NICKEL

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

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

The U.S. economy began contracting in March 2001 after 10 years of expansion. At midyear, the United States was in a mild recession. Weak economic conditions persisted throughout the summer and were worsened by the terrorist attacks of September 11 on the United States. The terrorist attacks had a disruptive impact on the U.S. economy, hurting manufacturing sales and discouraging investment in new ventures. The stock market turned bearish, forcing many large corporations to reduce capital expenditures and to lay off employees. The Federal Reserve Board, which had already begun lowering the federal funds rate in January, responded aggressively and cut the key short term interest rate 11 times during the year, eventually dropping it to 1.75%—the lowest since the 1960s. The U.S. steel industry, already weakened by competition from imported steels, had an especially difficult year. Between 1998 and 2002, 33 steel companies filed for bankruptcy, including Bethlehem Steel Corporation—the leading U.S. producer of carbon and alloy steel plate. U.S. stainless steel producers—the largest consumers of nickel—fared somewhat better than their carbon steel counterparts. The U.S. steel industry produced 1.01 million metric tons (Mt), gross weight, of austenitic stainless steel in 2001, down 18% from 1.24 Mt in 2000.

Overseas and in Canada, nickel producers focused more on midterm trends than on the events of September 11. They continued to commission new mines and add capacity because of optimistic forecasts for long-term growth in demand for stainless steel and nickel-based batteries. More than 870,000 metric tons (t) of capacity (on a contained nickel basis) was scheduled to come onstream between 2002 and 2015 (tables 13, 14). In Western Australia, three new laterite mines were commissioned between 1998 and 2000, and at least three others were in various stages of development (Western Australian Department of Resources Development, 1999, p. 3-18; Griffiths, 2000). Two new sulfide mines in Western Australia were shipping concentrates or matte to smelting and refining complexes in Canada and Finland. In addition to the expansion in Australia, new mining projects were at various stages of development in Brazil, Canada, Indonesia, New Caledonia, the Philippines, and Venezuela. Exports of primary nickel from Russia were up less than 2% from 2000 levels. Russian exports in 2001 exceeded demand inside the country by more than 9 to 1. Russian consumption of nickel has been severely depressed for the past 5 years largely because the former Soviet stainless steel industry has had problems adjusting to a market economy.

Legislation and Government Programs

Decontamination of Radioactive Nickel Metal.—For more than a decade, the U.S. Department of Energy (DOE) has been exploring ways of reusing nickel metal scrap contaminated with trace amounts of natural and manmade radioactive isotopes. The DOE has some 6,000 t of volumetrically contaminated nickel stored at the East Tennessee Technology Park in Oak Ridge, TN. The principal contaminants in the Oak Ridge nickel reportedly are technetium-99 (a beta emitter with a half-life of 211,000 years) and uranium-235.

In late 2001, the DOE accelerated plans to complete the cleanup of Oak Ridge and several other former nuclear weapons production sites. Accelerated cleanup of the East Tennessee Technology Park may be able to be completed by the end of fiscal year 2008, but the cleanup would cost an estimated $2.4 billion (U.S. Department of Energy, Oak Ridge Operations, 2002). The DOE was working with regulators to streamline cleanup operations in Idaho, Nevada, New Mexico, and Washington, in addition to those in Tennessee. Preliminary cleanup agreements were signed with the U.S. Environmental Protection Agency (EPA) and each of the five States in the first half of 2002 (U.S. Department of Energy, 2002a). Previous plans would have stretched out the cleanup during a 70-year period at an estimated cost of $300 billion. The DOE's Office of Environmental Management has created an $800 million "expedited cleanup account" to be used initially by participating States. The new accelerated program was expected to cost $6.7 billion in fiscal year 2003 (U.S. Department of Energy, 2002b).

The cleanup of the weapons production sites and the decommissioning of obsolete commercial nuclear powerplants will generate significant quantities of nickel-bearing scrap metal during the next 10 years. Part of the scrap metal will be already uncontaminated and, after screening, can be introduced directly into the commercial recycling stream without any health or regulatory concerns. Other material, though, will have surface contamination or be volumetrically contaminated, presenting disposal problems. To date, the U.S. steel industry and other domestic metal recyclers have opposed the release of any

decontaminated material. In the past, there have been many incidents in which a radioactive source has ended up in a shipment of purchased scrap and been accidentally smelted, contaminating the melting facility. Fatalities have even occurred in a few instances. Decontamination of a meltshop is an expensive proposition. To avoid future incidents, many scrapyards in Europe and the United States now have low-level radiation detection equipment at their truck entrances.

On December 21, 1999, the Nickel Development Institute (NiDI) presented a brief to the U.S. Nuclear Regulatory Commission (NRC) opposing entry of any "low-level" radioactive nickel into the commercial recycling stream (Nickel Development Institute, 1999). The American Iron and Steel Institute (AISI) and other members of the Metals Industry Recycling Coalition also have adopted a "zero tolerance" position. In response to the concerns of the scrap metals industry, consumer protection groups, and Congress, on January 12, 2000, the Secretary of Energy placed a moratorium on the release of all volumetrically contaminated metals and scrap from DOE facilities. The moratorium was to remain in effect until improvements in DOE release criteria and management could be developed and implemented.

The moratorium announcement was followed by a formal memorandum on July 13, 2000. The July memorandum (DOE Order 5400.5) directed DOE managers and contractors to suspend the unrestricted release of metal from radiological areas until DOE release criteria and monitoring practices could be improved. The Secretary also ordered a feasibility study of a proposed specialty steel mill equipped to handle low-level radioactive scrap. The specially NRC-licensed facility would recycle surplus carbon steel, stainless steel, and nickel from DOE facilities undergoing decontamination and decommissioning. The remelt alloys would be used to make radioactive waste containers. The DOE gaseous diffusion plant site at Portsmouth, OH, was being considered as a possible site for the proposed meltshop. Uranium enrichment operations at Portsmouth were halted in May 2001.

The NRC has begun developing national treatment standards for all volumetrically contaminated materials, including the DOE nickel. The National Academy of Sciences also was tasked to study the disposal issue and make recommendations to the DOE. In November 2002, the Board on Radioactive Waste Management (a unit of the National Academies' Division of Earth and Life Studies) launched a study aimed at improving practices for managing low-level radioactive waste.

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

From December 13 to 15, 2000, the NTP Board of Scientific Counselors met in Washington, DC, to review the evidence on nickel. The Board was composed of scientists from the public and private sectors and had been providing primary scientific oversight to the NTP Executive Committee. J&L Specialty Steel Inc., the Specialty Steel Industry of North America, Inco US Inc., the Nickel Producers Environmental Research Association (NiPERA), and the U.S. Food and Drug Administration all made presentations to the Board. The NiPERA representative pointed out that two alloys with the same nickel content can have completely different nickel release rates and, thus, different levels of carcinogenicity. After the presentations, the Board voted to include metallic nickel in the 10th Edition of the Report on Carcinogens. The Board recommended that metallic nickel be treated in the future as a "reasonably anticipated carcinogen." However, the Board voted not to list nickel alloys without more conclusive research and test data. The 10th report was released to the public on December 11, 2002 (U.S. Department of Health and Human Services, Public Health Service, National Toxicology Program, 2002).

Environmental Programs.—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 Rechargeable Battery Recycling Corporation (RBRC) of Atlanta, GA. The RBRC was supported by more than 285 manufacturer/marketer licensees and a network of 26,000 collection locations across the United States and Canada. The program was made possible by the passage of the Mercury-Containing and Rechargeable Battery Management Act (Public Law 104-142) in 1996. The bulk of the spent nickel-cadmium (NiCd) and nickel-metal hydride (NiMH) batteries was being shipped to a pyrometallurgical reclamation facility at Ellwood City, PA. The facility was operated by the International Metals Reclamation Co. Inc. (Inmetco) (a subsidiary of Inco Limited).

New Coinage.—The European Union (EU) and the United States have issued new coinage after years of preparation, only to encounter unexpected results. The two Governments had taken different positions with respect to nickel. The EU has limited nickel in its new coinage to minimize the risk of hypersensitive members of the public contracting nickel dermatitis. The U.S. Mint continued to produce (1) solid cupronickel coins containing 25% Ni and (2) coins of copper sandwiched between cupronickel cladding. The U.S. Mint has used cupronickel for more than 140 years and apparently has received few complaints about the cupronickel causing nickel dermatitis.

Commemorative Quarters.—The U.S. Mint produced 4.81 billion quarters (25-cent coins) in 2001, down from 6.47 billion in 2000. The cupronickel-cladded coins were part of the popular 50 State Quarters™ Program launched in December 1998. Between 40 and 60 billion quarters will have been minted when the program ends in 2008. The five States honored in 2001 were New York, North Carolina, Rhode Island, Vermont, and Kentucky (in order of minting). Since each coin weighs 5.67 grams (g) and contains 8.33% Ni, the total quantity of nickel ending up in the five commemoratives released in 2001 was about 2,270 t.

The Golden Dollar.—The U.S. Mint began releasing the new golden dollar coin on January 27, 2000, and produced 1.29 billion of the coins that year. By the beginning of 2001, some 700 million coins were in circulation. The dollar coin has an overall composition of 88.5% copper (Cu), 6.0% zinc, 3.5%

manganese, and 2.0% Ni. Each coin costs about 12 cents to produce. An additional 133 million were minted in 2001, but the new coin has been less popular than the State quarters. Only 7 million golden dollars were produced in the first 9 months of 2002 (U.S. Mint, 2002§[1]).

The General Accounting Office originally estimated that the dollar coin would save taxpayers about $500 million each year because the coin would last much longer than the paper note and would cost less to distribute. A $67.1 million, 3-year marketing campaign by the U.S. Mint, however, failed to overcome public and commercial resistance to the new coin. In mid-2001, the dollar coin was being used in only 1% of dollar transactions. The U.S. Mint was expecting circulation to increase after the novelty of the dollar coin tapered off (U.S. Mint, 2001§). Several complaints were linked to the weight of the coin. Some people considered the ease of carrying the bill to be more beneficial than the durability of the coin. This was the second time in the past 30 years that a dollar coin has failed to achieve widespread use. The previous silvery Susan B. Anthony dollar—a cupronickel coin—was too easily mistaken for a quarter (Kellman, 2002).

Euro Coinage.—The European Monetary Union (EMU) began circulating its new Euro coinage on January 1, 2002. On that day, 12 of the 15 member countries of the EU formally abandoned their national currencies and adopted the Euro. Fifteen mints in the 12 participating countries had been working on the exchange since 1993 under the direction of the European Central Bank and the Mint Director Working Group. In November 2001, Eurozone banks began selling small packets of the new coins to the general public so that consumers would be more familiar with the Euro during the exchange period. At the same time, the national mints began shipping huge tonnages of new coins to the banks from stockpiles built up over the previous 4 years. More than 60 billion coins were involved. Some 4 million coin vending machines had to be modified throughout the EMU. Because coins of the individual member States would no longer be legal tender after July 1, 2002, the mints had contractors start collecting the old national coins from the banks and haul the coins to undisclosed locations for scrapping. The old coins—many of which contained significant nickel—were being defaced and stockpiled until they could be melted down by the contractors into remelt alloys. Melting of the old French coins was expected to produce at least 11,000 t of nickel for recycling. Old coins from Belgium, Luxembourg, and the Netherlands should generate an additional 10,000 t of nickel (Plumail, 2001; Wilkinson, 2001).

Six of the eight new denominations contain no nickel. The EMU used a nickel-free alloy called Nordic Gold for the 10-, 20-, and 50-eurocent pieces and copper-covered steel for the 1-, 2-, and 5-eurocent pieces (Outokumpu Oyj, 1998b). The switch to the Nordic Gold alloy was driven by concerns from some sectors of the public about nickel dermatitis. Only the 1- and 2-euro coins contained nickel (Outokumpu Oyj, 1998a). When the exchange began, the EMU had 4.8 billion 1-euro and 2.7 billion 2-euro pieces containing more than 11,000 t of nickel in stock (Plumail, 2001).

[1]References that include a section twist (§) are found in the Internet References Cited section.

National Defense Stockpile.—There has been no nickel in the National Defense Stockpile since 1999.

Exploration

Duluth Complex of Minnesota.—Exploration of the Duluth Complex in northeastern Minnesota continued despite the volatile price of nickel. The driving force for the exploration is the positive long-term outlook for consumption of nickel and coproduct platinum-group elements (PGE). The Duluth Complex covers some 5,000 square kilometers (km^2) of territory in St. Louis, Lake, and Carlton Counties. The complex is composed of about 40 separate sheet-like or cone-like intrusions, which produced rock types with a wide range in composition—from anorthosite to ferrogabbro and troctolite. The complex is associated with the Midcontinent Rift System of Middle Proterozoic age and is 1.1 billion years old (Mining Journal, 1998). Most of the exploration has focused on the western edge of the complex where it intrudes the Mesabi Iron Range and the younger Virginia Slate. Work during the 1960s and 1980s identified a belt of eight deposits of low-grade copper-nickel and PGE bordering the Iron Range. From northeast to southwest, the eight deposits are Spruce Road, Maturi, Dunka Pit, Serpentine, Minnamax, NorthMet, Wetlegs, and Wyman Creek. Teck Cominco Limited of Vancouver, British Columbia, Canada, has leased the Minnamax site and was trying to determine if the deposit could be economically developed using proprietary technology (Bloomquist, 2001). According to Wallbridge Mining Company Limited of Lively, Ontario, Canada, the eight deposits contain 3.6 billion metric tons (Gt) of sulfide mineralization grading 0.66% Cu and 0.2% Ni. The principal ore minerals are chalcopyrite ($CuFeS_2$), cubanite ($CuFe_2S_3$), pentlandite [$(Fe,Ni)_9S_8$], and pyrrhotite ($Fe_{1-x}S$) (Sims and Carter, 1996, p. 92-93).

Birch Lake Project.—Lehmann Exploration Management Inc. of Minneapolis, MN, was managing an exploration project at Birch Lake Reservoir for the Beaver Bay Joint Venture. The joint venture was a Minnesota enterprise comprising three privately owned Midwestern corporations: North Central Mineral Ventures, Powell Production Company, and Connor Management Inc. The Beaver Bay property is about 10 kilometers (km) east of the town of Babbitt in St. Louis County, and less than 2 km east of the Biwabik Iron Formation. Interest in the Birch Lake area was rekindled in 1985 when the Minnesota Department of Natural Resources (MDNR) found commercially significant amounts of platinum and palladium in core that the Duval Corporation had drilled near the reservoir during the late 1960s and early 1970s, and later turned over to MDNR. The platinum and palladium were associated with copper-nickel mineralization. In 2000, Lehmann Exploration and the joint venture signed a memorandum of understanding with Impala Platinum Holdings Limited (Implats) of Johannesburg, South Africa. Implats agreed to spend $5 million on the Birch Lake project before the end of 2003.

NorthMet Project.—PolyMet Mining Corporation was reassessing the NorthMet deposit some 19 km south of Babbitt, also in St. Louis County. The deposit, formerly known as Dunka Road, was discovered by the U.S. Steel Corporation (now USX Corp.) during the late 1960s. In 1989, PolyMet

obtained a 20-year renewable lease agreement with USX. PolyMet has considered using both biooxidation and pressure oxidation leaching to recover the copper, nickel, cobalt, and precious metals (Clifford, 1999; Gentry and Mach, 2000; PolyMet Mining Corporation, 2001a). On July 20, 2001, PolyMet announced the completion of a comprehensive prefeasibility study of NorthMet. The study, prepared by Independent Mining Consultants Inc., recommended that $18 million to $20 million be spent on a final bankable feasibility study. The prefeasibility study concluded that the deposit contains 335 Mt of measured resources averaging 0.303% Cu and 0.084% Ni, and an additional 308 Mt of indicated resources averaging 0.329% Cu and 0.085% Ni. The total resource of 643 Mt is believed to average 66 grams per metric ton (g/t) cobalt (Co), 0.30 g/t palladium (Pd), 0.081 g/t platinum (Pt), and 0.042 g/t gold (Au) (PolyMet Mining Corporation, 2001b).

Spruce Road and Maturi Projects.—In late 1999, Wallbridge began evaluating earlier test work on the Spruce Road and Maturi deposits. Part of the property was held under a joint-venture agreement with American Copper & Nickel Company Inc. (ACNC) (a subsidiary of Inco Limited). ACNC outlined the two deposits while exploring the area between 1950 and 1975. Reassaying of ACNC drill core stored since the 1960s indicated that the Maturi deposit may contain economically significant amounts of palladium and other PGEs. In the 1960s, few mining companies assayed for palladium because demand for the element was minimal. According to Wallbridge officials, the Maturi deposit contains an estimated 52 Mt of resources at a grade of 1.05% combined Cu and Ni (Wallbridge Mining Company Limited, 2001, p. 13-15).

Production

Primary Production.—The United States did not have any active nickel mines in 2001. Glenbrook Nickel Co. decommissioned its mining and smelting complex at Riddle, OR, in 2000. All the electric arc furnaces were dismantled and scrapped. The commissioning of the Loma de Niquel ferronickel operation in Venezuela in December 2000 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.

Limited quantities of byproduct nickel were recovered at some copper and precious-metals refineries. Stillwater Mining Company has been mining platinum-group metals (PGMs) and gold since 1986 from the Stillwater Complex at Nye in Montana's Beartooth Mountains. The ore is associated with the 45-km-long J-M Reef. The Nye mill processed a total of 827,000 t of ore and subgrade material in 2001, with a mill head grade of 21 g/t of palladium plus platinum. About 96% of the ore came from the Stillwater Mine at the eastern end of the reef. Concentrates from the Nye mill were being trucked to the company's smelting and refining complex at Columbus, MT, where a filter cake containing approximately 60% palladium and platinum was being produced. In 2001, the refinery also produced byproduct nickel sulfate and shipped 358 t of nickel in solutions or crystals (Stillwater Mining Company, 2002a, p. 16-17; b, p. 7-14).

Stillwater was in the process of expanding the Columbus smelter and commissioned a centralized concentrate sampling and drying facility in May. A second top-blown rotary converter was brought online in November. The expansion was needed to accommodate concentrates from the new East Boulder Mine under development in the western half of the J-M Reef. Several improvements also were made to the refinery in 2000 and 2001. A nickel sulfate crystallizer circuit became operational in the second quarter of 2001. The new crystallizer circuit allowed the company to ship its nickel sulfate byproduct as a solid rather than a liquid, making the nickel more marketable, reducing shipping costs, and minimizing environmental risks. A copper dissolve pressure leach circuit was incorporated to increase PGM recovery and provide an improved solution feed for the electrowinning circuit.

Development of the East Boulder Mine near Big Timber has been underway since mid-1998. Excavations for most of the underground infrastructure had been completed by yearend 2001. Above ground, the 1,800-metric-ton-per-day (t/d) concentrator was commissioned in mid-2001 and was operated intermittently until yearend using development material as feed. The East Boulder Mine began commercial production in 2002 at a rate of 900 t/d of ore—only 50% of its design capacity. Stillwater's management decided to reduce its planned production when the price of palladium declined sharply following the terrorist attacks of September 11, 2001 (Stillwater Mining Company, 2002a, p. 14-15).

Limited tonnages of primary nickel are recovered during the refining of some crude oils. Like vanadium, nickel occurs in the crude oil as porphyrins or other organometallic compounds. The nickel and vanadium contents of crude oil are quite variable and reflect several factors, such as the density of the oil, the sulfur content of the oil, the field location, geologic occurrence, and geologic age. Aromatic crudes, like those from the Yucatan Peninsula of Mexico, generally contain more sulfur and transition metals than paraffinic crudes from West Texas and naphthenic crudes from Louisiana. Venezuela is noted for its heavy and ultraheavy crudes with very low American Petroleum Institute specific gravities (densities) (°API) and high metal contents. For example, Leona crude from the Venezuelan State of Anzoátegui has an °API of 24, a sulfur content of 1.52 weight percent, a nickel content of 42 g/t, and a vanadium content of 139 g/t. Heavy, sour Merey crude from Anzoátegui State has an even lower °API of 14.7, a higher sulfur content of 2.74%, a nickel content of 84 g/t, and a vanadium content of 303 g/t. In contrast, sweet Cossack crude from offshore northwestern Australia has an °API of 47.3, a sulfur content of 0.03%, a nickel content of only 1 g/t, and a vanadium content of less than 1 g/t (Tippee and others, 1998). As a rule of thumb, crude oils with low °API values have high nickel and vanadium contents.

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

RBRC program has been encouraging consumers to return their spent NiCd and NiMH batteries to commercial outlets where they are stockpiled and eventually shipped to Ellwood City. Inmetco also reclaims large industrial cells that are used by railroads, electric utilities, the military, and telecommunication companies for backup power. An estimated 1,800 t of NiCd batteries was collected in the United States and Canada in 2001. Although the tonnage of nickel-based batteries being recycled has increased dramatically since 1996, a significant number still end up in landfills.

Spent catalysts are another U.S. source of nickel. Nickel is incorporated into the structure of some catalysts (for example, nickel molybdate) and can be recovered when the spent catalyst is autoclaved and separated from its carrier. In 2000, CS Metals of Louisiana, LLC commissioned a spent catalyst reclamation facility on the Mississippi River at Convent, LA. The plant is now recovering vanadium oxide and molybdenum oxide from spent catalysts used in oil refining and petrochemical operations. The facility also produces a nickel-cobalt byproduct. CS Metals is a joint venture of Strategic Minerals Corporation (Danbury, CT) and CRI International Inc. (Houston, TX), a wholly owned member of the Royal Dutch/Shell Group of companies. The fully permitted plant is in the Baton Rouge/New Orleans refining corridor and uses a patented hydrometallurgical process that produces no solid waste (Strategic Minerals Corporation, 1999). In September 2002, Strategic Minerals announced that it was selling its 50% interest in the joint venture to CRI.

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

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

Consumption

In 2001, demand for primary nickel in the Western World was reported to be 979,100 t, down 4% from the alltime high of 1,024,000 t (revised) reached in 2000 (International Nickel Study Group, 2002c, p. 3-17). U.S. apparent consumption of primary nickel was 129,000 t, or about 13% of Western demand. U.S. industry consumed an additional 101,000 t of nickel in scrap. Within the United States, the share of primary nickel consumed in the production of stainless and alloy steels increased slightly to 40% in 2001 from 39% in 2000, despite lower production of specialty steels. The small gain in market share was attributed to even sharper drops in demand for electroplating products and many nonferrous alloys—copper-nickel alloys, nickel-base corrosion-resistant alloys, superalloys, etc. The estimated value of apparent primary consumption in the United States in 2001 was only $767 million, down from $1.27 billion in 2000. The 40% drop in value reflected not only a 12% drop in apparent primary consumption, but also a 31% drop in the London Metal Exchange (LME) cash price. Lower prices for primary nickel kept many stainless steel producers and other nickel consumers from cutting back operations even more. U.S. sales of stainless steel—already weak because of the recession—declined sharply after the terrorist attacks of September 11. Demand for superalloys—key fabrication materials for jet engines—also deteriorated after September 11 but has slowly begun to recover. U.S. airlines were forced to cancel orders for new civil jet transport because of the sharp drop in passengers carried and declining revenues.

Stainless Steel and Low-Alloy Steels.—In 2001, the United States and world demand for nickel continued to be driven by the stainless steel industry. Stainless steel producers accounted for 34% of primary nickel demand in the United States and more than 60% of primary demand in the world. Production of raw stainless steel in Western countries has more than doubled in the past 15 years, growing to 18.69 Mt in 2000 from 7.92 Mt in 1985 (Inco Limited, 2001f, p. 1-8). Utilization of stainless melt capacity in the Western World has climbed to an estimated 85% in 2001 from 74% in 1996. Because of the high utilization rate, additional melt capacity will have to be brought onstream by 2005 to accommodate the projected growth in demand for stainless steel. In anticipation of this growth, Yieh United Steel Corporation (YUSCO) expanded melt capacity at its plant in Kaohsiung County, Taiwan, in 2000 to 1,000,000 metric tons per year (t/yr) from 800,000 t/yr. The YUSCO facility is the largest integrated stainless steel mill in Southeast Asia. Between 2002 and 2005, additional capacity is expected to start up in the EU, China, the Republic of Korea, and the United States. In the interim, reduced growth in demand in East Asia and other overseas markets since 1997 encouraged foreign stainless steel producers to increase their exports to the United States. The recessionary forces of 2001 and the events of September 11, however, adversely affected U.S. imports as well as production. Total U.S. imports of stainless steel mill products declined to 847,000 t in 2001, a drop of 21% from the record 1.07 Mt of 2000.

Production of raw stainless and heat-resisting steel in the United States totaled 1.82 Mt in 2001, down 17% from the record 2.19 Mt of 2000. The decrease in production, like the decrease in imports, was attributed to the weakening economy in the aftermath of September 11. Nickel-bearing grades accounted for 1.01 Mt, or 56% of the total stainless production for 2001 (American Iron and Steel Institute, 2002b). Net shipments of all types of stainless totaled 1.67 Mt, down significantly from the 11-year high of 1.93 Mt reached in 2000 (American Iron and Steel Institute, 2002a, p. 26-29). Shipments of sheets and strip decreased 14% to 1.31 Mt, down from an alltime record of 1.53 Mt set in 2000. Shipments of plate, the next largest category, were 184,000 t, or 2% less than that of 2000.

North American Stainless [a subsidiary of Acerinox SA (Madrid, Spain)] was building a meltshop at its steel rolling operations in Ghent, KY. The new meltshop was designed to produce about 800,000 t/yr of hot metal and was expected to be a major consumer of primary nickel and stainless steel scrap.

Superalloys and Related Nickel-Base Alloys.—About 33% of the primary nickel consumed in the United States was used to make high-performance superalloys and related nickel-base alloys for the aerospace, electric power, and petrochemical industries. U.S. production of nickel-base alloys was down from that of 2000 because of a weakening of sales to aircraft manufacturers. Sales to manufacturers of turbines for land-based powerplants remained at 2000 levels. The industrial gas turbine (IGT) market has been in a period of rapid growth and was less affected by the recessionary events of 2001 because of the long lead-times in powerplant construction.

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 2001, the U.S. aerospace industry earned $8.7 billion on sales of $151 billion—the second highest profits on record (Napier, 2001). Total sales were 3.3% greater than those of 2000. The U.S. Government accounted for 50% of domestic aerospace products and services compared with 70% a decade ago (Aerospace Industries Association of America, Inc., 2001). The Boeing Company and its McDonnell Douglas Corporation subsidiary saw their backlog of orders for civil jet transports shrink dramatically after September 11, when airlines experienced serious financial difficulties and were forced to cancel orders. A total of 271 net orders for large civil jet transports was received in 2001, compared with 585 in 2000. Between 2000 and 2001, actual shipments increased, rising to 526 aircraft from 485. On December 31, 2001, Boeing had a backlog of 1,357 aircraft, down from 1,612 at yearend 2000 (Aerospace Industries Association of America, Inc., 2002).

In 2000, Airbus Industrie S.A.S. began manufacturing the A380, the first of a family of innovative superjumbo jets. The A380 is the largest passenger aircraft built to date and will be powered by four Rolls-Royce Plc or Electric Alliance jet engines. Electric Alliance is a partnership between General Electric Co. and Pratt & Whitney Co., Inc. About 40% of the aircraft's structure was being manufactured from the latest generation of carbon composites and advanced metallic materials. The upper fuselage shell of the A380 was being fashioned from GLARE, a laminate of alternating layers of aluminum and glass-fiber reinforced adhesive. The Airbus jumbo jet should begin coming off assembly lines in the EU in 2006 (Charrier, 2002§). Boeing, Airbus's principal competitor, was developing the B-20XX, a near-supersonic aircraft designed for long distance TransPacific and transpolar routes. The B-20XX is to have completely redesigned engines fabricated from advanced superalloys.

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

At the beginning of 2000, Allegheny Technologies Inc. emerged from a major restructuring and series of spinoffs that transformed the company into one of the world's larger producers of specialty steels and high-value alloys. The reconfigured company had combined sales of $2.13 billion in 2001, down from $2.46 billion in 2000. The aerospace, automotive, chemical processing, and electrical energy markets accounted for 21%, 11%, 11%, and 13%, respectively, of total sales. In terms of products, nickel-based alloys and related specialty steels generated 22% of total sales. Commodity stainless steel sheet and plate accounted for an additional 20%. The company reported record shipments of nickel-based alloys and related superalloys to the commercial aerospace industry in 2001 (Allegheny Technologies Inc., 2002, p. 1-15).

On December 10, 2001, the management of Allegheny Technologies announced that the company was permanently idling its stainless steel meltshop at Houston, PA. The cost-reduction action would eliminate 227,000 t/yr of melt capacity. Allegheny, though, would continue to operate Houston's Steckel mill. The idling reduced the company's stainless steel melt capacity by nearly 30% (Allegheny Technologies Inc., 2002, p. 1-15).

AK Steel Corporation introduced a new line of coated stainless steels in 2001. The steels are coated with AgION™, an antimicrobial compound that suppresses the growth of a wide range of microorganisms, including bacteria, molds, and fungi. The antimicrobial-coated steels could help eliminate a number of vexing health problems associated with home appliances, ventilation and air conditioning systems, food processing equipment, and medical equipment (AK Steel Holding Corporation, 2002, inside back cover). The company was formed on September 30, 1999, when Armco Inc. merged with AK Steel's predecessor of the same name. AK Steel produces specialty stainless steels at Butler, PA, and Mansfield, OH.

On October 15, 2001, Bethlehem Steel Corporation filed for protection under Chapter 11 of the Federal Bankruptcy Code. Bethlehem Steel is the second-largest integrated steel manufacturer in the United States and the leading producer of carbon and alloy steel plate. The company had revenues of $2.6 billion in 2000 but has been struggling since mid-1988 to compete against record levels of steel imports. A second problem is that Bethlehem Steel has been producing steel since 1904 and is now burdened by a $3-billion retiree healthcare obligation (Bethlehem Steel Corporation, 2001). Bethlehem Lukens Plate, a subsidiary in Coatesville, PA, is a significant consumer of nickel. The Coatesville operation produces low-carbon alloy steel plate containing 9% Ni, as well as armor plate and several types of stainless steel plate. The 9% Ni plate is recommended for cryogenic pressure vessels and used to store oxygen, nitrogen, and other liquified gases. Duracorr®, an ASTM 1010 stainless steel produced by Bethlehem Lukens in a variety of forms, contains 11% chromium, 1.0 % Ni, and 0.25% molybdenum.

In September, The Hall Chemical Co., Inc. of Wickliffe, OH, closed after 55 years of operation. The company's plant in Ohio was shuttered, but the plant in Arab, AL, was sold in December to Umicore, SA of Belgium for an undisclosed sum. Hall produced cobalt, manganese, and nickel products for the

chemical industry. Umicore was planning to use the Alabama plant to recycle cobalt-bearing catalysts.

Advanced Castings and Forgings Industry.—Nickel is used in a variety of brass, stainless steel, and superalloy castings. Nickel also is added to gray-iron castings to toughen the iron, promote graphitization, and improve machinability. The U.S. castings industry shipped an estimated 1.2 Mt of steel castings and 2.1 Mt of nonferrous castings in 2000. Iron castings shipments (gray, ductile, and malleable) were about 9.1 Mt. The U.S. foundry industry has consolidated dramatically during the past 40 years. The number of foundries in North America has declined to 3,000 in 2001 from approximately 6,000 in the 1960s. In 2001, there were only 350 steel foundries and 650 iron foundries in the United States. At the same time, capacity utilization has increased to 85% from 45%. Cast components are becoming increasingly complex, especially those going to the aerospace and power generation sectors (Atchison Casting Corporation, 2002, inside front cover, p. 4-17).

In June 2000, Alcoa Inc. completed its acquisition of Howmet International Inc. Howmet is the largest manufacturer of investment cast turbine engine components in the world and a significant consumer of nickel. Many of the advanced superalloy castings produced by the company are incorporated into jet aircraft engines or industrial gas turbines (Alcoa, 2000). The purchase brought Alcoa closer to Airbus because of Howmet's business in both new-generation and after-market jet engine components. The purchase also provided Alcoa with an entry into the fast-growing IGT market.

Precision Castparts Corp. (PCC) of Portland, OR, had record sales for the sixth year in a row. The company manufactures high-quality investment castings and forgings for aerospace and power generation applications. Many of these castings and forgings are made of stainless steel or nickel-based superalloys. PCC also makes investment castings for general industrial, automotive, nuclear, and medical applications. In 2000, PCC acquired the Wyman-Gordon Co. and two other producers of high-quality forgings as part of a diversification strategy to reduce PCC's exposure to the cyclical lows of the aerospace market. The acquisition of Wyman-Gordon greatly increased PCC's presence in the rapidly growing IGT market. At yearend 2001, PCC had at least a 30% share of the IGT casting market. Because turbine temperatures may exceed 1,315° C (or 2,400° F), the airfoils (the stationary vanes or rotating blades) of the turbine are usually made from special nickel-based superalloys. IGT airfoils are generally larger than those for aircraft engines and more difficult to cast. Much of this work was being done at PCC Airfoils in Beachwood, OH. Wyman-Gordon Lincoln Ltd. (the newly acquired subsidiary of PCC in the United Kingdom) produces forged engine discs, engine shafts, and airframe and landing gear components, primarily for British jet engine maker Rolls-Royce. In late 2001, PCC became sole owner of Western Australian Specialty Alloys Ltd. The Australian company is now providing nickel-based billets directly to Wyman-Gordon's forging operations at a cost considerably less than Wyman-Gordon previously had been paying for ingot on the open market. PCC was planning to increase the billet output of the Perth-based nickel alloy producer by 400% by 2005 (Precision Castparts Corp., 2002, p. 1-19).

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

Battery Manufacturing.—Texaco Ovonic Battery Systems LLC manufactures rechargeable NiMH batteries for electric, hybrid electric, and fuel cell electric vehicles. The main plant is at Kettering, OH. Some key battery components, though, are produced in development facilities operated in Troy, MI, by Ovonic Battery Company, Inc.—one of Texaco Ovonic's two parents. Ovonic Battery is owned in turn by Energy Conversion Devices, Inc. (ECD) (91.4% equity). ECD is a leading developer of advanced energy technologies and is perhaps best known for its patents on the NiMH battery. Sanyo Electric Co. Ltd., Hitachi Maxell Ltd., and other ECD licensees produced more than a billion NiMH batteries in 2001.

The Kettering operation originally had been a joint venture of Ovonic Battery and General Motors Corporation (GM). GM, however, turned over its interests in the joint venture to Texaco on July 17, 2001. GM has since designated Texaco Ovonic as a preferred supplier for its NiMH battery requirements and is collaborating on a development program with the battery manufacturer. In 2000, Texaco formed two other joint ventures with ECD that were aimed at further developing and eventually commercializing fuel cells for automobile propulsion (Energy Conversion Devices, Inc., 2002, p. 7-16).

Electric and Hybrid Electric Vehicles.—Although electric vehicles (EVs) were being commercially manufactured in the EU, Japan, and the United States, production and sales were still limited. In the past 2 years, sales of hybrid gas- and electric-powered vehicles have soared past those of purely electric vehicles. Two hybrid vehicles were being leased or sold at U.S. auto dealerships in 2001—the two-seat Honda Insight coupe and the five-seat Toyota Prius sedan. The Insight was rated at 3.7 liters per 100 kilometers (L/100km) or 64 miles per gallon (mpg), while the Prius was rated at 4.9 L/100 km or 48 mpg (Heilprin, 2001). A total of 10,134 Honda Insight coupes and 31,132 Toyota Prius sedans was sold or leased between October 1999 and March 2002 (Electric Vehicle Association of the Americas, 2002§). By the beginning of 2002, Toyota had sold or leased more than 100,000 Prius sedans worldwide.

At yearend 2001, at least five EV models equipped with NiMH batteries were being sold or leased in the United States. A total of 733 battery electric light-duty passenger vehicles and trucks was reported leased or sold in 2001. A significant number of the 733 vehicles, especially trucks, used lead-acid batteries as a cost-savings measure. The new Generation I NiMH battery made by Texaco Ovonic can store twice the energy of a conventional lead-acid battery for the same weight and volume. More than 5,200 pure EVs were on U.S. highways.

On December 22, 1999, the U.S. Postal Service (USPS) ordered 500 electric mail delivery vehicles from Ford Motor Company and its partner Baker Electromotive, Inc. of Rome, NY. The USPS had an option to order 5,500 additional vehicles. The design of the delivery vehicle was based largely on Ford's Ranger EV. Production began in the fall of 2000 and continued through 2001 at the rate of 45 vehicles per month (Ford Motor Company and Baker Electromotive, 1999).

Stocks

On December 31, 2001, U.S. consumer stocks of primary nickel (cathode, pellets, briquets, powder, etc.) totaled 4,180 t—35% less than the 6,400 t (revised) at yearend 2000. Stocks in LME warehouses worldwide, in contrast, almost doubled during 2001 to 19,188 t. LME stock levels have gone through two major cycles since 1990. LME stocks declined almost continuously between December 1998 and March 2001—starting at 65,964 t and bottoming out at 9,000 t. LME stocks at yearend 2000 and 1999 were 9,678 t and 46,962 t, respectively. Data collected by the International Nickel Study Group indicated that, at yearend 2001, world nickel producers (excluding those in Austria, China, the former Yugoslavia, and the Ural area of Russia) had approximately 91,400 t of nickel in primary products in stock (International Nickel Study Group, 2002b, p. 10-11). About 77% or 70,300 t of the LME material was Class I materials. Class I materials are refined products with a nickel content of 99% or greater (electrolytic cathode, pellets, briquets, rondelles, powder, etc.). Class II materials include ferronickel, oxide sinter, and East Asian utility nickel—products with a nickel content less than 99%.

Prices

The monthly average cash price for 99.8% pure metal on the LME was $6,995 per metric ton ($3.173 per pound) for January 2001. The monthly average price peaked in May at $7,061 per ton ($3.203 per pound) and then gradually declined until October, when it bottomed out at $4,825 per ton ($2.189 per pound). By yearend, the price had returned to $5,264 per ton ($2.388 per pound). The prices for January and February 2002 were somewhat higher—$6,043 per ton ($2.741 per pound) and $6,029 per ton ($2.735 per pound), respectively. The weakening of prices during summer 2001 was attributed primarily to the economic slowdown in the United States and parts of East Asia. Geopolitical concerns in the aftermath of September 11 apparently put additional downward pressure on the price during the fourth quarter. The downward pressure was partially offset by a strengthening of demand for stainless steel in East Asia. To satisfy higher Asian demand, Japanese production of austenitic stainless steel increased to 2.14 Mt gross weight in 2001 from 2.07 Mt in 2000, an increase of 3% (International Nickel Study Group, 2002b, p. 18). The East Asian recovery also led to increases in stainless steel production in the Republic of Korea and Taiwan (World Bureau of Metal Statistics, 2002, p. 8).

In 2001, the last weekly price (for the 2-business-day week ending December 28) was $5,701 per ton ($2.586 per pound). The annual average price was $5,945 per ton ($2.696 per pound). The average price in 2001 was 31% less than the 2000 average of $8,638 per ton ($3.918 per pound).

Prices for nickel-bearing scrap tracked those for primary nickel, decreasing throughout most of 2001 because of the deteriorating economic outlook in the EU, the United States, and parts of East Asia. Large exports of scrap from the Russian Federation added to the downward pressure on primary and secondary prices.

Foreign Trade

U.S. net import reliance as a percentage of apparent consumption was 46% in 2001—significantly less than the 56% for 2000 because of increased substitution of scrap for primary nickel by consumers. Imports accounted for essentially 100% of primary supply. The United States imported 136,000 t of primary nickel in 2001, 13% less than the 156,000 t for 2000. Class I materials accounted for 88% 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 Norwegian nickel was produced from foreign matte processed at Falconbridge Limited's refinery in Kristiansand. Australia was close behind, in third place, with increased shipments from Bulong, Cawse, and Murrin Murrin—three new pressure-acid leach operations near Kalgoorlie. Russia dropped to fourth place and was slightly ahead of the Dominican Republic. Norilsk Nickel Mining and Metallurgical Company has been an important source of nickel metal for the United States since the dissolution of the Soviet Union.

Russia was the second largest exporter of nickel-bearing scrap in 2001, after the United States. Most of the Russian scrap, however, was consumed in the EU and did not enter the U.S. market. The EU imported 229,000 t (gross weight) of stainless steel scrap from Russia in 2001, down from 344,000 t in 2000 (International Nickel Study Group, 2002b, p. 64-65). U.S. exports of stainless steel scrap to the EU totaled 65,500 t (gross weight), up 30% from 2000 levels.

In terms of contained nickel, total U.S. exports of stainless steel scrap declined to 32,900 t in 2001 from 35,100 t in 2000, a drop of 6%. Taiwan was the largest importing nation, purchasing 11,600 t of contained nickel in 2001. The Republic of Korea dropped to second place, with 8,950 t of contained nickel.

During the past 5 years, U.S. producers of specialty steels concerned about the country's continuing high level of specialty steel imports have filed numerous antidumping and countervailing duty petitions with the U.S. Department of Commerce and the U.S. International Trade Commission (ITC). In 2000, specialty steel imports reached a record 811,000 t (gross weight). Stainless steel accounted for 628,000 t or 77% of the 811,000 t total. Electrical steel constituted 14%, and tool steel, 9% (Specialty Steel Industry of North America, 2001). Total imports of all stainless steel long products (bar, rod, and wire) captured 52% of the U.S. market that year. In 2001, imports of stainless steel slowed somewhat because of the worldwide recession but were still a major factor in the U.S. market and a serious threat to the financial stability of the U.S. specialty steel industry. The situation was of even greater concern to U.S. producers of carbon steels.

In June 2001, the President formally asked the ITC to determine whether the surge in steel imports during 1999 and 2000 had seriously damaged the U.S. steel industry. The ITC proceeded to conduct an injury investigation under section 201 of the Trade Act of 1974 (as amended). Section 201 is often referred to as "safeguard" or "escape clause" authority because it allows the President to take action without a finding of dumping or illegal subsidy. The investigators looked only at the effects of

import growth and did not consider questions of dumping or illegal subsidy. On December 19, 2001, the ITC ruled that imports had indeed seriously injured the industry and recommended that the President issue import quotas and raise selected tariffs between 10% and 40%, depending on the type of steel (Bush, 2002b).

On March 5, 2002, the U.S. Government took steps to slow the flow of foreign steel into the United States by temporarily raising tariffs on many finished steel products, including some forms of nickel-bearing stainless steel (Bush, 2002a, b). The higher tariffs were to remain in effect for 3 years. The tariff hikes were designed to give the U.S. steel industry an opportunity to restructure, merge synergistic business units, consolidate, and continue with its long-term modernization program. Steel industry executives, labor union leaders, and their political allies claimed that a surge of low-priced imports plus unfair trading practices by foreign countries were responsible for the latest round of U.S. steel company bankruptcies, job layoffs, and plant closures. In December 2001, domestic steel prices were at their lowest levels in 20 years (American Iron and Steel Institute, 2002c; Pearlstein, 2002; Pearlstein and Allen, 2002; Sanger, 2002; White House Office of the Press Secretary, 2002a, b).

Several major consumers of steel—manufacturers of automobiles, farm machinery, appliances, etc.—opposed the administration's action. Steel users complained that the resulting higher prices for foreign steel would put their U.S. operations at risk, weaken the competitiveness of these U.S. operations in the global marketplace, and jeopardize far more American jobs than just those at risk in the U.S. steel industry. The trade action also could force some American companies to move manufacturing operations that consume large quantities of steel to overseas locations (Pearlstein and Allen, 2002; Sanger, 2002; Stevenson, 2002).

The new tariffs included increased duties on stainless steel bar, wire rod, and wire (Kuck, 2002). Stainless steel sheet and strip, which account for most U.S. imports of stainless steel products, were not part of the investigation and were not covered by the Presidential order. The ITC also found that imports of semifinished stainless steel slabs had not injured U.S. slab producers. Other stainless steel products with negative findings were plate, pipe, wire cloth, and wire rope.

The temporary tariff changes took effect on March 20, 2002. The new tariff hikes were not uniform and were to be stepped back to zero during the 3-year period. The increases did not apply to steel produced in Canada or Mexico—U.S. partners in the North American Free Trade Agreement—and some developing countries. Semifinished carbon steel slabs would not be subjected to the higher tariffs unless their volume of imports exceeds the levels of 2000. In contrast, carbon and alloy steel plate, including coated sheet and tin-plate, initially would have tariffs of 30%.

Since 1998, 33 steel companies have filed for bankruptcy. To date, the steel producers most at risk have been the old-line integrated steelworks, such as Bethlehem Steel, Geneva Steel LLC, LTV Steel Corporation, and Wheeling-Pittsburgh Steel Corporation—companies that use blast furnaces to produce steel from iron ore and coke. Several electric furnace operations, which primarily use scrap as feed, also have been hurt by the recent surge in steel imports. For example, Laclede Steel Co., an electric arc steelmaker in Alton, IL, ceased operations in August 2001. The import relief program was designed to help American stainless steel producers as well as the carbon steel sector. The specialty steel industry, like the carbon steel sector, was struggling with problems of global production overcapacity, dumping, and excessive foreign government subsidization (Specialty Steel Industry of North America, 2000, 2002).

One of the principal problems has been the legacy costs of the integrated steel companies—primarily health and pension benefits for retired steelworkers. Health benefits for some 500,000 steelworkers could be affected if the new tariffs fail to limit imports. Health care benefits were a key issue because retirees could completely lose these benefits if the steel companies are forced into liquidation. Fortunately, the pension benefits of the steelworkers are insured (guaranteed) up to a certain point by the Pension Benefit Guarantee Corporation. In some steelmaking communities, like Weirton, WV, retirees outnumber active workers by as much as 10 to 1. Some supporters of the tariff hikes proposed that the money raised by the new tariffs be used to reduce these legacy costs.

World Review

The world's largest nickel producer was Norilsk Nickel, followed by Inco. Other major producers were BHP Billiton Dlc of the United Kingdom, 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 2001. More than 30 medium- to small-companies supplied the remaining 34%. The nickel industry has become highly competitive as a result of recent corporate alliances and new developments in extractive metallurgy.

In spring 2001, two giants of the mining industry—BHP Limited of Melbourne, Australia, and Billiton Plc of London, United Kingdom—agreed to merge (BHP Limited and Billiton Plc, 2001). The merger plan was announced on March 19, 2001, and was designed to create a global resources group with a diversity of mineral interests and ready access to major capital markets (Billiton Plc, 2001a, p. 1-44). On May 15, Billiton shareholders voted to form a dual listed company (Dlc). On May 18, BHP shareholders also voted in favor of the merger. The new company—BHP Billiton—had assets in excess of $35 billion and was to be based in Melbourne. The merger was the largest corporate transaction in the history of Australia (Ratner, Marsh, and Wyatt, 2001). BHP Billiton is now a leading producer of aluminum, coal, copper, iron ore, titanium minerals, and ferroalloys including ferronickel.

Billiton had been involved in exploration, mining, and metallurgy since its incorporation in 1860. The company became part of the Royal Dutch/Shell group in 1970 and was sold to Gencor Limited of South Africa in 1994. Billiton was spun off by Gencor in 1997. As a result of key acquisitions and mergers during the 1990s, Billiton had essentially 100% equity in the following two nickel producers: Cerro Matoso, SA of Colombia and QNI Pty. Limited of Australia. QNI operates the Yabulu refinery at Townsville, Queensland, and recently increased its interest in the Ravensthorpe laterite deposit in Western Australia. (More information is available under

"Australia" later in this section.) In June 2000, Billiton and Falconbridge formed a joint venture to further evaluate the Gag Island laterite deposits in Indonesia, but Falconbridge withdrew from the project at the end of 2001. (More information is available under "Indonesia" later in this section.)

In December 2000, Anglo American plc commissioned its mining and smelting complex in Venezuela at Loma de Niquel. The mining giant increased or retained its holdings in several other medium-sized nickel producers. At yearend 2001, Anglo American had interests in the following six 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%), Minera Loma de Niquel, C.A. of Venezuela (85.5%), and Tati Nickel Mining Company (Pty.) Ltd. of Botswana (43.35%). Anglo American also was involved in the Barro Alto project (Brazil) but has withdrawn from the Kabanga project (Tanzania). In September 2002, Anglo American sold its 43.35% equity in Tati to LionOre Mining International Ltd.

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 Congo (Kinshasa), France, Germany, Malaysia, Thailand, and the United States before these actions were taken. In April 2000, OMG bought the nickel refinery at Harjavalta, Finland, from Outokumpu Oyj (Juusela, 2000). (More information can be found under "Finland" later in this section.) OMG also formed a partnership with Weda Bay Minerals Inc. to evaluate the Halmahera laterite deposits in Indonesia. (More information can be found under "Indonesia" later in this section.)

Global competition among stainless steel producers has been intensifying since 1999. The increased competition and associated antidumping actions led to at least one key merger. On January 22, 2001, Avesta Sheffield AB and Outokumpu Steel Oyj merged their stainless steel manufacturing operations. The new consolidated company, AvestaPolarit Oyj Abp, became the world's second largest producer of stainless steel slabs. AvestaPolarit now has about 8,900 employees and had net sales of €3.5 billion (about $3.2 billion) in 2001. Key production plants are located in Finland, Sweden, the United Kingdom, and the United States. The company's meltshop facilities in the four countries have a combined stainless steel slab capacity of about 1.7 million metric tons per year (Mt/yr) (Outokumpu Oyj and Avesta Sheffield AB, 2000; Avesta Sheffield AB, 2001; Outokumpu Oyj, 2001).

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

Australia.—In 2001, Australia was the third largest nickel producing country in the world and was beginning to rival Canada. Most of the nickel properties under development are in Western Australia. By yearend 2003, nickel production capacity of Western Australia is projected to reach 200,000 t/yr. WMC Limited was still the largest nickel producer in the state, recovering 104,591 t of nickel in sulfide concentrate in calendar year 2001, down from 107,458 t in 2000 (WMC Limited, 2002b).

Australian Sulfide Operations.—WMC decreased production at two of its three operations in Western Australia because of weakening nickel prices. Only one operation—Mount Keith—produced more in 2001 than in 2000. The Leinster Mines showed the biggest drop, with output of concentrate decreasing to 38,008 t of contained nickel in 2001 from 40,724 t. Production at the Kambalda Mines decreased to 18,653 t from 19,202 t. Production at the huge Mount Keith Mine northwest of Leinster continued its upward trend, but at a slower rate, rising to a record high 47,930 t from 47,532 t (WMC Limited, 2002b). WMC's smelter at Kalgoorlie produced 96,000 t of nickel in matte, down from 103,000 t in 2000. In 2000, WMC acquired the Yakabindie deposit, 25 km south of Mount Keith. The Yakabindie deposit contains an estimated 287 Mt of resources averaging 0.56% Ni (WMC Limited, 2002a, p. 57).

On October 17, 2001, WMC announced that it was considering restructuring or selling the company. Discussions were held with Alcoa Inc. and several other potential buyers or investors (WMC Limited, 2001; Financial Times, 2001§). Alcoa was considering buying all of WMC in order to acquire WMC's 40% interest in Alcoa World Alumina and Chemicals (AWAC)—the world's largest alumina producer. The purchase of WMC would have raised Alcoa's equity in AWAC to 100% from 60%, giving Alcoa total control of the alumina joint venture. WMC made the announcement in response to a request from the Australian Stock Exchange. Exchange officials became concerned about excessive speculation in WMC stock after the value of an ordinary share rose 17% in 3 days of trading (Reuters Limited, 2001d; Marsh, 2001§). The restructuring discussions were at a preliminary stage and were not at a point requiring disclosure under the rules of the exchange. Some analysts believe that WMC as a whole is worth more than $5 billion (Regan, 2000; Jacques and others, 2001§).

In November, LionOre Australia (Nickel) Ltd. began producing nickel concentrate at its new Emily Ann Mine. The mine, located in the Lake Johnston greenstone belt of Western Australia, had been under construction since December 2000. The concentrator was commissioned on October 23, 2001, and was using conventional flotation technology to upgrade ore averaging 1.57% Ni. The Emily Ann operation was expected to produce 5,700 t of nickel in concentrate in 2002 and 6,700 t in 2003. The final concentrate has been assaying about 12.5% Ni. The concentrate was being stockpiled onsite and eventually will be shipped to Canada for smelting and refining at Inco's

Manitoba Division. LionOre Nickel also has a 31% interest in the Maggie Hays deposit about 3 km south of Emily Ann. In 2002, LionOre Nickel discovered additional nickel sulfide mineralization at its Waterloo deposit in the Northeastern Goldfields region (LionOre Mining International Ltd., 2002, p. 15-24). LionOre Australia Pty. Ltd. (a wholly owned subsidiary of LionOre Mining International Ltd.) holds an 80% share in LionOre Nickel.

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

Murrin Murrin.—Anaconda Nickel Ltd. began producing nickel metal briquets at its new Murrin Murrin refinery in May 1999. Briquets produced in the fourth quarter of 2000 reportedly averaged 99.93% Ni, 0.026% Co, and 0.002% Cu (Anaconda Nickel Ltd., 2001). The original development plan called for production to be gradually increased during 1999 to the full stage I design capacity of 45,000 t/yr of nickel and 3,000 t/yr of cobalt (Anaconda Nickel Ltd., 1999). Nickel production for 1999 was supposed to have been about 16,000 t, but startup problems resulted in an actual output of only 1,000 t. Key parts of the PAL plant had to be reengineered. The Murrin Murrin refinery produced about 4,100 t of nickel in the fourth quarter of 2000. The complex is now scheduled to reach the original target of 45,000 t/yr of nickel in the first half of 2002.

Anaconda had been preparing to launch stage II and expand the capacity of Murrin Murrin to 106,000 t/yr of nickel and 7,600 t/yr of cobalt. However, the company experienced financial difficulties and was forced to restructure and delay its expansion plans when the price of nickel weakened. Stage II was to have used a process developed in-house instead of the original Sherritt process (Anaconda Nickel Ltd., 2001). The expansion eventually could make Murrin Murrin the largest nickel mine in Australia, surpassing Mount Keith. According to Anaconda officials, the resources of the Murrin Murrin project (including the Abednego property) now total more than 355 Mt of ore grading 0.99% Ni and 0.07% Co (Anaconda Nickel Ltd., 2001).

Mount Margaret Project.—Anaconda continued to evaluate its Mount Margaret property 100 km northwest of Murrin Murrin. Total resources in the Mount Margaret region reportedly exceed 585 Mt and average 0.67% Ni. Drilling was underway to better delineate the resources at Mount Margaret, and a feasibility study was in progress.

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.

The Cawse complex is in the Eastern Goldfields region 60 km northwest of Kalgoorlie. The complex produced its first cobalt sulfide concentrate, assaying 40% Co, on December 25, 1998, and the first nickel cathode was made on January 20, 1999 (Western Australian Department of Resources Development, 1999). At the beginning of 2001, the Cawse complex was owned and operated by Centaur Mining and Exploration Limited. The A$350 million PAL plant reached design autoclave throughput capacity in May 2000. The leachate from the autoclaves was being fed into a solvent extraction circuit to separate the nickel from the cobalt. The nickel was then being recovered as a metal by electrowinning. The Cawse operation produced 5,484 t of nickel metal and 1,023 t of contained cobalt in fiscal year 1999-2000 (Centaur Mining and Exploration Ltd., 2000, p. 12-14).

On December 27, 2001, OMG announced that it had bought Cawse from Centaur. The price of the transaction was not disclosed. At the time of the sale, the operation had an annual production capacity of 8,000 t of nickel metal and 1,300 t of cobalt in sulfide. In November 1999, Anaconda and Centaur had proposed working together to expand the capacity of Cawse to more than 50,000 t/yr, but the expansion project never materialized because of financial problems at both companies. Administrators were appointed to manage Cawse in March 2001 after Centaur began to have difficulty servicing $225 million in high-yield U.S. bondholder debt (Reuters Limited, 2001b). OMG acquired Cawse as part of a strategic business plan to strengthen OMG's vertical integration in metal-based specialty chemicals (OM Group, Inc., 2001).

The transaction included the mineral rights as well as the chemical processing facilities. According to Centaur officials, Cawse Central, the immediate mining area, has 24.4 Mt of proven reserves averaging 1.0% Ni and 0.03% Co. There are also an additional 5.1 Mt of probable reserves reportedly averaging 0.9% Ni and 0.13% Co. The extended project area (Cawse Central, Cawse Extended JV, Siberia JV, Siberia Tank JV, and Heron Strategic Alliance) is estimated to contain 680 Mt of resources averaging 0.7% Ni and 0.04% Co (Centaur Mining and Exploration Ltd., 2000, p. 69-73).

On January 8, 2002, OMG announced that it was shutting down Cawse's nickel refinery and was laying off 60 of the operation's 160 employees. For the near term, Cawse would produce technical-grade nickel hydroxide paste—an intermediate product—instead of nickel metal. The 2001 volume of production would be maintained for the time being. The nickel hydroxide would be used as feedstock for OMG's Harjavalta and Kokkola refineries in Finland (Reuters Limited, 2002).

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

Ravensthorpe Project.—Ravensthorpe is the first of second generation PAL plants being considered for Australia. A definitive feasibility study was scheduled to begin in early 2002.

The Ravensthorpe processing plant was being designed to produce a high-grade feed for the Yabulu refinery at Townsville, Queensland. The Yabulu refinery is operated by QNI Pty. Ltd. (a subsidiary of BHP Billiton).

The Ravensthorpe property is in Western Australia about 150 km from the southern port of Esperance. Construction of the Halley's cut—the proposed initial pit on Bandalup Hill—had been scheduled to begin in early 2001 but was postponed while BHP Billiton reassessed the entire project. The first of three pits would have a projected life of 10 to 15 years. Like Marlborough, the ore would be beneficiated before being fed into an autoclave. The beneficiated ore would have a nickel content of 2.0%. In BHP Billiton's latest plan, the PAL plant would adjoin the ore beneficiation plant and produce an intermediate nickel and cobalt concentrate for Yabulu. QNI would expand the capacity of Yabulu to accommodate the new concentrates.

The Ravensthorpe project was originally controlled by Comet Resources Limited. In November 1999, QNI paid Comet $22 million for a 40% interest in the project. In September 2000, QNI acquired an additional 10% from a third joint-venture partner. On March 9, 2001, QNI agreed to purchase Comet's remaining interest in Ravensthorpe for $14.3 million plus the cancellation of its 19.9% interest in Comet. Comet's shareholders voted in favor of QNI's offer in July (Billiton Plc, 2001a, p. 161-162).

BHP Billiton plc also bought two exploration tenements near Ravensthorpe from Anaconda Nickel for A$600,000 (about US$500,000). The two tenements cover about 156 km^2 and adjoin the proposed mine site at Ravensthorpe (BHP Billiton Ltd. and BHP Billiton plc, 2001).

Processing of Intermediates and Refining.—QNI produced 28,960 t of nickel metal at its Yabulu refinery during fiscal year 2000-01, a record high for the recently upgraded refinery (Billiton Plc, 2001a). Laterite feed for the refinery was being supplied by PT Aneka Tambang (Persero) Tbk. in Indonesia, Hinatuan Mining Corporation in the Philippines, and four mining companies in New Caledonia.

Canada.—Key events of 2001 are summarized in the nickel chapter of the Canadian Minerals Yearbook (Bill McCutcheon, Natural Resources Canada, written commun. and unpub. data, 2002).

Labrador.—Inco Limited and its subsidiary Voisey's Bay Nickel Company Limited (VBNC) 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, 2001a). On January 11, 2000, Inco and the Provincial Government mutually agreed to suspend negotiations on the Voisey's Bay project. Despite the impasse, Inco was permitted to push ahead with its surface exploration program. Confidential negotiations were resumed on June 18, 2001, in an attempt to resolve several outstanding issues that stalled the huge mining project. The two negotiating teams began meeting on an almost weekly basis. In October, Inco and the Provincial Government agreed to extend negotiations on the development project until the end of 2001 (Inco Limited, 2001c; Matthews, 2001). At yearend, the two parties were close to reaching an agreement.

Development of the deposit 35 km southwest of Nain had been on hold since July 1998, when the Provincial Government broke off negotiations with Inco for the first time and refused to grant a mining lease to the company. Several key issues reportedly were resolved in November 1999 after Inco proposed using pressure acid leaching technology instead of flash smelting to process concentrates made from the pentlandite-chalcopyrite ores. Some of the issues still under discussion in 2001 included the following:

- the location of the proposed hydrometallurgical processing and refining complex,
- the shipment of concentrates outside the Province prior to commissioning the hydrometallurgical processing facility,
- mining and other applicable taxes,
- industrial and employment benefits,
- future research and development programs, and
- project timelines (Matthews, 2001).

A new issue also emerged during 2001. The terrorist attacks of September 11 and the global economic uncertainty created in the aftermath of those events intensified the project's financial risks.

On September 30, 2001, VBNC closed its exploration camp near the deposit (Inco Limited, 2001b). The initial Voisey's Bay exploration program had been completed. VBNC (a wholly owned subsidiary of Inco) took over the original program when Inco acquired Diamond Fields Resources Inc. in August 1996. Only a four-person security and maintenance team remained at the site. VBNC and Diamond Fields have spent C$100 million and C$60 million, respectively, on the Voisey's Bay exploration program. Since 1994, the two companies have drilled a total of 555 holes and collected 350 km of downhole data. According to Inco officials, the program has delineated 31 Mt of proven mineral reserves that are amenable to surface mining. The reserves average 2.88% Ni, 1.69% Cu, and 0.14% Co. In addition, there is 97 Mt of indicated resources averaging 1.29% Ni, 0.61% Cu, and 0.08% Co. Inco geologists estimate that the deposit also has 14 Mt of inferred resources averaging 0.98% Ni, 0.66% Cu, and 0.06% Co (Voisey's Bay Nickel Company Limited, 2002§).

South Voisey's Bay, Labrador.—On September 7, 2001, Falconbridge agreed to help a consortium of 12 companies explore a 625-km^2 package of claims in the South Voisey's Bay (SVB) area. The consortium was led by Donner Minerals Ltd. of Vancouver, British Columbia, an exploration company with interests ranging from 25% to 100% in the individual claim blocks. Falconbridge can earn 50% interest in the properties by spending $23 million exploring the claims during the next 5 years. The area is centered 90 km south of Inco's Voisey's Bay deposit and 75 km west of the Labrador Sea coast (Donner Minerals Ltd., 2001; Falconbridge Limited, 2001c, p. 5-6; Northern Miner, 2001a; Platts Metals Week, 2001b).

On September 27, Donner and Falconbridge signed agreements with the Innu Nation that defined terms under which the exploration would be carried out and addressed key Innu concerns about the program. The South Voisey's Bay agreements covered a variety of issues, including archeological studies, environmental monitoring, and the creation of business and employment opportunities for the Innu. Crews already had begun archeological work on the area. Disagreements with the Innu had forced Donner and Teck Cominco Ltd.—a major

shareholder in Donner and the project's lead contractor—to suspend SVB exploration activities in summer 1999.

Ontario.—The Sudbury region of Ontario, northwest of Lake Nipissing, has been the principal nickel-producing district in Canada since 1883. Inco operates a smelting complex at Copper Cliff on the western edge of Sudbury. Falconbridge has a somewhat smaller smelter near the town of Falconbridge. Concentrates for the two smelters come from a number of underground mines ringing the perimeter of the Sudbury Basin. Ore production at Falconbridge's four Sudbury mines totaled 1.95 Mt and was up 9% from 1.79 Mt in 2000 when a prolonged labor strike seriously affected production. The ore averaged 1.61% Ni and 1.35% Cu (Falconbridge Limited, 2002, p. 19-21).

In 2001, Falconbridge, Inco, and two major producers of PGM accelerated their exploration efforts in the Sudbury district. More than 10 copper-nickel deposits have been discovered along the margins of the Sudbury Basin since 1990. Two recent discoveries of copper-nickel sulfides on the southern perimeter of the basin—at Kelly Lake and Totten—contributed to the expansion of exploration activities.

Inco continued to evaluate its Kelly Lake discovery. Management was reviewing several other development projects in the Sudbury area and had not decided when the Kelly Lake deposit should be brought into production. The deposit is 2 km south of Copper Cliff and Highway 17 and reportedly is accessible from existing mine workings near Inco's Copper Cliff South Mine. Inco geologists also continued to evaluate a new area of mineralization in and around the Totten Mine, near Worthington on the Canadian Pacific Railway. The mineralization was discovered in late 1999. Subsequent drilling indicated that the Totten deposit has at least 8.4 Mt of resources averaging 1.42% Ni, 1.90% Cu, and 4.7 g/t PGM (Inco Limited, 2000a). Inco began the environmental permitting process in 2001 and was hoping to bring the Totten deposit into production by 2005.

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

Inco was developing previously unexploited ore bodies in and around several operating mines at Sudbury. The Creighton Deep project began producing ore for the first time. About $13 million was expended on the Creighton Deep project during 2001. In 2002, Inco was expecting to produce 2,300 t of nickel, 1,200 t of copper, and 2,200 troy ounces (68 kg) of PGM from ore mined at Creighton Deep. In 2000, Inco began developing a high-grade ore body at the McCreedy East Mine. The $33 million expansion at McCreedy East was scheduled to be completed by 2004. A low-grade zone also was being developed at the Stobie Mine (Inco Limited, 2002, p. 42).

In November 2001, Falconbridge announced that drill crews had intersected significant copper-nickel mineralization at a point 2.7 km north of the Sudbury airport. The mineralization occurs along the main contact between the Sudbury Igneous Complex and the underlying footwall rocks. The footwall rocks in the discovery hole are composed of brecciated granodiorite and the Sudbury breccias (Falconbridge Limited, 2001b).

Falconbridge's original drill hole (MAC-100) intersected a 0.1-meter (m)-thick mineralized zone at a depth of 1,443 m that assayed 1.89% Ni and 0.71% Cu. The same hole intersected a chalcopyrite vein in the footwall at a depth of 1,561 m that assayed 0.26% Ni and 20.30% Cu over 0.3 m. An adjoining inclined hole (MAC-100A) identified seven zones of significant copper-nickel mineralization at core depths between 1,440 and 1,663 m. Platinum values in six of the seven zones ranged from 1.2 to 20 g/t, while palladium values ranged from 0.42 to 26 g/t. The discovery site is about 2 km southeast of Falconbridge's Nickel Rim deposit. The Nickel Rim deposit reportedly contains 1.6 Mt of inferred resources averaging 1.6% Ni, 10.1% Cu, 4.2 g/t Pt, 3.5 g/t Pd, and 2.5 g/t Au (Falconbridge Limited, 2001b).

Early in 2000, geologists employed by Inco discovered several nickel-PGM deposits in and around the company's Copper Cliff North Mine. One of the nickel-PGM discoveries was made 400 m north of the Copper Cliff North Mine shaft and reportedly is an extension of an existing Copper Cliff ore body. Mining of the newly discovered deposit began in late 2000. The deposit has 300,000 t of proven reserves averaging 0.9% Ni, 4.5% Cu, and 16.4 g/t combined Pt-Pd-Au. Inco geologists also were evaluating a second nickel-PGM deposit—Pump Lake—2.5 km north of the North Mine shaft. The Pump Lake deposit is estimated to contain 3.5 Mt of resources averaging 1.4% Ni, 1.0% Cu, and 1.5 g/t combined Pt-Pd-Au (Inco Limited, 2001e).

Several companies were actively exploring for nickel in the Porcupine mining district of northern Ontario. On May 25, 2001, Falconbridge purchased the Montcalm copper-nickel deposit northwest of Timmins from Outokumpu Oyj. Falconbridge paid C$14 million for the Montcalm property, which is estimated to have 7.02 Mt of indicated resources grading 1.4% Ni and 0.71% Cu. Falconbridge also will pay Outokumpu a per-ton production royalty and was planning to spend C$9 million on an advanced exploration program. If the proposed feasibility study is positive and development is approved, the mine could produce up to 750,000 t/yr of ore. The ore would be milled and concentrated at Falconbridge's existing Kidd Metallurgical Division in Timmins. The concentrate would then be sent to Falconbridge's smelter at Sudbury for conversion to matte and eventual separation of the nickel from the copper (Falconbridge Limited and Outokumpu Group, 2001).

High PGM prices spurred exploration in the Thunder Bay region of southwestern Ontario. On January 16, 2002, NovaWest Resources Inc. of Vancouver, British Columbia, Canada, released preliminary results for its Nickel Royale property. NovaWest has assembled more than 2,400 hectares (or 6,000 acres) of claims in the Hemlo-Schreiber greenstone belt northeast of Thunder Bay. The belt is better known for its gold deposits. The NovaWest property is about 14 km west of the town of Schreiber. The mineralization at the Nickel Royale property is close to the surface, permitting sampling by trenching. Two separate areas of sulfide mineralization have been identified to date. Samples from the two mineralized areas have assayed from 0.14% to 6.2% Ni. NovaWest was planning

to follow up its trenching program with a geophysical evaluation and diamond drilling (NovaWest Resources Inc., 2002).

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

The Raglan mining and milling complex completed its third full year of operation. The new nickel-copper mine is in the Nunavik region of northern Quebec near Katinniq at the tip of the Ungava Peninsula. Falconbridge spent C$25 million in 2000 to increase milling capacity to 1 Mt/yr of ore from 800,000 t/yr. In 2001, Raglan recovered 961,000 t of ore averaging 2.98% Ni and 0.91% Cu. This equated to a mine production of 24,570 t of nickel in concentrate. The nickel concentrate also contained 6,915 t of copper and 318 t of cobalt (Falconbridge Limited, 2002, p. 19-21). Falconbridge was hoping to eventually raise production capacity to 30,000 t of nickel in concentrate. At yearend 2001, Raglan had 19.5 Mt of proven and probable reserves, averaging 2.87% Ni and 0.79% Cu. In addition to the reserves, Raglan had 3.07 Mt of indicated resources averaging 1.93% Ni and 0.70% Cu (Falconbridge Limited, 2002, p. 7).

Manitoba.—Inco's Manitoba Division produced about 49,000 t of electrolytic nickel, the highest tonnage since 1993 (Inco Limited, 2002, p. 8, 42). There were two principal mines—the Birchtree and Thompson. Work continued on the $48 million project to deepen the Birchtree. The deepening of the Birchtree will enable mine production to be increased by 90%. The project will allow crews to develop 13.6 Mt of proven ore reserves, extending the life of the Birchtree by 15 years (Inco Limited, 2002, p. 42).

Canmine Resources Corp. continued to evaluate 2,000 km^2 of claims northeast and west of the Thompson Belt. 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 in Nopiming Provincial Park from the Province of Manitoba. Canmine spent C$14.5 million to acquire and upgrade a cobalt-nickel refinery at Cobalt, Ontario. The refinery was built in 1995 at an estimated cost of C$30 million. Canmine began experiencing financial difficulties in 2001 and was forced to seek court protection from its creditors (Canmine Resources Corp., 2002).

Alberta.—Sherritt International Corporation continued to improve operations at its Fort Saskatchewan refinery. Finished nickel production was 29,225 t, up 4% from the 28,070 t of 2000—breaking the record of 28,643 t set in 1999 (Sherritt International Corporation, 2002, p. 22). The bulk of the feedstock—nickel-cobalt sulfide precipitate—came from Moa Nickel S.A., a mining and concentrating operation of Metals Enterprise in eastern Cuba. Metals Enterprise is a 50-50 joint venture between Sherritt and the Government of Cuba.

Nunavut.—Starfield Resources Inc. has identified a narrow horizon of platinum and palladium in a zone of nickel-copper-cobalt mineralization on the west side of Ferguson Lake. Ferguson Lake is 250 km west of Rankin Inlet on the northwest side of Hudson Bay. The area had been explored intermittently since 1950, first by Inco and then by Homestake Mining Company. Pyrrhotite, pyrite, and chalcopyrite occur as massive pods, lenses, stringers, and veinlets in hornblendite. The hornblendite, in turn, forms bands in a metamorphosed gabbroic sill of Precambrian age. Magnetite forms small blebs in the sulfide ore, but in most cases the nickel-bearing pentlandite cannot be seen with the naked eye (Schuster, 2001).

The principal mineralized unit has been traced east and west of Ferguson Lake over a strike length of 10 km. Starfield geologists are using barite and biotite as horizon markers to trace the nickel-copper-PGM mineralization. The mineralized unit has been subdivided into three zones—East 1, East 2, and West—to simplify resource evaluation. The West zone currently accounts for 92% of the tonnage. The entire Ferguson Lake project reportedly has 60.1 Mt of inferred resources grading 0.59% Ni, 0.93% Cu, 1.32 g/t Pd, and 0.19 g/t Pt based on a 1% combined Ni and Cu cutoff (Northern Miner, 2001b, c).

On December 28, 2001, Starfield announced that a broad spectrum assay of elements revealed the presence of elevated levels of rhodium at one point in the horizon. The company has begun reassaying a number of horizon samples for rhodium (Starfield Resources Inc., 2001).

Colombia.—On January 1, 2001, Billiton Plc commissioned a second ferronickel production line at its Cerro Matoso S.A. (CMSA) subsidiary in northwestern Colombia. The commissioning marked the turning point in a 5-year project to expand operations and reduce production bottlenecks at the mining and smelting complex near Montelibano. Billiton launched the expansion project in February 1999. Startup was achieved 3 months ahead of schedule, while costs were kept below the $353 million budgeted. Production on the second line was gradually increased during 2001 and the first half of 2002, until the design capacity of 27,000 t/yr of contained nickel finally was reached. When the rampup is completed, the two lines will have a combined production capacity of 55,000 t/yr of nickel in ferronickel (Billiton Plc, 2001b, c). The expanded plant reportedly has been designed so that intermediate products can be exchanged between the two lines if one of the kilns or furnaces should require repair or maintenance (Nacken, 2000).

In 2001, CMSA produced 38,447 t of nickel in ferronickel and exported 38,189 t, building up stocks in the process. Only 2,007 t, or 5% of CMSA's total exports, went to the United States. About 71% of the ferronickel exports went to Europe (International Nickel Study Group, 2002b, p. 30).

Cuba.—Metals Enterprise, the joint venture of the Cuban Government and Sherritt, produced 32,360 t of nickel-plus-cobalt in mixed sulfides at Moa in 2001—10% higher than the previous record of 29,520 t set in 2000. The material provided about 90% of the feed for the venture's Fort Saskatchewan refinery in Alberta, Canada (Sherritt International Corporation, 2002, p. 11). Mixed sulfide production at Moa has increased more than 200% since 1994, the year when the joint venture was formed.

Finland.—In 2001, the OMG nickel plant produced 54,573 t of refined nickel. The bulk of the nickel was recovered from matte produced at the Harjavalta smelter. The Harjavalta matte was supplemented with matte imported from Australia (10,773 t gross weight) and Brazil (19,853 t gross weight) (International Nickel Study Group, 2002b, p. 31). The nickel was leached

from the matte and separated from the other transition metals by solvent extraction. Most of the nickel was recovered as cathode by electrowinning. Some of the nickel, however, was reduced with hydrogen and made into briquets. After acquiring the Harjavalta refinery in 2000, OMG began shifting the plant's production to higher value-added products, including battery chemicals, other specialty nickel salts, and nickel powders. OMG began producing metal powders in July 2001 and, in 2002, was considering spending $25 million on equipment to produce nickel salts. In 2002, briquets and cathode still made up 80% of the production at the Harjavalta facility (OM Group, Inc., 2002, p. 8-13).

Guatemala.—In January 1998, Chesbar Resources Inc. of Toronto, Ontario, Canada, purchased a 25% interest in a Guatemalan exploration company, Minera Mayamerica S.A. The remaining 75% was retained by the original owner, Intrepid Minerals Corporation. The joint venture focused its efforts on the Buena Vista laterite deposits in the eastern provinces of Alta Verapaz and Izabal. The Government of Guatemala issued the necessary exploration licenses directly to Mayamerica under the new Mining Act of 1997. Between May 1999 and December 2000, Chesbar spent $525,000 evaluating the nickel-cobalt laterites and, in doing so, increased its equity in Mayamerica to 70%. Chesbar acquired the remaining 30% from Intrepid in 2002. Metallurgical testing to date indicates that nickel and cobalt could be economically recovered from the laterite by pressure acid leaching.

The deposit occurs within an east-west trending belt of peridotites and other ultramafic intrusives. A similar deposit in the same belt was developed by Inco in the 1970s and produced nickel for a short period of time. The Inco Eximbal operation relied principally on fuel oil for energy and was forced to close in 1980 when world oil prices rose sharply. Mayamerica has concentrated on two properties—Marichaj and Sechol. Work to date has consisted principally of digging test pits and assaying samples systematically collected from the pits. A previous property owner, Transmetales Limitada, estimated that the Sechol property has 33.7 Mt of resources averaging 1.81% Ni. In the early 1990s, Cominco Limited evaluated the Sechol property and considered using it as a source of direct shipping ore for its Glenbrook nickel smelter at Riddle, OR. Cominco substantiated Transmetales work and estimated that one high-grade area contains 9.96 Mt of resources averaging 2.18% Ni. Transmetales calculated that the Marichaj property contains 34.8 Mt of resources grading 1.47% Ni. Dynatec Corporation has been evaluating the metallurgical characteristics of lateritic and saprolitic samples from the Sechol property. The work was being carried out at Dynatec's research facility in Fort Saskatchewan, Alberta (Chesbar Resources Inc., 2000; 2002a, b).

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 2001 for all of Indonesia was 102,000 t of contained nickel. All 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 nickel in matte. The company added a fourth electric furnace smelting line and upgraded the existing three lines. The upgraded operation produced 62,600 t of nickel in matte in 2001, the highest annual production ever. At the end of 2001, PT Inco had 97 Mt of proven and probable reserves in the Soroako area averaging 1.70% Ni. The company has an additional 70 Mt of indicated resources averaging 1.78% Ni and 267 Mt of inferred resources averaging 1.80% Ni (Inco Limited, 2002, p. 20-21).

In July 1999, AnTam announced that it would begin building a third line at its ferronickel smelter at Pomalaa. The third line would raise the capacity of the smelter to 24,000 t/yr of nickel in ferronickel from 11,000 t/yr. Money for the expansion was to have come from funds raised in the company's initial public offering of November 1997. The subsequent devaluation of the Rupiah has forced AnTam to seek additional funds, delaying the expansion. IKB Deutsche Industriebank AG and Bank Mandiri were spearheading the loan efforts. If the financing can be arranged, then the third line could be operational by 2005 (PT Aneka Tambang (Persero) Tbk., 1999; 2002, p. 16-17).

Gag Island.—On July 12, 2000, Falconbridge Limited and BHP Limited (now BHP Billiton) announced that they had tentatively formed a joint venture to further evaluate nickel laterite deposits on Gag Island (BHP Limited, 2000; Falconbridge Limited, 2000). Several environmental matters related to the management of the island's forests, however, could not be resolved with the Government of Indonesia. On December 31, 2001, Falconbridge withdrew from the project because of the forestry issue (Falconbridge Limited, 2002, p. 28). AnTam had a 25% interest in the venture prior to Falconbridge's withdrawal and remained committed to the project. BHP and AnTam had been working together on the Gag Island project since August 1996. According to AnTam officials, the deposit has 240 Mt (wet) of resources grading 1.35% Ni. Gag Island is about 40 km southeast of Gebe Island, Maluku, where AnTam has one of its three principal nickel mines.

Halmahera Island.—In summer 2001, AnTam opened a fourth mine—Tanjung Buli, North Maluku. Tanjung Buli is on Halmahera Island at a location northeast of the Gee Mine (another AnTam nickel operation). On August 25, the inaugural shipment of high-grade ore from Tanjung Buli was sent to Pacific Metals Co. Ltd. in Japan. AnTam also was planning to eventually ship ore from Tanjung Buli to the company's ferronickel smelter at Pomalaa (PT Aneka Tambang (Persero) Tbk, 2002, p. 9, 13).

Weda Bay Minerals Inc. of Vancouver, British Columbia, Canada, and AnTam have been jointly evaluating laterite deposits on Halmahera Island since May 1996. At least 11 areas between Cape Ulie and the Jira River were under investigation. The project is held under a contract of work between the Government of Indonesia and PT Weda Bay Nickel [a joint venture of Weda Bay Minerals (90%) and AnTam (10%)] (Weda Bay Minerals Inc., 2000a, b; PT Aneka Tambang (Persero) Tbk., 2002, p. 64-65).

New Caledonia.—Société Métallurgique le Nickel (SLN) accounted for 47% of New Caledonian mine production in 2001. The other 53% of mine production was divided among J.C.

Berton Mines, Nickel Mining Corp., Société des Mines de la Tontouta (SMT), Société Minière du Sud Pacifique S.A. (SMSP), and several other independent mining companies. Mine production totaled 117,554 t on a contained nickel basis, down 8% from 127,493 t (revised) in 2000. In 2001, the French overseas territory exported 46,431 t of nickel in ore, which included 25,206 t of nickel in limonitic laterites shipped to Australia, 19,718 t in garnierite shipped to Japan, and 1,506 t in unspecified material to Ukraine. The remaining 71,123 t of nickel in ore was processed at the SLN smelter outside Doniambo (International Nickel Study Group, 2002b, p. 52-53).

SLN's Mining and Smelting Operations.—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. All five mines are on La Grande Terre, the main island of New Caledonia. SLN's ore production was 3% less than that of 2000. SLN and its subcontractors mined 3.58 Mt of wet lateritic ore, down from 3.71 Mt (revised). Garnierite ore accounted for 3.30 Mt or 92% of total production. The remaining 281,000 t was limonitic laterite. Eramet's management was evaluating a proposal to expand the capacity of the new Tiébaghi Mine in the Northern Province to 1 Mt/yr of ore from 250,000 t/yr. In October 2000, preparatory work was begun to resume mining laterites at Bonini in the Poro region on the east coast of La Grande Terre. The Bonini mine site was abandoned in the early 1980s. The reopened mine, which is now referred to as the Poro Mine, began shipping ore in 2001 to Australia (Eramet Group, 2002, p. 32-37).

In 2001, the Doniambo smelter produced 45,912 t of nickel in ferronickel and 13,061 t of nickel in matte. The combined output of 58,973 t was an alltime high for Doniambo, edging out the previous record of 57,463 t (revised) set in 2000. The refining capacity of the plant was 49,000 t/yr, while matte capacity was about 14,000 t/yr of contained nickel. SLN was planning to increase the capacity of Doniambo to 75,000 t/yr sometime in 2004 or 2005 (Eramet Group, 2002, p. 32-37). Expansion of the smelter and improvement of operations at Tiébaghi were expected to cost €200 million—about $180 million (Reuters Limited, 2001a). Part of the funds would be used to construct a beneficiation plant at Tiébaghi.

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

Inco's Goro Project.—On April 25, 2001, Inco announced that it had decided to construct a $1.4 billion nickel-cobalt mining and processing complex at Goro (Inco Limited, 2001d). The decision was made after 17 months of onsite pilot-plant work and more than 9 years of feasibility studies. Construction began in early 2002, with commissioning scheduled for late 2004. The fully integrated facility would have a production capacity of 54,000 t/yr of nickel in oxide and 5,400 t/yr of cobalt in carbonate. The nickel oxide would contain about 78% Ni and be shipped primarily to stainless steel meltshops in the Republic of Korea, Taiwan, and possibly China.

Inco will use proprietary PAL and solvent extraction technologies to recover the nickel and cobalt from limonitic laterites. Inco developed the extraction technologies in-house specifically for the Goro ores. The underlying saprolitic ores would be phased in, beginning in 2010. The deposits are at the southern tip of La Grande Terre—near the mouth of the Yaté River and the Plain of Lakes. The main deposit has more than 200 Mt of lateritic resources averaging 1.57% Ni and 0.18% Co (Inco Limited, 2000b, p. 22-23). Inco was planning to mill about 4 Mt/yr of ore. The mill tailings would be impounded onshore near the Plain of Lakes, avoiding a number of environmental problems associated with ocean disposal. A port facility would be built on the Baie de Prony to receive sulfur, limestone, bunker oil, diesel fuel, and other imported necessities.

Inco was still negotiating key arrangements with regulatory authorities and prospective financial backers. The French Government was considering providing partial financial support as part of a program designed to stimulate investment in French overseas territories. New Caledonian authorities have agreed to grant Inco a 15-year 100% tax exemption followed by a 5-year 50% tax exemption. The Congress of New Caledonia was reviewing draft legislation authorizing the tax agreement. The mining and processing complex would have about 800 employees and indirectly generate jobs for an additional 1,500 individuals. About 90% of the jobs would be filled by New Caledonians (Mining Journal, 2001a). A joint venture of Bechtel Overseas Corporation and Technip France S.A. would act as prime contractor during construction.

Inco has had mining interests in New Caledonia since the creation of its predecessor, International Nickel Company in 1902. In 1991, Inco formed a joint venture with France's Bureau de Recherches Géologiques et Minières (BRGM) to evaluate the potential of lateritic nickel resources controlled on La Grande Terre by the two companies (Mining Journal, 1991). Shortly afterward, Inco purchased the BRGM subsidiary Société de Promotion des Mines (Sopramines), which held mining titles to several deposits at the south end of the island. Inco currently has an 85% interest in Goro Nickel S.A., while BRGM has the remaining 15%. Inco reportedly has had discussions with several companies interested in acquiring a minority interest in the $1.4 billion project (Platts Metals Week, 2001a). If a suitable partner can be found, the complex could be operational by the end of 2004. Eramet Group acknowledged that it had been contacted by Inco and had been evaluating Inco's proposal. The Government of France, a stockholder in Eramet, had already committed $350 million to the project.

Nakéty PAL Project.—Argosy Minerals Inc. and SMT were considering building a PAL plant at Nakéty on the east-central coast of La Grand Terre. SMT, an independent New Caledonian mining company, has been operating on the island for more than a decade. Ore for the PAL plant would come from the following four SMT concessions: Barbouille, Belle Asashi 2, Lucienne 2, and Lucienne 2H. Argosy, an Australian-Canadian exploration and development company, was headquartered in Vancouver, British Columbia, Canada.

In August 1999, Argosy formed a joint venture with SMT to evaluate the Nakéty concessions. More than 675 holes have been drilled within the Nakéty deposit to date. Dynatec Engineering Corp. has performed extensive metallurgical tests on the Nakéty ores, and Kvaerner Metals ASA has completed a preliminary engineering study of the deposit. According to Resources Service Group (an Argosy contractor), the Nakéty deposit has measured, indicated, and inferred resources in excess

of 48 Mt (dry) that are estimated to average 1.42% Ni and 0.12% Co. Measured and indicated resources consist of 21.0 Mt (dry) of limonitic ore averaging 1.33% Ni and 0.14% Co and an additional 13.5 Mt (dry) of underlying, magnesium-rich saprolitic ore averaging 1.83% Ni and 0.06% Co. SMT is currently mining the saprolite zone on a small scale for export. The limonitic ore reportedly is better suited than the saprolite for pressure acid leaching (Argosy Minerals Inc., 2000a, 2001b).

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

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

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

Philippines.—Three companies mined laterite ore in 2001—Hinatuan Mining Corporation, Rio Tuba Nickel Mining Corporation, and Taganito Mining Corporation. Combined production amounted to 27,359 t of contained nickel, 57% more than in 2000. None of the ore was smelted in the Philippines. About 50% of the material was exported to Japan; another 25% went to Australia. The remaining 25% was stockpiled in anticipation of the construction of a proposed PAL operation (International Nickel Study Group, 2002a; c, p. 46).

Russia.—The Russian Federation produced more than 252,000 t of nickel in refined products. Norilsk Nickel was by far the largest producer in Russia, accounting for at least 218,000 t of nickel in metal or limited amounts of ferronickel as well as 391,000 t of copper metal and 4,650 t of cobalt. Norilsk Nickel produced 30% more nickel in 2001 than in 1996, when the company had a reported output of 177,185 t (Platt's Metals Week, 1998). A 1997 amendment to the Federation's Law on State Secrets prohibits Norilsk Nickel from divulging detailed production figures for its different subsidiaries. In September 2002, Federation authorities gave Norilsk Nickel permission to release the following summary production figures for nickel: 1996—171,000 t; 1997—210,000 t; 1998—207,000 t; 1999—209,000 t; 2000—217,000 t; and 2001—223,000 t (Prokhorov, 2002).

Norilsk Nickel Mining and Metallurgical Company.—In 2001, Norilsk Nickel Mining and Metallurgical Company (formerly RAO Norilsk Nickel) was the largest producer of nickel in the world, accounting for about 19% of world refinery production (RAO Norilsk Nickel, 2000a, b). The company was restructured in 2000 and 2001. Despite the restructuring, Norilsk Nickel continued to subsidize housing, the importation of food, and municipal services in the cities of Norilsk, Monchegorsk, and Zapolyarny.

In 1998, RAO Norilsk Nickel launched a 10-year development program aimed at modernizing operations on both the Kola Peninsula and the Taimyr Peninsula. The program required raising $3 billion to $5 billion from foreign investors. The initial $200 million was being used to expand Norilsk Nickel's product line, improve sales to Russian consumers, create an overseas sales network, and improve the company's transport infrastructure. The 10-year development program would allow Norilsk Mining Company and Kola Metallurgical and Mining Company to develop new levels in existing underground mines, construct new mines, and carry out local exploration work designed to transform inferred resources into measured reserves. If the plans are fully implemented, then the Kola Combine would remain open past 2007 and possibly continue to operate until 2015 (RAO Norilsk Nickel, 2000b).

Norilsk Nickel intensified its mine development work on the Taimyr Peninsula of north-central Siberia. A major program was underway to replace declining reserves, even though some 50 years of reserves still exist. The bulk of the Taimyr ores comes from the Oktyabr and the Talnakh deposits. The two deposits reportedly contain more than 35% of the world's nickel reserves (RAO Norilsk Nickel, 2000a). Production from the new Skalisty Mine helped to 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.

On September 3, 2001, Outokumpu Oyj and Norilsk Nickel signed two letters of intent aimed at increasing Outokumpu's existing technological and engineering support role on the Taimyr Peninsula (Mining Journal, 2001b; Sintonen, 2001). Norilsk Nickel operates seven nickel-copper mines, two concentrators, and three metallurgical complexes in the south-central part of the Peninsula (Bond and Levine, 2001). The feasibility of an eighth mining project was being studied.

In the first document, Outokumpu agreed to construct a new

concentrator at the city of Norilsk. The new concentrator would be capable of processing 10 Mt/yr of nickel-copper sulfide ore. Outokumpu Mintec Oy, a Finnish subsidiary of Outokumpu's Metallurgy business group, would be responsible for constructing and commissioning the turnkey facility. Outokumpu Mintec also would be responsible for delivering all necessary equipment and building materials to the remote site. The new concentrator was scheduled to come onstream in late 2004 and would cost Norilsk Nickel about $150 million.

In the second document, Outokumpu agreed to help Norilsk Nickel expand its existing concentrator at Talnakh. The expanded facility would be capable of converting 15 Mt/yr of nickel-copper ores into concentrates. The current capacity of the concentrator is about 7 Mt/yr. Again, Outokumpu Mintec would be responsible for installation and commissioning of the new equipment. The expansion would be housed in the existing concentrator buildings. The expanded facility could be onstream as early as 2003 and was expected to cost between $80 million and $100 million.

The final commercial agreements were expected to be signed in mid-2002. Outokumpu has been supplying technological and engineering support to Norilsk Nickel for about 25 years. In February 2001, the two companies signed a cooperation agreement reaffirming their relationship. Outokumpu has begun modernizing both lines of the Nadezhda smelter in Norilsk. The modernization will cost €64 million (about $59 million) (Sintonen, 2001).

On June 15, 2001, RAO Norilsk Nickel launched a major securities program in the United States designed to raise capital for the group's mining and metallurgical operations in Russia (Reuters Limited, 2001c). The mining group began issuing 50 million level-1 American depository receipts (ADRs). ADRs are negotiable U.S. securities that represent a non-U.S. company's publicly traded equity. The Bank of New York was serving as the depository. Each ADR was equivalent to one ordinary nominal (i.e., common) share in Norilsk Nickel. The entire issue equated to slightly more than 20% of the group's charter capital (RAO Norilsk Nickel, 2001a-d).

Norilsk Nickel is one of the first companies in Russia authorized under new parliamentary legislation to raise capital in this manner. The Russian Federal Securities Commission approved the issuance of the ADRs on June 6, 2001. This was also the first time that Norilsk Nickel shares had been permitted to trade outside of Russia. Norilsk Nickel began filing documents about the ADR offering with the U.S. Securities and Exchange Commission in 1997. In 2001, the ADRs were not listed on any stock exchange in the United States but were being traded as over-the-counter (OTC) equity securities. The trading symbol is NLKNY (CUSIP: 65602P109).

The group's board of directors asked all shareholders to exchange their shares in RAO Norilsk Nickel, the existing holding company at the time, for shares in a new entity, Norilsk Nickel Mining and Metallurgical Company. The new company later was made the main operating arm of the group as part of a major corporate restructuring. The share exchange and shifting of Norilsk Nickel's main Russian listing were designed to increase liquidity of the stock and improve accounting transparency. The management of Norilsk was hoping that these actions would raise share price in the foreign investment market. Management also believed that the restructuring would make the group more tax efficient, as well as, more transparent and attractive to investors. The issuance of the ADRs was designed to reassure foreign investors, who were able to trade their securities without interruption during the exchange period (Cottrell, 2001; Smith, 2001). The Bank of New York was responsible for exchanging the securities held in the depository. The ADRs were to remain in circulation after the completion of the company's restructuring.

The exchange of Norilsk Nickel shares for shares in Norilsk Nickel Mining and Metallurgical Company began on March 23, 2001. At that time, shareholders living in the Norilsk industrial region, on the Kola Peninsula, and in other places where the group's works are located, were asked to submit their stock certificates. Some 41,000 shareholders complied with the request. By June 15, more than 10 million shares had been exchanged, representing about 5% of the company's charter capital. A second exchange round began nationwide on June 21 and ended on August 21. Norilsk Nickel was hoping to raise $3 billion to $5 billion from foreign investors to help pay for the group's 10-year development program. The money would be used to reequip production facilities, develop and implement more effective extraction techniques, and adopt state-of-the-art technology.

Enterprises in the Ural Mountains.—The board of directors of RAO Yuzhural Nickel was 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 was already the largest shareholder in Yuzhural Nickel. Orenburg Copper-Nickel Co., which has a 20% interest in the nickel producer, opposed the asset-debt swap. Orenburg is a parastatal controlled by the Orenburg regional administration (Interfax International Ltd., 2000).

Venezuela.—The new Loma de Niquel mining and smelting complex produced its first ferronickel in December 2000. The greenfield operation is about 80 km southwest of Caracas. The complex was designed to produce 17,500 t of nickel in ferronickel but made only 10,600 t in 2001. Full capacity should be reached by yearend 2002 (Minera Loma de Niquel, C.A., 2000).

Outlook

Employment data and other business indicators for 2002 suggest that the decline in U.S. economic activity, which began in March 2001, may be coming to an end (Hall and others, 2001, 2002). Weak economic conditions, however, are expected to persist throughout a large segment of the U.S. steel industry.

There is little chance that ferronickel production in the United States can be revived in the near term. The use of PAL technology to recover nickel from lateritic ores in New Caledonia, the Philippines, and Western Australia is expected to keep nickel prices in check for at least a decade. The combined rate of refined nickel production for the three existing Australian PAL operations passed the 9,000 t/yr mark at the beginning of 2001 and was expected to keep growing for at least another 3 years, eventually surpassing 100,000 t/yr. Plans to develop additional lateritic nickel deposits in the Kalgoorlie region of

Western Australia have accelerated since the completion of the Goldfields natural gas pipeline in 1996 (Griffiths, 2000). The availability of inexpensive natural gas from offshore fields on the North West Shelf of the Indian Ocean has made it economically possible to produce refined nickel at several other laterite deposits previously rejected because of their remote locations. At least part of the new ferronickel production from Cerro Matoso (Colombia) and Loma de Níquel (Venezuela) has begun to come to the United States. The proposed Goro and Koniambo projects in New Caledonia would put additional material into the U.S. supply line.

The immense resources of the Voisey's Bay nickel-copper-cobalt deposit in northeastern Labrador (Canada) continue to overshadow the market. In June 2002, Inco and the Provincial Government of Newfoundland reached an agreement on developing the subarctic deposit. Depending on market conditions, the proposed Voisey's Bay mining and milling complex would be capable of producing from 60,000 to 123,000 t/yr of nickel in sulfide concentrates. In Ontario (Canada), Falconbridge and Inco continue to find new ore along the edges of the Sudbury Basin. In Manitoba and Quebec (Canada), exploration crews have identified several promising occurrences for future followup.

The long-term outlook for increased nickel consumption is extremely positive, despite the terrorist attacks of September 11 and the recent economic crises in East Asia. Several forces are helping to sustain long-term growth in nickel consumption. The population of the world continues to grow. Faster transport, the explosive expansion of telecommunications systems, and the globalization of markets are making society as a whole increasingly dependent on products fabricated from sophisticated starting materials, many of which contain significant quantities of nickel. A technologically advancing society is continually demanding new materials with improved resistance to corrosion and heat, again favoring nickel.

Demand for austenitic stainless steel will continue to drive the world nickel market for at least another 20 years. For the present, growing demand for stainless steel in China, Europe, and the Western Hemisphere has offset weak demand in Japan. Beginning in 2003, world stainless steel consumption is forecast to grow between 2% and 5% per year until 2008. After 2008, 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 long-term growth in steel imports. Stainless steel production in the United States could exceed 2.6 Mt in 2003—an alltime high for the country. The austenitic share of the production is expected to remain unchanged at 59%. This percentage is lower than corresponding austenitic percentages reported by other member countries of the Organisation for Economic Cooperation and Development because the U.S. automobile manufacturing industry consumes more than 500,000 t/yr of ferritic stainless, about 18% of total U.S. stainless consumption.

Demand for nickel-bearing superalloys is expected to grow. The aerospace industry has been gradually shifting from a defense-oriented market to one that is more evenly balanced between commercial and Government purchases. Advanced nickel and titanium alloys are increasingly being incorporated in aircraft. The engines of new aircraft like the B-20XX are expected to be fabricated from advanced nickel-base superalloys.

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 NiMH cells in their third-generation EVs or second-generation hybrid vehicles. Automobile manufacturers are considering replacing the current 12-volt electrical systems in vehicles with 42-volt systems. If adopted, the change could drastically change the types of metals used in batteries for conventional automobiles. A NiMH battery has a higher energy density and longer cycle life than its advanced lead-acid counterpart. Performance and environmental requirements favor the NiMH battery, but problems starting the automobile at low temperatures need to be resolved (Jouhanneaud, 2001). Fuel-cell-powered vehicles are being developed, but are not expected to be in commercial production for at least 15 years.

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TABLE 1
SALIENT NICKEL STATISTICS 1/

(Metric tons of contained nickel, unless otherwise specified)

	1997	1998	1999	2000	2001
United States:					
Mine production	--	--	--	--	--
Plant production	16,000	4,290	--	--	--
Secondary recovery from purchased scrap:					
From ferrous scrap	58,200	52,700	58,600	71,800 r/	89,700
From nonferrous scrap	10,200	10,400	12,400	12,200	11,300
Shipments of purchased scrap 2/	97,600	89,700	93,000	123,000	141,000
Exports:					
Primary	16,400	8,440	7,440	8,150	8,450
Secondary	40,200	35,100	31,400	49,900	48,600
Imports for consumption:					
Ore	17,600	1,420	--	--	--
Primary	147,000	148,000	139,000	156,000	136,000
Secondary	11,000	8,500	9,480	10,700	8,760
Consumption:					
Reported:					
Primary	120,000	116,000	116,000	115,000	98,800
Secondary (purchased scrap) 3/	68,400	63,100	71,000	84,000	101,000
Total	188,000	179,000	187,000	199,000	200,000
Apparent:					
Primary	154,000	149,000	140,000	147,000	129,000
Secondary (purchased scrap) 4/	37,700	36,900	49,400	42,000	59,300
Total	192,000	186,000	190,000	189,000	188,000
Apparent primary plus reported secondary	222,000	212,000	211,000	231,000	230,000
Stocks, yearend:					
Government	8,530	2,600	--	--	--
Producers and traders	12,600	13,100	12,700	12,300	12,600
Consumer, primary	10,300 r/	10,500	4,980 r/	6,400 r/	4,180
Consumer, secondary	5,770	5,460	5,070	7,860	9,720
Total yearend stocks	37,300	31,600 r/	22,800 r/	26,600	26,500
Employment, yearend:					
Mine	7	7	5 r/	1	--
Smelter	264	6	6	(5/)	--
Port facility	22	1	1	--	--
Price, cash, London Metal Exchange:					
Per metric ton, average annual	$6,927	$4,630	$6,011	$8,638	$5,945
Per pound, average annual	$3.142	$2.100	$2.727	$3.918	$2.696
World, mine production	1,140,000 r/	1,180,000 r/	1,160,000 r/	1,290,000 r/	1,330,000 e/

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

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

2/ Defined as scrap receipts less shipments by consumers plus exports minus imports plus adjustments for consumer stock changes.

3/ More nearly represents amount consumed than does apparent secondary consumption.

4/ Internal evaluation indicates that apparent secondary consumption is considerably understated.

5/ The smelter at Riddle, OR, was decommissioned in 2000.

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

(Metric tons of contained nickel)

	2000	2001
Kind of scrap:		
Aluminum-base 2/	4,290	3,620
Copper-base	3,310	2,480
Ferrous-base 3/	71,800 r/	89,700
Nickel-base	4,620	5,200
Total	84,000	101,000
Form of recovery:		
Aluminum-base alloys	4,290	3,620
Copper-base alloys	5,300	4,130
Ferrous alloys	71,800	89,700
Nickel-base alloys	2,610	3,550
Miscellaneous and unspecified	1	--
Total	84,000	101,000

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	2000	2001
Primary:		
Metal	94,500 r/	84,000
Ferronickel	13,500	10,500
Oxide and oxide sinter 2/	3,610	1,830
Chemicals	1,340	1,150
Other	1,590	1,370
Total	115,000	98,800
Secondary (scrap) 3/	84,000	101,000
Grand total	199,000	200,000

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 2001, 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 2001	Grand total 2000
Cast irons	109	W	--	--	52	161	731	892	198 r/
Chemicals and chemical uses	961	--	W	672	--	1,630	--	1,630	991
Electric, magnet, expansion alloys	273	--	--	--	--	273	W	273	479
Electroplating (sales to platers)	12,400	--	--	33	W	12,500	--	12,500	15,700
Nickel-copper and copper-nickel alloys	3,210	W	W	--	33	3,240	3,640	6,880	9,940 r/
Other nickel and nickel alloys	14,800	--	W	--	86	14,800	3,370	18,200	18,200
Steel:									
Stainless and heat resistant	21,300	10,400	1,710	W	372	33,700	87,500	121,000	108,000
Alloys (excludes stainless)	5,980	64	--	--	131	6,180	1,440	7,620	7,700
Superalloys	17,600	--	W	W	595	18,200	184	18,400	19,400
Other 2/	7,460	8	124	447	103	8,140	4,110	12,300	17,800
Total	84,000	10,500	1,830	1,150	1,370	98,800	101,000	200,000	199,000
Total all companies, apparent	XX	XX	XX	XX	XX	129,000	59,300	188,000	189,000

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

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

(Metric tons of contained nickel)

Form	2000	2001
Primary:		
Metal	4,650 r/	3,000
Ferronickel	768	543
Oxide and oxide sinter	610	268
Chemicals	194 r/	139
Other	179 r/	229
Total	6,400 r/	4,180
Secondary (scrap)	7,860	9,720
Grand total	14,300	13,900

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	2000 Quantity	2000 Value (thousands)	2001 Quantity	2001 Value (thousands)
Unwrought primary:				
Cathodes, pellets, briquets, shot	1,690	$15,100	1,400	$10,000
Ferronickel	37	202	50	478
Powder and flakes	1,260	18,700	1,380	25,100
Metallurgical-grade oxide	1,930	6,350	1,940	8,370
Chemicals:				
Catalysts	1,880	70,100	2,560	77,900
Salts 3/	1,350	13,800	1,120	11,700
Total	8,150	124,000	8,450	134,000
Unwrought secondary:				
Stainless steel scrap	35,100	310,000	32,900	270,000
Waste and scrap	14,800	60,900	15,700	55,400
Total	49,900	371,000	48,600	325,000
Grand total	58,100	495,000	57,000	459,000
Wrought:				
Bars, rods, profiles, wire	520	9,200	447	7,110
Sheets, strip, foil	741	13,000	1,160	16,900
Tubes and pipes	147	1,550	802	3,480
Total	1,410	23,700	2,400	27,500
Alloyed (gross weight):				
Unwrought alloyed ingot	9,850	91,400	13,400	148,000
Bars, rods, profiles, wire	7,270	120,000	9,550	161,000
Sheets, strip, foil	7,930	112,000	7,180	108,000
Tubes and pipes	1,010	23,900	1,900	32,200
Other alloyed articles	2,670	86,500	3,970	88,200
Total	28,700	433,000	36,000	538,000

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 Export Commodity Code 2836.99.9050).

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

TABLE 7
U.S. EXPORTS OF NICKEL PRODUCTS IN 2001, 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 2001	Total 2000	Wrought nickel 4/
Australia	--	7	--	--	52	14	18	91	16	6
Belgium	--	68	--	--	36	382	344	830	1,800	2
Brazil	62	14	--	--	--	100	9	185	149	1
Canada	54	257	39	1,770	9,920	2,670	497	15,200	15,500	111
China	--	1	4	10	221	2,200	39	2,480	1,980	29
Colombia	86	7	--	2	--	15	17	127	103	(5/)
Finland	--	--	--	--	--	(5/)	12	12	10	--
France	210	134	--	--	2	20	8	375	444	338
Germany	8	121	7	2	379	1,270	62	1,850	953	65
India	2	6	--	(5/)	256	1,650	5	1,920	1,340	1
Italy	--	25	--	78	--	272	9	384	78	3
Japan	2	46	--	7	1,250	1,930	505	3,740	5,370	19
Korea, Republic of	--	77	--	--	1,270	8,950	652	10,900	15,200	45
Mexico	927	68	1	19	66	84	317	1,480	1,560	700
Netherlands	--	35	--	--	227	997	19	1,280	1,340	22
South Africa	--	14	--	14	272	55	3	358	1,300	4
Spain	2	--	--	--	25	1	3	31	1,620	51
Sweden	--	5	--	6	474	9	82	576	759	4
Taiwan	--	38	--	(5/)	55	11,600	138	11,900	6,210	14
United Kingdom	23	115	--	19	237	137	68	599	440	186
Other	25	340	(5/)	12	978	492	872	2,720	1,890 r/	803
Total	1,400	1,380	50	1,940	15,700	32,900	3,680	57,000	58,100	2,410

r/ Revised. -- Zero.

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

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

3/ Chemical-grade oxide is included in the "Chemicals" category.

4/ Excluded from "Total."

5/ Less than 1/2 unit.

Source: U.S. Census Bureau.

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

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

Class	2000		2001	
	Quantity	Value (thousands)	Quantity	Value (thousands)
Unwrought primary:				
Cathodes, pellets, briquets, shot	119,000	$1,020,000	111,000	$715,000
Ferronickel	16,400	125,000	11,600	62,300
Flakes	942	9,320	1	62
Powder	13,500	146,000	8,300	81,200
Metallurgical-grade oxide	2,540	27,200	1,350	10,700
Chemicals:				
Catalysts	1,690	61,700	1,250	58,800
Salts 3/	2,000	25,400	1,940	21,700
Total	156,000	1,410,000	136,000	950,000
Unwrought secondary:				
Stainless steel scrap	4,220	35,500	3,180	24,100
Waste and scrap	6,530	56,400	5,580	45,900
Total	10,700	91,900	8,760	69,900
Grand total	167,000	1,500,000	144,000	1,020,000
Wrought:				
Bars, rods, profiles, wire	438	6,370	460	5,930
Sheets, strip, foil	503	13,600	358	8,350
Tubes and pipes	51	452	317	4,770
Total	992	20,400	1,140	19,000
Alloyed (gross weight):				
Unwrought alloyed ingot	4,710	61,800	4,110	62,900
Bars, rods, profiles, wire	7,270	85,000	8,880	107,000
Sheets, strip, foil	3,470	58,900	3,080	50,800
Tubes and pipes	2,040	32,400	2,600	40,000
Other	1,550	32,400	1,770	38,300
Total	19,000	270,000	20,400	299,000

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 subheading 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 2001	Total 2000	Wrought nickel 4/
Australia	16,000	1,110	--	81	6	--	--	17,200	15,500	5
Austria	--	(5/)	13	--	8	(5/)	--	22	143	90
Belgium	39	44	--	--	134	12	454	683	509	2
Brazil	3,380	--	--	--	--	2	1	3,380	6,080	31
Canada	51,500	4,520	--	1,260	1,290	2,060	108	60,700	67,500	19
China	--	8	--	--	13	--	70	92	161	28
Colombia	--	--	1,930	--	5	7	(5/)	1,950	2,030	--
Dominican Republic	--	--	4,390	--	--	1	--	4,390	8,010	--
Finland	6,760	1,210	--	--	--	--	803	8,770	4,870	--
France	2,580	--	--	--	1,500	--	269	4,340	3,640	44
Germany	570	95	--	--	784	--	223	1,670	1,190	677
Japan	--	30	--	5	98	5	457	595	1,300	105
Mexico	--	(5/)	--	--	103	947	33	1,080	1,770	(5/)
Netherlands 6/	270	--	--	--	9	--	478	757	2,050	15
New Caledonia	--	--	3,350	--	--	--	--	3,350	6,390	--
Norway	18,900	--	--	--	31	3	--	18,900	18,400	--
Russia	8,220	998	57	--	--	--	--	9,280	20,800	--
South Africa	256	100	--	--	10	--	--	366	244	--
United Kingdom	1,170	111	(5/)	--	1,160	8	115	2,560	3,460	27
Venezuela	--	--	1,850	--	--	65	--	1,920	152	--
Zimbabwe	932	--	--	--	--	--	--	932	1,600	20
Other	637	77	--	--	435	70	187	1,410	1,100 r/	72
Total	111,000	8,310	11,600	1,350	5,580	3,180	3,200	144,000	167,000	1,140

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/ Excluded from "Total."

5/ Less than 1/2 unit.

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

Source: U.S. Census Bureau.

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

(Metric tons of nickel content)

Country	1997	1998	1999	2000	2001
Australia, content of concentrate	123,372	143,513	119,226 r/	165,700 r/	197,000 p/
Botswana, content of ore milled	19,860	21,700	33,733	34,465	26,200 e/
Brazil, content of ore	31,936	36,764	41,522	45,317	45,400 e/
Burma, content of ore	38	30	76	40	40 e/
Canada, content of concentrate	190,529	208,201	186,236	190,793 r/	193,361 p/
China e/	46,600	48,700	49,500	50,300 r/	51,500
Colombia, content of laterite ore	31,230	29,422	39,274	58,927	52,962
Cuba, content of oxide, oxide sinter, oxide powder, sulfide, ammoniacal liquor 3/	58,881	64,752	63,627	68,182 r/	70,662
Dominican Republic, content of laterite ore	49,152	40,311	39,997	39,943	31,000 e/
Finland, content of concentrate	3,252	1,967	70	2,600	2,000 e/
Greece, content of laterite ore	18,419	16,985	16,050	19,535	20,830
Indonesia, content of laterite ore	71,127	74,063	89,111	98,200	102,000
Kazakhstan, content of laterite ore e/	-- r/	--	--	30 r/	3,200
Macedonia, content of ferronickel produced e/	5,300	5,800	1,900	--	--
New Caledonia, content of ore	136,467	125,319	110,062	128,789 r/	117,554
Norway, content of concentrate	2,454	2,959	2,965	2,538	2,500 e/
Philippines, content of ore	18,137	23,713 r/	20,689 r/	17,388 r/	27,359
Russia e/ 4/	280,000 r/	290,000 r/	300,000 r/	315,000 r/	325,000
Serbia and Montenegro, content of ferronickel produced	2,440	466	--	--	--
South Africa, content of concentrate	34,830	36,679	36,202 r/	36,616	36,443
Ukraine, content of laterite ore	--	--	--	--	1,500
Venezuela, content of laterite ore	--	--	--	2,540 r/	13,600 e/
Zimbabwe, content of concentrate	12,963	12,872	11,164	8,160	8,145
Total	1,140,000 r/	1,180,000 r/	1,160,000 r/	1,290,000 r/	1,330,000

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

1/ World totals 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 29, 2002.

3/ The Government of Cuba reports plant production on a contained nickel plus cobalt basis. The tonnages shown in this table for Cuba have been adjusted downward to correct for the cobalt. The cobalt content was determined to be 1.16% for granular and powdered oxide, 1.21% for oxide sinter, 7.56% for sulfide precipitate, and 33% for leach ammoniacal precipitate.

4/ Nickel content of ore mined.

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

(Metric tons of nickel content)

Country and product 3/	1997	1998	1999	2000	2001
Australia:					
Metal	58,824	64,322	75,952	99,400 r/	117,000
Unspecified	14,762	15,256	7,648	9,155	10,000
Total	73,586	79,578	83,600 4/	108,555 r/ 4/	127,000
Austria, ferronickel e/	2,000	1,800	1,700	1,700	1,600
Brazil: 5/					
Ferronickel	9,350	8,077	6,502	6,347	6,000 e/
Metal	8,849	13,006	16,429	16,906	16,000 e/
Total	18,199	21,083	22,931	23,253	22,000 e/
Canada, unspecified 6/	131,639	146,715	124,260	134,225 r/	140,521 p/
China, metal e/	43,300	40,100	44,400	50,900	49,500
Colombia, ferronickel	25,171	28,143	28,345	27,720	38,447
Cuba, oxide sinter and oxides 7/	33,571	38,192	37,510	39,510 r/	40,748
Dominican Republic, ferronickel	32,558	25,220	24,449	27,829 r/	21,661
Finland:					
Metal	34,228	46,200	51,948	50,619	54,600 p/
Chemicals	4,990	4,518	4,143	3,711	3,700
Total	39,218	50,718	56,091	54,330	58,300
France:					
Metal	8,750	9,778	9,458	10,100	11,033 p/
Chemicals	1,952	2,000 e/	2,244	2,176 r/	2,000
Total 8/	10,702	11,778	11,702	12,276 r/	13,033
Greece, ferronickel	17,610	15,005	12,964	17,470	17,675 p/
Indonesia, ferronickel	9,999	8,452	9,205	10,111	10,302
Japan:					
Ferronickel	72,079	69,202	67,166	74,753 r/	69,112
Metal	26,889	29,397	30,481	36,230	32,526
Oxide sinter	26,899	25,435	34,482	47,020 r/	49,600
Chemicals	2,536	2,511	2,570	2,700	2,400
Total	128,403	126,545	134,699	160,703	153,638
Korea, Republic of, metal	(9/)	(9/)	(9/)	(9/)	(9/)
Macedonia, ferronickel e/	5,300	5,800	1,900	--	--
New Caledonia, ferronickel	44,312	44,491	45,289	43,914	45,912
Norway, metal	62,702	70,152	74,137	58,679	68,200
Poland, chemicals 10/	364	376	396	430	400
Russia: e/ 11/					
Ferronickel	8,000 r/	8,000 r/	9,000 r/	7,000 r/	8,000
Metal	208,000 r/	203,000 r/	215,000	225,000	230,000
Oxide sinter	12,000 r/	14,000 r/	12,000 r/	14,000 r/	12,000
Chemicals	2,000	2,000	2,000	2,000	2,000
Total	230,000	227,000	238,000	248,000	252,000
Serbia and Montenegro, ferronickel	2,440	466	--	--	--
South Africa:					
Metal	28,830	29,039	28,345	30,900 r/	30,500
Chemicals 12/	6,000	7,640	7,855	5,720 r/ e/	5,940 e/
Total	34,830	36,679	36,200	36,616	36,443
Taiwan, metal	(9/)	(9/)	(9/)	(9/)	(9/)
Ukraine, ferronickel	--	--	--	650 r/	2,500
United Kingdom, metal	36,091	41,994	39,467	37,976	33,817
United States, ferronickel	16,000	4,290	--	--	--
Venezuela, ferronickel	--	--	--	40	9,700 e/
Zimbabwe, metal:					
Refined from domestic materials 13/	10,300	8,732	9,106	6,676 r/	7,440
Toll refined from imported materials 14/	7,346	8,709	10,676	12,931 r/	12,084
Total	17,646	17,441	19,782	19,607 r/	19,524
Grand total:	1,020,000	1,040,000	1,050,000	1,110,000 r/	1,160,000
Of which:					
Ferronickel	245,000 r/	219,000 r/	207,000 r/	218,000 r/	231,000
Metal	534,000 r/	564,000 r/	605,000	636,000 r/	663,000
Oxide sinter	72,500 r/	77,600 r/	84,000 r/	101,000 r/	102,000
Chemicals	17,800	19,000	19,200	16,700 r/	16,400
Unspecified	146,000	162,000	132,000	143,000	151,000

See footnotes at end of table.

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

e/ Estimated. p/ Preliminary. r/ Revised. -- Zero.
1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.
2/ Table includes data available through July 29, 2002.
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/ Includes estimated production of pressure acid leach operations.
5/ Brazil produced nickel carbonate (an intermediate product), in metric tons: 1997--10,487; 1998--13,952 (revised); 1999--17,153; 2000--17,223; and 2001--17,000 (estimated).
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 Republic of Korea and Taiwan. See footnote 8.
7/ Cuba also produces nickel sulfide but, because it is used as feed material elsewhere, it is not included to avoid double counting. Combined output of processed sulfide and ammoniacal liquor precipitate was, as follows, in metric tons of contained nickel: 1997--25,225 (revised); 1998--26,413 (revised); 1999--25,998 (revised); 2000--28,732 (revised); and 2001--31,871. 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: Republic of Korea: 1997--18,452; 1998--20,183; 1999--20,235; 2000--29,890; and 2001--30,000 and Taiwan: 1997-98--10,500; 1999-2000--10,000; and 2001--11,500.
10/ Nickel content of nickel sulfate ($NiSO_4 \sim 6H_2O$). Most of the nickel sulfate was a byproduct of the concentrating, smelting, and refining of domestically mined copper ores. Some production, however, may have been derived from imported nickeliferous raw materials that were blended with the domestic copper concentrates.
11/ Includes production from sulfidized concentrates shipped from Cuba for toll refining.
12/ Include nickel sulfate plus exported metal in concentrate.
13/ Data represent production from domestic nickel ore.
14/ Previously published as "Other, metal." Data represent production from imported Botswanan matte, as well as from South African nickel sulfate.

TABLE 12
NICKEL: WORLD PRODUCTION OF INTERMEDIATE PRODUCTS FOR EXPORT, BY COUNTRY 1/ 2/

(Metric tons of nickel content)

Country	1997	1998	1999	2000	2001
Matte:					
Australia 3/	37,010	47,459	28,190	41,771	34,978
Botswana	20,157	22,851	22,898	21,446 r/	22,454 p/
Brazil 4/	1,180	4,670	9,306	8,475	8,500
Canada e/ 5/	45,000	48,000	52,000	37,000	49,000
Indonesia	33,654	35,697	45,400	59,200	62,600
New Caledonia	10,580	12,011	11,353	13,549	13,061
Russia e/ 6/	366	98	114	517 r/	97
Total	148,000	171,000	169,000	182,000 r/	191,000
Other, Cuba: 7/					
Sulfide precipitate	24,507	25,176	24,999	27,288	29,913
Ammoniacal liquor precipitate	717 r/	1,237 r/	999 r/	1,444 r/	1,958
Total	25,224 r/	26,413 r/	25,998 r/	28,732 r/	31,871

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

1/ Table includes data available through July 29, 2002. Data represent nickel content of matte and other intermediate materials produced for export.

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

3/ Total matte production on a contained nickel basis, in metric tons, was as follows: 1997--85,800; 1998--100,071; 1999--79,668; 2000--103,000; and 2001--98,000 (estimated).

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/ Russian export figures reported primarily by the importing countries of France and Norway. Russian exports to Norway were estimated to have a nickel content of 40%.

7/ Corrected for coproduct cobalt.

TABLE 13
NICKEL: NEW LATERITE PROJECTS SCHEDULED FOR COMPLETION, BY YEAR, BEFORE 2015

(Metric tons unless otherwise specified)

Projected year of first production	Country and state/province	Project and company	Resource grade (% nickel)	Estimated resources (thousands) 1/	Annual production capacity (of contained nickel)	Nickel product
2004	New Caledonia	Goro Inco Ltd., Bureau de Recherches Geologiques et Minieres, and Sumitomo consortium	1.57	200,000	55,000	Ni oxide.
2004	Philippines (Mindanao)	Adlay BHP Billiton plc.	1.61	6,000	5,000	Ore.
2004	Philippines (Palawan)	Rio Tuba Coral Bay Nickel Corp.	1.26	16,000	10,000	Ni-Co sulfide.
2006	Australia (Western Australia)	Ravensthorpe BHP Billiton plc.	0.90	150,000	45,000	Ni-Co hydroxide.
2007	New Caledonia	Koniambo Falconbridge Ltd. and Soc. Miniere du Sud Pacifique S.A.	2.50	150,000	60,000	Ferronickel.
2008	Brazil (Pará)	Vermelho Companhia Vale do Rio Doce	1.23	220,000	45,000	Metal or oxide.
2008	Indonesia (Halmahera Island)	Weda Bay Weda Bay Minerals, Inc. and PT Aneka Tambang	1.35	220,000	48,000	Ni-Co sulfide.
2009	Brazil (Pará)	Onca-Puma Canico Resource Corp. and Inco Ltd.	2.22	33,000	25,000	Matte or oxide.
2009	Cuba (Holguin)	Pinares de Mayari West Government of Cuba	1.10	200,000	40,000	Metal or oxide.
2009	Indonesia (Maluku)	Gag Island BHP Billiton plc. and PT Aneka Tambang	1.35	240,000	30,000	Intermediate, metal, or ferronickel.
2009	New Caledonia	Nakety-Bogota Argosy Minerals, Inc. and Soc. des Mines de la Tontouta	1.47	88,000	52,000	NA
2010	Australia (Queensland)	Marlborough Preston Resources Ltd.	1.02	210,000	25,000	Metal.
2010	Cuba (Camaguey)	San Felipe BHP Billiton plc. and Government of Cuba	1.30	250,000	45,000	Metal or oxide.
2011	Australia (Western Australia)	Mount Margaret Anaconda Nickel Ltd.	0.78	170,000	45,000	Ni-Co hydroxide.
2011	Philippines (Mindoro Island)	Sablayan Crew Development Corp.	0.94	72,000	40,000	Metal.
2012	Australia (New South Wales)	Syerston Black Range Minerals Ltd.	0.65	96,000	18,000	Ni-Co sulfide.
2013	Papua New Guinea	Ramu River Highlands Pacific Ltd. and Orogen Minerals Ltd.	0.91	76,000	33,000	Metal.
2014	Australia (Western Australia)	Goongarrie and Kalpini Heron Resources Ltd.	0.83	330,000	12,000	Ore.
2014	Cote d'Ivoire	Biankouma, Touba, and Sipilou Falconbridge Ltd. and Soc. d'Etat pour le Developpement Minier	1.48	260,000	45,000	Ni-Co intermediate or ferronickel.

NA Not available.
1/ Gross weight, dry. "Estimated resources" are rounded to no more than two significant digits.

Sources: Company annual reports, presentations, and press releases; CRU International, Ltd.

TABLE 14
NICKEL: NEW SULFIDE PROJECTS SCHEDULED FOR COMPLETION, BY YEAR, BEFORE 2015

(Metric tons unless otherwise specified)

Projected year of first production	Country and state/province	Project and company	Resource grade (% nickel)	Estimated resources (thousands) 1/	Annual production capacity (of contained nickel)	Nickel product
2001	Australia	Emily Ann and Maggie Hays	3.98	2,000	6,700	Concentrates.
	(Western Australia)	LionOre Australia Ltd.	1.47	12,000		
2002	Zimbabwe	Ngezi platinum	0.12	32,000	1,300	Matte.
	(Mhondoro region)	Makwiro Platinum Mines (Pvt) Ltd. and Zimbabwe Platinum Mines Ltd.				
2003	Australia	Cosmos Deeps	7.20	520	10,000	Concentrates.
	(Western Australia)	Jubilee Mines NL	3.90	110		
2004	Do.	Forrestania-New Morning and Diggers South	1.63	3,000	3,000	Do.
	Do.	Western Areas NL				
2004	Do.	Sally Malay	1.80	4,000	8,000	Do.
	Do.	Sally Malay Mining Ltd.				
2004	Canada	McCreedy West/Levack	1.40	NA	NA	NA
	(Ontario)	Fort Knox Gold Resources, Inc. and Dynatec Corp.				
2004	Spain	Aguablanca	0.67	23,000	10,000	Concentrates.
	(Extremadura Province)	Rio Narcea Gold Mines Ltd.				
2005	Canada	Montcalm	1.48	7,700	8,000	Do.
	(Ontario)	Falconbridge Ltd.				
2006	Canada	Voisey's Bay	2.88	31,000	50,000	Concentrates, initially.
	(Labrador)	Inco Ltd.	1.29	97,000		
			0.98	14,000		
2007	Canada	Norman	0.95	NA	NA	NA
	(Ontario)	Fort Knox Gold Resources, Inc. and Dynatec Corp.				
2008	Australia	Honeymoon Well	0.82	140,000	30,000	Concentrates, initially.
	(Western Australia)	Mining Project Investors Pty. Ltd. and OM Group, Inc.				
2008	Do.	Yakabindie	0.56	290,000	32,000	Ore.
	Do.	WMC Ltd.				
2008	Canada	Nickel Rim South	2.20	4,200	10,000	Concentrates.
	(Ontario)	Falconbridge Ltd.				
2009	Canada	Maskwa	1.27	2,900	3,800	Do.
	(Manitoba)	Canmine Resources Corp.				
2009	Tanzania	Kabanga	2.18	21,000	17,000	Do.
	(Kagera region)	Barrick Gold Corp.				

NA Not available.
1/ Gross weight, dry. "Estimated resources" are rounded to no more than two significant digits.

Sources: Canadian Minerals Yearbook, 2000; company annual reports, presentations, and press releases; and CRU International, Ltd.