Centaur Mining to expand Centaur's Cawse operation (Anaconda Nickel Limited, 1999a). Anaconda and Centaur have proposed raising Cawse's capacity to produce cathode from 9,000 t/yr to more than 50,000 t/yr if the expansion feasibility study is positive. The two companies were expecting to complete the study by mid-2001. Production of cobalt as cobalt sulfide could be raised from 1,300 t/yr to more than 2,500 t/yr. Anaconda would be responsible for the financing, construction, commissioning, and operation of the expanded plant. Anaconda can earn as much as a 60% interest in Cawse. Under the new agreement, Anaconda's equity would be linked to the capacity of the expanded facility.

Marlborough.—Preston 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. In September 1998, the Queensland Government granted Marlborough "major project status" to expedite regulatory approval. The proposed hydrometallurgical complex would produce 25,000 t/yr of nickel metal and 2,000 t/yr of cobalt metal (Preston Resources Limited, 1999). Barclays Capital, the investment banking division of Barclays Bank PLC, has agreed to provide the A$700 million needed for construction. Barclays Physical Trading Limited, another subsidiary of the bank, holds the rights to market the nickel and cobalt produced during the first 10 years of operation. The original production startup date of 2001 has apparently slipped about 2 years.

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. These resources are contained in 10 separate deposits. Four of the deposits have been elevated to the reserve category by a comprehensive program of drilling and metallurgical testing. The current minable reserve is reported to be 52 Mt averaging 0.88% Ni and 0.06% Co. Preparatory beneficiation would raise the grade of the feed material to 1.50% Ni and 0.13% Co. More than 1.8 Mt/yr of ore would be mined initially from a cluster of open pits and trucked to a central processing plant (Preston Resources Limited, 1999). Marlborough's metallurgical process design was strongly influenced by Preston's experiences with its Bulong operation.

Ravensthorpe Project.—Comet Resources Limited completed its feasibility study of the Ravensthorpe nickel project in southern Western Australia in November 1998. Multiplex Constructions Pty. Ltd. is responsible for the engineering, construction, and commissioning of the project. The property is 35 km east of Ravensthorpe, close to the Indian Ocean, and only 150 km from the port of Esperance. Comet's original plan called for the Ravensthorpe complex to have a design capacity of 22,000 t/yr of nickel metal and 1,400 t/yr of cobalt sulfide. However, on September 14, 1999, Comet announced that the design capacity of the complex would be raised to 35,000 t/yr of nickel (Comet Resources Limited, 1999).

Comet holds mining leases on two deposits—Halleys and Hale-Bopp—and has applied for a lease on a third deposit, Shoemaker-Levy (Comet Resources Limited, 2000). The three deposits reportedly had a combined resource of 152 Mt grading 0.9% Ni and 0.04% Co (Western Australian Department of Resources Development, 1999). Comet's 1998 feasibility study was based on the mining and processing of ore from the Halleys deposit, which according to company officials had 50.9 Mt of measured resources. Construction was scheduled to begin in early 2001; the Halleys cut—the proposed initial open pit on Bandalup Hill—would have a projected life of 10 to 15 years. The three deposits are close to the surface, forming a ridge above the surrounding countryside. Stripping ratios are less than 0.6:1. 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 mid-November, QNI Pty. Limited announced that it had agreed to help Comet develop Ravensthorpe (Mining Journal, 1999f). The new QNI 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 in Queensland.

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 in Indonesia, Hinatuan Mining Corporation in the Philippines, and four mining companies in New Caledonia.

Calliope Metals Corporation and Argosy Mining Corp. merged on May 7, 1999, forming Argosy Minerals Inc. (Argosy Minerals Inc., 2000, p. 1-4). The new management canceled Calliope's plans to build a A$465 million nickel and cobalt processing plant at Gladstone. The new 20,000-t/yr nickel operation was to be built in New Caledonia instead. The proposed PAL plant would use laterite ore from mining concessions held by Société des Mines de la Tontouta at Nakety.

***Canada*.**—Key events of 1999 are summarized in the nickel chapter of the Canadian Minerals Yearbook (McCutcheon, 2000).

Inco Limited and its subsidiary, Voisey's Bay Nickel Company Limited, 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 Limited, 1999a). In July 1998, the Provincial Government broke off negotiations with Inco and refused to grant a mining lease to the company. The Provincial Government wanted assurances from Inco that the nickel concentrates from the huge sulfide deposit would be refined within the Province (Government of Newfoundland and Labrador, Executive Council, 2000; Government of Newfoundland and Labrador, Ministry of Mines and Energy, 1999; Grimes, 1999).

Weak nickel prices, which continued into the first half of 1999, forced Inco to reassess its original plans to build a fully integrated smelter and refinery at Argentia on the Avalon Peninsula of Newfoundland. The company reportedly has shelved plans drawn up in 1996 to construct a facility based on Outokumpu flash smelting technology. Inco now wants to recover the nickel using a new hydrometallurgical process developed in-house. Inco also was reluctant to proceed with critical parts of the project until representatives of the Innu Nation, one of two principal aboriginal peoples in the region, concluded their land claim negotiations with the Federal and Provincial Governments. The Labrador Inuit Association, the second aboriginal group, voted to accept its land claims agreement with the two Governments in July 1999.

On November 14, 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 Limited, 2000f). Inco also would have spent about $65 million on underground exploration at the mine site.

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 had hoped to begin constructing the mine and mill during the summer of 2000. The proposed mine and mill would have cost $500 million and processed 6,000 t/d of ore (Inco Limited, 2000f). The Canadian nickel producer had to postpone construction for at least a year (Platt's Metals Week, 2000). Critical construction is limited to the warmer months because of the site's extreme northern latitude (56º 20' N, 62º 07' N).

A key environmental hurdle was overcome on April 1, 1999, when the five-member panel overseeing the environmental review process for the proposed mine and mill recommended that Inco be given tentative approval to proceed with the project, subject to a number of stipulations. The panel made 107 recommendations as part of its report (Inco Limited, 1997; 1999d).

In September 1997, the Newfoundland Court of Appeal ruled that construction of a temporary road and airstrip to support an underground exploration program at Voisey's Bay could not start until the environmental review and approval process had been completed (Inco Limited, 2000a, p. 25-29). Inco, however, was permitted to continue its 1999 surface exploration program even though formal negotiations were suspended. The surface exploration program was aimed at better defining the Reid Brook and Eastern Deeps sections of the deposit. Crews also began evaluating new targets in neighboring claim blocks (Inco Limited, 2000c). During the first half of 1999, four diamond drill rigs were operating either in the sector where the Voisey's Bay deposit is located or in four neighboring sectors. A total of 28,385 m was drilled during the 6-month period (Inco Limited, 1999c). In September, crews began delineation drilling of the Eastern Deeps zone in preparation for eventual underground exploration. Regional stratigraphic drilling in an area 1,000 m east of the Far Eastern Deeps section intercepted troctolitic rocks that were unmineralized. Nickel mineralization, though, was intercepted at a depth of 250 m at the Sarah prospect 5.5 km north of the Ovoid, the first ore body identified at Voisey's Bay. Work also continued on the Kiglapaits property 60 km north of the main claim area (Inco Limited, 1999b).

South Voisey's Bay, Labrador.—Donner Minerals Limited 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 Limited, 1999a).

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 Limited of Toronto 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.

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. In 1999, world demand for palladium and platinum exceeded supply, driving PGM prices upward (Mining Journal, 2000d). Pentlandite, the principal nickel mineral at Sudbury, is sometimes accompanied by froodite ($PdBi_2$), sperrylite ($PtAs_2$), and other trace minerals of the platinum-group elements. 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 Deposit.—In 1997, Inco geologists identified a significant nickel-PGM deposit at Kelly Lake, 2 km south of Copper Cliff and Highway 17. The company did not announce the discovery until March 2000. The principal ore zone is at a depth of 1,370 m. According to company officials, the Kelly Lake deposit has 10.5 Mt of resources averaging 1.77% Ni, 1.34% Cu, and 3.6 g/t PGM. The deposit reportedly is accessible from existing mine workings near Inco's Copper Cliff South Mine (Inco Limited, 2000e; Mining Journal, 2000b).

Totten Mine Deposit.—In late 1999, an Inco exploration team discovered sizable resources in and around the Totten Mine, near Worthington on the Canadian Pacific Railway. 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 PGM (Inco Limited, 2000d). This estimate includes 1.6 Mt of inferred resources grading 1.26% Ni, 1.90% Cu, and 5.7 g/t PGM. The deposit is still open at depth. The latest drillhole data suggest that mineralization continues to the south and that metal grades increase with depth. Geophysical surveys identified several new targets for future drilling (Mining Journal, 2000f).

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 in 1999 was 1.41% Ni, 1.40% Cu, and 1.8 g/t PGM. Because of the two new finds, Inco was planning to spend $7.7 million in 2000 exploring several high potential targets in the region. This would be Inco's highest annual exploration expenditure (in nominal dollars) in Ontario since the 1970's.

Other Nickel-PGM Targets.—Anglo American Platinum Corp. Ltd. (Amplats) of Johannesburg, South Africa, 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, joined forces to explore parts of the intrusion adjoining PNWC's license area (Mining Journal, 2000e).

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).

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.

Raglan District.—The Raglan mining and milling complex completed its first 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. Plans were already underway to increase Raglan's annual rated capacity of 21,000 t of nickel in concentrate to 26,000 t (Falconbridge Limited, 2000a, p. 10). Falconbridge was planning to spend C$25 million in 2000 to increase annual milling capacity from 800,000 t of ore to 1 Mt. In 1999, Raglan recovered 784,000 t of ore averaging 2.96% Ni and 0.83% Cu. This equated to a mine production figure of 19,524 t of nickel in concentrate. The nickel concentrate also contained 4,930 t of copper and 238 t of cobalt (Falconbridge Limited, 2000a, p. 20).

Falconbridge was hoping to eventually raise production capacity to 30,000 t of nickel in concentrate. To meet this new goal, the company has begun expanding its regional exploration program and was extending its 2000 drilling season from 4 to 8 months. At yearend 1999, Raglan had 19.7 Mt of proven and probable reserves, averaging 2.82 % Ni and 0.77%

Cu. In addition to the reserves, Raglan had 2.22 Mt of indicated resources averaging 1.88% Ni and 0.73% Cu (Falconbridge Limited, 2000a, p. 14). All of the resources occur in the northeastern part of the Cape Smith Fold Belt, which extends across the entire width of the Ungava Peninsula.

Lac Rocher District.—Donner Minerals Limited and several other exploration companies had projects underway in the Lac Rocher area. Lac Rocher is roughly 230 km southeast of the southern tip of James Bay and about 40 km southeast of Lac Evans. The nearest town of any size is Matagami, 120 km to the southwest. Donner is conducting the bulk of its fieldwork on ground optioned from Falconbridge Limited and Noranda Inc. (Donner Minerals Limited, 1999b). Helicopter-borne electromagnetic and magnetic surveys have been completed over all of the optioned claims. A portion of the area was previously surveyed by the Canadian Government. Several geophysical anomalies initially identified by the Government have been resurveyed in detail by Donner.

Exploration activity in the Lac Rocher area soared after Nuinsco Resources Limited's January 1999 announcement that one of its drilling crews had intersected a 61.5-m-thick zone of disseminated and massive sulfides, assaying 1.69% Ni and 0.49% Cu. The assays also revealed significant cobalt, palladium, and platinum values. The intersection included a 3.2-m interval of sulfides assaying 10.8% Ni. Six months prior to Nuinsco's discovery, Falconbridge completed a regional compilation of geologic, airborne magnetic, electromagnetic, and lake sediment geochemical data. This information allowed Falconbridge to identify and stake several promising targets immediately after Nuinsco announced the assays from its discovery hole, LR-1-99.

The assay results from subsequent holes drilled by Nuinsco were not as high as expected. However, drill hole 99-34 did intersect 8.2 m of mineralization grading 1.89% Ni and 0.58% Cu (Northern Miner, 1999a). Nuinsco has identified at least 23 targets for future drill testing (Northern Miner, 1999b). In July, Nuinsco optioned 144 claims held by Freewest Resources Canada Inc. (Northern Miner, 1999c). In November and December, Nuinsco drilled an additional six holes in the vicinity of LR-1-99, but none of them intersected significant sulfide mineralization.

In February 1999, Donner entered into an agreement with Falconbridge. Donner now has an option to earn a 50% interest in 24 claim blocks (511 claims on 8,176 hectares (ha)) previously staked by Falconbridge. Three of Falconbridge's 24 claim blocks are contiguous to the eastern and southern sides of the Nuinsco property (Donner Minerals Limited, 1999c). Donner also signed a joint agreement with Noranda and Falconbridge a month later. This second agreement gave Donner options on 1,100 claims acquired by Noranda in the Lac Rocher area. The 1,100 claims cover 17,000 ha (Donner Minerals Limited, 1999d). Noranda, which owns 49.9% of Falconbridge's common stock, has been mining zinc and copper in the Matagami district for more than 20 years.

Inco's Manitoba Division produced about 34,000 t of nickel, down 29% from 47,935 t in 1998 (McCutcheon, 2000). Operations at the division's two mines—the Birchtree and Thompson—were suspended from September 20 to December 9 because of a labor disagreement. Inco was considering deepening the Birchtree over the next 5 years and was resurveying the entire Thompson Nickel Belt (Inco Limited, 2000b).

Canmine Projects.—Canmine Resources Corporation continued to evaluate 2,000 square kilometers of claims northeast and west of the Thompson Belt (Canmine Resources Corporation, 1999b). In late 1998, Canmine crews had drilled a promising geophysical anomaly at Osik Lake, some 70 km west of Thompson. The anomaly turned out to be a large peridotite body with a background nickel content of 0.22%. In November 1999, Geoterrex-Dighem (now part of Fugro N.V.) completed an extensive airborne electromagnetic survey of Canmine's BINCO claims northeast of Thompson. In early 2000, Canmine transferred its interests in the BINCO project to a wholly owned subsidiary named BINCO Resources Corporation.

In March 1999, Canmine obtained 21-year renewable surface and mineral right leases on its Maskwa property from the Province of Manitoba. The property, 120 km northeast of Winnipeg, includes the site of the former Maswka-Dumbarton chromite mine and is part of Nopiming Provincial Park. The leases replaced earlier leases that were due to expire in about 3½ years. The new leases gave Canmine the long-term security required to construct a C$20 million nickel mine and mill at Maskwa (Canmine Resources Corporation, 1999a).

For the fourth consecutive year, Sherritt set new production records for both nickel and cobalt at its Fort Saskatchewan refinery. Finished nickel production was 28,643 t, or 4% greater than the previous record of 27,434 t set in 1998 (Sherritt International Corporation, 2000, p. 6-8). 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.

Colombia.—Cerro Matoso S.A. (CMSA) had almost completed a 5-year project to reduce production bottlenecks at its ferronickel plant near Montelibano. The company was constructing a second production line (dryer, calciner, and furnace) that should increase capacity from 29,000 t/yr to 58,000 t/yr of Ni in ferronickel. The $353 million project was scheduled for completion in April 2001, but full capacity apparently will not be reached until 2004 (Nacken, 2000).

In 1999, CMSA produced 28,345 t of Ni in ferronickel and exported 28,480 t by drawing down stocks. Only 1,852 t, or 7% of CMSA's total exports, went to the United States. Almost 70% of the ferronickel exports went to Europe (International Nickel Study Group, 2000b, p. 30).

Cuba.—Metals Enterprise, the joint venture of the Cuban Government and Sherritt, produced 27,020 t of nickel-plus-cobalt in mixed sulfides at Moa in 1999. The material provided about 90% of the feed for the venture's Fort Saskatchewan refinery in Alberta (Sherritt International Corporation, 2000, p. 6-8). Mixed sulfide production at Moa has increased 115% since 1994, the year when the joint venture was formed.

In 1998, Billiton and the Government of Cuba renegotiated their agreement to evaluate the San Felipe laterite deposits in Camaguey Province. Initial work indicates that the San Felipe deposits contain some 200 to 250 Mt (dry) of resources grading more than 1.3% Ni. The lateritic ore reportedly is amenable to pressure acid leaching. QNI, the Australian subsidiary of Billiton, has a 75% interest in the venture. The remaining 25% is controlled by Geominera, a Cuban parastatal organization responsible for nonferrous metal exploration (Netscher, 2000).

European Union—Finland.—In late 1999, OMG offered to buy the nickel refinery at Harjavalta from Outokumpu (Outokumpu Oyj, 2000a, b). Negotiations were underway at yearend. 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 copper-nickel smelter at Harjavalta was not part of the proposed transaction. Outokumpu would continue to operate the smelter, processing nickel-copper concentrates from Outokumpu's mines in Australia.

In 1999, the Outokumpu nickel plant produced some 53,000 t of refined nickel and 700 t of cobalt in cake. The bulk of the nickel was recovered from matte produced at the Harjavalta smelter. The Harjavalta matte was supplemented by about 22,000 t (gross weight) of matte imported from Australia and Brazil.

Indonesia.—PT International Nickel Indonesia Tbk. (PT Inco) and PT Aneka Tambang (Persero) Tbk. (AnTam) continued to add mining and smelting capacity to their operations on the island of Sulawesi. Total mine production in 1999 for all of Indonesia was 89,115 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. A second hydroelectric powerplant was constructed on the Larona River, adding 93 megawatts (MW) of generating capacity. The original hydroelectric generating facility can supply 165 MW in normal weather. In 1997 and early 1998, El Niňo weather phenomenon led to a severe drought sharply reducing water levels and limiting power availability. At the end of 1999, PT Inco had 106 Mt of proven and probable reserves in the Soroako area containing 1.9 Mt of nickel (Inco Limited, 2000a, p. 21-24).

On July 27, 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. Construction was to have begun in late 1998, but had to be postponed because of the Southeast Asian debt crisis. If all goes well, the third line could be operational by 2002 (PT Aneka Tambang Tbk., 1999).

Gee Island.—In January 1998, AnTam began shipping ore from its mine on Gee Island, Maluku, to Pomalaa. Gee Island is one of the Halmahera Islands and reportedly has at least 4.4 Mt of minable ore. AnTam has a Contract of Work from the Government of Indonesia authorizing mining on the island for 30 years and was planning to ship 425,000 t/yr of ore (PT Aneka Tambang Tbk., 1998).

Gag Island.—Falconbridge and the Broken Hill Proprietary Company Ltd. (BHP) of Melbourne, Australia, were considering forming a joint venture to further evaluate nickel laterite deposits on Gag Island, Maluku. Several matters, however, had to be resolved before the joint venture could become reality (Falconbridge Limited, 2000b). Commercial arrangements with AnTam, BHP's partner, needed to be clarified. There were also issues involving management of the island's forests.

Gag Island is about 40 km southeast of Gebe Island, Maluku, where AnTam has one of its two principal nickel mines. AnTam's second mine is near the company's ferronickel smelter at Pomalaa in southeastern Sulawesi. 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 (Broken Hill Proprietary Company Ltd., 2000). Details of this latest BHP estimate are shown in table 16.

Halmahera Island.—AnTam and Weda Bay Minerals Inc. of Vancouver, British Columbia, 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 (Weda Bay Minerals Inc., 2000). (See table 16.)

New Caledonia.—Société Métallurgique Le Nickel (SLN) accounted for 47% of New Caledonian mine production in 1999. The other 53% of mine production was divided among J.C. Berton Mines, Nickel Mining Corp., Société des Mines de la Tontouta, Société Minière du Sud Pacifique S.A. (SMSP), and several other independent mining companies. Mine production totaled 110,082 t on a contained nickel basis, down 12% from 125,280 t in 1998. In 1999, the French overseas territory exported 52,882 t of nickel in ore, which included 33,958 t of nickel in garnierite shipped to Japan and 18,924 t in limonitic laterites shipped to Australia. The remaining 57,200 t of nickel in ore was processed at the SLN smelter outside Doniambo (International Nickel Study Group, 2000b, p. 47-48).

SLN operated the following four nickel mines: Thio, Kouaoua, Népoui-Kopéto, and Tiébaghi. A fifth mine, Kaala-Gomen (also known as Etoile du Nord), was operated by an SLN contractor. The new Tiébaghi Mine began delivering ore to the Doniambo smelter in September 1998. SLN's total ore production was slightly less than that of 1998. SLN and its subcontractors mined 3.11 Mt of wet lateritic ore, down from 3.15 Mt (revised) in 1998. Mines operated directly by SLN accounted for 2.77 Mt, or 89% of the 3.11 Mt (Eramet Group, 2000, p. 35-36).

In 1999, the Doniambo smelter produced 45,289 t of nickel in ferronickel and 11,353 t of nickel in matte. The combined output of 56,642 t was an alltime high for Doniambo, edging out the previous record of 56,502 t set in 1998. A fifth rotary kiln was commissioned in late 1998, raising the annual capacity of the plant to 63,000 t of contained nickel. SLN was planning to increase the annual capacity of Doniambo to

70,000 t sometime between 2003 and 2005.

The Paris-based Eramet Group controlled only 60% of the shares of SLN, down from 90% in 1998. In July 1999, Eramet acquired all of the Sima Group companies and exchanged a 30% interest in SLN for shares of Sima. The Sima Group includes Aubert & Duval and Special Metals Corporation (a 38.5% holding). Sima activities complement those of Erasteel, another unit of the Eramet Group. The Sima activities have been grouped together with those of Erasteel, forming the Eramet Alliages Division. The new division is now the world's leading producer of nickel alloys and superalloys as well as a major producer of specialty steels (Eramet Group, 2000, p. 6, 20-25, and 72).

In 1996, Falconbridge and SMSP formed a partnership with the intention of building a ferronickel plant in the North Province. The plant would have an annual capacity of 54,000 t of nickel in ferronickel and use local lateritic ores as feedstock. SMSP was to have a 51% interest in the project and Falconbridge, 49%. The project is rapidly approaching reality. Under the Bercy Agreements of 1998, SMSP gained access to SLN's deposit in the Koniambo massif. In exchange, SLN received $167 million as compensation plus mining rights to smaller and poorer deposits in the Poum massif held by SMSP (Falconbridge Limited, 1998). Falconbridge has set up project offices in Kone and Nouméa, and the Koniambo drilling program is well underway. The Koniambo deposit has at least 132 Mt of saprolitic resources grading 2.46% Ni plus an undetermined amount of limonitic resources (Falconbridge Limited, 2000a, p. 13, 30).

On October 22, 1999, Inco commissioned its on-site pilot plant for the Goro Project. The $50 million project is a joint venture of Inco (85%) and Bureau de Recherches Géologiques et Minières, an agency of the French Government (15%). The two partners will use the integrated pilot plant to validate proprietary PAL and solvent extraction technologies specifically developed by Inco for the Goro laterite ores. The main deposit has more than 200 Mt of lateritic resources averaging 1.57% Ni and 0.18% Co. Drilling has delineated 47 Mt of proven and probable reserves—enough to supply a commercial-sized plant for 20 years (Inco Limited, 1999e; 2000g, p. 22-23).

Preliminary pilot-plant work indicates that the Inco process can be used successfully on a commercial scale. The proposed commercial plant would be capable of producing 54,000 t of Ni and 5,400 t of Co annually (Inco Limited, 2000a, p. 24). Inco's proprietary technology would allow the leaching to be carried out at a temperature higher than any temperature currently used in the Australian laterite autoclaves. The higher temperature would make leaching much faster, reducing unit production costs. The nickel would be in the form of oxide, the bulk of which would go to refineries in Japan, the Republic of Korea, or Taiwan—refineries in which Inco has significant equity interests. The capital cost of the commercial plant would be about $1.4 billion. Construction of the plant would take about 3 years (Inco Limited, 1999e).

Philippines.—Three companies mined laterite ore in 1999—Hinatuan Mining Corporation, Rio Tuba Nickel Mining Corporation, and Taganito Mining Corporation. Combined production amounted to 12,389 t of contained nickel, 40% less than in 1998. None of the ore was smelted in the Philippines. Almost 80% of the material was exported to Japan; the remaining 20% went to Australia (International Nickel Study Group, 2000a; 2000b, p. 49).

Crew Development Corporation of Vancouver, BC, has been evaluating a large nickel laterite deposit on the island of Mindoro, about 120 km south of Manila. According to company officials, the laterite deposit has at least 72 Mt (dry) of resources grading 0.94% Ni and 0.06% Co (Crew Development Corporation, 2000a, b). Crew acquired the 110-square-kilometer concession when it merged with Mindex ASA, a Norwegian exploration company, in September 1999. Kvaerner Philippines Construction Inc., a subsidiary of Kvaerner Metals ASA, completed a pre-feasibility study of the project for Mindex in August 1998. 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 during 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 new offshore field being developed near Palawan Island. The sulfur needed for leaching the nickel would come from the Pamplona sulfur deposit on the island of Negros, 300 km to the southeast (Northern Miner, 2000a, b).

Russia.—The Russian Federation produced 228,000 t of nickel in refined products, up slightly from 227,000 t in 1998 (International Nickel Study Group, 2000b, p. 50-52). Norilsk Nickel was by far the largest producer in Russia, accounting for 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 22% more nickel in 1999 than in 1996, when the company had a reported output of 177,185 t (Platt's Metals Week, 1998; Interfax International Limited, 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. Under Russian law, ore reserves do not belong to the company. All usable mineral resources in the Russian Federation are State property and must be worked under license. The licenses granted to Norilsk Nickel's subsidiaries run for 25 years, with most due to expire in 2020.

In 1999, Norilsk Nickel was the largest producer of nickel in the world, accounting for about 21% of total refinery production (RAO Norilsk Nickel, 2000a, c). The company has had difficulty modernizing its operations and reducing its work force. Norilsk Nickel has a heavy tax burden and, because of the location of the company's operations in the Russian Far North, enormous local social and civic responsibilities. The company continues to subsidize housing, the importation of food, and municipal services in the cities of Norilsk, Monchegorsk, and Zapolyarny. In 1999, the Russian Government placed new restrictions on the export of byproduct platinum, rhodium, and other precious metals, seriously impacting the company's earnings for the year. The new export limits prevented Norilsk Nickel from selling more than $300 million worth of platinum and rhodium to the Western World (RAO Norilsk Nickel, 2000b).

10-Year Development Program.—On November 9, 1998, the board of directors of Norilsk Nickel approved, in principle, a 10-year development plan aimed at modernizing the mining, smelting, and refining operations of its subsidiaries in northern Russia (RAO Norilsk Nickel, 1999c, 2000a). The subsidiaries would reequip their production facilities, use more effective extraction techniques, and adopt state-of-the-art technology. The plan was designed to improve metal recoveries, reduce energy consumption, and cut overall production costs. The plan was proposed in the wake of the partial privatization and major restructuring of the world's largest nickel producer. The Norilsk Mining Company was created to manage the A.P. Zavenyagin Norilsk Mining and Metallurgical Combine on the Taimyr Peninsula of north-central Siberia. The Kola Metallurgical and Mining Company, 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 10-year development program would allow both subsidiaries to develop new levels in existing underground mines, construct new mines, and carry out local exploration work designed to transform inferred resources of varying economic grades into bankable, measured reserves.

In April 1999, the board of directors of INTERROS Holding Company, the principal shareholder in Norilsk Nickel, also approved the 10-year plan, permitting Norilsk's management to transform the plan into a viable program. Norilsk's management will have to obtain $3 to $5 billion from foreign investors to pay for all of the projects outlined in the plan. According to the plan, the investment funds would be distributed as follows: 42% for exploration and mining, 16% for ore beneficiation facilities, 17% for metallurgical processing facilities, and 25% for power generation, heating supply systems, and other production-related infrastructure (RAO Norilsk Nickel, 1999a, c). The first step of the program required that $200 million be raised immediately. The International Finance Company Bank, Norilsk's financial consultant, would be responsible for developing the necessary market instruments needed to attract the $200 million. INTERROS would guarantee the investments (Budrys, 2000).

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 come 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). The Oktyabrsky and Taimyrsky underground mines are in the Oktyabr deposit. The Oktyabrsky Mine, commissioned in 1974, is 1,000 m deep and has almost 3,000 employees. The Taimyrsky Mine is even deeper—1,500 m—and has about 1,800 employees. The Komsomolsky Mine is in the Talnakh deposit and has about 1,500 employees. The Medvezhy Ruchey (or Bear Creek) open pit, located in the Norilsk-1 deposit, was begun in 1948 and is the oldest active production unit at Norilsk. Other underground mines include the Mayak Mine, the Zapolyarny (or Polar) Mine, and the new Skalisty Mine. Production from the 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.

In 1998, the Norilsk Combine upgraded ore beneficiation operations at its Talnakh concentrator, dramatically improving the quality of the nickel concentrates and increasing yield. The concentrator, built in 1981, employs 718 people and was designed to process 9 Mt/yr of ore. Despite the improvements, the concentrator was still only operating at 40% of capacity. The Combine also has an older concentrating and agglomerating unit at Norilsk. Improvement of ore beneficiation operations would be a key part of the 10-year program. In 1999, the Combine replaced key turbines at its No. 1 heating and powerplant in the city of Norilsk. The new turbines will help stabilize the supply of electricity to the city, mines, and smelting-refining complexes. Development of the Pelyatka gas condensate field is well underway, and construction of a pipeline from the field to Norilsk has begun. The natural gas was scheduled to reach Norilsk sometime in 2001 (RAO Norilsk Nickel, 2000e).

Penchenganickel.—Norilsk Nickel originally had planned to phase out mining in the Pechenga area by 2007. The closure of the mining and smelting operations, however, would have led to a serious decline in economic activity throughout the Nikel district and sharply reduced tax revenues for the local and regional governments. If all of the funding for the 10-year development plan materializes, mining at Pechenganickel may be able to be extended to 2015 (RAO Norilsk Nickel, 2000d).

The Tsentralny Mine accounts for about 85% of the nickel ore mined in the Pechenga area. Much of the mining equipment at the Tsentralny Mine needs to be upgraded or replaced because of excessive wear and tear. In addition, reserves are projected to be exhausted by 2006 if the production level for 2000 is maintained. Additional levels could be developed at the Severny underground mine. About $140 million would be spent on developing new levels in the underground part of the Tsentralny Mine. These new levels would initially provide 2.5 Mt/yr of ore, with mining rising to more than 4.0 Mt/yr by 2015. Reserves would continue to be worked at the Kaula Kotselvaara Mine and the Tsentralny and Zapadny open pits.

Improvements to the Pechenga concentrator would raise output between 7% and 10%. The roaster would be modernized at a cost of about $11 million. Sulfur dioxide emissions in the city of Zapolyarny would be sharply reduced. Company officials would like to close the Nikel agglomeration plant by 2005. The agglomeration plant continues to emit excessive amounts of sulfur dioxide and, since its commissioning in 1945, has been a major source of pollution on the Kola Peninsula. The total development program for the Pechenganickel operation would cost between $250 million and $300 million.

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 Limited, 2000).

Serbia and Montenegro.—The armed conflict in Kosovo completely disrupted operations at Feronikl Kosovo. The mining and smelting complex at Glogovac was forced to halt production in March 1998, 2 months after the violence began. Electric power blackouts and shortages of diesel fuel, gasoline, and other critical supplies made production impossible. The company's 1,500 employees reportedly were unwilling to work, fearing reprisals from both the ethnic-Albanian Kosovo Liberation Army and Serb militias (Metal Bulletin, 1998). Serb forces later occupied the ferronickel smelter and adjoining buildings. In April 1999, military aircraft of the North Atlantic Treaty Organization (NATO) bombed the facilities (Platt's Metals Week, 1999b). After hostilities ceased, the United Nations Mission in Kosovo began exploring ways of reopening the damaged complex. About 200 former employees were trying to repair the plant and salvage the remaining vehicles and mining equipment. International development agencies were trying to put together a financial assistance package with help from potential and past customers in the EU.

The Glogovac complex was commissioned in 1984, with a single production line. The original plant had a design capacity of 7,000 t/yr of Ni in ferronickel. A second production line was added in January 1998. Ore for the plant came from two open pit mines. The Çikatova Mine is only 1.5 km from the plant. The second mine, Gllavica, is 25 km away. The Çikatova ores were hauled directly to Glogovac in dump trucks, while the Gllavica ores came by rail. Ore from the two mines had been averaging 1.3% to 1.4% Ni.

Venezuela.—The new Loma de Niquel mining and smelting complex was in the final stages of construction. Construction began 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 was scheduled to begin smelting ore in fourth quarter 2000 (Minera Loma de Niquel, C.A., 2000). Full capacity should be reached by 2001.

Current Research and Technology

New Architectural Uses.—Austenitic stainless steel is becoming an increasingly popular building material. Architects are finding that stainless steel has a number of inherent advantages for both exterior and interior applications (Specialty Steel Industry of North America, 2000b). One principal advantage is the material's resistance to corrosion and wind fatigue. Stainless steel has a relatively high tensile strength and can be used in thinner gauges than several competing alloys. It is also relatively easy to clean and does not pit or tarnish, reducing maintenance costs. Type 300 Cr-Ni steels are suitable for roofing, flashing, gutters, and window sills. The thickness of the sheet typically ranges from 0.25 to 1.6 millimeters (U.S. Standard Gauge 32 to 16). There are a myriad of interior uses, including bathroom and kitchen counter tops, column covers, door bumpers, paneling, plumbing fixtures, railings, sinks, and skywalks.

Stainless steel is especially cost-effective for cladding unconventionally shaped public buildings (Nickel Development Institute, 1999b). The exterior superstructure of the futuristic Walt Disney Concert Hall that is being built in downtown Los Angeles will be clad almost entirely in stainless steel. (See www.disneyhall.org for details.) The roof of the half-moon-shaped Fresno City Hall in Fresno, CA, is made of stainless steel and covers 0.8 ha (2 acres); stainless steel is also extensively used inside the building.

Revolutionary aerospace stiffeners are now being used to attach stainless steel panels to precast concrete walls. A special two-sided tape is used to secure Z-shaped stiffeners to the backside of the 2-millimeter-thick stainless steel panels. The secured panels form a rigid structure that can withstand significant wind loads. The tape was developed by the Minnesota Mining and Manufacturing Company (3M) to affix sheets of metal to airplane fuselages (Nickel Development Institute, 1999a).

Electric Bicycles and Scooters.—ZAPWORLD.COM (ZAP) has begun delivering thousands of electric bicycles and folding electric scooters worldwide. The bulk of the sales have been to commuters and recreational cyclists in Japan, Scandinavia, and the United States. The company currently employs 83 workers at its Sebastopol manufacturing facility in Sonoma County, California (ZAPWORLD.COM, 2000). Other manufacturers of electric bicycles, tricycles, and/or scooters include the following: EV Global Motors Company of Los Angeles, CA; EV Rider, Inc. of Sarasota, FL; Oz eBike.com of Attadale, Western Australia; and Worksman Trading Corporation of Ozone Park, NY. Many existing electric bicycles and scooters are powered by sealed lead-acid batteries. Nickel-based batteries, however, have a greater energy density than lead-acid batteries and eventually should be able to capture a sizable part of the e-bike market.

Outlook

The near-term prospects for reviving ferronickel production in the United States are not good. 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 is expected to pass the 9,000 t/yr mark at the beginning of 2001 and 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) is expected 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 upon 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 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 the Americas and Europe has offset decreased demand in Japan. Beginning in 2001, world stainless steel consumption is forecast to grow between 2% and 5% per year to the year 2006. After 2006, 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 had been projected to reach 2.6 Mt in 2000—an alltime high for the country, but this level was never reached because of the fourth quarter economic slowdown. The austenitic share of the production is expected to decline slightly to 56%. 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 400,000 t/yr of ferritic stainless.

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.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

TABLE 1
SALIENT NICKEL STATISTICS 1/

(Metric tons of contained nickel, unless otherwise specified)

	1995	1996	1997	1998	1999
United States:					
Mine production	1,560	1,330	--	--	--
Plant production	8,290	15,100	16,000	4,290	--
Secondary recovery from purchased scrap:					
From ferrous scrap	54,400	48,800	58,200	52,700 r/	58,600
From nonferrous scrap	10,200	10,500	10,200	10,400	12,500
Shipments of purchased scrap 2/	98,400	84,900	97,600	89,700	93,000
Exports:					
Primary	9,750	13,100	16,400	8,440	7,430
Secondary	41,800	33,600	40,200	35,100	31,400
Imports for consumption:					
Ore	8,200	15,000	17,600	1,420	--
Primary	149,000	142,000	147,000	148,000	139,000
Secondary	7,930	8,060	11,000	8,500	9,480
Consumption:					
Reported:					
Primary	123,000 r/	118,000 r/	120,000 r/	114,000 r/	115,000
Secondary (purchased scrap) 3/	64,500	59,300	68,400	63,100 r/	71,000
Total	187,000 r/	177,000 r/	188,000 r/	177,000 r/	186,000
Apparent:					
Primary	151,000 r/	146,000 r/	154,000 r/	149,000 r/	140,000
Secondary (purchased scrap) 4/	29,500	33,700	37,700	36,900 r/	49,500
Total	181,000 r/	180,000 r/	192,000 r/	186,000 r/	190,000
Apparent primary plus reported secondary	216,000	206,000	222,000	212,000	211,000
Stocks, yearend:					
Government	19,800	15,900	8,530	2,600	--
Producers and traders	12,700	13,300	12,600	13,100	12,700
Consumer, primary	8,200 r/	9,270 r/	10,300	10,400 r/	4,720
Consumer, secondary	4,150	4,230	5,770	5,470 r/	5,070
Total yearend stocks	44,800 r/	42,700 r/	37,200 r/	31,500 r/	22,500
Employment, yearend:					
Mine	17	8	7	7	1
Smelter	253	253	264	6	6
Port facility	25	23	22	1	1
Price, cash, London Metal Exchange:					
Per metric ton, average annual	$8,228	$7,501	$6,927	$4,630	$6,011
Per pound, average annual	$3.732	$3.402	$3.142	$2.100	$2.727
World, mine production	1,040,000	1,060,000	1,130,000 r/	1,140,000	1,120,000

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.

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)

	1998	1999
Kind of scrap:		
Aluminum-base 2/	4,120	4,450
Copper-base	2,270	2,860
Ferrous-base 3/	52,700 r/	58,600
Nickel-base	4,030 r/	5,170
Total	63,100 r/	71,000
Form of recovery:		
Aluminum-base alloys	4,120	4,450
Copper-base alloys	3,830 r/	5,180
Ferrous alloys	52,800 r/	58,600
Nickel-base alloys	2,420 r/	2,790
Miscellaneous and unspecified	-- r/	2
Total	63,100 r/	71,000

r/ Revised. -- Zero.

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	1998	1999
Primary:		
Metal	90,000 r/	93,600
Ferronickel	16,800	12,700
Oxide and oxide sinter 2/	3,580 r/	5,160
Chemicals	1,650 r/	1,660
Other	1,910	1,810
Total primary	114,000 r/	115,000
Secondary (scrap) 3/	63,100 r/	71,000
Grand total	177,000 r/	186,000

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 1999, 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 1999	Grand total 1998
Cast irons	57	W	--	W	80	137	348	485	908 r/
Chemicals and chemical uses	811	W	W	757	--	1,570	--	1,570	1,970 r/
Electric, magnet, expansion alloys	478	--	--	--	(2/)	478	W	478	516
Electroplating (sales to platers)	15,200	--	--	117	(2/)	15,300	--	15,300	16,400
Nickel-copper and copper-nickel alloys	6,420	W	W	--	31	6,450	4,000	10,500	7,470 r/
Other nickel and nickel alloys	12,500	(2/)	W	--	41	12,600	2,660	15,200	17,500 r/
Steel:									
Stainless and heat resistant	26,900	12,500	4,300	--	131	43,900	56,900	101,000	93,000 r/
Alloys (excludes stainless)	5,040	104	756	--	1,140	7,040	1,280	8,320	9,590 r/
Superalloys	17,300	--	W	W	392	17,700	W	17,700	18,600
Other 3/	8,820	58	97	790	1	9,760	5,820	15,600	11,100 r/
Total reported	93,600	12,700	5,150	1,660	1,810	115,000	71,000	186,000	177,000 r/
Total all companies, apparent	XX	XX	XX	XX	XX	140,000	49,500	190,000	186,000

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/ Less than 1/2 unit.
3/ 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	1998	1999
Primary:		
Metal	7,450 r/	3,470
Ferronickel	881	418
Oxide and oxide sinter	1,370	390
Chemicals	438 r/	221
Other	234	225
Total primary	10,400 r/	4,720
Secondary (scrap)	5,470 r/	5,070
Grand total	15,800	9,790

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/

(Metric tons of contained nickel, unless otherwise specified) 2/

Class	1998 Quantity	1998 Value (thousands)	1999 Quantity	1999 Value (thousands)
Unwrought primary:				
Cathodes, pellets, briquets, shot	1,210	$4,970	831	$6,610
Ferronickel	918	10,500	59	161
Powder and flakes	1,080	14,200	909	14,200
Metallurgical-grade oxide	1,230	2,640	1,470	2,730
Chemicals:				
Catalysts	3,340	107,000	3,360	110,000
Salts 3/	675	6,900	803	6,860
Total	8,440	147,000	7,440	140,000
Unwrought secondary:				
Stainless steel scrap	22,400	176,000	19,500	151,000
Waste and scrap	12,700	54,400	12,000	40,300
Total	35,100	230,000	31,400	192,000
Grand total	43,500	377,000	38,900	332,000
Wrought:				
Bars, rods, profiles, wire	226	3,100	382	4,300
Sheets, strip, foil	173	3,120	280	4,700
Tubes and pipes	593	4,610	260	2,550
Total	992	10,800	922	11,500
Alloyed (gross weight):				
Unwrought alloyed ingot	5,970	82,800	9,140	76,100
Bars, rods, profiles, wire	6,650	108,000	6,360	101,000
Sheets, strip, foil	9,190	118,000	7,430	90,500
Tubes and pipes	1,170	26,300	828	20,400
Other alloyed articles	3,040	101,000	3,550	82,400
Total	26,000	436,000	27,300	371,000

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 1999, BY COUNTRY 1/

(Metric tons of contained nickel) 2/

Country	Cathodes, pellets, and briquets, (unwrought)	Powder and flakes	Ferro-nickel	Metal-lurgical grade oxide 3/	Waste and scrap	Stainless steel scrap	Chemicals	Total		Wrought nickel 4/
								1999	1998	
Australia	--	(5/)	--	--	9	1	18	28	12	19
Belgium	--	96	--	--	590	8	180	874	693	34
Canada	101	255	17	1,460	8,890	2,160	482	13,400	12,400	163
China	(5/)	7	--	--	139	349	237	732	1,460	23
Colombia	38	1	--	--	--	--	5	44	29	(5/)
Finland	--	(5/)	--	--	--	--	(5/)	(5/)	28	(5/)
France	27	74	--	(5/)	23	--	6	130	69	29
Germany	3	83	--	3	263	179	96	627	666	27
India	(5/)	3	--	(5/)	29	263	1	296	1,190	1
Italy	(5/)	12	--	(5/)	--	2	11	25	1,480	5
Japan	(5/)	34	--	--	1,440	1,090	744	3,310	3,650	14
Korea, Republic of	37	29	--	3	7	7,800	200	8,080	5,380	17
Mexico	546	124	--	--	3	24	613	1,310	1,740	218
Netherlands	(5/)	6	--	(5/)	84	105	51	246	605	4
South Africa	--	1	--	--	51	1,230	35	1,320	1,320	--
Spain	--	13	--	--	10	2,000	3	2,030	5,570	2
Sweden	--	12	(5/)	--	110	21	1	144	3,260	1
Taiwan	--	7	--	--	--	3,720	325	4,050	2,180	23
United Kingdom	(5/)	62	43	(5/)	291	288	59	743	406	120
Venezuela	--	(5/)	--	--	1	--	28	29	275	1
Other	79	89	--	1	27	231	1,070	1,490	1,090	221
Total	831	908	60	1,470	12,000	19,500	4,160	38,900	43,500	922

-- 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/ Not included in "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/

(Metric tons of contained nickel, unless otherwise specified) 2/

	1998		1999	
Class	Quantity	Value (thousands)	Quantity	Value (thousands)
Unwrought primary:				
Cathodes, pellets, briquets, shot	120,000	$625,000	109,000	$607,000
Ferronickel	12,800	64,000	14,300	73,000
Flakes	1	130	206	1,200
Powder	9,850	89,600	9,170	84,700
Metallurgical-grade oxide	2,140	10,400	3,270	20,500
Chemicals:				
Catalysts	1,080	43,300	996	47,600
Salts 3/	2,060	25,500	1,810	20,200
Total	148,000	858,000	139,000	854,000
Unwrought secondary:				
Stainless steel scrap	4,290	21,600	4,960	27,700
Waste and scrap	4,210	28,900	4,520	27,100
Total	8,500	50,500	9,480	54,800
Grand total	156,000	908,000	149,000	909,000
Wrought:				
Bars, rods, profiles, wire	299	3,770	535	4,950
Sheets, strip, foil	513	12,000	540	12,600
Tubes and pipes	7	240	11	382
Total	819	16,000	1,090	17,900
Alloyed (gross weight):				
Unwrought alloyed ingot	2,250	30,500	2,360	26,400
Bars, rods, profiles, wire	5,840	70,800	6,320	70,700
Sheets, strip, foil	1,880	25,000	2,560	35,500
Tubes and pipes	1,600	35,200	1,230	21,500
Other alloyed articles	559	21,100	818	29,600
Total	12,100	183,000	13,300	184,000

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; 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, and briquets (unwrought)	Powder and flakes	Ferro-nickel	Metal-lurgical grade oxide 3/	Waste and scrap	Stainless steel scrap	Chemicals	Total 1999	Total 1998	Wrought nickel 4/
Australia	13,600	936	--	37	1	--	--	14,600	15,600	--
Austria	348	303	--	--	6	--	--	657	263	72
Belgium	--	28	1	--	107	--	352	488	533	1
Brazil	5,580	--	--	--	87	11	--	5,680	2,910	6
Canada	45,500	5,740	--	3,230	1,510	3,360	59	59,400	63,300	34
China	500	(5/)	--	8	--	--	173	681	222	34
Colombia	--	--	1,840	--	--	--	--	1,840	1,940	--
Dominican Republic	--	--	7,540	--	--	3	--	7,550	6,530	--
Finland	3,680	747	--	--	--	(5/)	585	5,010	4,080	--
France	1,590	--	--	--	941	7	184	2,720	2,570	46
Germany	9	13	1	(5/)	499	5	258	785	616	571
Japan	(5/)	16	--	--	143	3	681	843	1,000	207
Mexico	--	--	--	--	143	1,520	19	1,690	1,620	79
New Caledonia	--	--	4,960	--	--	--	--	4,960	3,960	--
Norway	22,600	--	--	--	28	--	--	22,700	21,100	--
Russia	12,900	873	--	--	6	1	--	13,800	22,900	--
South Africa	783	39	--	--	--	--	4	826	569	--
United Kingdom	906	611	--	--	747	--	54	2,320	1,940	14
Zimbabwe	1,190	--	--	--	--	--	--	1,190	2,060 r/	--
Other	127	66	--	(5/)	307	51	436	987	2,880 r/	22
Total	109,000	9,380	14,300	3,270	4,520	4,960	2,810	149,000	156,000	1,090

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 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; stainless steel scrap, 7.5% nickel.
3/ Primarily oxide, rondelles, and sinter.
4/ Not included in "Total."
5/ Less than 1/2 unit.

Source: U.S. Census Bureau.

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

(Metric tons of nickel content)

Country	1995	1996	1997	1998	1999
Australia (content of concentrate)	98,467	113,134	123,372	143,513	126,000
Botswana (content of ore milled) e/	21,107 r/ 3/	21,910 r/ 3/	22,800 r/	24,800 r/	25,800
Brazil (content of ore)	29,124	25,245	31,936	36,764	43,784
Burma (content of ore)	62 r/	105 r/	35 r/	48 r/	50 e/
Canada (content of concentrate)	181,820	192,649	190,529	208,201	188,218
China e/	41,800	43,800	46,600	48,700	50,100
Colombia (content of laterite ore)	24,194	27,700	31,230	29,422	39,300
Cuba (content of oxide, oxide sinter, sulfide) 4/	40,845	51,289	59,041	65,080 r/	64,407
Dominican Republic (content of laterite ore)	46,523	45,168	49,152	40,300 r/	39,500 e/
Finland (content of concentrate)	3,439	2,136	3,252	1,967	730
Greece (content of laterite ore)	19,947	21,600	18,419	16,985	16,050
Indonesia (content of ore)	88,183	87,911	71,127	74,063	89,100
Kazakhstan e/	9,900 3/	7,000	7,000	6,000	7,000
Macedonia (content of ferronickel produced) e/	3,500 3/	3,000	5,300 r/	5,800 r/	1,900
New Caledonia (content of ore)	119,905	122,486	136,467	125,319 r/	110,062
Norway (content of concentrate)	3,386	3,135	2,454	2,959	2,732
Philippines	15,075	14,539	18,132	12,840	8,450
Russia e/	251,000	230,000	260,000	250,000	260,000
Serbia and Montenegro (content of ferronickel produced)	962	2,556	2,440 r/	466 r/	--
South Africa (content of concentrate)	29,803	33,861	34,830	36,411 r/	35,802
Ukraine (content of ferronickel produced) e/	1,400	500	--	--	--
United States (content of local ore processed)	1,560	1,330	--	--	--
Zimbabwe (content of concentrate)	11,721	11,561	12,963 r/	12,872 r/	11,164
Total	1,040,000	1,060,000	1,130,000 r/	1,140,000	1,120,000

e/ Estimated. 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 28, 2000.

3/ Reported figure.

4/ The data series reported by the Government of Cuba for intermediate products represents nickel plus cobalt content in the ratio of approximately 80 to 1. The tonnages shown in this table for Cuba have been adjusted downward to correct for the cobalt.

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

(Metric tons of nickel content)

Country and product 3/	1995	1996	1997	1998	1999
Albania: Metal e/	50	50	--	--	--
Australia:					
Metal	58,321	61,377	58,824	64,322	75,942
Unspecified	18,612 r/	12,636 r/	14,762 r/	15,256 r/	9,058
Total 4/	76,933	74,013	73,586	79,578	85,000
Austria: Ferronickel e/	2,000	2,000	2,000	1,800	1,700
Brazil: 5/					
Ferronickel	8,497	9,091	9,350	8,077	6,502
Metal	7,179	7,849	8,849	13,006	16,429
Total	15,676	16,940	18,199	21,083	22,931
Canada: Unspecified 6/	125,311	130,136	131,639	146,715	123,944
China: Metal e/	38,900	44,600	43,300	40,100 r/	44,800
Colombia: Ferronickel	24,565	22,934	25,171	28,143	28,345
Cuba: Oxide sinter 7/	21,388	26,700	33,992	38,661	38,500
Dominican Republic: Ferronickel	30,897	30,376	32,558	25,220	24,449
Finland:					
Metal	16,927 r/	28,815	34,228	41,500	52,800
Chemicals	4,280	4,508	4,990	4,518	4,143
Total	21,207 r/	33,323	39,218	46,018	56,943
France:					
Metal	9,106	9,070	8,750	9,778	9,458
Chemicals	1,199	2,101	1,952	2,000 e/	2,244
Total 8/	10,305	11,171	10,702	11,778	11,702
Greece: Ferronickel	17,164	17,801	17,610	15,005	12,964
Indonesia: Ferronickel	10,735	9,553	9,999	8,452	9,205
Japan:					
Ferronickel	69,876	66,796	72,079 r/	69,202	66,458
Metal	26,824	26,564	26,889	29,397	30,481
Oxide sinter	35,966	34,772 r/	26,899	25,435	35,190
Chemicals	2,297	2,323	2,536	2,511	2,570
Total	134,963	130,455 r/	128,403 r/	126,545	134,699
Korea, Republic of: Metal	(9/)	(9/)	(9/)	(9/)	(9/)
Macedonia: Ferronickel e/	3,500 10/	3,000	5,300 r/	5,800 r/	1,900
New Caledonia: Ferronickel	42,200	42,173	44,312	44,491	45,289
Norway: Metal	53,237	61,582	62,702	70,152	74,137
Poland: Chemicals 11/	374	359	364	376	396
Russia: e/ 12/					
Ferronickel	14,000	10,000	10,000	10,000	11,000
Metal	181,000	170,000	210,000	205,000 r/	215,000
Oxide sinter	4,100	8,000	8,000	10,000	10,000
Chemicals	2,000	2,000	2,000	2,000	2,000
Total	201,100	190,000	230,000	227,000 r/	238,000
Serbia and Montenegro: Ferronickel	962	2,556	2,440 r/	466 r/	--
South Africa:					
Metal 13/	29,803	33,362	27,700 r/	29,039 r/	28,345
Chemicals	NA	NA	6,000	2,000	7,458
Total	29,803	33,362	33,700	31,039	35,803
Sweden: Metal e/	500	--	--	--	--
Taiwan: Metal	(9/)	(9/)	(9/)	(9/)	(9/)
Ukraine: Ferronickel e/	1,400	500	--	--	--
United Kingdom: Metal	35,156	38,561	36,091	39,050	38,086
United States: Ferronickel	8,290	15,100	15,996	4,285	--
Zimbabwe: Metal 14/	10,864	9,694	10,300	8,732 r/	10,500 e/
Other: Metal 15/	4,641	6,518	7,346	8,709 r/	6,696
Grand total:	922,000 r/	953,000 r/	1,010,000	1,030,000 r/	1,050,000
Of which:					
Ferronickel	234,000	232,000	247,000 r/	221,000 r/	208,000
Metal	473,000 r/	498,000 r/	535,000 r/	559,000 r/	603,000
Oxide sinter	61,500	69,500 r/	68,900	74,100	83,700
Chemicals	10,200	11,300	17,800 r/	19,000 r/	18,800
Unspecified	144,000 r/	143,000 r/	146,000 r/	162,000 r/	133,000

See footnotes at end of table.

TABLE 11--Continued

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

e/ Estimated. r/ Revised. NA Not available. -- Zero.

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

2/ Table includes data available through July 28, 2000.

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 reliable 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/ Excludes production of pressure acid leach producers.

5/ Brazil produced nickel carbonate (an intermediate product), in metric tons: 1995--8,051; 1996--9,210; 1997--10,487; 1998--13,133; and 1999--17,153.

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. Output of processed sulfide was as follows, in metric tons of contained nickel: 1995--19,457; 1996--24,589; 1997--25,457; 1998--26,881; and 1999--28,000 (estimated). 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: 1995-96--10,000; 1997-18,000; 1998--20,183 (revised); and 1999--20,235; and Taiwan: 1995-96--10,000; 1997-98--10,500; and 1999--10,000.

10/ Reported figure.

11/ Nickel content of nickel sulfate ($NiSO_4 6H_2O$). 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.

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

13/ Figures include nickel sulfate exported for toll refining.

14/ Production from domestic nickel ore. Figures exclude production from imported Botswanan matte, as well as from South African nickel sulfates.

15/ Cross-border tolling.

TABLE 12

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

(Metric tons of nickel content)

Country	1995	1996	1997	1998	1999
Matte:					
Australia 3/	26,554	28,768	37,010	47,459 r/	28,190
Botswana	18,089	17,460 r/	20,157	22,851	23,098
Brazil 4/	--	--	1,180	4,670	9,306
Canada e/ 5/	43,000	50,000	45,000	52,000	52,000
Indonesia	49,333	49,000	33,654	35,697	45,901
New Caledonia	10,143	11,239	10,580	12,011	11,353
Russia e/ 6/	699	320	366	98	42
Total	148,000	157,000 r/	148,000	175,000	170,000
Other: Cuba, sulfide precipitate 7/	19,457	24,589	25,457	26,882 r/	26,369

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

1/ Table includes data available through July 28, 2000. Data represent nickel content of matte and other intermediate materials produced for export.

2/ World totals, U.S. data, 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: 1995--77,000; 1996--74,000; 1997--85,800; 1998--100,100; and 1999--85,000.

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.

TABLE 13
CHEMICAL COMPOSITION OF THE ALLOY LAYER
U.S. DOLLAR

(Percent)

Chemical element	Golden	Susan B. Anthony
Copper	77	75
Manganese	7	--
Nickel	4	25
Zinc	12	--
Total	100	100

-- Zero.

TABLE 14
SHIPMENTS AND SALES FROM THE NATIONAL DEFENSE STOCKPILE

(Metric tons of contained nickel)

Calendar year	Yearend stocks	Shipments	Sales
1992	33,760	--	--
1993	31,551	2,209	2,586
1994	26,757	4,794	5,550
1995	19,797	6,960	9,060
1996	15,859	3,938	6,183
1997	8,525	7,334	6,969
1998	2,598	5,927	1,842
1999	--	2,185	1,404
Adjustments	XX	413	166
Total	XX	33,760	33,760

-- Zero. XX Not applicable.

Source: Defense National Stockpile Center, Defense Logistics Agency.

TABLE 15
RESOURCES OF MURRIN MURRIN LATERITE MINING COMPLEX,
WESTERN AUSTRALIA

Deposit	Resources (million dry metric tons)	Nickel grade (percent)	Cobalt grade (percent)
Murrin Murrin	164	0.99	0.065
Murrin Murrin East	76	1.02	0.075
Abednego	75	0.97	0.056
Total	315	0.99	0.065

Source: Anaconda Nickel Limited, 1999e, p.6.

TABLE 16
INDONESIA: RESOURCE ESTIMATES FOR NEW LATERITE PROJECTS

Deposit	Resources (million dry metric tons)	Nickel grade (percent)	Cobalt grade (percent)
Gag Island: 1/			
Measured	12	1.33	0.09
Indicated	93	1.46	0.07
Inferred	135	1.30	0.09
Total	240	1.35	0.08
Halmahera Island: 2/			
Indicated and inferred:			
Santa Monica	76	1.38	0.12
Big Kahuna	40	1.32	0.17
9 other areas	86	NA	NA
Total	202	1.37	0.12
Grand total	442	1.36	0.10

NA Not available.
1/ Broken Hill Proprietary Company Ltd., 2000.
2/ Weda Bay Minerals Inc., 2000.